CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Tropical AgriSciences

BIOGAS PRODUCTION AS A STRATEGIC WAY OF URBAN WASTE MANAGEMENT IN LAGOS NIGERIA: (A CASE STUDY OF OLUSOSUN LANDFILL)

MASTER'S THESIS

Prague 2023

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Declaration

I hereby declare that I have done this thesis entitled “Biogas production as a strategic way of urban waste management in Lagos State, 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 15/04/2023

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Temitayo Oladeji

Acknowledgements

I would like to thank my thesis supervisor Assoc. Prof. Hynek Roubík for his continued guidance and an endless supply of fascinating projects. His unassuming approach to research and science is a source of inspiration. This approach is reflected by his simple but clear writing style, which is something I hope to carry forward throughout my career. I would like to thank to the Biogas Research Team and all the Staffs of FTA as I have been fortunate to be a part of the faculty, for their advice and valuable suggestions during my programme.

I would also like to recognize the help of Moshobalaje Yusuff BSc., for helping with the data collection, and who took it upon himself to assist with the sampling in the field, your input will always be remembered. I am grateful for my parents Mr. and Late Mrs. Yemi Oladeji, whose constant love and support kept me motivated and confident. My accomplishments and success are because they believed in me. Deepest thanks to my partner Abisola Adams and my siblings Olaide Olasupo, Temitope Oladeji and my son Oladeji Kikiola Jamaal, who kept me grounded, reminded me of what is important in life, and are always supportive of my adventures.

Finally, I owe my deepest gratitude to Agunbiade Gafar who preached the idea of this programme, Oladehin Olakunle and Alade Abiola Innocent, who stood by with unconditional love and support throughout the entire thesis process and every other day.

Abstract

The growing need for sustainable energy sources has fuelled interest in the generation of biogas from organic waste. In this study, the researcher examined the optimization of biogas production from organic waste at Olusosun Landfill in Lagos State, Nigeria, where waste disposal is still a serious issue. Nigeria, like many other developing countries, is facing a waste management issue due to inadequate trash collection, disposal, and recycling facilities. The growing population and urbanization have resulted in vast volumes of trash, raising health and environmental issues.

The research aim was to examine biogas as a way of managing waste at Olusosun Landfill, Lagos and to evaluate the optimal technology of the production of biogas in developing countries. Data was collected based on the response from the respondents whose opinion was sampled. 300 targeted questionnaires were sent across while 222 were retrieved as well based on the investigation conducted.

The responses were verified, sorted, classified, and analyzed. Biogas Production is a qualitative dependent variable: hence, the model for the estimation of the logistic regression dependent variable was adopted. Analysis of Variance (ANOVA) was used to analyze the relationship between the variables under this study to determine if there was a significant difference between the research questions. Binomial logistic regression estimates the probability of having Biogas Production from the municipal solid waste which is measured if greater than or equal to 0.5, it returns positive which statistics classifies the event as occurring. The coefficient of determination R2 which is 0.030 and signify that 3.0% of the total variation in the Biogas Production is explained by the regression equation $Logit(\pi i) = \beta 0 + \beta 1X1i + \beta 2X2i + \beta 3X3i$ which indicates that the prediction made on Biogas Production is reliable at 3.0% percent. This shows that biogas production is possible from municipal solid waste.

The study finds that biogas production reduces deforestation, ecological imbalance, climate change, and environmental pollution, in which ecological imbalance contributed significantly to biogas production. This research comes in a right time when the world has high attention on climate and emissions caused mainly by energy demand and use. The success of this research would benefit the environment, economy, and sustainable development of countries around the world. There is still a long way to go on the path to perfection, but certainly the steps that have already been taken have been significant.

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List of Abbreviations used in the Thesis

ANOVA	Analysis of Variance
BMP	Biomethane potential
C/N	Carbon-nitrogen
DGNRER	The Directorate General of New and Renewable Energy Resources
DOC	Degradable Organic Carbon
GHG	Greenhouse gases
LCA	Life Cycle assessment
LPG	Liquified petroleum Gas
MCF	Methane Correction Factor
MSW	Municipal Solid Waste
NBP	National Biodigester Program
NPV	Net Present Value
OYSWMA	Oyo State Waste Management Authority
PAC	Percentage Accuracy in Classification
PAT	Pakistan Council of Appropriate Technology
PCRET	Pakistan Council of Renew Energy Technologies
PSP	Private Sector
RSPN	Pakistan Rural Support Programs Network RSPN
SWM	Solid Waste Management
TS	Total solids
UNDP	United Nations Development programme
UNFCCC	United Nations Framework Convention on Climate Change
VS	Volatile solids

1. Introduction

As a renewable fuel, biogas appears to play a significant part in Africa's energy balance. Every day, energy is used along the entire value chain, from cultivation to processing to manufacture to packing to storage to marketing to distribution to consumption. In order to achieve sustainable development, Africa's energy availability and poverty in both rural and urban areas must be addressed. Biogas can be produced in several ways. The most common is to decompose various types of nutrients in an airtight tank. The ingredients can be food waste, manure, abattoir waste, crops or sewage slurry. Successful research is being carried out to develop various techniques of decomposition. Biogas is formed when microorganisms break down organic material in a non-oxygen environment, Lutge and Sandish, 2013). This is a natural process that takes place in many oxygen-deficient environments, such as swamps, rice paddies and in the stomachs of ruminants. The power of nature is harnessed in biogas plants to produce an energy gas without environmental impact.

The majority of people in emerging nations reside in rural areas (Sagar et al., 2007). They rely heavily on solid fuels to meet their basic energy requirements, where traditional biomass is the dominant contributor. The reliance on these traditional fuels comes at great environmental, social, and human costs (Sagar et al., 2007). The deforestation rates in developing countries are among the highest in the region, and fuel wood is one of the factors that contributes to this. The harmful environmental, health and social effects associated with the use of traditional biomass and fossil fuels have increased the growing interest in the search for alternative cleaner sources of energy globally (Akinbami et al. 2016). Efforts to reduce the enormous environmental impacts and associated human health and socioeconomic implications by switching to efficient and cleaner biomass-derived fuels (biogas) have had some success, but much more needs to be done. Biogas can positively contribute to climate goals and rural livelihoods.

Fossil fuel reserves are limited in nature and are likely to finish sooner or later. The growth in population, ongoing developments around the world, and human efforts for a better life make it unlikely that today's consumption will not increase in the future. So, we need to think, what should we do about it? After the oil crisis of the 1970s, the world has diverted its attention and looked for replacement of fossil fuels with alternative/renewable energy sources (Afgan et al., 2002). It is now believed that after the 2050s, 50% of the world's energy share will come from renewable energy resources. Conventional use of fossil fuels also causes stress on the environment and contributes to greenhouse effects, global warming, and atmospheric pollution. There is also a pressing need to find alternative and ecologically sound energy sources for the future. Most emerging alternative sources of energy include solar energy, nuclear energy, and bioenergy (biomass). Among these, bioenergy is more promising, cost effective, and ever available. There are three main ways biomass energy is used: direct burning, conversion to gas, and conversion to biofuels (ethanol and biodiesel).

The energy of the future must be regenerative and sustainable and bioenergy (biogas), the biological conversion of organic materials/waste by anaerobic digestion using a technology widely used for the treatment of organic waste for the production of biogas production; (Ismail et al., 2016). In addition to being an important source of energy, particularly for the rural community, (Raja, 1997), it contributes to the mitigation of climate change by saving greenhouse gas emissions from the decay of organic materials and promotes the preservation of the traditional extensive uses of ecosystems, (Malico, 2016).

Developing countries face challenges with increased waste production caused by population and economic growth, industrialisation, and urbanisation (Dhokhikah and Trihadingrum, 2012). In highly populated developing countries, human resources are an essential factor for development, including improved waste management practises (Dhokhikah et al., 2015; Fiksel and Lal, 2018). Access to affordable and clean energy contributes to alleviation of poverty and human development, as recognised by various international programmes focussing on the implementation of appropriate energy (Martí-Herrero et al., 2015). One such technology is small-scale biogas plants that turn organic waste materials into energy (biogas) and fertiliser (digestate) (Roubík et al., 2016a).

A developing country such as Nigeria is experiencing enormous environmental and socioeconomic challenges due to the increased production of municipal solid waste (MSW), which is mainly attributed to the growth of urban population and rural-to-urban migration (Bongaarts 2009). In Nigeria, MSW disposal management through the open dumping method has become the routine management option for managing MSW (Scarlat et al., 2015 and Ezeah et al., 2010). However, the current waste management system in Nigeria follows the principles of collection-transportation and open dumping outside city limits according to the con cept of "out of sight out of mind" (Arukwe et al., 2012). In other words, Nigeria does not have a centralized MSW system with extensive recycling and resource recovery. (Arukwe et al. 2012).

In Nigeria, private waste collection services such as Girl-Child Scavenger in the Oyo state of Ibadan and public sectors such as the Oyo State Waste Management Authority (OYSWMA) have initiated several procedures to collect waste in many states whose effectiveness is ultimately influenced by location and household income to be able to afford expenses involved in rendering these services (Babayemi, 2009). MSW in Nigeria is generally characterized by inadequate handling and coverage of the collection system, an inefficient collection method, and inappropriate waste disposal, (Ogwueleka, 2009).

According to (Arukwe et al. 2012), it is widely observed that MSW disposal practices in Nigeria are a direct consequence of a combination of lack of waste separation at the point source, lack of modern technology, political and individual willingness and strength for solid waste management policy and enforcement, effective monitoring and control, household income and adequate environmental awareness and education. This is further supported by a study conducted by Abel 2007, who opined that income, education and social status were the key factors influencing per capita MSW production in Ogbomoso, Oyo state Nigeria.

Furthermore, (Ajani, 2007), also posited that location, age, occupation, and price for waste collection influenced the use of public waste collection services in Ibadan, Oyo state such as the Oyo State Waste Management Authority (OYSWMA). Therefore, it is important to note that large production in MSW can be a potential harmful source of contaminants to receptors (surrounding environment and humans) if not properly contained in disposal sites, (Arukwe et al. 2012). The increase in the generation of MSW poses some serious environmental and human health hazards through the release of contaminants from waste disposal sites, (Arukwe et al. 2012). Contaminants such as phthalates, bisphenol-A, non-ionic surfactants such as Alkylphenol Polyethoxylates (APEs), Pharmaceuticals and personal care products (PPCPs), and Perfluorinated Compounds (PFCs), have been reported to be detectable in most environmental matrices, Muray, 2010 and in biota (Yeaung et al, 2009). To mitigate the potential adverse effects on environmental and human health issues arising from contaminants released from uncontrolled MSW dumps in Nigeria, sustainable management of MSW is highly recommended.

Solid waste is useless and unwanted substances in the solid state, discarded by members of society. It can be defined as any product or substance that has no further use or value for the person or organization that owns it and that is or will be discarded (Kolekara et al., 2016). Solid waste can be classified according to its source, such as municipal solid waste, industrial solid waste, and agricultural solid waste (Orhorhoro et al., 2016b). Solid waste generation and management are major problems facing sub-Saharan African countries such as Nigeria, Ghana, Cameroon, etc. Most cities and towns in this region spend 20-50% of their environmental budget on solid waste management and only 20-80% of the waste is collected, (Orhorhoro et al., 2016b). The standard of waste management in sub-Saharan African countries is at its lowest with an inefficient storage and collection system and underutilization of disposal sites, Orhorhoro et al., 2016b). Therefore, the disposal of solid waste has become a threat in countries in sub-Saharan Africa due to their poor waste management policy.

In the nooks and crannies of the main cities and towns in sub-Saharan African countries, one can see a pile of solid waste rotting in open places such as markets, institutions, streets, drainage systems, and unfinished buildings, etc. (Orhorhoro et al., 2016b). Poor solid waste management in sub-Saharan African countries is a source of concern to society. The generated waste poses a threat to urban management, defaces the aesthetics of cities and towns across the country, and is a health hazard to citizens through the blockage of drainage systems, causing erosion and flooding. It is a breeding ground for mosquitoes, thus posing a serious health risk to the population of sub-Saharan African countries (Orhorhoro et al., 2016b).

2. Literature Review

2.1. Waste Management Strategies in Nigeria

The handling of solid waste management in Nigeria requires immediate attention and the adoption of the best practicable environmental approach to the preservation of the environment. To achieve a sustainable SWM strategy, all steps of the management process must be fully functional and effective. They include; solid waste generation and characterization, solid waste collection and transportation, and solid waste disposal/treatment (Federal Ministry of Environment, 2000). Researchers (Sha'Ato et al., 2007; Olanrewaju & Ilemobade, 2009; Uwadiegwu, 2013; Onuigbo & Bello, 2014) have reported a similar management pattern in the different steps of solid waste management.

2.1.1. Waste Generation and Characterization

Waste generation and characterization are fundamental steps taken for effective waste management, (Sha'Ato et al. 2007) carried out a study of the waste generation profile of Makurdi, in North-Central Nigeria. He reported that most of the solid waste generated in the area originated from households, rather than from commercial, institutional, and industrial premises. These wastes constituted mainly various putrescible materials, such as ash, dust, and sand. However, a study of solid medical waste showed that health facilities and hospitals in the Federal Capital Territory, Abuja, generate a large amount of solid waste collected daily that poses serious harm to the environment and human beings (Bassey et al., 2006). The study stated that of the total solid waste generated daily, 26.5% was hazardous in nature and waste segregation was found not to be practiced in any of the hospitals sampled. Similarly, (Fadipe et al. 2011) pointed out that medical waste in Osun state is not being properly disposed of and as such pathological waste such as unclaimed dead bodies, placentas, umbilical cords are being dumped into unlined pits and other wastes in open dumps.

A comparative analysis of the composition of municipal solid waste (MSW) in three local government areas in Rivers State revealed that the waste generation rate was 0.45, 0.98 and 1.16 kg/capita/day for Emougha, Obio/Akpor and Port Harcourt, respectively (Babatunde et al., 2013). The most prominent categories identified were organic waste, paper, and nylon. The mean percentage composition was 59, 65.5 ,65 for organic waste, 6, 11 and 13% for paper, and 14, 16 and 12% for nylon in Emougha, Obio/Akpor and Port Harcourt LGAs, respectively. They pointed out that there are potentials for resource recovery and energy generation. Similarly, (Sha'Ato 2007) noted that of the waste from households, a substantial proportion consists of various putrescible materials (36-57%) and suggested composting as the best form of waste management.

The rate of generation of plastics, waterproof materials, and diapers has assumed an upward trend (Nnaji, 2015). Most food waste was found to constitute close to 50% of total municipal solid waste in Nigerian cities (Nnaji, 2015; Aliyu, 2010). Due to the dysfunctional state of many municipal waste management authorities, many cities in Nigeria have been overrun by open dumps. Both governments and individuals must adopt holistic and sustainable waste management strategies to protect public / environmental health (Nnaji, 2015). Sustained cooperation could be developed between all key actors (government, waste managers, public health workers, and inhabitants) to implement reliable, sustainable and economic management practices in Nigeria (Olukanni & Mnenga, 2015). The provision of significant funds by the government and the proper education of the people, among others, will help sustainably manage the problem of solid waste.

2.1.2. Solid Waste Collection and Transportation

Waste collection and disposal are the main problems that developing countries face in solid waste management (Aliu et al., 2014). However, it is one of the most difficult operational problems faced by most urban areas in Nigeria (Ogwueleka, 2009a). Udoh and Inyang (2016) reported some of the solid waste collection problems which include singular dumpsite in the study area resulting to inherent routing issues, singular type of waste receptacle used for all categories of waste, size of bins not considered for overpopulated areas leading to opened receptacles, and overflow of waste which subsequently serves as a breeding ground for rodents, fleas and vermin. On the other hand, (Olukanni et al., 2016) also identified local factors that affect solid waste collection, ranging from poor management infrastructure, people's attitude towards waste management, weak policies, lack of sufficient funds to power the waste management sector, household economic status and ad hoc location of facilities.

In remedying these problems stated, (Egbu & Okoroigwe, 2015) noted that the collection of urban household solid waste traditionally rests on government agencies designated with such responsibility. Adding that for effective waste collection, household patronage of informal private solid waste collectors against government-provided community/street collection containers was to be encouraged. Similarly, Aliu et al. (2014) revealed several strategies that have been applied for efficient municipal solid waste management in developing economies adding that strong positive perception of public-private partnership as a waste collection policy framework to solve solid collection problems. Olukanni and Mnenga (2015) also notified that there is currently no investment in the existing development plan to initiate a modern waste collection system, calling for innovative remedies to curb the problem. Other remedies to the underlying problems surrounding the collection and transportation of solid waste in Nigeria include; the integration and collaboration of all stakeholders through broad-based sensitization and communication of effective and sustainable waste management (Hammed et al., 2016), as well as the need for SWM between the government and the people, the enforcement of sanitary laws and adequate fund allocation for all concerned agencies, the participation of the private sector (PSP) and awareness campaigns (Oloruntade et al., 2014).

Although solid waste collection and transportation of solid waste can share the same setbacks, Ayantoyinbo and Adepoju (2018) identified a problem peculiar to solid waste transportation and logistics, street traffic, especially in urban areas, affects waste logistics. However, they noted the role the government and the private sector could play in the effective management of solid waste.

2.1.3 Solid Waste Disposal/Treatment

After waste is generated, collected and transported, the final step in the management process is the disposal of the waste. In some Nigerian cities, the status of waste dump sites and the continual introduction of illegal dump sites have been a result of a failed waste management system (Nnaji, 2015). Illegal dump sites result in the loss of aesthetic beauty, endangers man and the environment, causing the spread of diseases and the pollution of the entire environment (Momodu et al., 2011). Port Harcourt, the capital of Rivers state, was at a time referred to as the Nigerian garden city due to its clean environment, beautiful vegetation, and serene nature. However, this is no longer the case there, as there exist pockets of refuse dumps litter several areas of the once beautiful city (Ayotamuno & Gobo, 2004).

According to Nnaji (2015), more than 50 percent of residents of Maiduguri in Northern Nigeria and Ughelli in Southern Nigeria dispose of their waste in open dumps. Although the open dump site disposal method is a commonly adopted method of disposal in Nigeria and other developing countries, involving people disposing of their waste on open grounds most often indiscriminately, they are generally unsanitary, unsanitary and smelly, attracting rats, insects, snakes, and flies (Udoh & Inyang, 2016). Onwughara et al. (2010) reported other non-obvious implications of open dumpsites such as landfill gasses and leachate, which contribute to global warming and urban ozone problem, thereby harming both humans and the natural environment. Similarly, (Aluko et al., 2003) reported characteristics of leachates found at dumpsites in Ibadan, Nigeria, and the serious problems they have contaminating the land and water around them. Dumpsites in the southern part of Nigeria are largely unsuitable owing to the highly waterlogged characteristics of the region (Leton & Omotosho, 2004). This requires a geological assessment of the areas before designing dump sites.

Although there are many other forms and methods of disposal of waste outside landfills, such as composting (Sha'Ato, 2007), waste reuse, source reduction and recycling (Longe et al., 2009) and incineration (Somorin et al., 2017; Onwughara et al., 2010), the option chosen should be beneficial to the environment and should require less energy, less resource use and a limited pollution rate. As observed by Kofoworola (2007), the treatment of waste does not exist, as such, collected waste that are transported to dumpsites are burnt most often to reduce the volume of waste which results in air pollution and the release of harmful gasses to the atmosphere. To this effect, Longe et al. (2009) advise the adoption of waste reduction, recycling, and reuse as an alternative.

2.3 Socio-Economic Value of Exploring Biogas Production in Nigeria

Given the many technological advantages and the population of Nigeria, it is expected that biogas technology will spread widely in the region. However, developments in biogas technology are hindered by a lack of policy commitments, lack of sufficient processing expertise, insufficient waste management, inadequate technology awareness, and related benefits. Barriers were found and attempts to resolve them had to be stepped up. Biogas technology has excellent potential in

Nigeria. Nigeria is estimated to generate approximately 542.5 million tons annually and these are mainly organic waste. Nigeria has been estimated to generate 169,542.66 MW of energy or 25.53 billion m3 of biogas if the organic waste materials generated in the country are channeled into anaerobic digestion. This will address some of the immediate energy issues of the country. Part of the renewable resource advantage that can be obtained from the exploration of biogas production via waste products also includes the fact that the byproduct from such activities can be used to produce bio fertilizers. This, it explored, can lead to an estimate of 88.19 million tons potential production of bio-fertilizer annually. This will allow the exploration of biogas production in Nigeria to have a positive environmental and economic impact on the country in the long run.

Many studies emphasized the significant factor of plants in the production of biogas, and these studies also noted that the treatment of animal waste by anaerobic digestion or biogas technology can potentially lead to the creation of a large number of renewable sources of energy (Roopnarain et al. al. 2017, Piwowar et al 2016 and Abdeshahian et al. 2016). Biogas has a great opportunity to replace fossil fuel. Several scientists have suggested the use of high-tech waste management technologies. These, according to the study by Deng et al. (2017), addressed the form of new technologies used in China to improve waste biogas production. These new methods and inexpensive sources of biowaste are found in many places in Nigeria, showing that the potential of biogas as a solution to basic challenges of waste management and energy is very possible in the country. According to the study in Shane et al. (2017), when the digester size increases, the initial cost of production for biogas plants will decrease and the number of biodigesters required for a specific area will reduce. Economic analyses reveal that the components of these digesters will be suitable with a positive net present value (NPV) at an ostensible pace of 18% to 37%. The payback period changes somewhere in the range of 1.3 to 3 years, depending on the sum invested (Shane, et al., 2017). Research also reports on the profitable feasibility of this method Shane et al., 2017, as this method could become an authentic source of energy and a renewable energy substitute that also provides agricultural biofertilizer.

2.4 Biogas as a solution for biowaste management

Rural area waste consists mainly of biodegradable materials, and those generated in urban areas or in cities are partially biodegradable, toxic, flammable, or hazardous (Igwe et al. 2002). In Nigeria, research has shown that 80% of the total waste generated is predominantly organic, (Igwe et all 2002 and CASSAQ, 1997). The compositions of solid wastes in the municipal areas vary depending on the place in which it is collected, and the season.

The enormous problems associated with the creation, collection, disposal and management of wastes in urban areas of developing countries have been widely documented (Audu et al., 2015; Onibokun et al., 1996). In an attempt to meet the needs of conservation of nature and natural resources, it is very important to know the composition of the waste to dispose of them and manage them properly. One of the problems faced by Nigerian urban centers is the issue of waste management (Audu et al, 2015). The cities of Nigeria, being one of the fastest growing cities in the world (Onibokun et al. 1996), face the problem of production and management of solid wastes. The consequences are serious when the country is growing rapidly, and the waste is not effectively managed. The inadequate disposal of domestic solid waste presents a potential danger to the environment and the natural ecosystem of the host country.

The available literature shows that the physical characteristics of urban solid waste are based on the density of the residues, their physical compositions, their moisture content, chemical composition and particle size distribution. The characterization of the residues is also carried out on the basis of flammability, organic composition, and microbiological population, respectively, (Charles, 2015). Most of the reviewed literature begins with the collection of waste from the source and the separation of it directly into material types. The weighing of the source and the sorting of household waste at the source facilitates, and the identification of waste eliminates any uncertainty regarding its source (Ogu et al. 2014 and Oyelola et al. 2008). Solid wastes are considered to be wastes generated as a result of operational activities carried out in various areas of land, such as residential, commercial and industrial. Household or Domestic waste is one that is regularly collected from households, such wastes include organic substances that are formed as a result of cooking and consuming food, rags, nylon and ash. Commercial wastes are produced from stores, supermarkets, markets and others; these include cardboard, polyethene and nylon bags. Industrial wastes are wastes obtained from industries; they can be solid, liquid, or lubricant, and are said to be toxic, hazardous, and special. Industrial waste includes metals, rubbish, chips and machine grains, sawdust, pieces of paper, and glass (Butu et al. 2014).

The current needs for sustainable urban development aim to focus on environmental issues in an overall decision-making process. In urban areas, the main environmental problems are usually associated with air quality problems caused by transport activities. Another important problem is the increase in the number of waste and inefficient waste handling, which are common in most cities. According to Ashira et al. (2017), most African countries face the challenge of converting waste into biogas. They also noted that biogas production technology will become a collective solution to both of the above-mentioned problems. Given the numerous technological advantages and the population of Nigeria, it is expected that biogas technology will spread widely throughout the country. However, progress in biogas technology is hampered by the lack of government commitments, the lack of adequate processing skills, ineffective waste management and insufficient knowledge of technology and its associated benefits (Ashira et al. 2017). Barriers were identified, and the need to intensify efforts to overcome them. The potential of biogas technology in Nigeria is excellent. The literature has shown that for the anaerobic digestion of 542.5 million tons of organic waste produced annually in Nigeria, it can generate 25.53 billion m3 of biogas or produce 169,541.66 MW of energy that addresses some of the immediate energy problems of the council. Additionally, as a by-product of the digestive process, it is possible to produce 88.19 million tons of biofertilizers annually, which will reduce the use of synthesized fertilizers. This will have a significant impact on agriculture, the level of deforestation and public health, and will improve the country's economy cumulatively, in the long run, (Ashira et al. 2017).

According to Arkadiusz et al. (2016), the use of biogas from agro-biogas plants is a progressively significant element for the distribution of power generation. In Peyman et al. (2016), they identified the potential of producing biogas from animal waste. There is a growing trend toward increased numbers of cattle in response to the growing demand for animal products that leads to the production of more organic wastes on farms and various slaughterhouses. They noted that the treatment of animal waste through anaerobic digestion or biogas technology can potentially contribute to the formation of a huge number of renewable energy sources (Peyman et al., 2016). Biogas has a new open window to replace natural gas. Many scientists have proposed the use of high-tech technology for waste processing. Some studies have also attempted to discuss various technologies for biogas treatment that are widely used around the world and key technologies in development or research. Widely adopted technologies are significantly important as a result of their modes of operation, (Rahul et al. 2017).

The study (Liangwei et al. 2017), discussed new technologies in China that are used to develop biogas from waste. With these new technologies and cheap sources of organic waste in Nigeria, we can say that the potential of biogas as a solution to the basic challenges of energy, agriculture and waste management is more real than ever. According to Agabu et al. (2017), the initial investment cost for biogas plants is reduced when the size of the digester is large, and this will reduce the number of biodigesters needed for a particular area or council. Economic analyses show that the dimensions of these digesters will be viable with a positive net present value (NPV) at a nominal rate of 18% to 37%. The payback period varies from 1.3 to 3 years, depending on the size and amount invested (Agabu et al. 2017). A study also reports on the economic viability of this process (Abdullah et al. 2017); noted that this process can become a reliable energy source and a clean energy alternative that also provides biofertilizer for agriculture.

2.5.1 Biogas production

Biogas is produced when organic matter is anaerobically broken down. It is largely composed of methane (CH4) and carbon dioxide (CO2) with small amounts of water and other gases. The composition of the biogas depends on the substrate and the digestion conditions. Biogas is produced in four stages: hydrolysis, acidogenesis, acetogenesis, and methanation, and its production is influenced by several factors including temperature, pH, and inoculation. Estimating the performance of substrates in a biodigestion process involves performing a number of preliminary tests on the substrate, including biomethane potential (BMP), total solids (TS) and volatile solids (VS), carbon–nitrogen (C/N) ratio and analysis of nutrient content.

Biogas is a gaseous mixture generated during anaerobic digestion processes using wastewater, solid waste (e.g., at landfills), organic waste, and other sources of biomass. Biogas can be upgraded to a level compatible with natural gas (‘green gas’) by cleaning (removal of H2S, ammonia, and some hydrocarbons from biogas) and increasing its share of methane (by removing CO_2). Subsequently, the resulting green gas can be delivered to the natural gas distribution grids. In developing countries, biogas could be an interesting energy option, particularly for those countries that rely heavily on traditional biomass for their energy needs.

2.5.2 Biomass and Biofuel

In recent decades, urbanisation, modernisation and industrialisation linked to energy production and utilisation have been a fundamental loop in various economic, scientific and social sectors (Ahmad Ansari et al. 2020; Shrivastava et al. 2019). The depletion of non-renewable fuel sources, accompanied with greenhouse gas emissions, has become a critical issue (Fawzy et al. 2020; Osman et al. 2021). Therefore, the necessary shift for exploring alternative options to overcome the world-scale looming energy crisis, considering the environmental concerns and its mitigation, while confronting the spiralling energy demand has become an urgent need of the hour.

Biomass, unlike other sustainable energy sources such as wind, solar, geothermal, marine and hydropower, can directly produce fuel along with chemicals (Quereshi et al. 2021; Farrell et al. 2019; Farrell et al. 2020). Thus, it is not feasible to substitute fossil-based fuels with the aforementioned sustainable energy sources; hence, biomass utilisation to produce fuel and chemicals is required (Bharti et al. 2021). Biomass is classified as non-lignocellulosic or lignocellulosic in nature and exists in various forms such as woody, herbaceous, aquatic debris, farming manure and byproducts and other forms (Osman et al. 2019; Kaloudas et al. 2021). Various technologies are used to convert biomass into fuel or chemicals, such as gasification, combustion, pyrolysis, enzymatic hydrolysis routes and the fermentation processes (Abou Rjeily et al. 2021; Peng et al. 2020).

Identifying sources of biofuels such as biodiesel and biochar can potentially reduce the environmental impacts of fossil fuels (Balajii and Niju 2019; Gunarathne et al. 2019). Biofuels can also counter the increasing use of fossil resources and prevent pressure on non-renewable sources (Peng et al. 2020; Hassan et al. 2020). However, it is important to use practical, scientific and robust tools to evaluate the real benefits of using biofuels over conventional energy sources (Chamkalani et al. 2020; Kargbo et al. 2021). Life cycle assessment (LCA) has been identified as a comprehensive evaluation approach (Astrup et al. 2015) to measure environmental impacts over the entire production chain of biofuels (Collotta et al. 2019).

2.5.3 Biofuels

A biofuel is a fuel that is produced through contemporary biological processes, such as agriculture and anaerobic digestion, rather than a fuel produced by geological processes such as those involved in the formation of fossil fuels, such as coal and petroleum, from prehistoric biological matter. Biofuels can be derived directly from plants, or indirectly from agricultural, commercial, domestic, and/or industrial wastes (Zehner, 2012). Renewable biofuels generally involve contemporary carbon fixation, such as that that occurs in plants or microalgae through the process of photosynthesis. Other renewable biofuels are made through the use or conversion of biomass (referring to recently living organisms, most often referring to plants or plant-derived materials). This biomass can be converted to convenient energy-containing substances in three different ways: thermal conversion, chemical conversion, and biochemical conversion. This biomass conversion can result in fuel in the form of solid, liquid, or gas. Solid biofuels include wood, sawdust, grass trimmings, domestic refuse, charcoal, agricultural waste, non-food energy crops, and dried manure. Biofuels are different from fossil fuels in terms of net greenhouse gas emissions, but are similar to fossil fuels in that biofuels contribute to air pollution. Burning produces airborne carbon particulates, carbon monoxide and nitrous oxides (Nylund and Koponen, 2013).

Based on the source of biomass, biofuels are broadly classified into two major categories. First-generation biofuels are derived from sources such as sugarcane and corn starch. The sugars present in this biomass are fermented to produce bioethanol, an alcohol fuel that can be used directly in a fuel cell to produce electricity or serve as an additive to gasoline. However, the use of food-based resources for fuel production only aggravates the food shortage problem (Nylund and Koponen, 2013). Second-generation biofuels, on the other hand, utilize non-food-based biomass sources such as agriculture and municipal waste. These biofuels mostly consist of lignocellulosic biomass, which is not edible and is a low-value waste for many industries. Although it is the favored alternative, the economical production of second-generation biofuel is not yet achieved due to technological issues.

2.6 Biogas composition and impurities

The main gases produced are methane and carbon dioxide. Biogas is approximately 20% lighter than air and has an ignition temperature in the range of 50 ° C to 750 ° C. It is an odourless and colourless gas that burns with a clear blue flame similar to that of an LPG gas. The calorific value of 1m3 is approximately 22 MJ if the burns are performed with 60% efficiency. The composition of gas varies with raw material used. However, the typical composition is given in the table below.

Table 1: Biogas Composition

Matter	Percentage
Methane, CH_4	50-75
Carbon dioxide, CO_2	25-50
Nitrogen, N_2	0-10
kHydrogen, H_2	0-1
Hydrogen sulfide, H_2S	Traces
Water vapor	Traces
Oxygen, O_2	0-2

Monnet, 2003 and Khurshid, 2009.

2.6.1. Types of Biogas Reactors

There are several designs, but two types of biogas reactors are popular: floating-drum plants and fixed-dome plants. The main design elements of small-scale biogas reactors common to both types re: a digesting chamber (airtight vessel) provided with an inlet and outlet, an airtight biogas collection (e.g., upper part of the reactor) and an expansion chamber. Optionally, there are connections from the toilet and a grinder/mixture for the kitchen and garden wastes.

2.6.2. Fixed-dome Reactors

A fixed-dome plant consists of a fixed digester combined with a non-movable gas holder, placed on top of the digester or gas collected in the space in the upper part of digester. When gas production starts, the slurry is displaced into the compensation tank. Gas pressure increases with the volume of gas generated and the height difference between the slurry level in the digester and the slurry level in the compensation tank.

The cost of a fixed-dome biogas plant is relatively low. The plant is simple as there are no moving parts and also no rusting steel parts and hence a long life of the plant (20 years or more) can be expected. The digesting tank is constructed underground to protect it from physical damage and saving space. While the underground digester is protected from low temperatures at night and during the cold seasons, sunshine and the warm seasons take longer to heat the digester. No day/night temperature fluctuations in the digester positively influence bacteriological processes. The construction of fixed dome plants is labor-intensive, thus creating local employment. Fixed-dome plants are not easy to build. They should only be built where construction can be supervised by experienced biogas technicians. Otherwise, plants may not be gas-tight (porosity and cracks).

2.6.3. Floating-drum Reactors

Floating-drum plants consist of an underground digester (cylindrical or dome-shaped) and a moving gasholder. The gas-holder floats over the fermentation slurry. Gas is collected in the drum, which moves up and down, depending on the amount of gas stored. The gas drum is prevented from tilting by a guiding frame. The position of the drum indicates the amount/pressure of gas available.

Construction is relatively easy; however, the cost of the steel drum is high and, furthermore, the steel parts are susceptible to corrosion. Therefore, floating drum plants have a shorter life span than fixed-dome plants. In addition, there are regular maintenance costs for the drum painting.

After the introduction of cheaper fixed-dome Chinese models, the floating drum plants are becoming obsolete. In addition to the high investment and maintenance cost of floating drum plants, they also have some design weaknesses.

2.7 Status and Prospective of Biogas Development

The potential for and benefits of small-scale biogas plants have been reviewed and are found considerable, particularly in the rural areas of developing countries, Shah,1997 and Andreasen, 2001. Over 80% of the population, however, reside in rural areas, (Arthur et al 2011). They rely heavily on solid fuels to meet their basic energy requirements, mainly for cooking and heating, where traditional biomass is the dominant contributor. It contributes to primary energy supply in Ghana about 72%, (Arthur et al 2011), 27% Pakistan (Mirza, et al 2008). Cambodia has the highest percentage (91%) of the population relying on fuel wood, and the highest per capita consumption of fuel wood, in the Asia-Pacific region (Arthur et al 2011).

Agriculture is the primary source of income and livelihood for the rural population. The dominant farming system is integrated livestock, and the crop cultivation system is based on biomass and animal manure (Suzuki, 2011). Usually, the livestock sector is dominated by smallholders, a few animals and chickens and most households have enough animals to run a small-scale biogas plant to produce biogas and organic fertilizers. For Cambodia around 500,000 rural households could install a biodigester (Buysman, 2013). Ghana has the technical potential to construct approximately 278,000 biogas plants (Arthur et al. 2011). An assessment of the potential of and need for, domestic biogas in Africa has been carried out by Felixter Heegde and Kai Sonder, Nes et al (2011). The technical potential based on the number of households that can meet the two basic requirements - sufficient availability of dung and water to run a biogas installation, are enormous. Although biogas can be generated from a score of organic materials, in Africa cattle dung from husbandry is best suited to feeding a domestic installation, (Nes et al 2011).

In order to contain the uncertainty usually associated with the transformation of the economy, the biogas, a renewable energy source, has been well taken around the world equally by developing and developed countries, and also oil exporting countries. National programmes have been started based on the target and the subsidy. A national biogas development program centered on Indian technology that provides electricity to every household. Srivastava, 2006, Cambodian National Biodigester Program (NBP) for implementation at small-scale farmer level, very much based on the Nepalese National Biogas Program, (Buysman, 2013). Biogas Initiative supported with government subsidies inspired implementation on the initial phase in Rwanda (Nes et al 2011). Denmark had well established technological practise regarding the digestion of manure and organic waste; 20 centralised and over 35 farm-scale plants have been installed up until 1998. But no new centralised plants have been established since 1998 while development of farmscale plants has also been slowed down, (Raven, et al., 2007 and Geels, 2007). However, policies for decentralised CHP and encouraging farmers to cooperate in small communities are in process (Raven, et al., 2007 and Geels, 2007).

Nigeria, a country that is rich in fossil fuels and an oil exporting country developing country has launched the Biogas Technology Programme, too (Geels, 2007). Although biogas development in Pakistan was initiated as early as 1959 and various departments and agencies were involved. Pakistan Rural Support Programs Network (RSPN) installed 5360 fixed dome biogas plants till 2014. Pakistan Council of Appropriate Technology (PCAT) Initiatives led to the installation of 1000 biogas plants. The Directorate General of New and Renewable Energy Resources (DGNRER) also supported the installation of biogas, (Doggar et al 2016 and PCRET, 2010). Different policies and policy instruments, as well as other factors, which influence a potential expansion of biogas systems have been identified and evaluated in many countries such as Sweden, UNDP 2010.

However, there are some limitations that may hinder this realisation. These include economic, technical and socio–cultural constraints. Overcoming these constraints can make biogas technology penetrate even more than already projected into the rural communities and poor urban households have been suggested, (Akinbami, 2001). A UNDP report on energy for sustainable development, UNDP 2010, indicates that in developing countries there is often a lack of clarity on the specific roles and responsibilities of various departments/institutions/ministries/agencies involved in disseminating energy services in the rural areas leading to functional overlaps and an increase in pressure on the already scarce resources. Controlled waste digestion yields several benefits and also some drawbacks. The advantages and disadvantages associated with biogas production and use are given in the following sections.

3. Problem Statement

Nigeria is currently facing air and solid waste pollution as a result of poor solid waste management and a high dependence on fossil fuels as a source of energy. Other challenges are urban migration and the post-harvest generation of agricultural waste. Although some researchers have treated the waste to biogas process in the country, a good number of Nigerians have little knowledge of what the process has to offer. The lack of experience in the technology of anaerobic digestion and biogas production from waste; and the lack of a biogas production program to meet local needs is taking its toll on the country in general. Given the numerous technological advantages and the ever-increasing population of Nigeria, biogas technology is expected to be widespread in the country. However, progress in biogas technology is hampered by a lack of government commitment at all levels. Waste generated from the agricultural sectors in Nigeria, though huge and considered worthless, can serve as raw materials for biogas, which is capable of maintaining and supporting wealth creation in the country. The Nigerian government must support relevant stakeholders to improve the technological use of Nigerians to help research on the transformation of waste products into biogas to improve the country's energy production. Research has shown the potential of emerging new technologies, especially with large digesters, which can help reduce the number of plants needed in a particular area and reduce the initial investment cost. Therefore, this study highlights the biogas waste to waste process, its benefits, and the strategic process of urban waste management.

Energy consumption has risen exponentially throughout the world and fossil fuels currently meet about 88% of this demand. Recent studies show that energy demand will increase to 50% by 2050. Biogas technology offers environmental advantages that are frequently considered a viable and strong option for hydrocarbon deposits. Along with the depletion of greenhouse gas (GHG) emissions, biogas will improve energy protection, especially, because of its impressive high energy potential. Biogas is a viable source of renewable energy; it enables the extraction of agricultural by-products and industrial waste with a depleting energy potential.

3.1. Research Objective

The general objective of this research work is to examine biogas production as a strategic way to manage urban waste in Lagos, Nigeria.

3.2. The Specific Objectives

This research will be guided by the following objectives.

i. To evaluate the cost-effectiveness of the production of biogas from municipal solid waste
ii. Identify the optimal technology for the production of biogas in developing countries such as Nigeria.
iii. To determine whether biogas production from municipal waste can prevent deforestation, ecological imbalance, climate change, and environmental pollution.

3.3. Research Question

i. Is the production of biogas from municipal solid waste cost-effective?
ii. What technologies are needed for the production of biogas in developing countries like Nigeria?
iii. Can biogas production reduce deforestation, ecological imbalance, climate change, and environmental pollution?

4. Research Methodology

Research Methodology is the systematic and theoretical analysis of the methods applied to a field of study, or the theoretical analysis of the body of methods and principles associated with a branch of knowledge. It typically encompasses concepts such as paradigm, theoretical model, phases and quantitative or qualitative techniques. This chapter guides a researcher through the systematic process of collecting, analyzing, and interpreting data to provide logical proofs from which the researcher can draw inferences concerning the relationship that exists between the variables under investigation.

4.1. Study Population

This comprehensively describes the total elements or persons covered by the problem under investigation. A total of 300 participants was sampled and used for the study. That is, 300 copies of the questionnaires was distributed to the study participants, which are the Olusosun landfill staff.

4.2. Data Requirement

The data requirement for this research work was both primary and secondary sources of data.

The relevance of the primary data to this study is to obtain information on biogas production as a strategic way of managing urban waste in Lagos, Nigeria.

Secondary data includes relevant information collected through the use of published and unpublished material from different journals, textbooks, and through the use of the Internet.

4.3. Sample Frame

Participants were sampled in different ages, gender, educational qualification, and job position. Therefore, the objective sampling technique was used as the sampling technique modality in this study. The sampled participants were all of different ages, locations, schools, and ethnicity.

Therefore, they were selected without bias to obtain the desired result that was used to generalize the study findings. Purposive sampling is a form of non-probability sampling technique, in which decisions concerning the participants included in the sample were taken by the researcher. This is usually based upon a variety of criteria, which may include: Specialist knowledge of the study issue of the researcher and / or the capacity and willingness of the participants to participate in the research.

4.4. Sample Size

For this investigation, a simple random sampling technique was employed. A total of 222 respondents are sampled by administering questionnaires. The study population comprises of the staff of Olusosun Landfill, Lagos, Nigeria. The total number of staff in the study population is approximately 500 staff. The sample size was calculated using the 'sample size determination table for research activities' by (Krejcie and Morgan, 2010). In estimating the sample size, a 5% margin of error (confidence interval) and a 95% confidence level were used. Therefore, the sample size for the study is two hundred and twenty-two (222) for a sample population.

The sample for the study is calculated thus.

$$n = \frac{N}{1 + N\ell^2}$$

$where;$
$n = Number\ of\ samples$
$N = Total\ number\ of\ population$
$\ell = error\ at\ tolerance\ (level)$

$$n = \frac{500}{1 + 500(0.05)^2} = \frac{500}{1 + 500(0.0025)}$$

$$n = \frac{500}{1 + 1.25} = \frac{500}{2.25} = 222.222$$

$$n \approx 222$$

$\therefore the\ required\ sample\ size\ for\ the\ study\ under\ consideration\ is\ 222$

4.5 Instruments for Data Collection

In the study, a structured questionnaire was used for data collection. The questionnaire was structured to collect vital information from the respondents on the objectives of the study. The questionnaire included a section on the production of biogas as a planned method of managing urban trash in Lagos, Nigeria.

4.6 Sampling Techniques

Basically, there are several types of sampling techniques/methods. Therefore, to obtain accurate information from respondents in carrying out this research work, a simple random sampling method was adopted. The population surveyed was random.

4.7 Method of Data Analysis

This section discusses the techniques for data analysis of data collected in any study. However, to achieve the objectives of this study, two forms of analysis were used which are the Analysis of Variance (ANOVA) and Logistic Regression. Logistic regression is a statistical analysis method that is used to model the probability of a binary response variable based on one or more predictor variables. In other words, it is used to model the relationship between a binary dependent variable (such as presence or absence of a disease, success, or failure in a task, etc.) and one or more independent variables (such as age, gender, income, education, etc.).

The logistic regression model assumes that the log odds of the outcome (the dependent variable) is a linear function of the predictor variables. The logit function is used to convert the probability of the outcome into log odds, and the regression coefficients are estimated using maximum likelihood estimation. The model outputs a probability score that represents the probability that the event will occur based on the input predictor variables. The logistic regression model was also used for multiclass classification by using methods such as one-vs-rest or softmax regression.

Logistic regression is commonly used in various fields such as medical research, social sciences, marketing, finance, and many others, to analyse and predict binary outcomes based on a set of independent variables. It is a simple but powerful tool to predict the probability of an event and can be used as a basis for decision making in a wide range of applications.

In addition, analysis of variance (ANOVA) is a statistical method that is used to determine if there is a significant difference between the means of three or more groups. This test was used to test hypotheses about the equality of means across several groups or treatments. The ANOVA method involves breaking down the total variation in a set of data into two components: the variation between groups and the variation within groups. The variation between groups is a measure of the differences between the group means, while the variation within groups is a measure of the differences within each group.

ANOVA uses an F-test to compare the ratio of the between-group variation to the within-group variation. If the ratio is large enough, it suggests that the group means are different enough to reject the null hypothesis of equal means.

ANOVA can be used in a wide range of applications, including in experimental research, clinical trials, and social science research. It is often used in conjunction with post-hoc tests, such as Tukey's range test, to identify which group means differ significantly.

ANOVA has several assumptions, including the assumption of normality, independence, and homogeneity of variances. Violations of these assumptions can affect the accuracy of the results, so it is important to check for them before using ANOVA and this was used to analyze the relationship between variables under this study**.** The researcher used Biogas production, cost effectiveness and optimal technology as the variables for the study.

4.8 Green House Gases Emissions

Greenhouse gases (GHGs) are gases that trap heat in the Earth's atmosphere, leading to the greenhouse effect and global warming. These gases, which include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and fluorinated gases, are emitted by human activities such as burning fossil fuels, deforestation, and agriculture. In this report, we will examine the sources and impacts of greenhouse gas emissions, as well as efforts to reduce them.

Sources of GHG Emissions:

GHG emissions come from various sources, including:

1. Energy Production: Burning fossil fuels like coal, oil, and natural gas releases CO_2 into the atmosphere, which is the primary contributor to climate change.
2. Transportation: Cars, trucks, and airplanes emit CO_2 and other pollutants that contribute to climate change.
3. Agriculture: Livestock farming, rice cultivation, and fertilizer use all contribute to GHG emissions.
4. Industry: Manufacturing and industrial processes release GHGs, including CO_2 and fluorinated gases.
5. Landfills:

Landfills are a significant source of greenhouse gas emissions, primarily methane (CH_4), which is a potent greenhouse gas that has a warming effect 28 times greater than CO_2 over a 100-year timescale. Landfills are one of the largest anthropogenic sources of CH_4 emissions, accounting for approximately 11% of global CH_4 emissions.

The main sources of CH_4 emissions from landfills include:

- Anaerobic decomposition: Organic waste, such as food waste and yard waste, decomposes anaerobically in landfills, producing CH_4 as a byproduct.
- Landfill gas collection systems: Landfills may have gas collection systems to capture CH_4 emissions, but even with these systems, some CH_4 may escape into the atmosphere.
- Landfill cover: The cover over a landfill can affect the amount of CH_4 emissions. If the cover is impermeable, it can trap CH_4 emissions and increase their concentration in the landfill.

Impacts of GHG Emissions:

The effects of GHG emissions are wide-ranging and can have significant impacts on the planet. Some of the most notable impacts include:

1. Global Warming: GHG emissions lead to an increase in the Earth's average temperature, which can cause rising sea levels, changes in weather patterns, and more frequent extreme weather events and thereby leading to climate change.
2. Ocean Acidification: Increased CO_2 levels in the atmosphere lead to increased ocean acidification, which can harm marine ecosystems and disrupt the food chain.
3. Public Health: Air pollution resulting from GHG emissions can lead to respiratory problems and other health issues particularly for people living near landfills.
4. Odor: CH_4 is odorless, but other gases emitted from landfills can produce unpleasant odors.

According to the United Nations Framework Convention on Climate Change (UNFCCC), Nigeria's GHG emissions increased from 142.3 million metric tons of CO_2 equivalent (MtCO2e) in 1990 to 490.6 MtCO2e in 2012, an increase of 245%.

Table 2: GHG Quantification Table of Olusosun Landfill

Component	Percentage (%)
Food Waste	10.36
Garden Waste	7.15
Plastics	4.05
Paper	4.35
Textile	0
Leather/Rubber	3.65
Glass	0.91
Metal	0.63
Hazardous Waste	0
Others	68.90
Total	100.00

Table 3: Default Values for Mix Waste Landfilling

Factor	Unit	Value	Remark
Amount of mix waste disposal	Tonnes/Month	1166	Default value based on composition
Amount Deposited	GG/Year	13.992	IPCC recommended default value
Degradable Organic Carbon-DOC	DOC	0.04724	Default value based on composition
Fraction of DOC decomposition under Anaerobic Condition	DOC_f	0.5	
Methane generation rate constant	k	0.05664	
Half- life time (t1/2, years)	h=In (2)/k	12.24	
Exp1	exp(-k)	0.94	
Process start in decomposition year, month-M	M	13	
Exp2	exp(-k((13-M)/12	1	
Fraction to CH_4	F	0.5	IPCC recommended default value
Methane Oxidation on Landfill cover	OX	0	Depends on the management conditions
MCF for the landfill/open dumpsite	MCF	0.4	This value should be changed according to the situation of landfill/dumpsites

Table 4: Methane Correction Factor (MCF) from different types of landfills

Type of Landfill	MCF
Managed (has landfill cover and liner)	1
Unmanaged-deep (> 5m waste)	0.8
Unmanaged-shallow (<5m waste)	0.4
Uncategorized	0.6

Table 5: Calculation of degradable organic Carbon (DOC)(Average Value of IPCC 2006)

Type of Waste	Default Values
Food waste	0.15
Garden waste	0.2
Paper	0.4
Wood and straw	0.43
Textile	0.24
DOC of mixed waste	**0.4724**

Table 6: Methane Generation Rate Constatnt(k)-Moist and Wet Tropical

Type of Watste	Default Values
Food waste	0.4
Garden waste	0.17
Paper	0.07
Wood and straw	0.035
Textile	0.07
Disposable nappies	0.17
Sewage sludge	0.4
Methane generation rate of constant mixed waste	**0.5664**

5. Results

Questions are a useful method and process used to gather information and investigate respondents to provide information that would help and enable researchers to execute a project as a partial fulfilment of the research topic. As a method it has particular advantages and disadvantages, and researcher should try to include a range of data collection methods in any evaluation and which the researcher should include methods which generate both quantitative data.

Questions also aids researcher to treat the information collected in a confidential way. Furthermore, the analysis of the data under study shall be carried out using appropriate statistical tools of Descriptive Statistics (Frequency and Percentage) and binary logistic **ANOVA** for hypothesis testing.

5.1 Data Analysis

5.1.1 Demographical Data of Respondent

Table 7: Respondents by Sex

Sex of Respondents

Response	Frequency	Percentage
Female	146	65.8
Male	76	34.2
Total	**222**	**100.0**

Source: Field Survey, 2023

Table 2 above revealed that the Female gender has the highest percentage of 65.8%, which followed by male gender with 34.2%.

Table 8. Respondents by Age

Age as last birthday

Response	Frequency	Percentage
30 years below	65	29.3
30-40 yrs	62	27.9
41-50yrs	67	30.2
51yrs and above	28	12.6
Total	**222**	**100.0**

Source: Field Survey, 2023

The table above revealed that the age group 41-50yrs has the highest percentages of 30.2%, which followed by age 30 years below with 29.3%, which followed by 30-40yrs with 27.9% and lastly 51yrs and above of 12.6%. This shows that majority of the workers of the waste management team are youth, it is advantageous since the younger generation can assist the older one in cleaning up their surroundings. Also, the workers get to communicate with one another, which is beneficial for gathering data for this research project.

Table 9. Respondents by Marital Status

Marital Status

Response	Frequency	Percentage
Married	74	33.3
Single	148	66.7
Total	**222**	**100.0**

Source: Field Survey, 2023

The table 3 above revealed that Single respondent has the highest response rate with 66.7%, which followed by Married response rate with 33.3%. This invariably means that most of the respondents are single. This shows that majority of the workers in the waste management agency are youth which makes their answer to the research questions valuable because they understand the problem.

Table 10. Respondents by Religion

Religion	Frequency	Percentage
Christianity	88	39.6
Islam	92	41.4
Traditional	42	18.9
Total	**222**	**100.0**

Source: Field Survey, 2023

The table 4 above showed that respondent with Islamic religion has the highest response rate of 41.4%, which followed by Christian religion with 39.6%, followed by Traditional religion with 18.9%, respectively. This merely identify the religion of the respondents and does not affect the research negatively or positively.

Table 11. Respondents by Ethnicity

Ethnicity	Frequency	Percentage
Igbo	33	14.9
Hausa	61	27.5
Yoruba	128	57.7
Total	**222**	**100.0**

Source: Field Survey, 2023

The table above showed that Yoruba respondent has the highest response rate of 57.7%, which followed by Hausa with 27.5% and Igbo with 14.9% respectively. Nigeria is a nation with different ethnic group and as shown in the above table, majority of the respondents are Yoruba which cannot be separated from the fact that the company under study is in a Yoruba state though, ethnic group does not influence the research in anyway.

Table 12. Respondents by Departments

Departments	**Frequency**	**Percentage**
Construction, Demolition and Disaster Waste Management	44	19.8
Engineering Services	71	32.0
Revenue Unit	14	6.3
Landfill R&S	20	9.0
Business Development	22	9.9
Project Unit	15	6.8
Special Duties	11	5.0
Waste Management Development	25	11.3
Total	**222**	**100.0**

Source: Field Survey, 2023

The table above showed that Engineering services respondent has the highest response rate of 32.0%, followed by Construction, Demolition and Disaster Waste Management with 19.8%, followed by Waste Management Development with 11.3% and lastly Special duties department with 5.0%. the table above shows the rate at which people in their engineer section responded to the question. This will have impact on the outcome of this research because engineers will understand the necessary questions asked to arrive at reasonable research finding. No doubt, the response of the engineer section will affect the outcome of the research.

Table 13. Respondents by Years of Experience

Years of Experience

Response	**Frequency**	**Percentage**
1-5 years	57	25.7
6-10 years	58	26.1
11-15 years	71	32.0
16 Years above	36	16.3
Total	**222**	**100.0**

Source: Field Survey, 2023

The table above showed that 11-15 years of Experience respondent has the highest response rate of 32.0%, followed by 6-10 years with 26.1%, followed by 1-5 years with 25.7% and lastly followed by 16 years above with 16.3%. this explains that people with experience in waste management participated well in the survey which increases the research confidence level because they understand the problem of waste management and how it can be converted into biogas, the question of if they know how to use it or now will be determined during the course of the research.

SECTION B: BIOGAS PRODUCTION AS A STRATEGIC WAY OF URBAN WASTE MANAGEMENT

QUESTION 1: Inadequate power supply has an impact on the high cost of biogas production from municipal solid waste

Table 14: Power Supply

Response	Frequency	Percentage
Strongly Agreed	77	34.7
Agreed	93	41.9
Strongly disagreed	45	20.3
Disagreed	7	3.2
Total	**222**	**100.0**

Source: Field Survey, 2023

From the above table, 41.9% of the respondents agree, 34.7% of the respondents strongly agree, 20.3% of the respondents Strongly disagree, 3.2% of the respondents Disagree that Inadequate power supply has an impact on the high cost of biogas production from municipal solid waste. The response confirms the sorry state of Nigeria in the aspect of electricity supply. It shows that unavailability of electricity supply will directly affect biogas production negatively.

QUESTION 2: The high price of equipment to be used in making biogas from municipal solid waste has an impact on the cost of producing biogas

Table 15: Price of Equipment

Response	Frequency	Percentage
Strongly Agreed	81	36.5
Agreed	109	49.1
Strongly disagreed	27	12.2
Disagreed	5	2.3
Total	**222**	**100.0**

Source: Field Survey, 2023

From the above table, 49.1% of the respondents agree, 36.5% of the respondents strongly agree, 12.2% of the respondents strongly disagree, 2.3% of the respondents Disagree that the high price of equipment to be used in making biogas from municipal solid waste has an impact on the cost of producing Biogas. The table confirms that Nigeria is country that relies heavily on foreign equipment's in the production of biogas, there is lack of government funding for the research and private firm are finding the cost of shipment of the equipment very expensive.

QUESTION 3: The lack of technical know-how in the country to produce biogas from municipal solid waste has an impact on the cost of producing biogas

Table 16: Lack of technical Know-how in the country

Response	Frequency	Percentage
Strongly Agreed	76	34.2
Agreed	77	34.7
Strongly disagreed	16	7.2
Disagreed	53	23.9
Total	**222**	**100.0**

Source: Field Survey, 2023

From the above table, 34.7% of the respondents agree, 34.2% of the respondents strongly agree, 23.9% of the respondents disagree, 7.2% of the respondents strongly disagree that lack of technical know-how in the country to produce biogas from municipal solid waste has an impact on the cost of producing Biogas. The respondents confirmed there is little or no technical personnel to handle the production of bigas from municipal waste which directly affect the production of biogas.

QUESTION 4: Inadequate funding of research institutes by the government has a negative impact on the production of biogas from municipal solid waste

Table 17: Funding Research Institutes

Response	Frequency	Percentage
Strongly Agreed	89	40.1
Agreed	110	49.5
Strongly disagreed	11	5.0
Disagreed	12	5.4
Total	**222**	**100.0**

Source: Field Survey, 2023

From the above table, 49.5% of the respondents agree, 40.1% of the respondents strongly agree, 5.4% of the respondents disagree, 5.0% of the respondents Strongly Disagree, that Inadequate funding of research institutes by the government has a negative impact on the production of biogas from municipal solid waste. The Nigerian government are lacking behind when it comes to research funding which has affected the production of biogas because with adequate research, biogas can be produced in different process if proper research is down.

QUESTION 5: Inadequate waste management and proper waste collection make waste availability difficult in biogas production.

Table 18: Waste management and Collection Method

Response	Frequency	Percentage
Strongly Agreed	74	33.3
Agreed	57	25.7
Strongly disagreed	38	17.1
Disagreed	53	23.9
Total	**222**	**100.0**

Source: Field Survey, 2023

From the above table, 33.3% of the respondents strongly agree, 25.7% of the respondents agree, 17.1% of the respondents disagree, and 23.9% of the respondents strongly disagree that the inadequate waste management and proper waste collection make waste availability difficult in biogas production. The respondents confirmed the bad culture of waste management in Nigeria, there is no specific waste collection process which make it difficult for the waste to be managed properly talk less of being converted to biogas.

QUESTION 6: The lack of availability of the necessary technology to aid biogas production in developing countries such as Nigeria has an impact on biogas production

Table 19: Lack of availability of the necessary technology to aid biogas production

Response	Frequency	Percentage
Strongly Agreed	92	41.4
Agreed	89	40.1
Strongly disagreed	18	8.1
Disagreed	23	10.4
Total	**222**	**100.0**

Source: Field Survey, 2023

From the above table, 41.4% of the respondents strongly agree, 40.1% of the respondents agree, 10.4% of the respondents disagree, and 8.1% of the respondents strongly disagree that the lack of availability of the necessary technology to aid biogas production in developing countries like Nigeria has an impact on biogas production. The unavailability of the required equipment's for biogas production has affected the rate of biogas production in the country.

QUESTION 7: There is inadequate government support for specific programs to promote biogas technologies

Table 20: Government support for specific programs to promote biogas technologies

Response	Frequency	Percentage
Strongly Agreed	98	44.1
Agreed	55	24.8
Strongly disagreed	22	9.9
Disagreed	47	21.2
Total	**222**	**100.0**

Source: Field Survey, 2023

From the above table, 44.1% of the respondents strongly agree, 24.8% of the respondent agrees, 21.2% of the respondents Disagree, 9.9% of the respondents strongly disagree, that there is inadequate government support for specific programs to promote biogas technologies. The respondents emphasize the poor support of the Nigerian government to promote biogas technology. Lack of government support has hindered the progress of biogas production in the country.

QUESTION 8: Soil disturbance, nutrient depletion and impaired water quality are also potential environmental effects from biomass feedstock production and utilization of agricultural and forest residues for energy.

Table 21. Soil disturbance, nutrient depletion and impaired water quality

Response	Frequency	Percentage
Strongly Agreed	77	34.7
Agreed	76	34.2
Strongly disagreed	47	21.2
Disagreed	22	9.9
Total	**222**	**100.0**

Source: Field Survey, 2023

From the above table, 34.7% of the respondents strongly agree, 34.2% of the respondent agree, 21.2% of the respondents strongly disagree, 9.9% of the respondents strongly disagree that Soil disturbance, nutrient depletion and impaired water quality are also potential environmental effects from biomass feedstock production and utilization of agricultural and forest residues for energy. This further explain the importance of waste management and how converting waste to biogas can check the environmental effects from biomass feedstock and utilization.

QUESTION 9: Biogas is renewable energy; it is eco-friendly, reliable and can reduce the amount of waste going to landfills.

Table 22: Biogas as renewable energy

Response	**Frequency**	**Percentage**
Strongly Agreed	103	46.4
Agreed	93	41.9
Strongly disagreed	22	9.9
Disagreed	4	1.8
Total	**222**	**100.0**

Source: Field Survey, 2023

From the above table, 46.4% of the respondents strongly agree, 41.9% of the respondent agrees, 9.9% of the respondent strongly disagrees, 1.8% of the respondent disagree that Biogas is renewable energy, it is eco-friendly, reliable and can reduce the amount of waste going to landfills.

The response further explains the importance of biogas production and how it reduces the amount of waste going to landfills, it stressed that biogas is a renewable energy which is ecofriendly and reliable.

QUESTION 10: The dangers of exposure to dioxins and furans increase for those who live near a landfill or burn their trash in backyard incinerators

Table 23: Dangers of exposure to dioxins and furans increase

Response	Frequency	Percentage
Strongly Agreed	75	33.8
Agreed	108	48.7
Strongly disagreed	19	8.6
Disagreed	20	9.0
Total	**222**	**100.0**

Source: Field Survey, 2023

From the above table, 48.2% of the respondents strongly agree, 33.8% of the respondent agree, 9.0% of the respondent disagree, 8.6% of the respondent strongly disagree, that the dangers of exposure to dioxins and furans increase for those who live near a landfill or burn their trash in backyard incinerators. This question captures the habit of burning waste in Nigeria and how it affects the residents near the landfill and also shows how important it is to use waste to produce biogas.

5.2. Estimation of Logistic Regression Equation

The variables in the Logistic Regression Equation are as specified below:

$$\textbf{logit}(\pi_i) = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i}$$

Where:

Y= Biogas Production, X_1 = Cost Effectiveness, X_2 = Optimal Technology, X_3 = Ecological Imbalance.

Where β_0, β_1 β_2 and β_3 are the coefficients of the above model, and they are the parameters to be estimated.

5.2.1. Variance explained

In order to understand how much variation in the dependent variable (Biogas Production) can be explained by the model (the equivalent of R^2 in multiple regression), the "**Model Summary**" table below explains it.

Table 24: Model Summary

Step	-2Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	289.014[a]	.044	.059

Estimation terminated at iteration number 4 because parameter estimates changed by less than .001.

This table contains the **Cox & Snell R Square** and **Nagelkerke R Square** values, which are both methods of calculating the explained variation. These values are sometimes referred to as *pseudo* R^2 values (and will have lower values than in multiple regression). However, they are interpreted in the same manner, but with more caution. Therefore, the explained variation in the dependent variable based on our model ranges from 4.4% to 5.9%, depending on whether referencing the Cox & Snell R^2 or Nagelkerke R^2 methods, respectively. Nagelkerke R^2 is a modification of Cox & Snell R^2, the latter of which cannot achieve a value of 1. For this reason, it is preferable to report the Nagelkerke R^2 value.

5.2.2. Category Prediction

Binomial logistic regression estimates the probability of an event (in this case, having Biogas Production) occurring. If the estimated probability of the event occurring is greater than or equal to 0.5 (better than even chance), the Statistics classifies the event as occurring (e.g., Production being present).

If the probability is less than 0.5, Statistics classifies the event as not occurring (e.g., Production not being present). It is very common to use binomial logistic regression to predict whether cases can be correctly classified (i.e., predicted) from the independent variables.

Therefore, it becomes necessary to have a method to assess the effectiveness of the predicted classification against the actual classification. There are many methods to assess this with their usefulness often depending on the nature of the study conducted. However, all methods revolve around the observed and predicted classifications, which are presented in the "**Classification Table**", as shown below:

Table 25: **Classification Table**

Classification Table[a]					
	Observed		Predicted		
			Biogas Production		Percentage Correct
			YES	NO	
Step 1	Biogas Production	YES	16	73	18.0
		NO	12	121	91.0
	Overall Percentage				61.7
a. The cut value is .500					

Firstly, it was noticed that the table has a subscript which states, "The cut value is .500". This means that if the probability of a case being classified into the "yes" category is greater than .500, then that particular production is classified into the "yes" category. Otherwise, the production is classified as in the "no" category (as mentioned previously).

Hence, Whilst the classification table appears to be very simple, it actually provides a lot of important information about the binomial logistic regression result, including:

- **A. The Percentage Accuracy in Classification (PAC)**, which reflects the percentage of Biogas Production that can be correctly classified as "no" production with the independent variables added (not just the overall model).
- **B. Sensitivity**, which is the percentage of cases that had the observed characteristic (e.g., "yes" for Biogas Production) which were correctly predicted by the model (i.e., true positives).

- **C. Specificity**, which is the percentage of cases that did not have the observed characteristic (e.g., "no" for Biogas Production) and were also correctly predicted as not having the observed characteristic (i.e., true negatives).
- **D.** The **positive predictive value**, which is the percentage of correctly predicted Biogas Production "with" the observed characteristic compared to the total number of Biogas Production predicted as having the characteristic.

E. The **negative predictive value**, which is the percentage of correctly predicted Biogas Production "without" the observed characteristic compared to the total number of Biogas Production predicted as not having the characteristic**.**

5.3. The Analysis of Variance (Anova)

5.3.1. Variables in the equation

The "**Variables in the Equation**" table shows the contribution of each independent variable to the model and its statistical significance. This table is shown below:

Table 26: Variables in the Equation

Variables in the Equation									
		β	S.E.	Wald	Df	Sig.	Exp(B)	95% C.I.for EXP(B)	
								Lower	Upper
tep 1[a]	Cost Effectiveness	-.176	.131	1.803	1	.179	.838	.648	1.084
	Optimal Technology	.335	.186	3.243	1	.072	1.398	.971	2.014
	Ecological Imbalance			5.183	3	.159			
	Ecological Imbalance (1)	-.141	.294	.229	1	.632	.869	.488	1.546
	Ecological Imbalance (2)	1.171	.596	3.860	1	.049	3.227	1.003	10.383
	Ecological Imbalance (3)	.760	1.197	.403	1	.525	2.139	.205	22.353
	Constant	.105	.402	.068	1	.794	1.111		

a. Variable(s) entered on step 1: Cost Effectiveness, Optimal Technology, Ecological Imbalance.

The Logistic Regression equation is given thus:

$$\textbf{logit}(\pi_i) = 0.105 - 0.176X_{1i} + 0.335X_{2i} + 1.171X_{3i}$$

The Wald test ("**Wald**" column) is used to determine statistical significance for each of the independent variables. The statistical significance of the test is found in the "**Sig.**" column.

From these results one can see that Cost Effectiveness ($p = 0.179$) and Optimal Technology ($p = 0.072$) did not add significantly to the model while Ecological Imbalance ($p = 0.049$) added significantly to the model.

From the above table, it is ascertained that Cost Effectiveness and Optimal Technology are not significantly contributed to the Biogas production while Ecological Imbalance contributed significantly to the Biogas production according to the respondents' opinion.

Also, "**Variables in the Equation**" table predict the probability of an event occurring based on a one unit change in an independent variable when all other independent variables are kept constant.

The table shows that the odds of having Biogas Production ("Strongly Agreed" category) is 0.838 times greater for others. According to the respondents' opinions, the researcher discovered that Ecological Imbalance considerably contributed to the production of biogas while Cost Effectiveness and Optimum Technology did not. The researcher concluded that the production of biogas through Ecological Imbalance had a significant effect on the production of biogas. According to the survey, Ecological Imbalance can cut trash production by 50% when compared to traditional waste management techniques.

5.4. Test Of Predictive Power

5.4.1. Hypothesis

The hypothesis to be tested is given as:

H_0 : *There is no significant difference between the predicted value and the actual value.*

H_1 : *There is significant difference between the predicted value and the actual value.*

Table 27. Table of Predictive Test

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.172	0.030	0.016	0.90652
a. Predictors: (Constant), Cost Effectiveness, Optimal Technology, Ecological Imbalance				

The coefficient of determination $\mathbf{R^2}$ which is **0.030** from the table above signify that **3.0%** of the total variation in the Biogas Production is explained by the regression equation $\mathbf{Logit(\pi_i) = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i}}$ which indicates that the prediction made on Biogas Production is reliable at **3.0%** percent.

Generally, the model, $\mathbf{Logit(\pi_i) = 0.105 - 0.176X_{1i} + 0.335X_{2i} + 1.171X_{3i}}$ is reliable for predictions since the result of the model (($\mathbf{Logit(\pi_i) = 0.105 - 0.176X_{1i} + 0.335X_{2i} + 1.171X_{3i}}$)), the R^2 which is (0.030) and the significant variable (Ecological Imbalance) indicates that the model is reliable for prediction.

As a result, the model is reliable for further prediction since the (Ecological Imbalance) variable is significant to the said fitted model.

6. Discussion Of Findings

The aim of this study was to investigate the potential of biogas production as a sustainable means of urban waste management in Lagos, Nigeria, using the Olusosun landfill as a case study. The research is related to the work of (Arkadiusz et all 2016), on the use of biogas from agro biogas plants is a progressively significant element for power generation distribution and (Peyman et all 2016), where they identified the potential of producing biogas from ani-mal waste. There is a growing trend towards an increase in the number of cattle in response to the growing demand for animal products that lead to the production of more organic wastes on farms and various slaughterhouses. A total of 300 questionnaires were distributed, and 222 responses were collected for analysis. The study found that a majority of respondents agreed or strongly agreed that inadequate power supply, high equipment costs, lack of technical know-how, and inadequate government funding for research institutes negatively impacted the production of biogas from municipal solid waste. The study also found that the main factors influencing biogas production were reported to be site characteristics, equipment availability and performance, feedstock quality, and process control. The findings suggested that a wide range of waste materials could be used as substrates for biogas production at the Olusosun landfill, including food waste, animal dung and straw. The results of this study can help government officials make decisions about the use of biogas in Lagos State. This result is related to the study of (Momoh et all, 2008) where they did studies on the effect of waste paper on biogas production from plant and animal waste in Nigeria

Furthermore, the study found that that Inadequate power supply has an impact on the high cost of biogas production from municipal solid waste. The high cost of biogas production is due to the fact that more than 90% of the energy input is used for aeration, which consumes most of the electricity. The study also finds out that the use of diesel engines for biogas production is a result of inadequate power supply and high cost of electricity in most developing countries. This is against the work of (Thomson, 2010), on energy recovery from solid wastes is the conversion of non-recyclable wastes materials into usable heat, electricity, or fuel through a variety of processes/technologies (i.e., combustion, gasification, pyrolysis, etc.). This process is often called waste-to-energy (WTE). Energy recovery serves two major purposes (i.e., wastes control and energy production)

It was observed that 49.1% of the respondents agree, 36.5% of the respondents strongly agree, 12.2% of the respondents strongly disagree, 2.3% of the respondents Disagree that the high price of equipment to be used in making biogas from municipal solid waste has an impact on the cost of producing Biogas. The study found that biogas production is expensive in Nigeria because high price of equipment to be used in making biogas from municipal solid waste has an impact on the cost of producing Biogas. A good example of this, was illustrated by a study (Leton & Omotosho, 2004) which found that, although the principle of landfilling is widely used in most open dumps across Nigerian cities, the geologic assessment conducted in the course of the study revealed that open dumps and landfilling are not suitable for some states in The Niger Delta. This is particularly true in Bayelsa state due to the fact that the area is overwhelmed with water. That is, highly waterlogged all year round. The same study suggested that Yenagoa and Bayelsa state as a whole should adopt alternative disposal or treatment method rather than landfill. Solid wastes in Nigeria are more corrosive, weighty and are saturated with water than those in industrialised nations (Ogwueleka, 2009). Hence, a different solid waste management approach is required. For example, Imam et al. (2008) argues that since the waste composition in Abuja shows that a large percentage of the waste generated are organic in nature, compaction trucks may not be appropriate. Yet about half of the collection vehicles owned by the state solid waste management agency are compaction trucks. Furthermore, Nabegu, (2010) reveals that the compaction trucks used in developed countries achieve just a little compression rate in Nigeria, due to the high density of solid waste. The study further revealed that compactor trucks will not be effective in some Nigerian cities. These results with the findings of this research work further explains how important the equipment of biogas is and the positive impact it can have on biogas production.

The respondents reiterated that 34.7% of the respondents agree, 34.2% of the respondents strongly agree, 23.9% of the respondents disagree, 7.2% of the respondents Strongly disagree that lack of technical know-how in the country to produce biogas from municipal solid waste has an impact on the cost of producing Biogas.The respondents opined that 49.5% of the respondents agree, 40.1% of the respondents strongly agree, 5.4% of the respondents disagree, 5.0% of the respondents Strongly Disagree, that Inadequate funding of research institutes by the government has a negative impact on the production of biogas from municipal solid waste. This is a cancer which has affected many research in Nigeria, the finding emphasize on the findings of To a large extent inadequate funding has been identified by several researchers as one of the most predominant factor affecting solid waste management in Nigeria, (Agunwamba, 2003; Ayotamuno & Gobo, 2004; Ezeah & Roberts, 2012; Izugbara & Umoh, 2004; Ogu, 2000; Ogwueleka, 2009). It has been suggested that the financial strength of environmental agencies in the country has not been able to parallel the rate at which solid waste is being generated. Ogwueleka (2009) argues that environmental agencies do not have the capacity to perform their duties effectively due to limited budgets. He suggested that the low morale among waste management agencies personnel resulting from poor remuneration, affect solid waste management. In Port Harcourt for instance, like most states in the country, the state government is the sole financier of solid waste management (Ayotamuno & Gobo, 2004). They argued that this system of funding is not sustainable. Hence, Imam et al. (2008) suggested that some form of user charge might help reduce the burden of funding on the government. A study of waste management in Benin (Ogu, 2000), Nigeria showed that waste management is capital intensive. The study added that despite the financial implication of waste management, there was no concrete plan being made for the recovery of some of the cost from residence. This was attributed to the fact that people are not used to paying for municipal waste management.

From the findings, 33.3% of the respondents strongly agree, 25.7% of the respondent agree, 23.9% of the respondents Disagree, 17.1% of the respondents strongly disagree that inadequate waste management and proper waste collection make waste availability difficult in biogas production. This is related to the work of Afon & Okewole (2007) noted that solid waste management is not regarded as important in the scheme of things by the three tiers of government in the country. Hence, there are some occasional long periods of financial neglect of the solid waste management agencies. Moreover, Ezeah & Roberts (2013) argues that since waste management agencies are not involved in budgetary allocations. Waste management departments are overlooked and underfunded. Hence, it is difficult them to employ and retain experts in waste management.

Ezeah & Roberts (2013) pointed out that as a result of shortage of funds waste management agencies are unable to purchase equipment's needed for efficient service delivery.

From the findings, 44.1% of the respondents strongly agree, 24.8% of the respondent agrees, 21.2% of the respondents Disagree, 9.9% of the respondents strongly disagree, that there is inadequate government support for specific programs to promote biogas technologies, this is related to the study of (Vaish, et all 2016) where they emphasize that "Governments must also come up with proper long-term objectives with appropriate planning and strategies for commercial biogas development on the continent"., the findings also agrees with the work of (Mulinda et al, 2013) that research support is much less intense in African countries, as governments fail to fund research activities to support their programmes where available, it has focussed on low-tech biogas solutions for domestic use.The research above stated that 34.7% of the respondents strongly agree, 34.2% of the respondents agree, 21.2% of the respondents strongly disagree, 9.9% of the respondents strongly disagree that soil disturbance, nutrient depletion, and impaired water quality are also potential environmental effects from biomass feedstock production and utilisation of agricultural and forest residues for energy.

From the findings, 46.4% of the respondents strongly agree, 41.9% of the respondents agree, respondents 9.9% of the respondent strongly disagree, and 1.8% of the respondents disagree that biogas is renewable energy, it is eco-friendly, reliable, and can reduce the amount of waste going to landfills. The respondent reiterated that, 48.2% of the respondents strongly agree, 33.8% of the respondent agree, 9.0% of the respondent disagree, 8.6% of the respondent strongly disagree, that the dangers of exposure to dioxins and furans increase for those who live near a landfill or burn their trash in backyard incinerators.

In conclusion, the study supports the notion that biogas production from municipal solid waste is cost-effective and has the potential to reduce deforestation, ecological imbalance, climate change, and environmental pollution. However, the challenges of inadequate infrastructure, technology, and government support must be addressed to fully realize the potential of biogas production in Nigeria. The study underscores the need for continued research and investment in this area to promote sustainable urban waste management practices. This is in agreement with the work of Igbinomwanhia, and Ohwovoriole (2012) reported economic, financial, technical, institutional, social and cultural as the major constraint limiting residential solid waste management in Nigeria. In sub-Sahara Africa countries just like every other developing country has a weak economic base, thus, insufficient funds for development of sustainable solid waste management systems (Ogawa, 1996). Considering the economic requirement of the family in this region, a monthly income of less than or equal to $300 cannot meet the economic demand of the family. Hence, they do without the service of a solid waste disposal agent. They simply engaged in crude open dumping of solid waste in drainages, around the streets and open market places, any peace of unused land, open air burning without air pollution control. Besides, economic constraints also make them to patronize cart pushers who are not able to get to the approved designated dump sites where the solid waste are expected to be managed properly.

Generally, solid waste management is given a very low priority in Nigeria and other sub-Sahara Africa. Solid waste management is given very low priority in the budget due to limited finances (Omran, and Read, 2007). As a result, very limited funds are provided to the solid waste management sector by the governments. The study found that biogas is renewable, eco-friendly, reliable, and can reduce the amount of waste going to landfills. However, respondents also recognized the dangers of exposure to dioxins and furans for those living near landfills or burning trash in backyard incinerators.

6.1 Conclusion

Biogas production is one of the most important and promising alternatives for replacing fossil fuels in an environmentally friendly manner. Waste management has been a major problem in Nigeria over the years and biogas production occupies an irreplaceable position due to the undeniable availability of biomass and the need to manage municipal waste (which appears unmanageable in Nigeria). Various scientists around the world that are conducting extensive research to develop low-cost and sustainable biogas that can be used for transportation, electricity, and heat generation which prompted the researcher to look into solving Nigeria waste management system and at the same time make biogas available for use. The success of this endeavour would benefit the environment, economy, and sustainable development of Nigeria while also managing the municipal solid waste.

The study established that biogas is a renewable energy source that can be used to produce electricity, heat and transportation fuel. Biogas is produced by anaerobic microbial digestion of organic matter in the absence of air. The main components of biogas are methane (CH4), carbon dioxide (CO2) and water vapour (H2O). Biogas is mainly produced from livestock manure or human waste, but it can also be produced from other types of organic materials including agricultural wastes, food processing wastes, municipal solid waste and industrial organic wastes

The findings of this research agree with various studies that has identified various resources as biogas feedstocks that show high energy potential, such as manure and slurry, energy crops, municipal waste, and others. The number of biogas plants operating in Nigeria is increasing every year due to the need for alternative means of providing energy and the massive rural to urban migration. According to the findings of the study, there are new techniques for choosing the best technology for producing biogas that is both affordable and sustainable, as well as for refining purpose but the Nigerian government are not tapping into this opportunity.

6.2. Recommendations

In view of the findings of this research; the researcher will recommend amongst others that;

1. Government should invest in the production of biogas from municipal solid waste by sponsoring research and making the necessary technology available for biogas producer and training of the staffs of the organization.
2. Government further informs the public about the risks associated with non-sustainable methods of waste disposal before introducing them to biogas technology through advocacy activities.
3. Private organization should dwell into the production of biogas and waste management.
4. To expand its potential as a source of renewable energy, relevant governmental organizations should investigate and develop new markets for the production of biogas from municipal solid waste.
5. To hasten the acceptance and use of biogas, the government should stimulate and promote both public and private investments in the field.

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Appendices

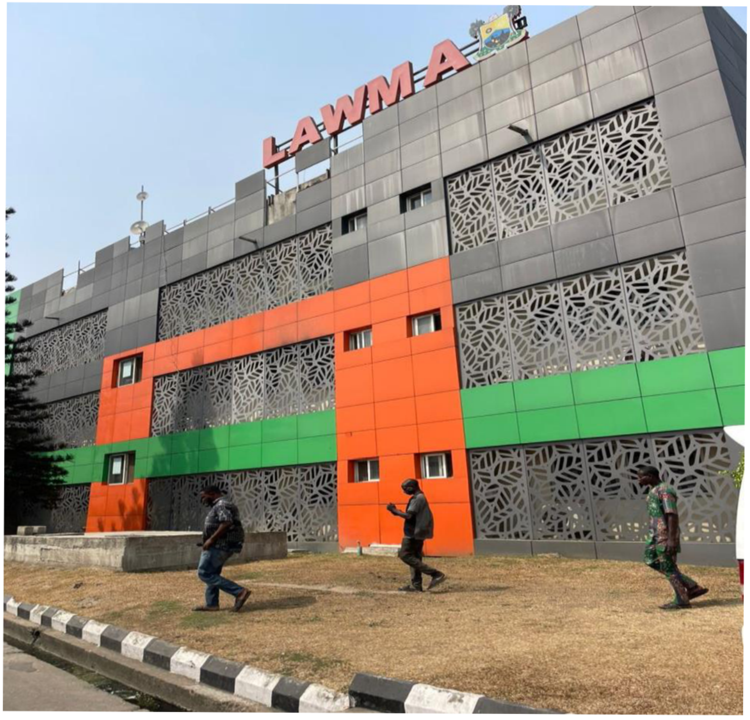
List of the Appendices

Schedule of Project Activities

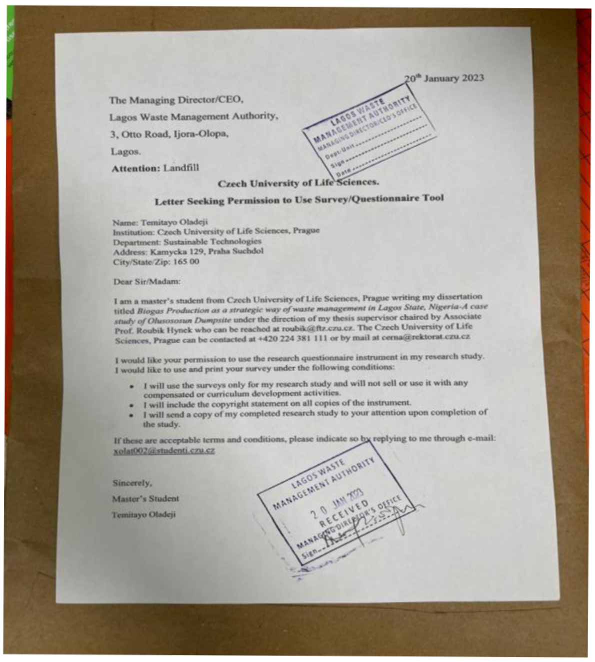
	Activity	**Time Frame**
1	Approval of master's Thesis Topic	September 2021
2	Writing and Approval of Proposal	December 2021
3	Review of Literature	4 weeks
4	Design of Methodology and Approval	1 week
5	Questionnaire Design and Approval	1 week
6	Data Collection and Collation	January 20th – January 30th
7	Data Entry and Analysis	February 3rd – 14th
8	Interpretation of Result	February 20th – 25th
9	Conclusion and Recommendation	March 3rd – March 25th
10	Review of Thesis	March 30th – April 20th
11	Final Submission	April 22nd

Appendix 2: Images of study area

Annex 1: Office of the Lagos State Waste Management board (LAWMA)



Annex 2: Letter of Approval from the LAWMA Office



20th January 2023

The Managing Director/CEO,
Lagos Waste Management Authority,
3, Otto Road, Ijora-Olopa,
Lagos.
Attention: Landfill

LAGOS WASTE MANAGEMENT AUTHORITY
MANAGING DIRECTOR/CEO'S OFFICE
Dept/Unit
Sign
Date

Czech University of Life Sciences.

Letter Seeking Permission to Use Survey/Questionnaire Tool

Name: Temitayo Oladeji
Institution: Czech University of Life Sciences, Prague
Department: Sustainable Technologies
Address: Kamycka 129, Praha Suchdol
City/State/Zip: 165 00

Dear Sir/Madam:

I am a master's student from Czech University of Life Sciences, Prague writing my dissertation titled *Biogas Production as a strategic way of waste management in Lagos State, Nigeria-A case study of Olusososun Dumpsite* under the direction of my thesis supervisor chaired by Associate Prof. Roubik Hynek who can be reached at roubik@ftz.czu.cz. The Czech University of Life Sciences, Prague can be contacted at +420 224 381 111 or by mail at cerna@rektorat.czu.cz

I would like your permission to use the research questionnaire instrument in my research study. I would like to use and print your survey under the following conditions:

- I will use the surveys only for my research study and will not sell or use it with any compensated or curriculum development activities.
- I will include the copyright statement on all copies of the instrument.
- I will send a copy of my completed research study to your attention upon completion of the study.

If these are acceptable terms and conditions, please indicate so by replying to me through e-mail: xolat002@studenti.czu.cz

Sincerely,
Master's Student
Temitayo Oladeji

LAGOS WASTE MANAGEMENT AUTHORITY
20 JAN 2023
RECEIVED
MANAGING DIRECTOR'S OFFICE
Sign

Annex 3: LAWMA Reception Office

Appendix 3: Questionnaire

TOPIC: ON BIOGAS PRODUCTION AS A STRATEGIC WAY FOR URBAN WASTE MANAGEMENT IN NIGERIA. A CASE STUDY OF OLUSOSUN LANDFILL

Dear Respondent,

I am a student at the Czech University of Life Sciences Prague (Czechia) working on research to determine the **BIOGAS PRODUCTION AS A STRATEGIC WAY FOR URBAN WASTE MANAGEMENT IN NIGERIA. A CASE STUDY OF OLUSOSUN LANDFILL**. I humbly request your cooperation and sincere opinion in completing the questionnaire over the next few minutes. Be rest assured that all information provided will be treated confidentially as this exercise is strictly for academic purposes. You are important for this study.

Thank you for your voluntary participation.

Researcher: **Oladeji Temitayo Paul**, **Czech University of Life Science, Prague.**

SECTION A

SOCIO-ECONOMIC CHARACTERISTICS

Instruction: Please tick (✓) the appropriate answer in agreement with your opinion.

1. Sex: Male ( ) Female ( )
2. Age: Below 30years ( ) 30-40years ( ) 41-50years ( ) 51years and above ( )
3. Marital Status: Single ( ) Married ( ) Divorced ( )
4. Religion: Christianity ( ) Islam ( ) Traditional ( )
5. Ethnicity Igbo ( ) Hausa ( ) Yoruba ( )
6. Department in organization…………………………………
7. Years of Experience: 1 - 5years ( ) 6-10years ( ) 11-15years ( ) 16yrs above ( )

SECTION B

[RESEARCH QUESTIONS]

SA= strongly agreed A= Agreed SD= Strongly Disagreed D= Disagreed

THE COST-EFFECTIVENESS OF THE PRODUCTION OF BIOGAS FROM MUNICIPAL SOLID WASTE

	Statement	**SA**	**A**	**SD**	**D**
8	Inadequate power supply has an impact on the high cost of biogas production from municipal solid waste				
9	The high price of equipment to be used in making biogas from municipal solid waste has an impact on the cost of producing biogas.				
10	The lack of technical know-how in the country to produce biogas from municipal solid waste has an impact on the cost of producing biogas				

11	Inadequate funding of research institutes by the government has a negative impact on the production of biogas from municipal solid waste				
12	Corruption from workers of the waste management team has a negative impact on the success rate of biogas production from municipal solid waste.				
13	Inadequate waste management and proper waste collection make waste availability difficult in biogas production.				
14	The excessive bureaucratic bottleneck has an impact on biogas production				

OPTIMUM TECHNOLOGY FOR THE PRODUCTION OF BIOGAS IN DEVELOPING COUNTRIES LIKE NIGERIA

	Statement	**SA**	**A**	**SD**	**D**
15	The lack of availability of the necessary technology to aid biogas production in developing countries like Nigeria has an impact on biogas production				
16	There is inadequate government support for specific programs to promote biogas technologies				
17	There is little or no international research partnership among concerned agencies to aid biogas technology.				
18	Little attention has been paid to the development of biogas technology in Nigeria				
19	The development and application of biogas technology have been hampered by a number of factors including storage difficulty of biomass residues and technical barriers				
20	Biogas technology can not only provide fuel but is also important for comprehensive utilization of biomass forestry, animal				

	husbandry, fishery, agricultural economy and protecting the environment				
21	Residues from livestock farming (manure) Previously unused plants/plant parts (intermediate fruits, plant residues) Energy crops (corn, sugar beet)				

BIOGAS PRODUCTION FROM MUNICIPAL WASTE CAN CHECK DEFORESTATION, ECOLOGICAL IMBALANCE, CLIMATE CHANGE AND ENVIRONMENTAL POLLUTION.

	Statement	SA	A	SD	D
22	As an alternative to burning polluting wood, dung, or fossil fuels for household energy, biogas could help slow climate change.				
23	Biogas reduces methane emissions that occur during the storage of animal waste				
24	Heat is released as well as electric power and organic fertilizer during the process of biogas. This heat can be used for heating in the greenhouse and residential places, which are close to the facility.				
25	Competition for arable lands required for food and fiber production is the major issue concerning biomass production				
26	Soil disturbance, nutrient depletion and impaired water quality are also potential environmental effects from biomass feedstock production and utilization of agricultural and forest residues for energy.				
27	Biogas is renewable energy, it is eco-friendly, reliable and can reduce the amount of waste going to landfills.				
28	Biogas can improve global health, reduce agricultural losses, increase energy access, and improve people's lives and businesses.				

CURRENT ENVIRONMENTAL PROBLEMS AND HAZARDS AT THE OLUSOUN LANDFILL

	Statement	SA	A	SD	D
29	There is high inhalation exposure to endotoxin, microorganisms, and aerosols from the waste site.				
30	fire and explosion, inhalation of toxic gases, and injury to children playing on or around the dumpsite are an unavoidable hazards around the dump site.				
31	Water-borne diseases such as typhoid, dysentery, fatigue and cholera are amongst the ailments mostly suffered by inhabitants within the vicinity of the dumpsite.				
32	There is a high probability of respiratory symptoms among residents living close to waste sites.				
33	Residents around the dumpsite are likely exposed to diseases carried by mosquitoes, flies and rodents.				
34	The dump site pollutes the atmosphere with a distinct choking odour.				
35	The dangers of exposure to dioxins and furans increase for those who live near a landfill or burn their trash in backyard incinerators.				

Thank you.