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CHALLENGES OF BIOGAS COMMERCIALIZATION IN NIGERIA

MASTER'S THESIS

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Declaration

I hereby declare that I have done this thesis entitled challenges of biogas commercialization in Nigeria independently, all texts in this thesis are original, and all the sources have been quoted and acknowledged by means of complete references and according to Citation rules of the FTA.

In Prague date

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Abstract

Energy is a daily touchstone for every individual in the world. With the world shifting toward sustainable living, sustainable renewable energy is the order of the day. One of the significant advancements in sustainable renewable energy is generating energy from organic matter decomposition under anaerobic digestion; biogas technology. Biogas technology addresses both waste and energy challenges in the world and still increases agricultural efficiency by using biogas residues as fertilizers and conditioners. Nigeria is a developing country with a wide gap between the energy supply and the energy demand of its citizens. A chance to complement this gap is the adoption of biogas by citizens. This study examines the factors that influence the commercialization of novel technology and possible solutions to the problems.

238 households and 35 energy retailers / marketers were sampled using the purposive sampling techniques. Data were collected using distinct structured questionnaires for household and energy retailers. Descriptive statistics and binary logistic regression (Logit) were the analysis used for the study. A significant omnibus test ($p<0.05$) revealed that the models fit the variables in the equation well. Education levels of graduates and postgraduates show a negative regression with the willingness to adopt the technology. The study results revealed that socio-economic factors (except education) do not influence the willingness to adopt technology among the tested population. This could be due to the dire need for energy in the country.

Although more than half of the sampled population (58.8%) are aware of biogas and are willing to adopt the technology, only a tiny percentage (5.5%) currently owns the technology; citing lack of adequate funds, inadequate information, poor infrastructure, inadequate skilled disseminators, a negative community attitude towards biogas energy, and lack of interest as significant challenges to the adoption of the technology. Energy retailer/marketers ranked, Capacity/Manpower hurdle as the most important. Institutional/Policy hurdle, Economic/financial hurdle, Information hurdle, Technical/infrastructural hurdle followed suite respectively, while Socio-cultural hurdle comes last in the list of important barriers with majority of the respondents disagreeing with it being a barrier.

The respondents believed that providing micro-finance or loans, increased awareness, increased government will and support, increased training programs for disseminators, community leadership programs in renewable energy, and establishing demonstration centers would go a long way in solving the issues of commercialization. The partial introduction of technology into the country and further study of the energy need or deficiency of the country will provide more evidence on the findings of this research as the energy needs of the country could be underestimated.

Keywords: Nigeria; Biogas; Commercialization; Challenges; Renewable energy.

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List of the abbreviations used in the thesis

ECN	Electricity Corporation of Nigeria
GHG	Greenhouse Gas
Gt	Gigaton
GWP	Global Warming Potential
MSW	Municipal Solid Waste
Mtce	Million Tonnes of coal equivalent
MTOE	Million Tonnes of Oil Equivalent
NBS	Nigeria's Bureau of Statistics
NDA	Niger Dam Authority
NEPA	National Electric Power Authority
NERC	Nigerian Electricity Regulatory Commission
NESCO	Nigerian Electricity Supply
NGEU	Nigerian Government Electricity Undertaking
NNPC	Nigerian National Petroleum Corporation
NPP	National Policy on Population for Sustainable Development
PV	Photovoltaic System
TWh	Terawatt Hour

1. INTRODUCTION

1.1 Background

Sustainability is very important as it looks to protect the human, ecological, and most importantly the natural environment. Environmental sustainability is one of the biggest issues faced presently in the world because of the bursting world population with a tremendous escalation in anthropogenic activities (Arora 2018). These anthropogenic activities have affected almost every aspect of the earth from the atmosphere to the lithosphere and the hydrosphere.

The world is shifting towards sustainable living such that, almost every single organization is making efforts to better their production and administrative processes to reduce their environmental footprint. One of the prominent advancements in sustainable renewable energy is the generation of energy from organic matter decomposition under anaerobic digestion. Anaerobic Digestion is a series of biological processes that involve the microbial breakdown of biodegradable material in the absence of oxygen (Som 2020), and biogas is the gas that is produced from biodegradation of the organic materials; it consists mainly of Methane and Carbon-dioxide. Methane from biogas is a source of renewable energy producing electricity in combined heat and power plants. Methane is an important component in biogas, as it is a highly flammable gas and can be utilized as fuel for cooking, lighting, water heating, and if the Sulphur in it is removed, it can be used to run biogas-fuelled generators to produce electricity (Mukumba et al. 2016). Apart from methane in biogas, other gases are undesirable (Şenol 2020). The term ‘’biogas plant’’ is often used for an anaerobic digester that treats wastes to generate energy (Aladeitan 2011).

Biogas technology is a renewable and sustainable technology that addresses both waste and energy challenges of the world and still increases agricultural efficiency using biogas residue as fertilizers and conditioners for soil through anaerobic digestion processes (Patinvoh & Taherzadeh 2019). The anaerobic digestion processes produce fewer greenhouse gases than waste treatment processes such as composting (Walker et al. 2009) and landfilling (Lou & Nair 2009).

1.2 Problem statement and justification

In Nigeria, most families living in villages and small towns depend on non-renewable energy like wood as their domestic fuel because other conventional fuels such as kerosene, electricity, and LPG are costly, unreliable, or unavailable (All 2021). To elucidate better on the current situation in Nigeria, (Akinbomi et al. 2014) made it known that:

> ''*Over the years, Nigeria has been facing numerous challenges including a severe electricity shortage, an inefficient waste management system, and environmental degradation. More than 60% of the population does not have access to the national power supply because they are not connected to the grid system; and even for those that are connected to the grid system, power outages are a common challenge. As a result of an unstable power supply, most people currently rely on generators for their supply of off-grid electricity, wood, and fossil fuel for cooking and transportation an unstainable option. Nigeria also faces the problem of an inefficient management system of wastes, including agricultural, municipal solid waste (MSW), and sewage, among others. The inadequate and inaccessible energy services have compelled most industries and businesses that could not afford the high cost of running their business operations, to close down shop''*.

Nigeria's ever-growing population (growing at the rate of about 2.8% annually, and have an estimated population of over 165 million - Factbook 2014; FAOSTAT 2014; Shaaban & Petinrin 2014), denotes a fact that increase in demand for energy (one that's currently insufficient) and waste generation is inevitable, and debate surrounding this context is a waste of time, for the question that looms now is how long can Nigeria continue on this path of wanton consumption, inefficient management and use of natural resources in such indiscriminate manner. If continued, the situation would not only tell on the country's economy, health, and environment but will translate to poverty vis-à-vis unemployment; a fact highlighted in 2006 by Resources Information Clearinghouse report on the interaction between poverty and natural resources. Hence, the need to search for renewable energy sources. A perspective acknowledged by Roubík et al (2016), by this statement: '*'Energy and environmental issues have become one of the most important problems of common concern and one of the first problems needing to be solved by mankind''*. In addition to the statement, Roubík et al. (2016) identified anaerobic digestion (via biogas production) as the sustainable solution to problems surrounding energy and waste management and made it known that the utilization of anaerobic digestion (AD) brings the solution to health, hygiene, and environmental problems. The research further made it known that the production of biogas through the AD process provides significant advantages over other forms of renewable energies. Similarly, Aladeitan 2011; Akinbomi et al. 2014; Mukumba et al. 2016 also identified AD as the solution to energy and waste crises.

It has been proven by Akinbomi et al. (2014) in the research on *''Development and Dissemination Strategies for Accelerating Biogas Production in Nigeria''* that Nigeria can generate biogas that could be used to satisfy the energy needs of about 763 million people, which are far greater than the Nigerian population as there are abundant raw materials (feedstock) to produce the gas as well as favorable climatic conditions. However, biogas technology is yet to be commercialized.

Considering these, it becomes necessary to evaluate and understand the challenges affecting the commercialization, knowingly fully well that biogas technology can address the challenges affecting energy in Nigeria.

2. LITERATURE REVIEW

This review takes notes and opinions from various sources and authors starting with an overview of the global energy sources and the unanticipated shift towards renewable energy, the history and early usage of biogas technology, the merits of biogas production based on greenhouse gases emission, and a few notable risks of its usage. The author further reviewed past publications on biogas technology in Africa, socio-economic factors affecting biogas adoption, Nigeria's energy transition, and complex policies. The last section review Nigeria's energy challenge: an opportunity for biogas, the biomass potential of Nigeria for biogas production, and the current establishments handling biogas production.

2.1. GLOBAL ENERGY SOURCES AND THE UNPRECEDENTED SHIFT TOWARD RENEWABLE ENERGY

Energy plays a vital role in economic development because of its dependency on virtually every living organism and its cost directly affects the prices and distribution of goods and services, social, economic, political, and environmental development (Amigun et al., 2012). Energy and sustainable livelihood are inseparable as energy scarcity, both in terms of availability and sufficiency are considered to be the single biggest factor affecting communities' well-being and livelihoods.

Global energy demand is always increasing due to industrial activity and advances in both developing and developed countries. Fossil fuel energy sources, such as coal, natural gas, and oil are used to meet energy demands for much of the world (Asdrubali and Desideri, 2019). Global energy demand has always been on the rise yearly but in 2020 fell by 4%, the largest decline since World War II and the largest ever absolute decline. This decline was attributed to the continued impacts of the pandemic on global energy use (IEA, 2021) as industries that consume the larger share of the global energy are yet to operate at full scale.

According to International Energy Agency (IEA, 2021), the drop in energy demand in 2020 did not affect all fuels evenly, and oil was by far the hardest hit, with restrictions on mobility causing demand for transport fuels to fall by 14% from 2019 levels. At the peak of restrictions in April, global oil demand was more than 20% below pre-crisis levels. Overall, oil demand was down by almost 9% across the year. Only in Asia and, notably, in China does oil demand climb well above pre-covid-19 levels (IEA, 2021).

It was also noted by IEA, 2021 that the year 2020 saw a coal demand drop by 220 million tonnes of coal equivalent (Mtce) or 4%. The largest declines in coal use for electricity generation were in advanced economies, down 15%, which accounts for more than half of coal's global decline. Coal was particularly squeezed in the power mix by lower electricity demand, increasing output from renewables, and low gas prices. In 2021, coal demand has rebounded strongly, reversing all the declines in 2020, though with major geographic variations. The decline in 2020 was concentrated in the United States and Europe, and demand in advanced economies is expected to recover only one-quarter of its 2020 drop, curtailed by renewables deployment, lower gas prices, and phase-out policies. Meanwhile, China is projected to account for 55% of the 2021 increase (IEA, 2021).

Lower prices enabled gas to be more resilient than coal in 2020, with demand falling only by 2%. The combination of continued lower prices and rapid growth in economies across Asia and the Middle East should drive the growth of 3% in gas demand in 2021. As a result, global natural gas demand in 2021 is projected to rise 1.3% above 2019 levels, the strongest anticipated rebound amongst fossil fuels (IEA, 2021).

Renewables have proven largely immune to the pandemic as new capacity has come online and as they have benefited from priority market access in many markets. Overall, renewables usage grew by 3% in 2020, largely due to an increase in electricity generation from solar PV and wind of 330 TWh. Generation from solar PV and wind is set to grow by 17% in 2021, up from 16% in 2020. Hydro and biomass generation should also accelerate, with total generation from renewables growing by 8.3% in 2021, which is faster than the 2020s 7% increase. Two years of rapid growth means the share of renewables in total electricity generation will reach almost 30%, up from less than 27% in 2019. Renewable energy use increased 3% in 2020 as demand for all other fuels declined. The primary driver was an almost 7% growth in electricity generation from renewable sources. Long-term contracts, priority access to the grid, and continuous installation of new plants underpinned renewables growth despite lower electricity demand, supply chain challenges, and construction delays in many parts of the world. Accordingly, the share of renewables in global electricity generation jumped to 29% in 2020, up from 27% in 2019. Bioenergy use in the industry grew 3% but was largely offset by a decline in biofuels as lower oil demand also reduced the use of blended biofuels (IEA, 2021).

The wind is set for the largest increase in renewable generation, growing by 275 TWh, or almost 17%, which is significantly greater than 2020 levels. Policy deadlines in China and the United States drove developers to complete a record amount of capacity late in the fourth quarter of 2020, leading to notable increases in a generation already from the first two months of 2021 (IEA, 2021)

The world's biogas volume is about 59 billion m3 biogas (35 billion m3 methane equivalent) with only the EU producing about half of the total volume (IEA, 2018), with Asia taking the lead in biogas production and use, particularly China and India. The implementation of biogas in developing countries varies greatly between countries due to climate conditions, technologies, developmental levels, endowment of natural resources, and socio-economic status (Mwirigi et al., 2014 and Gu et al., 2010).

2.2. HISTORY AND EARLY USAGE OF BIOGAS TECHNOLOGY

As far back as the 10th century, there are suggestions that biogas was used for heating bath water in Assyria and that anaerobic digestion of solid waste may well have been applied in ancient China in that same century (He, 2010). In the 17th Century, Jan Baptita Van Helmont discovered that flammable gases could evolve from decaying organic matter. Count Alessandro Volta also concluded in 1776 that there was a direct correlation between the amount of decaying organic matter and the amount of flammable gas produced. In 1808, Sir Humphry Davy determined that methane was present in the gases produced during the anaerobic digestion of cattle manure (Pennsylvania State University, 2012).

Vogeli et al., 2014 also described an early anaerobic digester in Mumbai, India, built-in 1859 for sewage treatment and widespread technology throughout Asia. However, well-documented attempts to harness the anaerobic digestion of biomass by humans date from the mid-nineteenth century, when digesters were constructed in New Zealand and India, with a sewage sludge digester built in Exeter, UK to fuel street lamps in the 1890s (University of Adelaide, 2010). In Guangdong Province, China, commercial use of biogas has been attributed to Guorui Luo, when he constructed an 8 m3 biogas tank fed with household waste in 1921, and later that decade founded a company to popularise the technology (He, 2010). Germany's first sewage treatment plant to feed biogas into the public gas supply began to do so in 1920, while her first large agricultural biogas plant began operating in 1950. The spread of biogas technology gained momentum in the 1970s when high oil prices motivated research into alternative energy sources (Bond and Templeton, 2011).

2.3. GREENHOUSE GAS EMISSION (GHG) IN BIOGAS TECHNOLOGY

The growing population and the increase of urbanization around the world demand constant and efficient energy production. The energy generation mostly emits CO_2 as one of its end products. Shahbaz et al., (2013) stated that the use of fossil fuels for daily life, massive smoke expulsion from the factories, and consumption of wood as an energy source boost the CO_2 emissions. Different research on the relationships between energy consumption, economic growth, and CO_2 emissions (Khan et al., 2020; Kasman and Duman 2015); Chaudhry (2010); Pao et al., (2010) have generally concluded that the development of every economy and energy consumption causes increased CO_2 emissions.

Although global CO_2 emissions declined by 5.8% in 2020, or almost 2 Gt CO_2 – the largest ever decline and almost five times greater than the 2009 decline that followed the global financial crisis. CO_2 emissions fell further than energy demand in 2020 owing to the pandemic hitting demand for oil and coal harder than other energy sources while renewables increased. Despite the decline in 2020, global energy-related CO_2 emissions remained at 31.5 Gt, which contributed to CO_2 reaching its highest-ever average annual concentration in the atmosphere of 412.5 parts per million in 2020 – around 50% higher than when the industrial revolution began**.** Emerging markets and developing economies now account for more than two-thirds of global CO_2 emissions, while emissions in advanced economies are in a structural decline (IEA, 2021).

Anaerobic digestion of biogas technology is associated with the production of several greenhouse gases, namely carbon dioxide, methane, and nitrous oxide (Paolini et al., 2018). The open storage of active material (e.g., insufficient fermented residues from batch fermentation systems), open digestate storage tanks, missing acidic scrubbers in front of bio-filters, or insufficient air supply during the post-composting of digestate can cause relevant GHG emissions (Daniel-Gromke et al., 2015). Biogas depending on the substrate input contains about 50-70% methane and 30-50% carbon dioxide (CO_2), and smaller amounts of other gases (Sovacool et al. 2015). Similarly, (Okoro et al. 2020) supported this view with a diagram that showcased the possible optimum range of gases obtained during biogas production ***figure 1.***

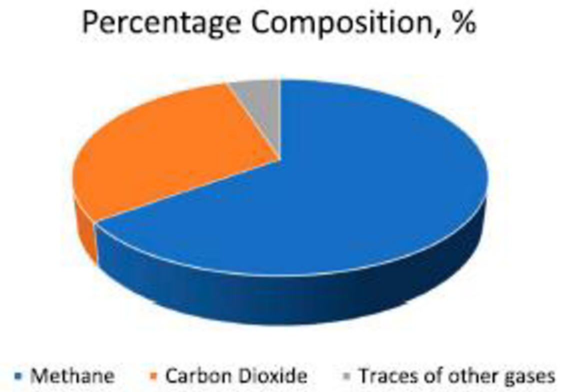

***Fig 1**: optimum range of gases obtained during biogas production* *Source:* (Okoro et al. 2020)

The CO_2 emitted from biogas is part of the CO_2 that plants absorbed by photosynthesis from the atmosphere during respiration, this indicates that no new CO_2 is produced and the net increase of CO_2 in the atmosphere turned to be zero (Shiratori et al. 2008) and as such, the CO_2 has not been included in greenhouse gas emission accounting (Shane et al. 2016). Biogas feed with crop residues, livestock dung, and forest residues burns more efficiently compared to burnt directly on an inefficient stove for energy production, it burns firewood and animal dung at about 60% efficiency compared to a 5-8% efficiency when burnt in an open fireplace (Mengistu et al. 2015).

There are also non- CO_2 emissions that also contribute the greenhouse gases, like Methane and Nitrous Oxides. Methane, an important component in biogas, is a highly flammable gas and can be utilized as fuel for cooking, lighting, water heating (Mukumba et al. 2016), is produced through enteric fermentation and manure management, while Nitrous Oxide includes emission from manure management and manure or fertilizer applications to the soil (Shane et al. 2016). Biogas technology burns methane which is the second most important greenhouse gas that has a global warming potential over 20 times that of carbon dioxide (USEPA 2010). Hence, through the combustion of methane and its conversion to carbon dioxide, biogas technology offers fewer global warming results (Bond et al. 2011). Agricultural production also contributes around 33% of total anthropogenic methane emissions, mostly from ruminant animals and rice cultivation. It has been estimated that biogas technology could potentially reduce global anthropogenic methane emissions by around 4% (ISAT/GTZ 1999c).

Energy conservation is one of the advantages which biogas has over other energy sources. Second, to solar energy, biogas is considered another form of sustainable energy as it can significantly reduce global warming potential (GWP) by up to 50% (Whiting et al. 2014). Various studies (Sovacool et al. 2015; Paolini et al. 2018; Scott et al. 2021) over time have concluded that biogas technology leaves little or no footprint as it regards greenhouse gas emissions if efficiently and effectively installed, but close attention needs to be given to the non- CO_2 gases.

2.4. NOTABLE RISKS OF BIOGAS

Every innovation comes with its negative side no matter how positive it seems at first. In biogas, worthy of mentioning is the presence of heavy metals. Various feedstocks such as feeds through the livestock and poultry breeding processes and human waste may contain heavy metals, most of which are discharged with metabolism, and as such when used in biogas production, ends up with the biogas digestate. The digestate which can be further used as soil fertilizers and farmland irrigation when not treated for heavy metals can cause damage to soil, water resources, and living organisms (Mingxue et al., 2019). On the risk assessment of heavy metals in air, water, vegetables, grains, and related soils irrigated with biogas slurry in China (Bian et al., 2015) concluded that biogas slurry for soil irrigation when not treated for heavy metals poses further risks to human health.

Ravishankara et al., 2009 also made it known that Nitrous Oxide (NO_2), a product of the anaerobic digestion of biogas technology, is also regarded as the biggest artificial threat to the ozone layer with a global warming potential of over 300 times that of Carbon-dioxide (CO_2). Due to its high greenhouse effect potential, NO_2 emissions from biogas production processes can result in a significant contribution to the global warming budget (Senbayram et al., 2014 and Jordan et al., 2016).

In the same vein, (Mukumba et al., 2016) also discovered that Hydrogen Sulphide (H_2S), a harmful gas that can cause corrosion in pipes, gas stoves, and internal combustion engines is also contained in a tangible quantity of the raw biogas produced from anaerobic digestion

2.5. BIOGAS TECHNOLOGY IN AFRICA

In Africa, biogas as technology is still in infancy, albeit recent initiatives in various African countries have led to an accelerated understanding and uptake of the technology (Roopnarain and Adeleke 2017). Worthy of mention is the African Biogas Program which sees several digesters installed in countries like Burundi, Botswana, Burkina Faso, Cote d'Ivoire, Ethiopia, Ghana, Guinea, Lesotho, Namibia, Nigeria, Rwanda, Zimbabwe, South Africa, and Uganda (Patinvoh et al., 2019) with most of the installations being family-sized plants (Cheng et al., 2014). (Roopnarain and Adeleke 2017) made it known that these countries have benefited significantly from the technology and serve as showpieces for African countries that can start up similar programs without outside assistance.

Biomass energy is widely distributed across Africa, so there are no geographical limitations to the employment of this technology, (Mwirigi et al., 2014) yet energy poverty prevails and access to energy is a major challenge; the rural poor are genuinely affected by the depletion of their energy resources, especially firewood. Insecurity and fear of attack or rape have also limited the collection of firewood by women in the forest as deforestation extends the distance traveled to its source. The level of energy poverty in Africa was better showcased in (Roopnarain and Adeleke 2017) research that highlighted Africa's portion of energy consumption on a global level. The research made it known that out of the 15 tera-watts (TW) per year global energy consumption, 7.8% (0.94 TW) is obtained from renewable resources. However, the total energy usage (from all energy sources) in sub-Saharan Africa accounts for 4% of the global consumption, even though 13% of the world's population resides in this region.

The research concluded that to reduce dependency on wood and fossil fuels, and to mitigate challenges surrounding energy in Africa. There is a need for alternative renewable energy resources, and one promising alternative is the use of biogas as an energy source.

2.6. SOCIO-ECONOMIC FACTORS AFFECTING BIOGAS ADOPTION

New technologies face several challenges in their popularization and adoption as a result of technical, economic, socio-demographic, institutional, and political constraints (Kabir et al., 2013). Renewable energy being the order of the day enjoys broad public support but is also often met with strong local opposition and rejection (Dumont et al., 2021), this can be attributed to the varying level of exposure and education between the two social settings. For instance, Dumont et al., (2021) found out that local communities rejected in principle, the consideration of small-scale biogas technology as they perceived it to be even more dangerous than any other form of energy they were currently using; due to the energy source (animal manure, food waste, and even human waste). In his research, respondents expressed physical disgust stating that using biogas would contaminate their environment and food with microbes and that it would cause diseases as it is believed that most of those wastes, especially human wastes should be buried far away from human eyes. This tenet could be attributed to limited awareness of the potential advantages and disadvantages of biogas, as this is one of the factors that hinder the adoption of biogas systems (Mwirigi et al., 2014).

Kabir et al., 2013 concluded that the socio-economic characteristics of a family are embedded with decisions on the adoption of biogas technology after testing eight variables against the adoption of biogas. In his research, four variables that included the year of education of household or family head, livestock farm size, family income, and gender of the family head, are statistically significant effects on the households' decision to adopt biogas technology. While the level of education of household or family head, livestock farm size, family income are found to be positively correlated to biogas adoption, gender of the family head was negatively correlated with adopting biogas technology. This corresponds with Jabeen et al., (2020) whose research concerning the socio-economic influence factors on biogas adoption revealed that the education of both household head and chef portrayed substantial contribution in the decision-making. The stance is also maintained by various authors that include Mengistu et al., 2016; Surendra et al., 2014; Mwirigi et al., 2009. However, Wang et al., 2011 and Walekhwa et al., 2009 had a contradictory perspective in their research that reported an inverse relationship between education and the adoption of biogas. Jabeen et al., 2020 added that households whose cooking sources were based only on fuelwood are more likely to adopt biogas technology than those using alternative sources that include natural gas and LPG.

The adoption of biogas technology can also be affected by the rising energy needs and demand of people and the power shortage of those who are energy deficient. Jan et al., (2018) state that there is a positive relationship between total hours of energy shortfall and the willingness of people to adopt a biogas system. The endless need for energy by a human due to its importance drives readiness to adopt any other available source. Kelebe et al., 2018 also concluded that access to electricity influenced the decision of households to install and use biogas digesters at home.

Ownership or claimant of renewable energy like biogas is also of utmost importance in its adoption. Renewable energy projects implemented as being co-owned by the community receive more support than those simply imposed on the community (Gross, 2007) as this approach allows community members to psychologically integrate such projects into their place identity (Warren et al., 2010) and therefore accepting it whole-heartedly.

Overall, the evidence reviewed here clearly indicated that socio-economic factors play a crucial role in the adoption of biogas technology.

2.7. NIGERIA'S ENERGY TRANSITION AND COMPLEX POLICIES

Across the globe, every country is faced with the need to ensure continual changes to its energy infrastructure due to the massive climate emergency we now face. And these changes are not only conceptualized but realized through policies. Hence, it is important to understand how Nigeria's current energy systems have been shaped via policies and governance.

It is profound that policies that concern energy and other states of the economy of most countries are majorly controlled by the government of the day, Nigeria, a developing country is no exception to this.

A study conducted by (Edomah, Foulds, and Jones 2016) reviewed works of literature boarding the evolution of energy systems and policies in Nigeria between 1800 – 2015 revealed that there is a complex connection between resources, trade, institutions, and political structures. The study further attributed that the above statement is due to the overlapping decision-making institutions within the era of energy use created to appease political thirst.

To further break down Edoma et al., (2016) conclusion, a systematic review of previous research detailing how the change in government nascent different policymaking institutions is done in a chronological (era) manner, starting from the pre-industrial era down to the Information era.

The Pre-industrial (agricultural) era up to the mid-1800s, is characterized mostly by energy produced from traditional biomass (firewood collection). Energy demand and supply are dependent on families and traditional rulers of this era (Deji, 2013). The Early industrial era also regarded as the advanced metallurgy era was up till the late 1800s. This era sees some metallurgical intervention in rail, agricultural tools, and a few other aspects although the traditional biomass was also the predominant energy source in this era. Later in the early industrial era, in 1896, the first Nigeria power plant was constructed in Lagos. Energy policies, demand, and supply at the time were more like that of the agricultural era, however, the colonial rule and institutions joined in the policymaking because of the newly constructed power plant.

The Industrial (steam engines) era of the early-mid 1900s is characterized by the discovery and development of coal (in Enugu), another primary energy source, with the coal being used extensively for thermal and mechanical needs in manufacturing, particularly in fabricating machine tools, metal machines, etc (Edomah et al., 2016). This era was dominated by colonial institutions, established to achieve specific infrastructural and policy targets (Aghalino, 2000) hence, policymaking has shifted hands from the families and traditional rulers solely to the colonial institutions as energy demand has grown and the demands could only be met by the new plants constructed and powered by coals and partly hydro-electric installed in Jos, North-central Nigeria. The Colonial rulers proceeded to establish the Nigerian Electricity Supply Company (NESCO) in 1922, an agency tasked with the responsibility of developing electrical energy supply (generation) infrastructure (Edomah et al. 2016).

The Late industrial (dynamo, internal combustion engines) era running from the mid to late 1900s was driven by more extensive energy use and demand, with dynamos and internal combustion engines being the main technology of the days. The discovery of crude oil and focus on hydroelectric power generation leads to a gradual decline in the use of coal for energy generation. Renewable hydroelectric power generation leads to the formation of the Niger Dam Authority (NDA); tasked with the generation of power from hydroelectric sources. Later in the same era, the Nigerian Government Electricity Undertaking Energies (NGEU) was set up in 1946 to pave the way for a future corporation and direct all policies as it regards electricity generation and supply. Also in the same era, The Electricity Corporation of Nigeria (ECN) was created in 1950, charged with the responsibility to plan the development of Nigeria's electrical energy potential in a manner as to provide the cheapest form of energy consistent with continuity of supply. This Era sees several military coups and countercoups that later gives all policies and decision-making to military heads (George et. al. 2012). The military head distributed energy policies to various establishments that include; Niger Dams Authority (NDA) established to develop Nigeria's hydropower potential; National Electric Power Authority (NEPA) established in 1972 to cater for electrical production and supply policies; Nigerian National Petroleum Corporation (NNPC) established in 1977 to participate and regulate Nigeria's petroleum industry; Energy Commission of Nigeria (ECN) established to strategically plan and coordinate Nigeria's national policies on energy.

The Information (microprocessor) era of the early 2000s onwards features democratic and civilian institutions (Stakeholders) (Mitchell 2011) and some of the previous military establishments involved in decision-making and policy processes. Key institutions added include Nigerian Electricity Regulatory Commission (NERC), established in 2007 as a regulatory body for the Nigerian power industry. In 2005, The Power Holding Company of Nigeria (PHCN) was established as a holding company, owning the various divisions responsible for the generation, transmission, and distribution of electrical energy (Edomah et al. 2016). The various division of the power holdings was later privatized leading to various distribution companies (DISCOs), Transmission Companies of Nigeria (TCN), and the abolishment of the PHCN whose activities and responsibilities now belong to the NERC. Then there is the Federal Ministry of Power (FMP), tasked to initiate, formulate, coordinate, and implement broad policies and programs that will promote the development of electricity generation. FMP has other agencies directly under it with various and overlapping roles in the energy market, they include the Rural Electrification Agency of Nigeria (REA), Electricity Management Services Limited (EMSL) of Nigeria, National Power Training Institute of Nigeria (NAPTIN). Other public stakeholders and policymakers in the energy market include the Federal Ministry of Environment (FMENV) established in 1999, with one of its departments, the Department of Climate Change that follows the objective to foster renewable energy and energy efficiency (GIZ/NESP/FMP, 2015).

The Renewable and Conventional Energy Technology Department of the Federal Ministry of Science and Technology (FMST) is responsible for energy issues in the FMST. The focus lies on nuclear, renewable, and alternative energy sources as well as energy efficiency. FMST also oversees the Energy Commission of Nigeria and the National Agency for Science and Engineering Infrastructure (GIZ/NESP/FMP, 2015).

At the Federal Ministry of Water Resources (FMWR), there is the Department of Dams and Reservoir Operations managing hydropower projects, while the FMWR handles civil works and issues water licenses, the Ministry of Power oversees the power generation aspects of the projects (GIZ/NESP/FMP, 2015). Each of these Ministries is headed by a political appointee (Minister/s) appointed by the ruling government. Other big players in the energy policy-making boat are the Nigerian Bulk Electricity Trading Plc (NBET), the Presidential Task Force on Power (PTFP), and the Nigerian Governor's Forum (NGF) (GIZ/NESP/FMP, 2015).

The dynamic and complexities surrounding the evolution of energy systems led to having many stakeholders employing different policies and lobbying mechanisms to make their perspectives prioritized and then adopted (Edomah et al. 2016). Likewise, (Ugwoke et al. 2020; Edomah et al. 2021) hold the view that there is no consensus standardized framework to harmonize the already available strategies and this lack of coordination and cohesiveness among stakeholder groups pose a challenge to effective electricity infrastructure interventions that address the needs of people in society.

2.8. NIGERIA'S ENERGY CHALLENGES: AN OPPORTUNITY FOR BIOGAS

Nigeria whose main source of energy is largely the hydro-electric plants, thermal plants, and petrochemicals, is facing energy challenges in severe electricity shortage with more than 60% of the country's population having little or no access to national power supply causing its citizen, industries, and businesses to rely on off-grid electricity supply through various means. Due to its insufficient refining capacity also, the country relies heavily on imported petroleum products despite being a major player in the oil sector in Africa (Akinbomi et al., 2014). The reliance has led to instability in its economy and brought about constant hardship and declination of the standard of living of the citizens as such that the country was tagged World center of poverty. The increase in poverty has pushed several citizens back to the era of wood burning (as an energy source) for cooking, leading to a diminishing of forest reserves.

Another challenge facing Nigeria is in waste management. Due to its high population of over 200 million citizens with an average annual growth rate of 2.6% (World Bank, 2020), huge amounts of waste are generated daily without an effective and efficient management system.

The two aforementioned challenges are a crucial part of biogas technology, which is used to generate energy from biological and agricultural waste. Despite the potential of biogas technology and its theoretical solution to Nigeria's energy and waste challenge, it is not yet completely accepted in the country (Akinbomi et al. 2014).

In an attempt to streamline barriers affecting the wider implementation of biogas as a source of energy in developing countries like Nigeria, a recent systematic literature review conducted by (Nevzorova and Kutcherov 2019) concluded that *Technological barriers* (Infrastructural challenges and lack of technical training and knowledge), *Economic barriers* (insufficient credit schemes and other financial support), *Institutional barriers* (lack of political support and specific programs to promote biogas technologies, and *Socio-cultural barriers* (Lack of public participation, and Cultural and religious outlook) are the major challenges affecting the deployment of biogas as a source of energy.

In the same vein, (Roopnarain and Adeleke 2017) discovered that lack of skills, lack of government commitment, a lack of skills, ineffective waste management system, limited awareness of the technology and its associated benefits, and the discontinuation and failure of previous projects hampered the progress and adaptation of biogas technology in Nigeria.

Biogas is not only one of the most efficient and effective renewable energy possibilities available but also requires less capital investment as compared to other renewable sources like hydropower, solar power, and wind power (Rao et al., 2010). In theory, any type of biomass can be degraded to biogas (Bond et al., 2011), as it has a wide range of sources: manure, straw, municipal waste, microalgae (Andriamanohiarisoamanana et al., 2018; Rahman et al., 2018; Taherdanak et al., 2014; You et al., 2014; Alkanok et al., 2014 Scano et al., 2014; Bohutskyi et al., 2014; Miao et al., 2014) and many more (Mingxue et al., 2019). Renewability and a wide range of sources gave it advantages over many other energy sources.

2.9. BIOGAS POTENTIAL IN NIGERIA

Despite the potential of biogas in African countries and the demonstration by several programs of the viability of biogas technology, the technology is not being well spread and large-scale application has not been successfully implemented (Patinvoh et al., 2019). Estimates for biogas potential in Nigeria by Aliyu et al., (2015) is 6.8 million cubic meters per day from animal manure and 913,440 tons of methane from municipal solid wastes, equivalent to 482 MW of electricity (Suberu et al., 2013).

Giwa et al., 2017 estimated that Nigeria has the potential to produce an estimated 47.97 million tonnes of oil equivalent (MTOE) annually from biomass resources. Likewise, 17, 459 billion MJ/day of solar energy is incident on the total surface of Nigeria. The biomass resources which can be tapped for renewable energy production in Nigeria include Jatropha with high oil contents, sweet sorghum, and molasses; food crops such as cassava, rice, coconut, cashew, millet, rice, oil palm, maize, and yam; agricultural residues and wastes from food crops such as cassava peels, cassava liquid sludge, mango peel, mango seed kernel, rice husks (RH), corn residues, oil palm derivatives, sugar cane straw, and bagasse; forest resources; municipal solid wastes; and animal wastes. These resources can be exploited to produce biogas, bioethanol, biodiesel, briquettes, and organic fertilizers through anaerobic digestion, transesterification, gasification, pyrolysis, and briquetting. Nigeria's Federal Institute of Industrial Research in 2017 puts the country's post-harvest losses at 9 billion USD with the quantity of crop loss placed at about 51.3 metric tonnes with huge amounts recorded in the rural communities. The Food and Agriculture Organization in its fact sheet after a survey on the six geo-political zones of the country also confirms the estimated value of post-harvest losses in Nigeria (Okoro et al., 2020).

Agricultural crop waste, a potential source of biogas energy, is a hugely available resource in Nigeria as almost every occupant of the rural region of the country practices farming and mainly with inadequate storage facilities to reduce losses (Akinbomi et al., 2014). One-quarter of expected farm outputs are lost to post-harvest activities which pose a concern to the rural area where this waste is generated (Bolarin et al., 2015). These losses can be minimized through their usage in the generation of energy. About 70% of the residues generated through harvesting and processing are often used for other purposes such as soil mulch, building materials, and feed (Jibrin et al., 2013). Crop residues from cassava and yam peels, cowpea husk, maize, millet and sorghum stovers, among others, are significant contributors to animal feed, hence the number of available residues that can be converted to biogas production can be said to have been reduced. Taking into account these diversions in the use of crop residues, the amount available for biogas production was estimated at approximately 52 million tonnes, of which 21 billion cubic meters of methane gas could be generated at 35 ^{o}C (Akinbomi et al., 2014)

Another source of raw material for biogas technology is the abattoir and animal waste which is also hugely generated in Nigeria as a result of the high production of livestock in the northern part of the country and the tremendous consumption of the southern part of the country. The abattoir waste largely includes animal blood, waste tissue, fats, bones, and intestinal content. Akinbomi et al., 2014 also estimated about 0.83 million tonnes of these wastes produced can be harnessed to produce about 0.34 billion cubic methane gas using the biogas technology. Like agricultural waste, animal waste is a by-product of animal husbandry and about 227,500 tons of fresh animal waste are generated per day (Ishola et al. 2013; Okeh et al. 2014). Animal waste represents 61 million tons of Nigeria's energy reserves annually (Mohammed et al. 2013).

Municipal solid waste is another crucial raw material for biogas technology. The quantity and composition of these raw materials in any region largely depends on several factors that include the socio-cultural differences of the people of the region, the standard of living, consumption patterns, and level of exposure and development of the region. Urban Nigeria generates about 0.44 - 0.66kg/capita/day of waste (Ogwueleka, 2009). Akinbomi et al., 2014, further estimated that approximately 37 million tonnes of organic municipal solid waste residues could be available for biogas production and approximately 13 billion cubic meters of methane gas.

Black and grey water that is largely a faction of human waste can also be fed into digesters for energy production. Most of these wastes are stored in septic tanks that collect and transmit the waste into a soak-away pit. These wastes (sludge) rarely have uses other than disposal into water bodies, landfills, agricultural use, and incineration, all of which incurs larger costs (Wang et al., 2017). With a focus on black water which is highly fecal, and sourced from every individual in the country, energy can be generated and produced through subjecting the waste to anaerobic digestion.

Okoro et al., (2020) concluded that Nigeria has a massive potential of producing biogas from different agricultural and animal waste across the different states, highlighting the potentials of each state. Notable among the states are numerous southern states including Delta, Ogun, Oyo, Kogi, among others, and some northern states that include, Benue, Niger, Kaduna. The agricultural waste includes waste from millet, sorghum, maize, yam, and largely cassava. The potentials are expected to rise in coming years due to an increase in waste generation, driven mainly by income growth, migration, urbanization, and geometrically increasing population.

2.10. BIOGAS COMPANIES AND PLANTS IN NIGERIA

As early as 1980, biogas was tested in Nigeria; a simple configuration of a digester was built in Sokoto State, at Usman Danfodiyo University. Since then, several pilot plants were tested across the country (Roopnarain and Adeleke 2017). Some of the locations of the plants are Zaria Prison in Kaduna, Ojokoro in Ijaiye, Lagos and Mayflower School, Ikene, Ogun state, all with digester capacities ranging from $10m^3$ to $20m^3$ (Akinbomi et al., 2014). Additionally, there are quite a few private biogas producing companies in the country; some of them include Avenam Links Intl Ltd., a renewable energy company incorporated to introduce affordable biogas digester and generator technology; Clarke Energy, a multinational specialist in engineering, installation and maintenance that utilizes liquid and solid waste from the distillation industry to generate biogas; and Chamraq biogas Nigeria, located in Minna, Niger state of the country. However, biogas is yet to be commercialized in Nigeria, and most plants are either non-operational or still at the research stage (Akinbomi et al. 2014). Although pilot schemes have been established, biogas as a technology is yet to be accepted by the general population (Roopnarain and Adeleke, 2017).

3. AIM OF THE THESIS

This study aimed to investigate, review, and provide insight on the state of biogas technology in Nigeria with specific attention to the challenges affecting the commercialization of biogas and proffer possible solutions to mitigate the challenges.

3.1. THE SPECIFIC OBJECTIVES

The specific objectives include:

1. Determine respondents' level of awareness of biogas technology and its existence within the region.
2. Assess respondent's perception of biogas; adoption and how accessible it is compared to other sources of energy.
3. Investigate the role of socio-economic factors, demographic factors, and cultural beliefs on the commercialization of biogas technology.
4. Assess the approaches used by biogas producing companies and the challenges faced in commercialization.
5. Assess the opportunities available for increasing the adoption of biogas technology within the study area.

3.2. HYPOTHESIS SET TO ACHIEVE THE OBJECTIVE

Research question 1: Is there any renewable energy source that may be preventing the adoption and commercialization of biogas technology?

Ho1: Current boom in the production of solar panels and solar energy production is providing the needed energy for the end-users

Ha1: People largely depend on energy produced by the government and as such are still energy-deficient

Research Question 2: What is the most important limiting factor in biogas adoption and commercialization in the study area?

Ho2: Socio-economic factor (gender) affects biogas adoption and commercialization the most

Ha2: There are other factors affecting the commercialization of biogas in the study area

Research Question 3: What are the major challenges that affect the accessibility to biogas feedstock/raw materials?

Ho3: Socio-cultural beliefs of the people won't allow them to utilize waste in any way, even for energy production

Ha3: Unavailability of raw materials in sufficient amount is the reason for the low adoption and commercialization rate

Research Question 4: What are the leading factors affecting biogas production?

Ho4: Government support and policies play a major role in biogas production and commercialization in Nigeria

Ha4: There are other leading factors building up in the low adoption and commercialization of biogas in Nigeria

4. MATERIAL AND METHODS

4.1. STUDY AREA DESCRIPTION

Nigeria is a democratic country located on the western coast of Africa, with diverse geography and climates, ranging from arid to humid equatorial. (*Nigeria Case-Study-A Rapidly Developing NEE (Newly Emerging Economy)* n.d.) Nigeria is bordered to the north by Niger, to the east by Chad and Cameroon, to the south by the Gulf of Guinea approximately 800 kilometers to the Atlantic Ocean, and the west by the Benin Republic. The country is not only large with a land area of 923,770 square kilometers (larger than the U.S. state of Texas) but also Africa's most populous country (About Nigeria 2021). (Okoli et al. 2020). Nigeria's 2020 population is estimated at 206,139,589 people at midyear according to the United Nation data, and the population density is 226km^2 (586 people per mi^2). According to The World Bank, approximately two-thirds of Nigeria's population live in rural areas (defined by the NPC as single geographic settings or communities with a population of fewer than 20,000 people).

Nigeria is a democratic country consisting of 36 states and the Federal Capital Territory. The states and the FCT are organized for political administration and are further divided into 774 Local Government Areas. The states have also been grouped, based on geographical proximity, ethnic homogeneity, and/or other political considerations, into six geopolitical zones – North-East, North-West, North-Central, South-West, South-East, and South-South (Okoli et al. 2020). It is interesting to note that these zones have not been entirely carved out based on geopolitical location, but rather states with similar cultures, ethnic groups, and common history were classified in the same zone. This explains the reason why regions in Nigeria are geopolitical, as well as evidence of different backgrounds, unique features, and unequal human development levels; this has been proven by several researchers (Ukiwo 2007; Okoli et al. 2020; Ighalo et al. 2021) that evaluated the level of disparities within the country across the various scope.

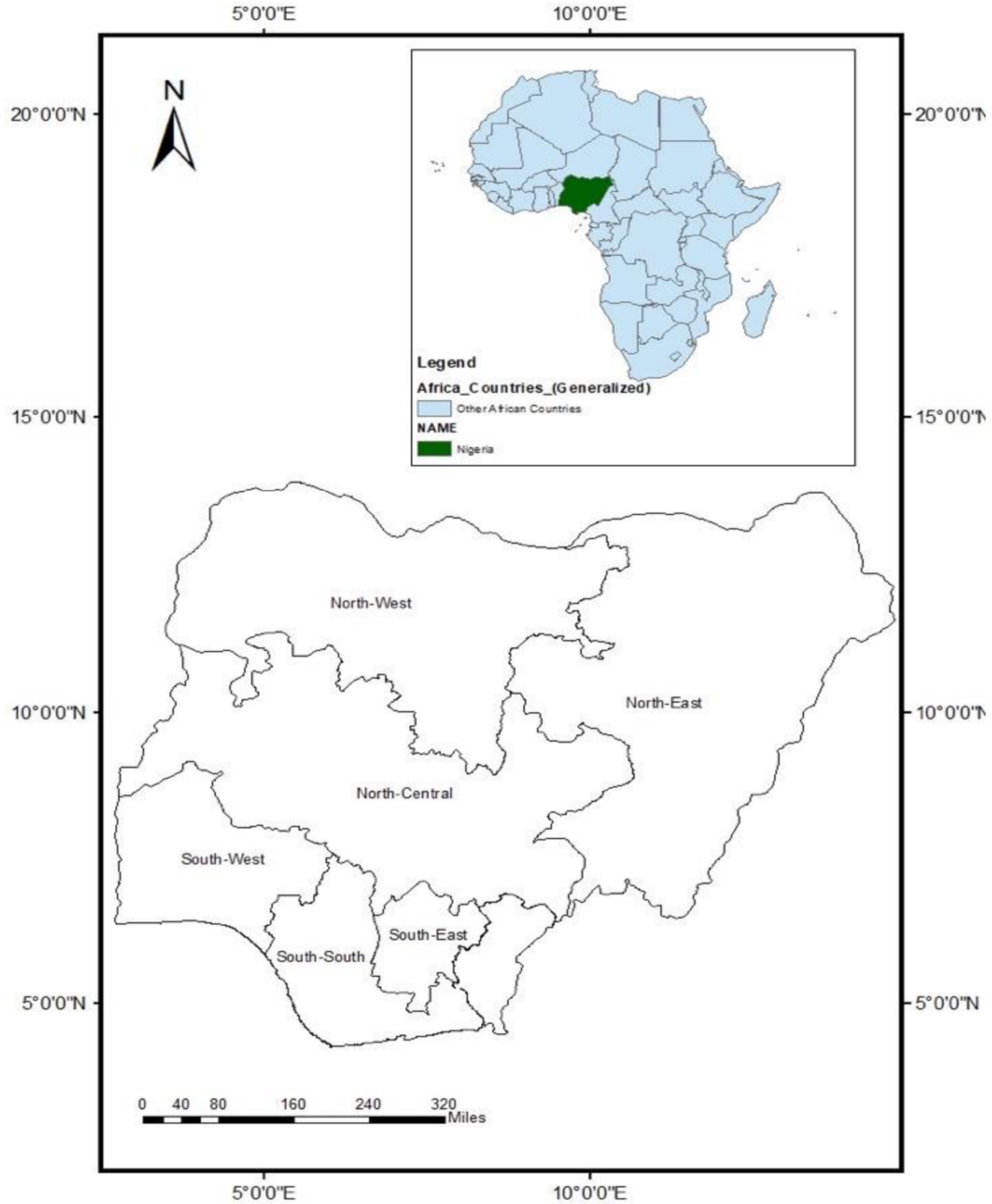

Fig 2: Map of Nigeria showing the Geopolitical zones

4.2. RESEARCH DESIGN

In research conducted by Kui-Wai Li (2017) the term commercialization was defined as a situation where technology has been transformed into household products consumed by individuals. From this definition, it can be agreed that the level of acceptance or/and adoption of technology can be used as a variable to measure commercialization. Similarly, (Kemausuor et al. 2018) made it known that a few factors set by energy-producing companies affect its adoption.

In view of this, to actualize the set objectives of this research, it is crucial to identify challenges affecting biogas commercialization via acceptance or adaptation purview- retailers / marketers and consumers perspectives.

Based on this, descriptive research will be employed. Descriptive research is a well-recognized approach employed to identify relationships or conditions that exist, attitudes held by people, and practices that prevail (Wachera 2014). This research was in nature of descriptive research, and it applied the utilization of survey method to actualize the aim of the research by obtaining data in the following format:

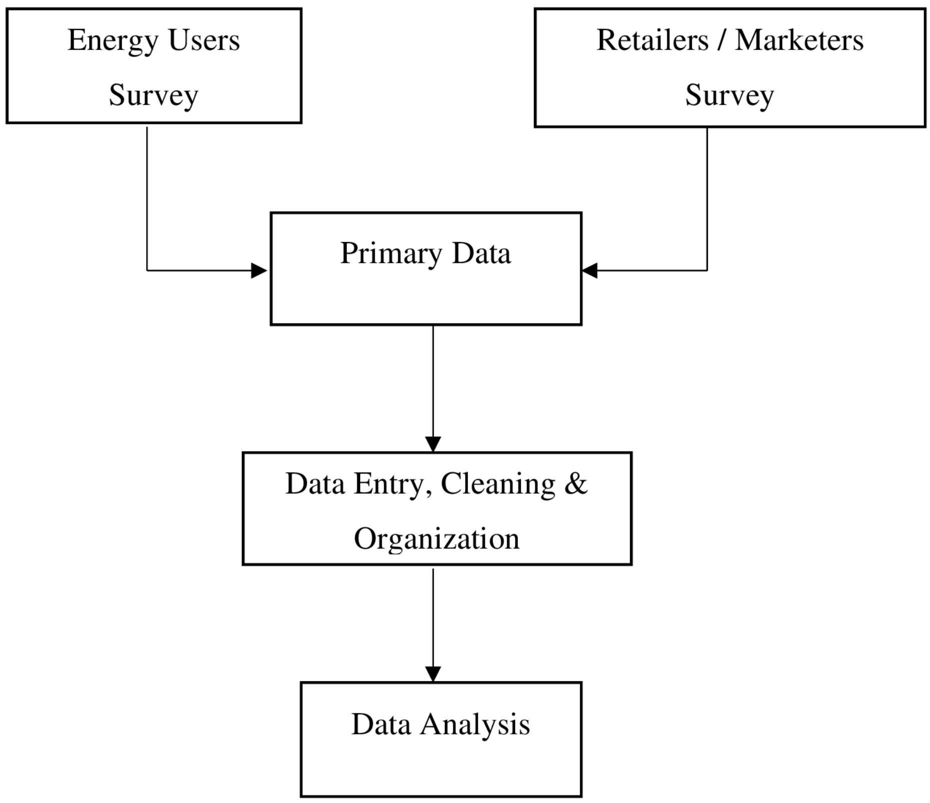

Figure 3: Research Plan

Methods of the presented thesis include data analysis from primary sources. Primary data were collected via semi-structured questionnaires among energy retailers/marketers and energy users. Collected data were converted to Microsoft Office Excel program mainly for qualitative analysis. All gathered data were also coded and processed with the help of the Statistical Package for Social Sciences (SPSS) and binary logistic regression (Logit) for quantitative analysis.

4.3. DATA COLLECTION

Before commencing data collection, two different types of semi-structured questionnaires were designed to obtain information from energy retailers/marketers and energy users across Nigeria. The questionnaires were self-constructed based on the study objectives and the hypothesis questions.

The first type of questionnaire (Appendix 1) targeting energy users was designed in a Google format and was distributed via majorly used social media in Nigeria. In some situations, incentives were given to encourage participants. A total of 238 response was received within 2 months.

The second type of questionnaire (Appendix 2) was designed and administered to energy retailers / marketers across the country by 8 different Enumerators. Prior to the visit to the energy retailers/marketers, training explaining the objective of the research was given to all the Enumerators. The explanation and interpretation of the questionnaires were made in local languages by the enumerators to respondents who lack knowledge of English, and a total of 35 questionnaires were administered in 2 months.

The questionnaire guides were designed in a way that included open and closed questions to capture data on the approaches used by energy-producing companies, problems encountered in production and marketing, the effect of socio-economic factors, cultural factors, availability, and cost of other energy sources on the commercialization of biogas. Semi-structured interview guides had open-ended questions to enable the participants to provide information that might have eluded the close-ended questions, while also collating advice on how best to mitigate challenges affecting biogas commercialization across the two different perspectives targeted.

4.4 SAMPLING TECHNIQUES

The main study respondents in this thesis were energy users and energy retailers / marketers throughout the country. The study obtained 238 responses from energy users and 35 responses from energy retailers / marketers throughout the country. These were sampled using simple random, purposive, and convenience sampling techniques to obtain effective data from the targeted population.

Criteria were established for the selection of the respondents, and these included:

i. Voluntary participation.
ii. Ownership of the energy-producing company or the license of a marketing company.

4.5 DATA ANALYSIS

Primary data collected from the selected participants were cleaned up for errors and blank spaces. The responses obtained from the Google form were exported to excel and further imported into SPSS (Statistical Package for Social Sciences) version 23. Each of the responses was assigned values (e.g male = 1, female = 2, prefer not to say = 3) and analyzed using a variety of approaches that include descriptive statistic; cross-tabulation, frequency and percentage tables and inferential statistics; correlation and binary logistic regression.

The Socioeconomic aspect of both questionnaires (Household and Energy retailers) are qualitative and nominal categorical data that are assigned values. These values do not exhibit quantitative characteristics and as such, arithmetic operations cannot be performed on them. Therefore, the mean (and standard deviation) are inappropriate (Jamieson, 2004). Descriptive statistics were then used to summarize the data with information providing, the mode, frequency and percentage.

The Energy demand and source section of the questionnaire that attends to the research question were present as a nominal categorical data and on a 4-point Likert scale, hence descriptive statistics were then used to summarize the data with information providing modal, frequency and percentage. This provides the answers to questions that include:

- What energy source is the most frequently used and less frequently used?

- How satisfied are the respondents with the supply of different energy sources and what are the reasons for dissatisfaction?
- What is the cost spent on energy per month and how many hours of energy do they have access to?

Research question 2 and its subsequent hypothesis were answered using the Binary logistic regression analysis. The binary logistic regression (Logit) test is used for test of effect of independent variables on a categorical variable. The result, if significant will mean adoption of the null hypothesis of research question two and mean otherwise if result is statistically insignificant. The willingness to use biogas, a dependent dichotomous categorical variable (Yes = 1, No + maybe = 0), was tested against socio-economic factors, independent categorical variable.

Research question 3 and 4 are based on 5-point Likert scale responses. The Likert based questions are ordinal from strongly disagree to strongly agree, hence, they are qualitative. Descriptive statistics using modal, frequency, percentage, and charts, which are the most suitable for easy interpretation (McLeod, 2019) are sufficient to answer the research questions. Hence, a Cronbach alpha test was used to check the reliability of the questions to answer each barrier and suggestions for commercialization of biogas.

Regarding the perspectives of energy retailers / marketers on challenges affecting biogas commercialization, field data (collected using questionnaires) were directly coded into the SPSS package by assigning values to each of the responses. The responses were also on a Likert scale (Appendix 2), hence, the analysis using descriptive statistics of the responses presented in tables containing modal values, frequencies, cross-tabulation, percentage and figures are the most appropriate.

4.6 LIMITATION OF THE STUDY

The study was limited by relatively small sample size as the purposive sampling approach was used.

At the commencement of data collection (Retailers / Marketers data), activities within the country were crippled by fuel scarcity, this made it difficult for Enumerators to cover much ground, and energy retailers / marketers were also finding it difficult to engage enumerators, as they were at the forefront of the crises.

Covid-19 pandemic and insurgency in the Northern part of the country also limited data collection across the region.

5. RESULTS AND DISCUSSION

This chapter presents the study results based on research objectives, starting with the socio-economic information, the source and use of energy, and the awareness of biogas technology. In addition, it presents challenges faced in the adoption of biogas technology and commercialization opportunities (ways to mitigate identified challenges). On the basis of the information contained in the results, discussions were also made in this chapter. 238 household respondents were surveyed and analyzed while 35 energy retailers / marketers were also surveyed for their opinions on the challenges and solution to the commercialization of biogas in Nigeria. The results are presented alternatively, with households responses first and energy retailers next for each objective.

5.1 HOUSEHOLD /ENERGY USERS PERSPECTIVES

5.1.1. SOCIO-ECONOMIC INFORMATION OF ENERGY USERS

From Figure 4, the results show that the study population is essentially respondents from the Southwest with about 69%. The most significant share of the region was of respondents from Lagos state (51.22%), with the least respondents from the Northeast covering approximately 4%.

The large population of the respondents being from the Southwest and Lagos can be attributed to high population of the state and rapid urbanization within the region. Hence, the high energy demand from the region, this stand is also maintained by Popoola and Adeleye, 2020. With Lagos occupying about 10% of Nigeria's population (including people living or working in the state), a high population of the respondents from the state and region can be a true representative for this study.

Table 1 below establishes the gender, age, and type of settlement. Only 39.5 % of the 238 respondents sampled were female, while 59.66% were male. The cultural norm in Nigeria dictates male to be the head of any family, this was also evident from the study population as the gender takes a larger share of the respondents. The low number of female responders can be attributed to the scenario that plays out in Nigeria where men are decision-makers on family resources, including energy usage, payment, and decision making. This finding is consistent with that of National Policy on Population for Sustainable Development (NPP, 2021) that made it known that in Nigeria, men are regarded as the head of households, and they dominate decision-making bodies.

The most significant percentage of the population (62.39%) is within 26-40. Nigeria's age distribution categorizes youth to be of age 18-29 (FMYSD, 2019), this age bracket covers two categories of the age classification of the respondents. The larger percentage of the respondents falling within this bracket also denotes the working force of the nation that to a more considerable extent, relies on energy availability for their day-to-day activities. These results reflect those of NPP (2021) report that also showed that 70% of Nigeria population is under the age of 30, and the large proportion of the population is youth. This implies that data acquired from this category of respondents can actually be a true representative of the scenario playing out in the country.

Furthermore, 83.76% of the respondents in this study claimed to be living in the urban settlement. An implication of this is the possibility that most of the population are drawn towards the urban center because of social and infrastructure influence. This agrees with Linard et al., 2012 assertion that majority of Africans live in urban centers on less than 21% of the continents' landmass, and also corroborate NPP (2021) report that made it known that about half of Nigeria population (51.16) live in urban areas, and there is an high level of rural to urban migration dominated by the young working age population.

Table 1: Sociodemographic status of the respondents

Characteristics		Frequency	Percentage
Gender	Male	142	59.66
	Female	94	39.50
	Prefer not to say	2	0.01
Total		238	100%
Age Bracket	18 – 25	86	36.75
	26 – 40	146	62.39
	Over 40	6	0.03
	Prefer not to say	2	0.01
Total		238	100%
Settlement Type	Rural	42	17.95
	Urban	196	83.76
Total		238	100%

Source: Author

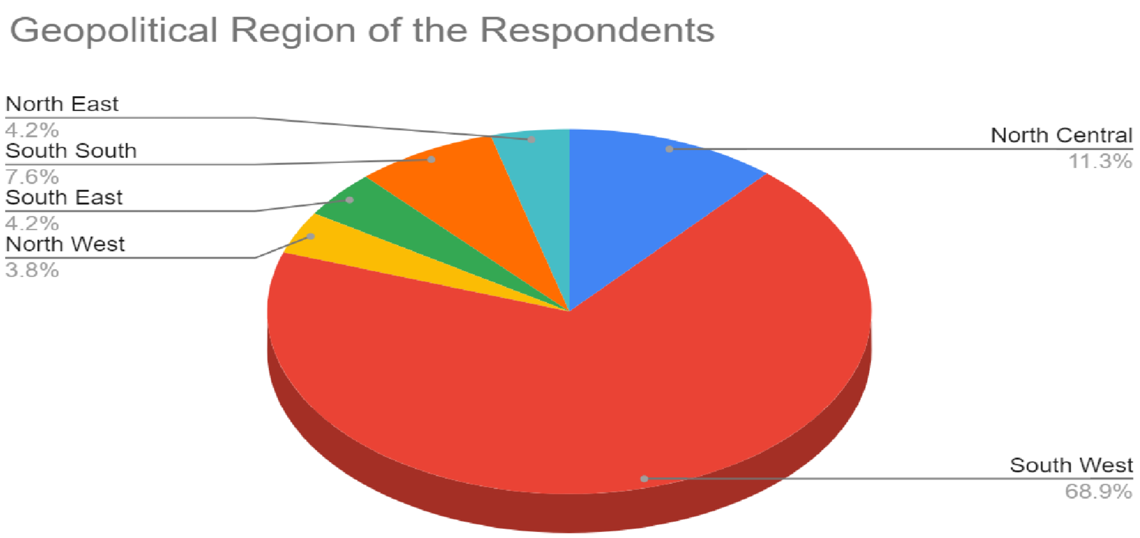

Figure 4 Geopolitical region of the respondents (n=238)

Table 2 below shows the level of education, access to the media, the size of the household and household income of the respondents. The level of education has been significantly linked to technology adoption in previous studies (Mengistu et al. 2016, Kabir et al., 2013, Mwirigi et al., 2009 and Mwakaje, 2008) since people with higher levels of education are expected to be open to innovations. The study population is highly constituted of graduates (n=146, 61.34%), with postgraduates being 38 out of the 238 sampled population. Undergraduates accounted for

19.7% of the population. Secondary school holders were the least of the respondents, with 0.03% of the total population. The level of education of the respondents implies high levels of modern technology.

The analysis of the household survey revealed that the majority of respondents (n=139) belong to a household of 3 - 5 individuals, while households with 10 and more individuals are the least of the respondents. The other household size represented in the survey includes 6-9 sized households with 23.5% and 1-2 size households with 14.3% of the sampled population.

An inquiry into the income of the respondents also showed that most of them earn above N101,000 monthly, a value that is triple the country's minimum wage. The lowest frequency household income classes are households earning less than N20,000 per month (n=19). These findings may help us understand the financial capability when considering how finance/income affects adoption of biogas technology.

The means of livelihood of the respondents are characterized by unemployed respondents with 40.76% of the respondents, self-employed (25.21%) and employed (34.03%). The high unemployment rate exceeds the values of 2021 cited by Adenomon and Folorunsho (2021) by about 5%. This value is an indication that there is an opportunity for biogas investors to enter the energy market through training of this unemployed personnel on installation, repair or maintenance of biogas plants.

An inquiry into the various access to media by the respondents revealed that most of the respondents have access to all enlisted media sources (Radio, Print Media, Television/Digital TV, Smartphone/Internet) and all of the respondents have access to one or more of the media sources. This indicates the promising opportunities of information dissemination across the country as almost all of the respondents have access to one or more of the media platform.

Table 2: Respondents' education level, household size, monthly income, and access to media

Sociodemographic Factors		Frequency	Percentage
Highest level of education	Graduate	146	61.3
	Postgraduate	38	16.0
	Secondary School	7	2.9
	Undergraduate	47	19.7
	Total	238	100.0
household size	1-2	34	14.3
	10 and above	9	3.8
	3-5	139	58.4
	6-9	56	23.5
	Total	238	100.0
monthly income of your household	101,000 and above	96	40.3
	Below N20,000	19	8.0
	N20,000 to N50,000	66	27.7
	N50,000 to N100,000	57	23.9
	Total	238	100.0
Access to media	All	133	55.9
	Print Media, Smartphone/Internet	1	0.4
	Print Media, Television/Digital TV, Smartphone/Internet	3	1.3
	Radio	2	0.8
	Radio, All	2	0.8
	Radio, Print Media, Television/Digital TV, Smartphone/Internet	2	0.8
	Radio, Print Media, Television/Digital TV, Smartphone/Internet, All	18	7.6
	Radio, Smartphone/Internet	3	1.3
	Radio, Television/Digital TV, Smartphone/Internet	11	4.6
	Smartphone/Internet	43	18.1
	Smartphone/Internet, All	2	0.8
	Television/Digital TV	4	1.7
	Television/Digital TV, Smartphone/Internet	14	5.9
	Total	238	100.0

Source: Author

5.1.2 SOURCE OF ENERGY AND USAGE

Various sources of energy including wood fuel/charcoal, liquefied petroleum gas, biogas, electricity, paraffin/kerosene, renewable energy, i.e., solar, wind, and hydropower, were tested among the respondents to reveal which energy source is the most widely used and how much of the energy sources are demanded by the respondents (Table 3).

Most of the respondents utilize liquefied petroleum gas and electricity daily (78.57% and 73.53% respectively). 23% and 32% of the respondents also use electricity monthly and weekly. 8% of the respondents claimed to have never used electricity. 20% and 21% of the respondents use liquefied petroleum gas monthly and weekly. The high utilization of liquefied petroleum gas seems to be consistent with Akinbomi et al. (2014) finding which showed that Nigeria economy heavily rely on fossil fuel. In the same vein, the finding further corroborates Owebor et al. (2021) statement regarding electricity being among the most demanded energy in Nigeria. A possible explanation for the high percentage of daily electricity and liquefied petroleum gas can be attributed to the majority of the respondents who occupy urban settlements.

Biogas sees the second lowest daily usage with 15.55% of the respondents, while 49% of the respondents claim to have never utilized the resource, the highest number of respondents who never used the resources (Figure 5) can be linked to the low popularity of the technology in Nigeria; a point highlighted by Akinbomi et al. (2014). Renewable energy sources are generally on the low in Nigeria as majority of the citizen depend on power supply by the government.

In light of this, there is a need to harness renewable energy sources as the country is blessed with abundant renewable energy sources (Oyedepo, 2012) these will build a new energy future for Nigeria. In this regard, the government has a responsibility to make renewable energy available and affordable to all.

Table (3) Respondents' energy sources and usage

Energy	Daily	Monthly	Never	Weekly
Wood	40 (16.8%)	29 (12.2%)	89 (37.4)	80(33.6)
Liquified Petroleum Gas	187 (78.6%)	20 (8.4%)	10 (4.2%)	21 (8.8%)
Biogas	37.0 (15.5%)	23.0 (9.7%)	117.0 (49.2%)	61.0 (25.6%)
Electricity	175.0 (73.5%)	23.0 (9.7%)	8.0 (3.4%)	32.0 (13.4%)
Paraffin/Kerosene	33 (13.9%)	45 (18.9%)	90 (37.8%)	70 (29.4%)
Solar/Wind/Hydroelectric	61.0 (25.6%)	18.0 (7.6%)	98.0 (41.2%)	61.0 (25.6%)

Source: Author

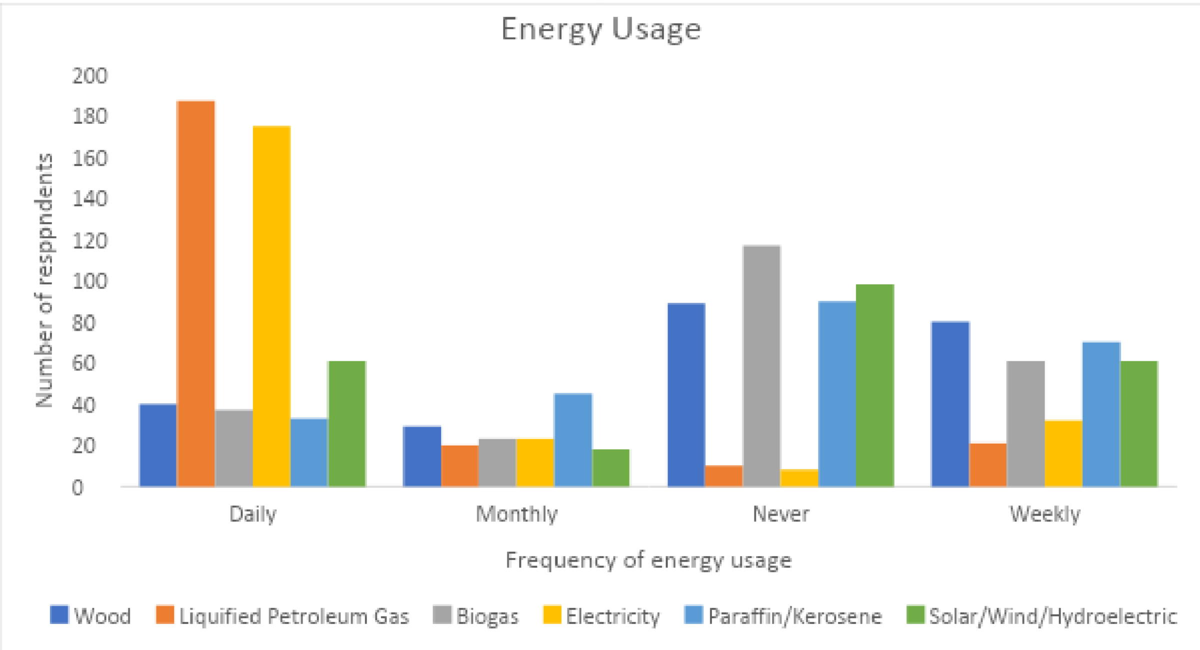

Figure 5: Energy usage of the respondents

The satisfaction of consumers with the energy available was also tested and analyzed. The result presented in the table below revealed that more than 70% of the respondents are not satisfied with the supply of wood fuel charcoal. A more significant percent (30.7%) of them consider it unreliable. Most of the respondents (n=134, 56.3%) are satisfied with the supply of liquefied petroleum gas. However, about 25% of the respondents consider it expensive.

About 79% of the respondents indicated that they are not satisfied with the supply of biogas, and only 21% consider its supply efficient. Despite the large percentage of respondents accessing electricity daily, only 31% of respondents are satisfied with its supply. In comparison, about half (49.2%) of the respondents find it unreliable, and 12% find it expensive. The supply of Paraffin/Kerosene is also considered inefficient by most respondents, with about 28.2% of them citing unreliable as the reason.

Most of the respondents considered the supply of renewable energy sources unsatisfactory. The few responses satisfied with the energy source supply can be the result of the recent increase in advertisements, sales, and adoption of solar panels and batteries in the country.

The result above translates to majority of household being dissatisfied with their sources of energy and would be open to innovations or technologies that can satisfy the household's energy demands. The challenges and low adoption rate of renewable energy sources in the country was attributed to decade-old renewable master plan of the country by Okonkwo et al., 2021.

Table 4: Respondents' level of satisfaction with available energy

Energy Source		**Frequency**	**Percent**
[Wood fuel/Charcoal]	No (Others specify)	57	23.9
	No, Its expensive	5	2.1
	No, its Inefficient	31	13.0
	No, its Unreliable	73	30.7
	Yes	72	30.3
	Total	238	100.0
[Liquified Petroleum Gas (Cooking gas)]	No (Others specify)	8	3.4
	No, Its expensive	59	24.8
	No, its Inefficient	2	0.8
	No, its Unreliable	35	14.7
	Yes	134	56.3
	Total	238	100.0
[Biogas]	No (Others specify)	78	32.8
	No, Its expensive	31	13.0
	No, its Inefficient	13	5.5
	No, its Unreliable	65	27.3
	Yes	51	21.4

	Total	238	100.0
[Electricity]	No (Others specify)	8	3.4
	No, Its expensive	29	12.2
	No, its Inefficient	8	3.4
	No, its Unreliable	117	49.2
	Yes	76	31.9
	Total	238	100.0
[Paraffin/Kerosene]	No (Others specify)	62	26.1
	No, Its expensive	13	5.5
	No, its Inefficient	36	15.1
	No, its Unreliable	67	28.2
	Yes	60	25.2
	Total	238	100.0
[Solar/Wind/Hydroelectric]	No (Others specify)	64	26.9
	No, Its expensive	35	14.7
	No, its Inefficient	7	2.9
	No, its Unreliable	63	26.5
	Yes	69	29.0
	Total	238	100.0

Source: Author

Although most of the respondents pay well over 2000 Naira / 5 USD (one-fifteenth of the minimum wage) on energy per month (Figure 6), a more significant percentage of the study population (n=104, 43.7%) enjoy between 2 and 6 hours of energy per day, while only about 16% access more than 12 hours of energy daily (Table 5). This situation also highlights the epileptic power supply in the country. The inefficacy in accessing energy is not limited to supply, as most of the respondents (n=133, 55.9%) attribute the inefficacy to the cost of energy. 35% of the study population also believes availability is a significant challenge in accessing energy. Nigeria's dependency on electricity as the most significant means of energy informed the result given above, as other energy sources, e.g LPG for cooking may not have been accounted for.

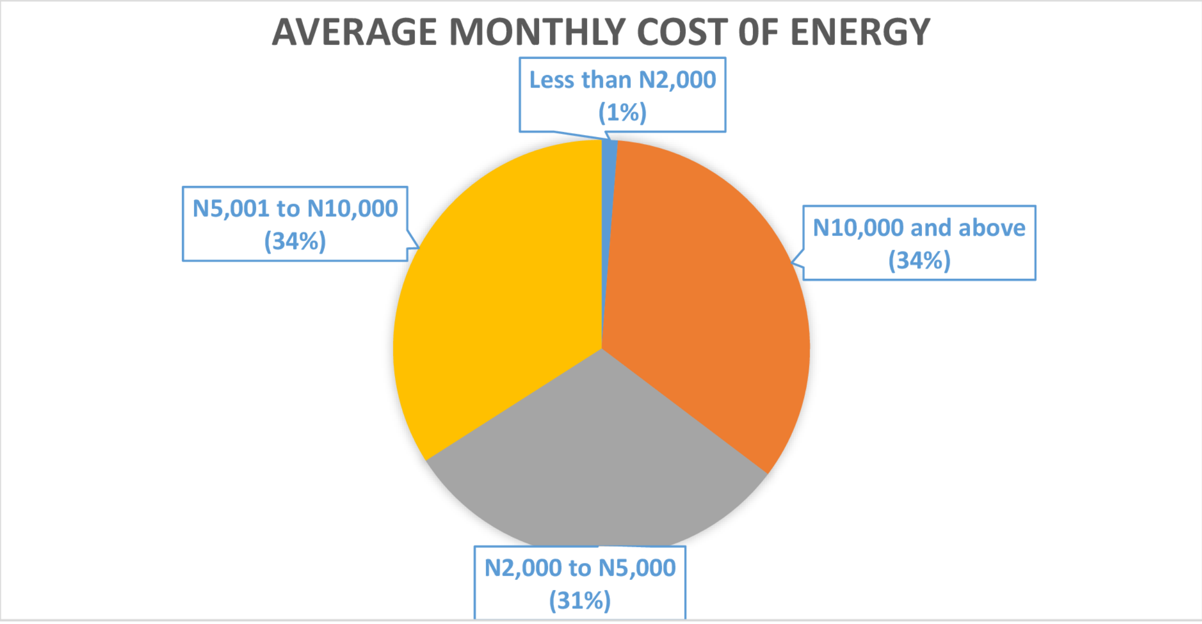

Figure 6: Average monthly cost of energy (n=238)

Table 5: *Respondents' level of access to energy and its challenges*

		Frequency	***Percent***
Access to energy per hour per day	2 hours to 6 hours	104	43.7
	7 hours to 12 hours	82	34.5
	Less than 2 hours	14	5.9
	more than 12 hours	38	16.0
	Total	238	100.0
Challenges in accessing energy	Accessibility	18	7.6
	Availability	84	35.3
	Bad governance	2	0.8
	Energy Costs	133	55.9
	Energy costs and availability	1	0.4
	Total	238	100.0

Source: Author

5.1.3 BIOGAS AWARENESS AND USAGE

Nigerians depend on the national grid for energy supply, which is complemented by liquefied petroleum gas (cooking gas) and petroleum products, all of which are supplied through the government. The over dependence on government has led to several private organizations reaching out to supply affordable renewable energy to the citizens. This section tests the awareness of biogas, a renewable energy source, among the sampled population.

More than half of the respondents (58.8%) testified that they had heard about biogas technology, but only about 5.5% currently own a biogas digester. Of the smaller percentage of biogas owners, those who use it less often take a larger share (46.15%), more often (38.46) and regularly (15%).

The above result shows that 1 in every 2 Nigerians has heard about biogas technology, but a rather low percentage of those who own the technology indicate a missing link between knowledge of the technology and adoption of the technology. Enumerating possible sites to cite industrial biogas plants, Okoro et al. (2020) suggests several ways to bridge the gap between knowledge and actualization of the technology.

The few biogas users were asked about the problem of its usage and 46.15% of the respondents blamed faulty digesters or poor maintenance. At the same time, 15% considered inadequate installation as the problem affecting its usage. These findings, while preliminary, suggest that the problem affecting biogas adoption / commercialization lies within the conference of the production. Another 38.46% of the respondents faulted the unavailability of biomass / sources. This outcome is contrary to that of Akinbomi et al. (2014) and Olugasa et al. (2014) that made it known that Nigeria has biomass to produce biogas that could be used to satisfy the energy needs of the country's population. This rather contradictory result may be due to the location of the household, which could be far from places generating high biomass. It is believed that the previous researchers' findings considered the biomass generated in all parts of the country.

Testing the willingness to use biogas technology (figure 7), most of the respondents (77.3%) are willing to use a biogas system if it is available; this complements the energy need and energy shortage in the country as only about 12% of the sample respondents enjoy more than 12 hours of energy per day (Table 5). Akinbomi et al (2014) asserted that more than 60% of the country is not connected to the national grid. This eventually leads to sourcing of cheap alternatives by majority of the citizens and interprets the high percentage of respondents willing to adopt the technology. In the same vein, this serves as an opportunity for biogas technology investors to introduce a small scale or household plant to satisfy the needs and willingness of the respondents.

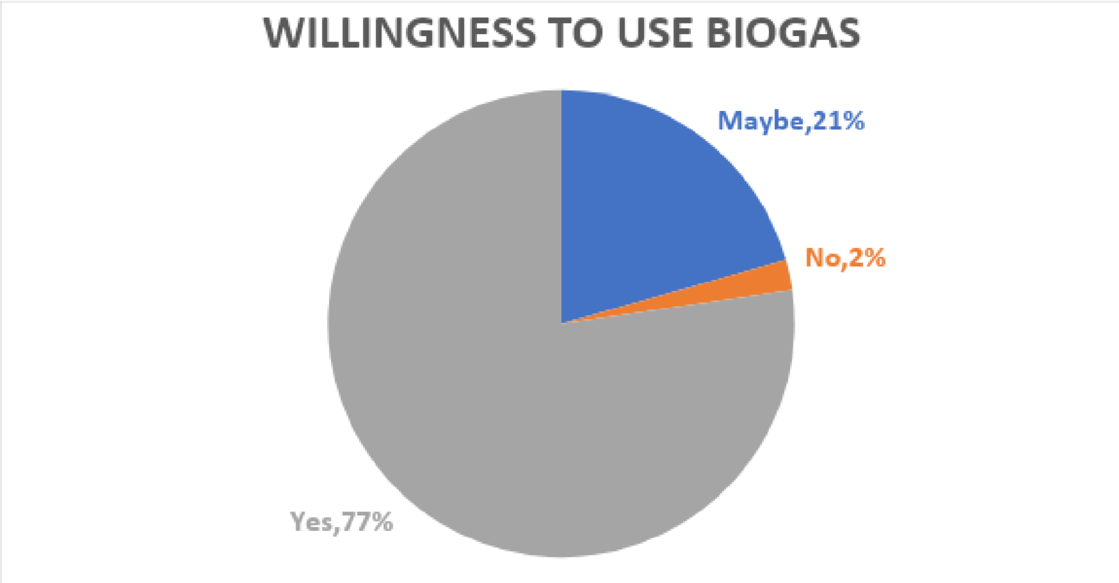

Figure 7: Respondents' willingness to use biogas (n=238)

5.1.4 FACTORS INFLUENCING WILLINGNESS TO ADOPT BIOGAS TECHNOLOGY

Previous studies have estimated relationships between energy and some socio-demographic factors. Onisanwo and Adaji (2020) result refutes the hypothesis that electricity consumption increases with the rising level of income. Mengistu et al., (2016) also analysed the possible socio-economic factors that could possibly affect biogas adoption. In the same vein, this study evaluated the relationship between some socio-demographic factors with the willingness of the respondents to adopt biogas technology. Logistic regression was performed to ascertain the effect of gender, geopolitical zone, household size, household income, settlement type, and means of livelihood on the willingness of the respondents to adopt biogas technology. The results of the analysis of the binary logistic regression model indicated that the model reasonably fitted with the observed data with an omnibus test result of $p < 0.05$ ($p = 0.025$). The model explained 23% (Nagelkerke R^2 coefficient = 0.230) of the variance in the willingness to adopt the technology and correctly classified 82.8% of the cases.

The parameter estimate is presented in Table 6. Among the eight independent variables included in the model, all except education level had no statistically significant ($p > 0.05$) influence on the adoption of biogas technology. The independent variables are discussed below:

Geographical Region

The Geographical region is a categorical variable with six categories: North-West, North-East, North-Central, South-South, South-East and South-West, with Northwest being the reference group. None of the region is statistically significant in predicting the willingness to adopt biogas. This translates that the respondents' willingness to adopt the technology is irrespective of the region they base. This result contradicts the findings of Mengistu et al. (2016) who observed that geographical location of households influences decision to adopt biogas technology. It is worth noting that Mengistu et al. (2016) findings were observed in a region that had large number of biogas installation. Low adoption of biogas in Nigeria yet, could be the reason for the statistical insignificant relationship between geographical region and the willingness to adopt. Perhaps, this result can change after the technology has been adopted by a larger population.

Age Group

Age of the respondents was found to be a statistically insignificant ($p > 0.05$) factor that influenced households' decision on adoption of biogas technology. This finding suggest that irrespective of the age, Nigerians are willing to adopt the technology. The Sustainable Development Goal 7 of the UN "Ensure access to affordable, reliable, sustainable and modern energy for all" also points in the direction that age shouldn't be a determinant for access to energy source. As also denoted by Akinbomi et al. (2014), energy is the catalyst for economic growth and poverty alleviation, two factors that directly or indirectly affect all ages, it is expected that every individual irrespective of age needs and should have access to stable energy source.

Household Income

Household income is a categorical variable with 5 levels; less than N20,000 / 50 USD (reference group), N21,000 – N50,000 (52.5 – 125 USD), N51,000 – N100,000 (127.5 – 250 USD), and N101,000 (252.5 USD) and above. None of the group shows any statistical significant. Nigeria as a developing country with a minimum monthly wage of N30,000 (60 USD less than 2 USD per day) and over 40% of the citizen living below poverty line (World Bank, 2022). This ravishing data has no impact on the willingness to adopt biogas technology in the country, as earlier quoted by Akinbomi et al. (2014), energy can be a means out of poverty, hence both the poor and rich are willing to access energy source as it's a basic human need.

Education Level

Four categories of education level were tested with the willingness to adopt biogas technology, with Education level-Secondary as the reference group, the rest variables of the categorical data show statistical significant. In this case, the graduate and post-graduate subgroup have a $p<0.05$ with regression coefficient -1.981 and -1.514 respectively. The negative regression value indicates that people with higher education are exposed to more option for energy and may not be willing to adopt the technology. This finding is in agreement with that obtained by Fleke and Zegeye (2006).

In general, there is an indication that the willingness of the respondents to adopt technology is irrespective of the age of the respondents, gender, type of settlement, household size, household income, and means of livelihood. This is also supported by an insignificant correlation between willingness to adopt biogas technology and selected socio-economic factors (Table 7). This finding is contrary to previous studies (Mengistu et al., 2016; Mwirigi et al., 2009; and Walekhwa, 2009) that discovered correlation between socio-demographic factors and the willingness to adopt technology.

Table 6: Relationship between socio-demographic factors and willingness to adopt biogas

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	Geopolitical Region (Northwest)			1.914	5	.861	
	Geopolitical Region(Northcentral)	-38.034	14035.109	.000	1	.998	.000
	Geopolitical Region(Southwest)	-38.322	14035.109	.000	1	.998	.000
	Geopolitical Region(Southeast)	-38.775	14035.109	.000	1	.998	.000
	Geopolitical Region(Southsouth)	-18.847	18607.107	.000	1	.999	.000
	Geopolitical Region(Northeast)	-37.877	14035.109	.000	1	.998	.000
	Gender-Male			.001	2	.999	
	Gender-Female	21.803	9924.317	.000	1	.998	2942864803.367
	Gender- Prefer not to say	21.817	9924.317	.000	1	.998	2986360518.619
	Age group (18-25)			.017	2	.991	
	Age group(25-40)	-19.228	15075.581	.000	1	.999	.000
	Age group(41 and above)	-19.292	15075.581	.000	1	.999	.000
	Settlement type-Urban			.000	1	.999	
	Settlement type- Rural	-.607	.583	1.084	1	.298	.545
	Means of livelihood (Self-employed)			2.988	2	.224	
	Means of livelihood(Unemployed)	.580	.506	1.311	1	.252	1.785
	Means of livelihood(Employed)	.861	.524	2.704	1	.100	2.367
	Level of Education (Secondary school)			5.516	3	.138	
	Level of Education(Undergraduate)	18.243	14154.187	.000	1	.999	83742663.623
	Level of Education(graduate)	-1.981	.886	5.001	1	.025	.138
	Level of Education(Postgraduate)	-1.514	.695	4.744	1	.029	.220
	Household size (1-2)			.744	3	.863	
	Household size(3-5)	-19.502	13047.432	.000	1	.999	.000
	Household size(6-10)	-20.008	13047.432	.000	1	.999	.000
	Household size(10 and above)	-20.079	13047.432	.000	1	.999	.000
	Household income (Less than N20,000)			4.209	3	.240	

Household income(21,000 – 50,000)	-.158	.718	.048	1	.826	.854
Household income(51,000 – 100,000)	.786	.519	2.298	1	.130	2.195
Household income(101,000 and above)	.763	.494	2.392	1	.122	2.146
Constant	58.555	22271.096	.000	1	.998	26916090131159190000000000.000

a. Variable(s) entered on step 1: Geopolitical Region, Gender, Age group, Settlement type, Means of livelihood, Level of Education, Household size, Household income.

Source: Author

Table 7: Correlation between willingness to use biogas and socio-demographic factors

Correlations

		What age group do you belong?	What is your gender?	Settlement type?	Level of education	Willingness to use a biogas technology if available?
What age group do you belong?	Pearson Correlation	1	-0.060	-.206**	.394**	-0.014
	Sig. (2-tailed)		0.355	0.002	0.000	0.830
	N	238	238	232	238	224
What is your gender?	Pearson Correlation	-0.060	1	-0.111	0.089	0.078
	Sig. (2-tailed)	0.355		0.092	0.169	0.246
	N	238	238	232	238	224
Settlement type?	Pearson Correlation	-.206**	-0.111	1	-.265**	-0.065
	Sig. (2-tailed)	0.002	0.092		0.000	0.339
	N	232	232	232	232	218
What is your highest level of education	Pearson Correlation	.394**	0.089	-.265**	1	-0.039
	Sig. (2-tailed)	0.000	0.169	0.000		0.564
	N	238	238	232	238	224
Willingness to use a biogas technology if available?	Pearson Correlation	-0.014	0.078	-0.065	-0.039	1
	Sig. (2-tailed)	0.830	0.246	0.339	0.564	
	N	224	224	218	224	224

***. Correlation is significant at the 0.01 level (2-tailed).*

5.1.5 CHALLENGES OF BIOGAS ADOPTION BY ENERGY USERS

Several perceived challenges were presented to the respondents, including lack of adequate funds, inadequate information, poor infrastructure, inadequate qualified disseminators, the negative attitude of the community towards biogas energy, and lack of interest to opine on their perception of the level of importance of each of the challenges (Table 8). Inadequate information had the highest opinion of being the most important with 72.7% of the respondents. Some of the respondents further explained that they had never heard of biogas or its details before the research was presented. The lack of adequate funds was classified as the next significant challenge to adopting biogas, with 71% of respondents stating it as very important. Most energy supplies in Nigeria are government controlled and subsidized, hence the sense of entitlement of the respondent. Poor infrastructure, i.e., lack of digestate, was ranked as very important by most of the respondents (66.8%).

Lack of interest and a negative attitude of the community toward community toward technology have the lowest opinion, therefore, considered the least of the challenges possibly affecting adoptability of the technology. According to NPP 2021 report, about 51.16% of the Nigerian population occupy urban centers and about 70% of Nigeria's population is under the age of 30, and these urban area habitants have a literacy level of about 80% - These are findings that align with this study socio-demographic status (as evident in Table 1 and Table 2). It is, therefore, possible that the reason for low opinions on lack of interest or negative attitudes of the community toward technology is due to the high level of education, exposure, and youthfulness of the respondents.

The enhancement of the Community Development Association under the State governments has also seen people with education taking up important roles in community leadership and decision making. The study by Mwakaje (2005) revealed that several people who have not accessed biogas technology had the perception that biogas is a dirty thing; however, on seeing physically the functioning of bio latrine, many households were motivated to adopt the technology.

Table 8: Respondents' perception on main challenges affecting biogas adoption

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Lack of Adequate fund	Less Important	11	4.6	4.6	4.6
	Moderately Important	51	Pi	21.4	26.1
	Not Important	7	2.9	2.9	29.0
	Very Important	169	71.0	71.0	100.0
	Total	238	100.0	100.0	
Inadequate information on Biogas	Less Important	10	4.2	4.2	4.2
	Moderately Important	51	21.4	21.4	25.6
	Not Important	4	1.7	1.7	27.3
	Very Important	173	72.7	72.7	100.0
	Total	238	100.0	100.0	
Poor infrastructure (lack of digestate)	Less Important	16	6.7	6.7	6.7
	Moderately Important	56	23.5	23.5	30.3
	Not Important	7	2.9	2.9	33.2
	Very Important	159	66.8	66.8	100.0
	Total	238	100.0	100.0	
Inadequate skilled disseminators	Less Important	11	4.6	4.6	4.6
	Moderately Important	69	29.0	29.0	33.6
	Not Important	5	2.1	2.1	35.7
	Very Important	153	64.3	64.3	100.0
	Total	238	100.0	100.0	
Community's negative attitude towards biogas energy	Less Important	29	12.2	12.2	12.2
	Moderately Important	73	30.7	30.7	42.9
	Not Important	9	3.8	3.8	46.6
	Very Important	127	53.4	53.4	100.0
	Total	238	100.0	100.0	
Lack of interest]	Less Important	32	13.4	13.4	13.4
	Moderately Important	59	24.8	24.8	38.2
	Not Important	15	6.3	6.3	44.5
	Very Important	132	55.5	55.5	100.0
	Total	238	100.0	100.0	

Source: Author

5.2. ENERGY RETAILERS / MARKETERS

5.2.1. SOCIODEMOGRAPHY OF ENERGY RETAILERS

The research took a quick peek into a few energy retailers / marketers perspectives to further understand the possible challenges facing the adoption and commercialization of biogas. The energy marketers tested are mainly located in Lagos state (45.7%), others are Ogun state (31.4%), Abuja (11.4%), Oyo state (5.7%), Ondo state, and Enugu state with 2.9% of the respondents. The large number of retailers / marketers accumulated from Lagos can be attributed to the state being the administrative headquarters of most establishments, the high population of the state and the state having the highest revenue generated internally within the country. The proximity of Ogun state to Lagos state also means that the state sheds several administrative functions to the latter. Energy producers with 10-20 employees and under 10 employees dominated the categories of energy producers tested. Only 8.6% have more than 50 employees, while 2.9% have between 21 and 50 employees.

More than half of the respondents have been in the energy sector for more than half a decade, with 72% of energy retailers / marketers possessing at least a first degree (Figure 8), and most of the respondents can be classified as elites with education and exposure to modern technologies. The majority of the respondents being a graduate and with half a decade of experience in the energy sector shows the scenario playing out in the country where the prerequisite for official employment from big employers like energy producers is the first degree with additional years of related experience. This positions the respondents to be a representative of the energy producers and indicate a high level of literacy and to an extent, an open mind for innovation and technologies that would not only generate revenue for the establishments but also keep the establishment in the loop of updated energy source.

Petroleum and liquefied petroleum gas lead the board of energy products retailed by the respondents with 42.86% each, the other energy type represented include solar/wind 11.43%, electricity and biogas 2.8% each. Petroleum and LPG having the highest respondent percentage among the energy producers confirms Akinbomi et al. (2014) finding which showed that Nigeria's economy heavily relies on fossil fuels and LPG being most daily utilized source of energy by the respondents (Table 3) completes the demand-supply chain. It can thus be suggested that the willingness of the respondents to adopt biogas technology can be an assurance to producers that investing in biogas technology will ultimately be a big step in the direction of staying in business and increasing the revenue for shareholders.

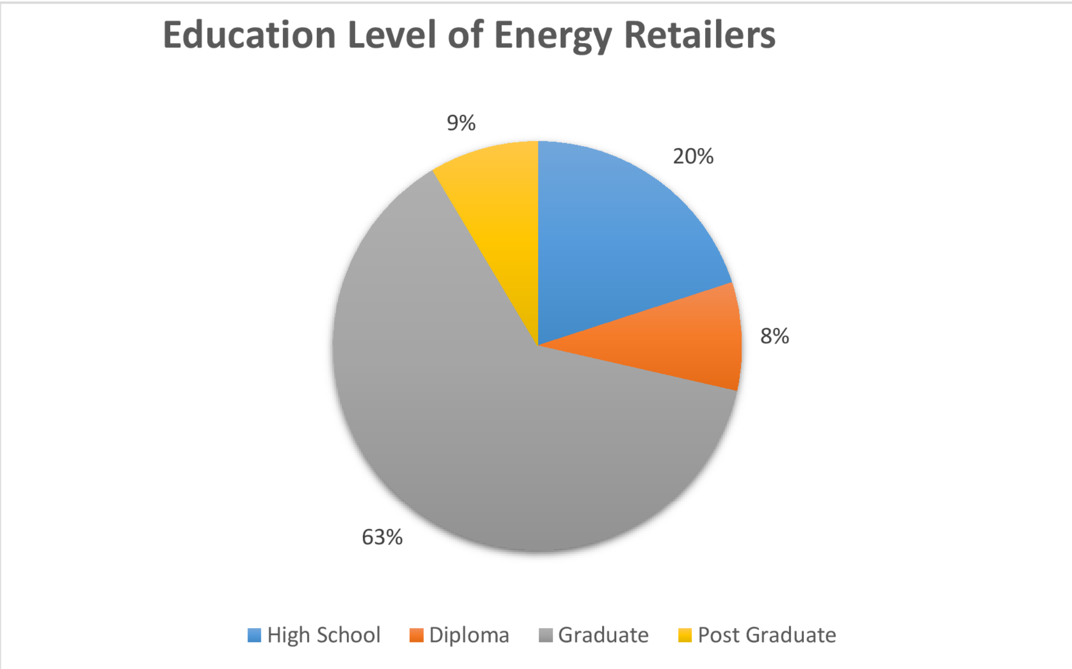

Figure 8: Retailers /marketers level of education (n=35)

5.2.2 ENERGY PRODUCTION

57.14% of the energy retailers / marketers surveyed expressed their willingness to adopt new technology in energy production and sales, and another 60% also showed interest in investing in new energy sources. This high percentage could be attributed to the interest of retailers / marketers in making more money by providing the deficient energy market. Although most of the respondents (64.9%) rate their knowledge of biogas technology as low, only about 5.8% of the respondents have high knowledge of biogas technology. Compared to other studies like Akinbomi et al. (2014) that suggests a very low level of awareness of biogas technology in Nigeria, about 31% of the study population expressed their knowledge of biogas as average.

5.2.3 CHALLENGES OF BIOGAS COMMERCIALIZATION AS PERCEIVED BY ENERGY RETAILERS

This research further extracted opinions of energy retailers / marketers about biogas commercialization challenges from the tested population. Barriers that include institutional / policy hurdle, Technical / Infrastructural hurdle, Economic / financial hurdle, information hurdle, capacity / manpower hurdle, and Socio-cultural hurdle using a 5-point Likert scale questionnaire, the scale was further collapsed to three (3) with strongly agree and agree converted to agree, strongly disagree and disagree combined to form disagree. At the same time, the undecided responses stayed the same.

This research tested institutional / policy hurdles with questions that include "lack of coordination among institutions, excessive bureaucratic bottleneck and lack of political support and specific programs to promote biogas technologies". The analysis result indicated that 80% of the repondents agreed with lack of coordination among institutions as a major challenge, another 80% also agreed with excessive bureaucratic bottleneck. 85.7% of the respondents are of the opinion that lack of political support and specific programs to promote biogas technologies is also a major challenge to the commercialization of biogas. This result indicate that about 81.9% of the respondents are of the opinion that institutional / policy hurdle is one of the limiting factors affecting biogas commercialization. This resonates the fact that government policies that a review of existing policies or enacting of new ones that will support renewable energy sources for both households and investors is urgently needed

The technical / infrastructural hurdle was analyzed using indicators that include ‘'lack of technical and marketing infrastructure, low or lack of cooperation / partnership with international bodies, Renewable Energy-Efficient Partnership (REEP) and non-availability feedstock. The analysis revealed that 88.5%, 82.9%, 74.3%, and 57% agreed with the barrier indicators respectively. A low level of respondents agreed with the "non-availability of feedstock/biomass" barrier. On an average, technical/infrastructural hurdle was opined by 75.7% of the respondents to be a challenge to biogas commercialization. Inbestors and energy retailers or producers will have to overcome this perceived hurdle through market penetration, public-private partnership and training of technical know-hows.

The high initial cost of production, lack of a low-interest rate available credit facility, perceived risks of biomass energy projects, and poor marketing strategies from energy retailers / marketers are the instruments used to measure the economic/financial hurdle that could hinder biogas commercialization in Nigeria. The analysis revealed that 82.9% opined that high initial cost of production of biogas is one of the important barriers to overcome in the commercialization of the energy source. 85.7% opined that lack of low-interest credit facility is also a major barrier. 71.4% of the respondent also agreed that risk of biomass energy project can also be a barrier while 86.7% of the respondents agreed that poor marketing strategy is an important hurdle in the commercialization of biogas. With 81.68% of the respondents indicating economic and financial hurdle as an important constraint to biogas commercialization, there is a huge need to research on using locally available materials in the construction of household biogas as this will reduce the cost of its production. Provision of low interest credit facility can also help in overcoming the economic/financial hurdles.

Information hurdle is tested using "lack of awareness and limited information from the national body and poor telecommunication infrastructure". The result revealed that 88.5% and 74.3% of the respondents find the barrier genuine respectively. A high number of the respondent has indicated access to various media with electronic media leading the tally, leveraging on this would allow to useful information on the benefit and basic information on biogas to be widely disseminated.

The capacity / manpower hurdle tested by 'limited availability of correctly trained and skilled labor' shows that 85.7% of the respondents are in unison that the barrier is absolutely significant. The unemployment figure is given as over 40% of the working class. Tapping from this ocean of work force to provide trainings and skills acquisition programme on biogas installation, repair and maintenance will go a long way in overcoming this constraint.

The socio-cultural hurdle was also tested using questions that include ‘’lack of public participation and consumer interest, stigmatization due to religion or traditional beliefs, low literacy level, and desire to maintain status-quo/resistance to change’’. 90% of the respondents agreed that lack of public participation is a significant problem in biogas commercialization. The number of respondents that agree (45%) that stigmatization due to religion or traditional beliefs can affect biogas commercialization is close to those that disagree (43%). Although 50% agreed that it is a barrier, 45% disagreed with this construct. The majority (71.4) of the respondents also agreed that a low literacy level is also a major barrier to the commercialization of the technology.

The desire to maintain the status quo was the lowest response, with 55% of respondents disagreeing with the construct. The status quo of energy in Nigeria is not a stable or sufficient one, hence, maintaining the status quo may not be an option as citizens are looking for a way to meet up with their daily need for energy. This is buttressed by the high percentage of respondents willing to adopt new technology (Fig 7). In general, therefore, it can be concluded that Akinbomi et al. (2014) finding that most people now rely on generators and unsustainable energy sources, for their supply of off-grid electricity is a statement of respondents disagreeing with the construct status quo of energy in Nigeria.

By way of ranking the most important barriers to commercialization of biogas in Nigeria by energy retailers, Capacity/Manpower hurdle was perceived to be the most important. Institutional/Policy hurdle, Economic/financial hurdle, Information hurdle, Technical/infrastructural hurdle followed suite respectively. Socio-cultural hurdle comes last in the list of important barriers.

5.2.3.1 SOCIO-DEMOGRAPHIC FACTORS

The energy retailers / marketers were also surveyed for their opinion on what socio-demographic factors could affect biogas commercialization. Income of the household, age, health considerations, level of education, religion, household size, occupation, and marital status were among the factors tested.

Most energy retailers / marketers opined that household income affects adoption and, hence, commercialization of biogas. Since income determines the expenditure, it is expected to affect the adoption of the resources. Most of the respondents (63%) disagree that age can affect the commercialization of biogas.

As established earlier, there was a close range of respondents who agree and respondents who disagree with the fact that the unavailability of resources or biomass could affect the commercialization of the technology, as 44% of the respondents agreed, while 45% disagreed. Akinbomi et al. (2014) quantified the amount of biomass in Nigeria to be about million tons of biomass available, which translates to abundance of the resources for energy production.

Health concerns about biogas digestate effluent are also opined to significantly influence the adoption of the resources, as 57.2% of the respondents agree with the factor, while 11.4% are undecided.

Level of education was disagreed to influence biogas commercialization. Religion, household size, marital status, and occupation were also believed to not affect biogas commercialization by energy retailers / marketers, with 80%, 68.5%, 74.3%, and 62.9% respectively disagreeing with this opinion. According to the World Bank, Nigeria has the largest energy access deficit in the world with over 85 million of the population not having access to energy. Perhaps the energy deficiency of the country is under quantified, as this study revealed that religion, household size, marital status, and occupation play no significant role in energy demand or use. This view was also shared by the household respondents of this study, with this socio-economic and demographical factor showing no significant relationship with the adoption of the technology. This finding shows that the gap in the energy sector will untimely lead to the citizen embracing alternatives to the present energy source.

5.3. COMMERCIALIZATION OPPORTUNITIES (WAYS TO MITIGATE IDENTIFIED CHALLENGES)

5.3.1 HOUSEHOLD RESPONDENTS

Understanding that biogas could supplement the energy supply of household respondents, several measures that could improve commercialization of the technology were suggested to respondents to classify their respective level of importance on a 4-point Likert scale of (less important, moderately important, not important, and very important). The tested measures include the provision of micro-finance or loans, increased awareness, increased government will and support, increased training programs for disseminators, community leadership programs in renewable energy, and establishing demonstration centres.

The majority of the respondents (87.8%) opined that biogas awareness is the most important of the measures. This workability of this measure may be supported by the recent adoption of solar energy in the country and the wide range of citizens with access to a different media source. Respondents ranked increased government will and support as very important (81.1%); this could be a result of the government being the sole provider of the majority of energy sources in the country. The respondents ranked increased training programs for disseminators next important (79.8%). Community leadership programs and the establishment of demonstration centers were opined as the next vital measure to improve biogas commercialization in the country with 76.9% and 73.5 % of the respondents, respectively. Provision of micro-finance or loan was ranked the least in importance, with only 57.1% of the respondents deeming it very important.

78 of the respondents also provided other measures / opinions on how the commercialization of biogas can be improved in the country. Some of these opinions include:

Accessibility of the material; adequate digital information; adequate location of plants and experts; advertisement about biogas in the media; availability and accessibility of biogas; availability at a subsidized rate; availability of biogas in both rural and urban areas; awareness campaigns and creation; affordable and government support; bio-augmentation, by making it readily available; considerable pricing for average Nigerians; creating the centre of biogas skill acquisition for uneducated persons; creation of awareness in both rural and urban areas; supporting small-scale business who are into biogas production so as to enhance accessibility and awareness to biogas production; education and training of youth on technology; government policy; micro-introduction of the technology in a community as a test sample; Internet publicity; making it readily available, more capital must be provided, municipal drafting of waste energy recovery incentive; price subsidization of biogas equipment for household use.

As earlier indicated in this study, there is a huge gap between awareness of the technology and its adoption. With cost of installation of biogas plant considered a constraint in biogas adoption and commercialization (Warchera, 2014), Making accessible and available, materials for biogas technology, adequate information dissemination, adequate location of plant and technical experts and access to installment payment or subsidized payment will go a long way in the adoption and commercialization of biogas technology.

Table 9: Measures to improve commercialization of biogas technology

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Provision of Micro-finance or loan	Less Important	15	6.3	6.3	6.3
	Moderately Important	78	32.8	32.8	39.1
	Not Important	9	3.8	3.8	42.9
	Very Important	136	57.1	57.1	100.0
	Total	238	100.0	100.0	
Increase awareness	Less Important	2	0.8	0.8	0.8
	Moderately Important	25	10.5	10.5	11.3
	Not Important	2	0.8	0.8	12.2
	Very Important	209	87.8	87.8	100.0
	Total	238	100.0	100.0	
Increased government will and support	Less Important	4	1.7	1.7	1.7
	Moderately Important	40	16.8	16.8	18.5
	Not Important	1	0.4	0.4	18.9
	Very Important	193	81.1	81.1	100.0
	Total	238	100.0	100.0	
Increased training programs for disseminators	Less Important	3	1.3	1.3	1.3
	Moderately Important	43	18.1	18.1	19.3
	Not Important	2	0.8	0.8	20.2
	Very Important	190	79.8	79.8	100.0
	Total	238	100.0	100.0	
Community leadership program in renewable energy	Less Important	6	2.5	2.5	2.5
	Moderately Important	47	19.7	19.7	22.3
	Not Important	2	0.8	0.8	23.1
	Very Important	183	76.9	76.9	100.0
	Total	238	100.0	100.0	
Establish demonstration centres	Less Important	7	2.9	2.9	2.9
	Moderately Important	53	22.3	22.3	25.2
	Not Important	3	1.3	1.3	26.5
	Very Important	175	73.5	73.5	100.0
	Total	238	100.0	100.0	

Source: Author

5.3.2 ENERGY RETAILERS / MARKETERS

Security measures, Improved household incomes, technology adoption by government, positive publicity, market availability, financial support from government / international bodies, awareness of environmental degradation, increased farming activities, water availability and land subdivision were pitched to the respondents for their opinion on being challenges to biogas commercialization. Water availability and Land subdivision are not relative to this research but were used to test the respondents' focus on the responses.

The security of farmers who essentially produce biomass was presented to the respondents to estimate their agreement with the solution to biogas commercialization. 60% of the respondents agree that security needs to be enhanced, and it is a great solution to the commercialization of the technology. This finding is in accord with NPP 2021 report that highlighted safety and security for farmers as one crucial point to address to ensure progress and development of the Nation.

Most energy marketers also opine that improving household income can help in the commercialization of biogas in the country. Household finance can accommodate adopting innovations to supplement the energy deficiency of each family.

Adoption of the technology by the government, positive publicity, market availability, financial support from government/international bodies, and awareness of environmental degradation were all opined to be the right direction in the commercialization of biogas technology. With the government being the biggest player in energy production and sales, a bigger share of responsibility will go to them as it concerns biogas technology. Adoption of the technology and provision of finances by the Government of Nigeria will lead to a paradigm shift in the adoption, production, utilization and commercialization of the technology.

The respondents mainly voted for undecided land subdivision and water availability, and this shows that the respondents were fully aware of the responses provided by the author and the implications of each construct.

6 CONCLUSIONS

This study was designed to investigate, review and provide information on the state of biogas technology in Nigeria, explicitly identifying the challenges that affect the commercialization of biogas technology in Nigeria and proposing possible solutions to mitigate the identified challenges. To achieve the objectives set, this research evaluated the perspective of energy users and energy retailers / marketers on the status of biogas within the country.

The study among energy users has shown that a more significant part of the respondents (84.1%) have less than 12 hours of energy per day, although they spend more than 2000 Naira / 5 USD (one-fifteenth of the country's minimum wage). This finding aligns with the statement by Akinbomi et al. in 2014 on the severe energy shortage within the country. Furthermore, this research discovered that energy users are willing to embrace any other alternative energy source that could help mitigate the current energy situation within the country. This position indicates that a large number of respondents were not satisfied with the energy available to them. It should be noted that the willingness of users to adopt the technology is irrespective of the age of the respondents, the sex, household income or size, and the type of settlement. Only the level of education shows some relationship with the willingness to adopt biogas. This result corresponds to the research by Mengistu et al., 2016; Mwirigi et al., 2009 and Mwakaje, 2008, which discovered that the level of education is significantly linked to the willingness to adopt new technology, although this study shows a negative relationship, which indicated that people with higher education may not be willing to adopt the technology as a result of exposure to other renewable sources.

This study has shown that the means of livelihood of the respondents are characterized by unemployed (40.76%) and self-employed (25.21%). The high unemployment rate exceeds the values of 2021 cited by Adenomon and Folorunsho (2021) by about 5%. This value is an indication that there is an opportunity for biogas investors to enter the energy market through training of this unemployed personnel in the installation, repair, or maintenance of biogas plants.

One of the bitter-sweet findings from this study is that more than half of the energy users (58.8%) testified to having heard about biogas technology. Still, only about 5.5% currently own biogas digester. Investigation of the challenges that affect biogas commercialization from the energy consumer's perspective was shown to include low awareness and lack of government will and support; this could be the result of the government being the only provider of most of the energy sources in the country.

This research has also shown that most energy retailers / marketers are willing to adopt new technology in energy production and sales. This high percentage could be attributed to the interest of retailers / marketers in making more money by providing the deficient energy market. Although, most of the respondents (64.9%) rate their knowledge of biogas technology as low, only about 5.8% of the respondents have high knowledge of biogas technology. The collective willingness to embrace new technology from the perspectives of retailers, marketers, and consumers highlights the opportunity available for biogas commercialization if the challenges affecting commercialization are addressed.

From the perspective of energy retailers / marketers, this study has also identified the challenges affecting biogas commercialization to include institutional / policy hurdles, economic / financial hurdles, information hurdles, capacity / manpower hurdles, and sociocultural (income in particular); since income determines expenditure, it is expected to affect adoption. Considering the willingness of the consumer to adopt new energy, analyzing the level of willingness in the context of biogas technology and income would be a fruitful area for further work.

In this research, a close range of respondents agree and disagree with the fact that stigmatization due to religion or traditional beliefs can affect biogas commercialization.

Furthermore, this research established that many respondents disagreed with the "nonavailability of feedstock / biomass" as a significant barrier that affects biogas commercialization. These finding complements those of earlier studies (Okoro et al., 2020; Akinbomi et al., 2014).

Taken together, these results suggest that since Nigeria has the biomass needed to generate sufficient biogas, increasing government will and support, providing financial loans to biogas retailers / marketers, community leadership programs, the establishment of demonstration centers, and the creation of more awareness of biogas will mitigate the challenges that affect biogas commercialization. Having been able to demonstrate through this research that both consumers and retailers / marketers are willing to embrace new technology, not forgetting that all respondents have access to one or more sources of media, the dissemination of biogas information is feasible, and the commercialization of the technology is achievable.

6.1. Recommendations

As a result of the high willingness to adopt the technology, it is recommended that biogas technology be partially introduced into the rural area where there is a large amount of waste from the agricultural harvest that could serve as biomass to produce energy.

Nigeria's policy is such that the government supplies the largest percentage of energy sources, therefore, for successful integration and dissemination of technology, investors must obtain the will and support of the government to ensure the sustainability and longevity of the technology.

More attention should also be directed to sensitize households on waste-to-energy initiatives, as this will in a larger way boost the willingness to not only adopt the technology but commercialize it on a large scale.

Identifying only a few biogas investors, policies that will support biogas, and training local experts on different biogas designs, maintenance, and repairs of the plants are needed to ensure continuity in the usage and reduce the construction and operational cost of the technology.

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Appendices

Appendix 1: Challenges of biogas commercialization in Nigeria (Energy users perspective)

SECTION ONE: SOCIO-ECONOMIC INFORMATION

1 a) General information

Geopolitical Region: ____________________________

State: ________________________________

Gender	Male [ ]	Female [ ]	Prefer not to say [ ]			
Age	18 -25 [ ]	26-40 [ ]	Over 40 [ ]			
Education Level	Primay [ ]	Secondary [ ]	Undergraduate [ ]	Graduate [ ]	Postgraduate [ ]	None [ ]
Settlement type	Rural [ ]	Urban [ ]				
Means of livelihood	Farmer [ ]	Casual Laborer [ ]	Self Employed [ ]	Employed [ ]		
Monthly Income	Below N20,000 [ ]	N20,000 – N50,000 [ ]	N51,000 – N100,000 [ ]	N101,000 and above [ ]		
Household Size	2 [ ]	3 – 5 [ ]	6 – 9 [ ]	10 and above [ ]		
Possession/Access to Electronic media	Radio [ ]	Print Media [ ]	Television/Digital TV [ ]	All [ ]		

SECTION TWO: ENERGY DEMAND AND SOURCES

What sources of energy do you use?

SOURCE OF ENERGY	DAILY	WEEKLY	MONTHLY	NEVER
Wood fuel				
Charcoal				
Liquid petroleum Gas (LPG)				
Biogas				
Electricity				
Paraffin/ Kerosene				
Solar/Wind				
Biogas				
Any other specify				

Are you satisfied with the energy supply used in the household at present? Indicate the number in the space provided

Energy Source	**Satisfaction** **Yes** **No**	**Reason for dissatisfaction** 1. **Unreliable** **3. Too expensive** 2. **Inefficient** **4. Others (specify)**
Wood		
Charcoal		
Liquid petroleum Gas (LPG)		
Biogas		
Electricity		
Paraffin/ Kerosene		
LPG		
Biogas		

Average Monthly Cost of Energy	Less than N2,000 [ ]	N2,000 – N5,000 [ ]	N5,000 - N10,000	Above N10,000 [ ]
How many hours of Energy do you have access to per day	Less than 2 hours [ ]	2hours to 6 hours [ ]	7hours to 12 hours [ ]	More than 12 hours [ ]
Challenges of accessing energy	Costs [ ]	Accessibility [ ]	Availability [ ]	(Others) Specify:

SECTION THREE: BIOGAS AWARENESS AND USAGE

Biogas technology is a technology that utilizes waste (often called Digestate) for the production of energy.

Which of these resources do you have access to	**Firewood or Forest resources [ ]**	**Farm Residue or Waste [ ]**	**Municipal Solid Waste [ ]**	**Animal Waste (Dung, Abattoir waste) [ ]**	**Human Waste (Black and Greywater) [ ]**
How much of the resources above do you have access to weekly?	Less than 10Kg [ ]	11kg to 50kg [ ]	51kg to 100kg [ ]	101kg to 200kg [ ]	Above 200 kg [ ]
Have you heard of Biogas Technology?	Yes [ ]	No [ ]	Maybe [ ]		
Do you possess a biogas plant/digester?	Yes [ ]	No [ ]			
Would you be willing to use biogas technology if available?	Yes [ ]	No [ ] Reason:		Maybe [ ] Reason:	

If you possess biogas technology, how often do you use the technology?	Regularly [ ]	More often [ ]	Less often [ ]	Rarely [ ]	
What would you say is the problem with its usage?	Inadequate installation [ ]	Faulty digester/poor maintenance [ ]	Unavailability of sources [ ]	Others [ ] Specify:	

In your opinion, what do you consider to be the main challenges of adopting biogas energy?

Limitations	**Very Important**	**Moderately Important**	**Less important**	**Not Important**
Lack of adequate funds				
Inadequate information on biogas				
Poor infrastructure (lack of digestate)				
Inadequately skilled disseminators				
Poverty				
Community's negative attitude toward biogas energy				
High installation cost				
Lack of interest				

In your opinion what are some of the measures that would improve the commercialization of biogas technology?

Possible Measures	**Very Important**	**Moderately Important**	**Less important**	**Not Important**
Provision of Micro-finance or loan				
Increase awareness				
Increased government will and support				
Increased training programs for disseminators				
Community leadership program in renewable energy				
Establish demonstration centers				
Any other Specify………………………… …………………………………..				

Appendix 2: Challenges of biogas commercialization in Nigeria (Retailers/Marketers perspective)

1. **Basic Information**

1.1 Company's Name_____________________________

1.2 Location: ____________________________________

1.3 Company size:

Under 10 employees (   ) 10-20 employees (   ) 20-50 employees (   ) over 50 employees (   )

1.4 Name of Respondent:____

1.5 Position in Company:________________________________

1.6 Gender: Male ( ) Female (   )

1.7 Highest achieved level of education:

1.8 Have you ever attended any formal training on biogas production: Yes ( ) No (   )

1.9 How many years of experience do you have with energy production: _______

1.10 What energy type do you deal in your company: Liquid petroleum Gas {LPG} (   ) Solar/wind (   ) Petroleum (   ) Electricity (   ) Biogas (   ) Others (   )

Biogas Production

2.1 Are you interested in further innovations in energy production and sales?

Yes (   ) No (   ) Not Sure (   )

2.2 Are you willing to adopt new technological approach in energy production?

Yes (   ) No (   ) Not Sure (   )

2.3 Are you willing to invest in new energy sources for production?

Yes (   ) No(   ) Not Sure (   )

2.4 How well will you rate your knowledge of biogas? On a scale of 1-5, with 1 being the least and 5 being the highest: ___________________________

2.5 Have you ever thought of producing biogas for commercial purposes

Yes (   ) No (   ) Not Sure (   )

2.6 If your answer to ***2.5*** is yes, what “primary” market(s) have you identified for biogas?

……………………………..……………………………………………………………………………………

2.7 What are the respective sizes of these markets?

……………………………………………………….

2.8 Who are the main competitors in the primary market(s) you are considering?

………………………………………………………………………………………………

2.9 Are there any “secondary” markets which you are considering in which biogas may have some use? (a) Yes ( ) (b) No ( )

2.10 If yes, please identify ………………………………………………………………….

2.11 What are your estimates of the Production or sales volume per month

………………………………………………………………………………………………

2.12 What are the projected costs of bringing biogas to market?

Materials	Cost (naira)

2.13 What is you estimated revenue per month from selling biogas?

…………………………………………………………………….

Biogas Commercialization

3.1 Rate your level of agreement with the following barriers to biogas commercialization

Barriers	**Strongly Agree**	**Agree**	**Undecided**	**Disagree**	**Strongly Disagree**
Institutional/ policy hurdle *Lack of coordination among institutions *Excessive bureaucratic bottleneck					

* Lack of political support and specific programs to promote biogas technologies					
Economic hurdle ***A lack of research and development funding * Competition with other fuels easily available * Uncertainties related to injection of biogas into the market					
Technical/infrastructure hurdle *Lack of technical and marketing infrastructure *Low to lack of cooperation/partnership with international bodies such as *Renewable Energy and Energy Efficient Partnership (REEEP) *Non-availability of feedstock					
Financial hurdle *High initial cost of production *Lack of available credit facility with low interest rate *Perceived risks of biomass energy projects act as a major barrier to investments					
Information hurdle					

*Lack of awareness and limited information on the national RE resource base *Poor telecommunications infrastructure (especially poor internet access and lack of adequate telephone access)					
Capacity/ manpower hurdle *Limited availability of correctly trained and skilled manpower					
Social-cultural hurdle * A lack of public participation and consumer interest. * Stigmatization due to religion/traditional beliefs * Low literacy level * Desire to maintain the status quo/Resistance to change					

3.2 Socio-economic factors

What do you think are the main obstacle to biogas commercialisation? Indicate as follows

	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
Income					
Age					
High cost of production					
Non availability of resources					
Health Consideration					
Environmental concerns					
Government policy					
Poor marketing					

Level of education					
Religion					
Household size					
Occupation					
Marital status					
Low level of awareness					
Others (Specify)					

3.3 S

	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
Security					
Improved household income					
Controlled livestock grazing					
Positive publicity					
Market availability					
Increased human population					
Environmental degradation					
Increased livestock numbers					
Water availability					
Land subdivision					
Others (specify)					

4 Please, feel free to share with us any other of your comments/information that could aid commercialization of biogas in Nigeria.

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