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BIOGAS A VIABLE SOURCE OF ENERGY: CASE STUDY, NIGERIA

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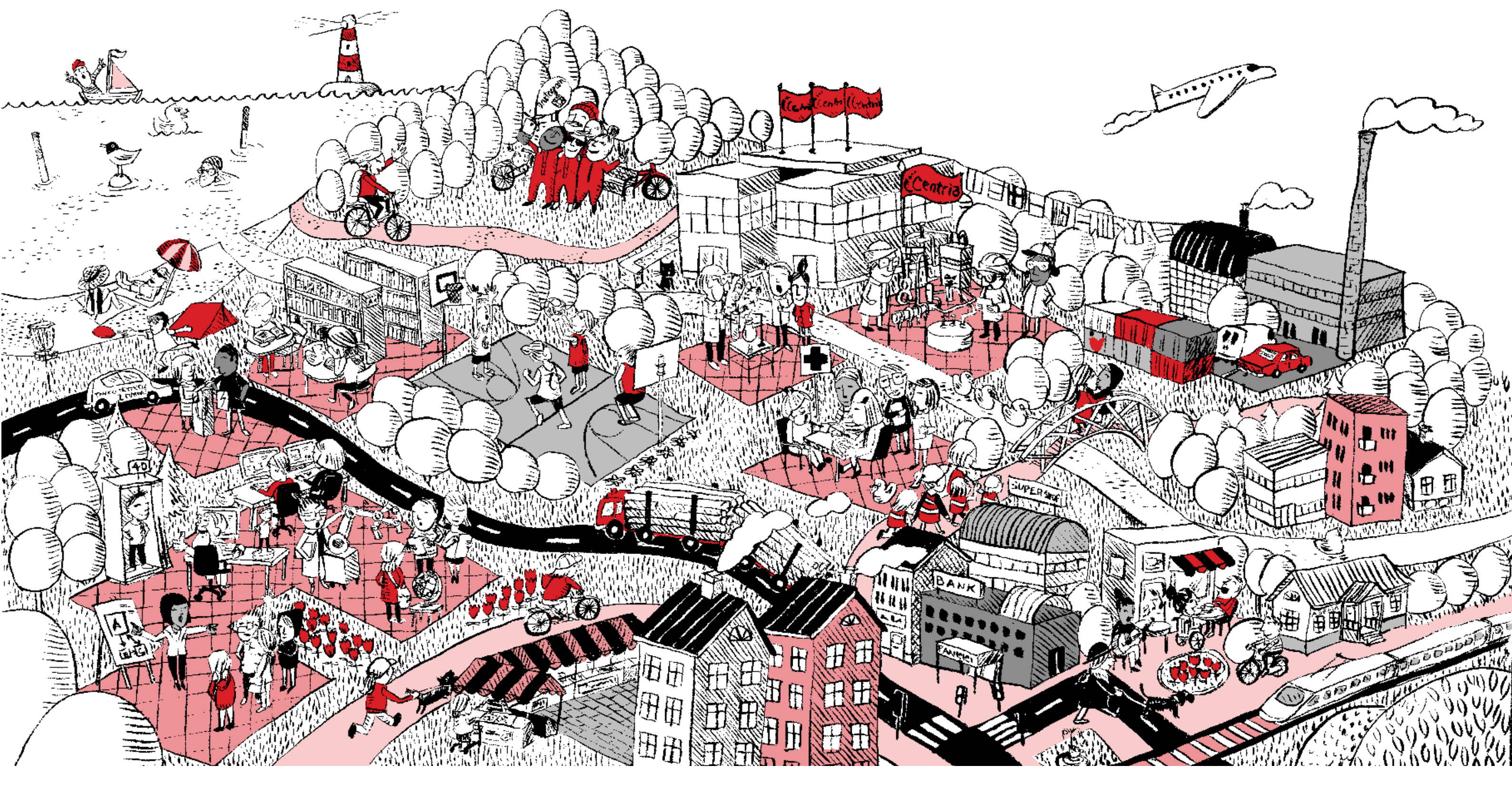

ABSTRACT

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Since the inception of man, energy has been an indispensable part of modern society which serves as an indicator of economic growth and development. In the early nineteenth century, coal is the major source of energy whereas oil in the twentieth century. This extensive use of fossil fuel has led to high emissions of carbon dioxide and other greenhouse gases.
The objective of this research is to ascertain the status of biogas technology to both urban and rural settings in Nigeria.
Nigeria holds a great potential for the production and use of biogas with its large population and abundant feedstock for production. However, biogas production is hindered due to low awareness and lack of skilled personnel in the field. In a bid to solve inconsistency in electricity in Nigeria, biogas can proffer solution to this problem which will increase business, and also attract foreign investors into the country due to available power at a low and affordable cost. The rise in inorganic fertilizers can be solved by the use of the liquid effluents obtained from biogas at a lower cost and better food security, this will on a long run reduce agricultural commodity prices in the nation and make food available for easy access.

Key words

Biodigester,biogas,greenhouse gases,biomass,biofuels,renewable energy

ABSTRACT
CONCEPT DEFINITIONS
CONTENTS

FIGURES

TABLES

1 INTRODUCTION

Energy has been an essential component of modern society since the dawn of time, serving as a barometer of economic growth and development. Coal was the primary source of energy in the early nineteenth century, whereas oil was the primary source of energy in the twentieth. Because of the widespread use of fossil fuels, there has been a significant increase in carbon dioxide and other greenhouse gas emissions..Biogas is the mixture of gases produced by the breakdown of organic matter in the absence of oxygen (anaerobically), primarily consisting of methane and carbon dioxide. Biogas can be produced from raw materials such as agricultural waste, manure, municipal waste, plant material, sewage, green waste or food waste.

According to the FAO (2010) report, Nigeria has the highest rate of deforestation in the world with 55.7% of her primary forest lost between 2000 and 2005. Records also show that fifty million tons of wood fuel is consumed per annum in Nigeria which makes Nigeria rank 8 in the world methane emission where 60% of emission is from bass flaring. Biogas technology can avert the problems of low power supply due to inadequate gas, lack of fertilizers for agriculture and also high burning of fossil fuel.

Nigeria holds a lot of opportunity for viable establishment of elaborate and sustainable biogas anaerobic digester project with an estimated bio potential energy of 610, 350 Tj per annum from organic waste which is equivalent to 169,541.66 megawatts which is able to displace kerosene and coal as a major fuel (Ngumah, C C., Ogbulie, J N., Orji, J C., and Amadi, E S. 2013).

The objective of this research is to ascertain the status of biogas technology to both urban and rural settings in Nigeria.

I) To evaluate the present status of household biogas digester in both urban and rural households.

II) To evaluate current opportunities and constraints of digester in both urban and rural areas in Nigeria

III) To generate resource inventory of both government and private industries as well as households currently using the biogas techniques of energy generation.

2 THE NIGERIAN POPULATION

Nigeria as shown in Figure 1, is a country in West Africa bordering Niger in the north, Chad in the northeast, Cameroon in the east, and Benin in the west. Its southern coast is on the Gulf of Guinea in the Atlantic Ocean. It is a federal republic comprising 36 states and the Federal Capital Territory, where the capital, Abuja, is located. Lagos is the most populous city in the country and the African continent, as well as one of the largest metropolitan areas in the world.

Nigeria gained her independence from the British colony in 1960 and was pronounced a republic in 1963. Nigeria is a multinational state inhabited by more than 250 ethnic groups speaking 500 distinct languages, all identifying with a wide variety of population (Pereltsvaig Asaya 2011). According to the Nigeria-CIA world fact book (2019), the three largest ethnic groups are the Hausa–Fulani in the north, Yoruba in the west, and Igbo in the east, together comprising over 60% of the total population. Based on the United Nations population data 2021, Nigeria holds a population of about 209,812,698 people, which makes it rank 7th as the world most populated nation, which explains the high production rate of organic waste as recorded by China et. al, (2012) which can be converted into renewable gas. The United State Energy Information Administration (2011) also reported that 83% of the total energy consumption in Nigeria comes from renewables (biomass) i.e. firewood used by most people in the rural areas for lighting, cooking and heating needs.

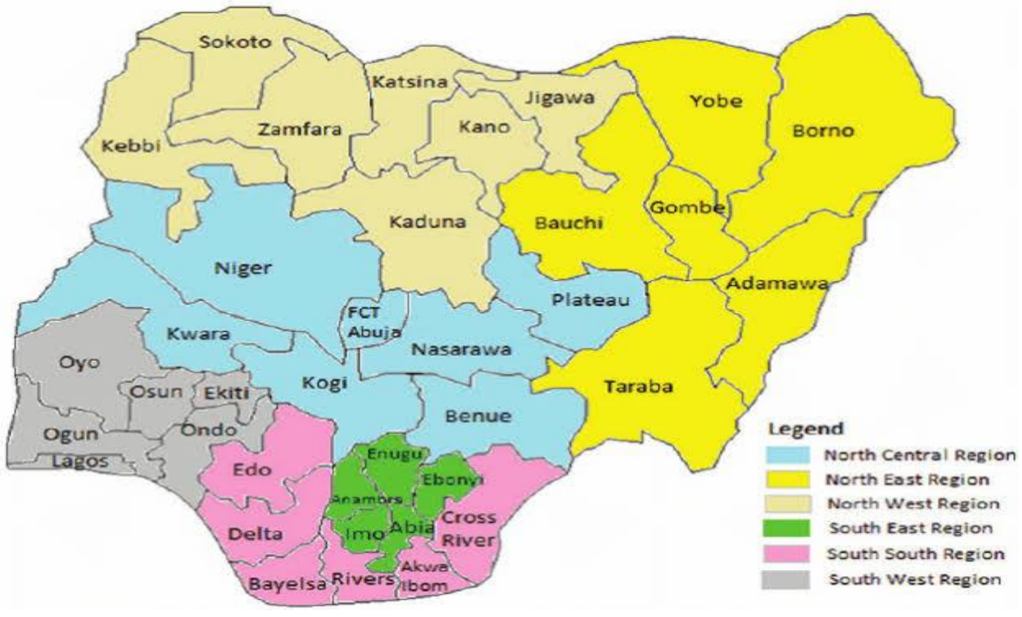


Figure 1. Nigerian Map showing all 36 states and regions of the country (Ezra Gayawan, 2014).

3 BIOGAS PRODUCTION SYSTEM

Biogas is a renewable energy source based on biomass, also referred to as natural gas or biofuels has become the alternate source of energy which works in harmony with the ecosystem and harness the emission of greenhouse gases in the atmosphere. Biogas generates different forms of energy which will reduces huge amount of greenhouse gas emission which is the major cause of global warming. According to Global Forest Resource 2010, nearly a billion ton of carbon are released into the atmosphere from burning of firewood. It is a common fact that majority of the total greenhouse gas concentration and that almost all may be directly estimated from the combustion activities (Boden et al., 2010).

Ashekuzzamana et.al., (2010) suggested that biogas has the innate potential to meet rural energy demand and contribute to new wealth generation. Carefully analyzing the global impact of renewable energy, it is clear that a noticeable relationship exists between renewable energy and climate change. Historical evidence indicates that Anaerobic digestion system is one of the oldest waste management techniques since 3000BC (Deubline & Steinhauser 2008), in recent times, many countries have adopted techniques for producing biofuel and bio fertilizers through anaerobic digestion systems.

3.1 Biogas Generation Techniques

Biogas is generated using an anaerobic digester technique (AD). Materials such as animal dungs and other biogas feedstock materials are ingested into closed chambers where organic matter are acted upon by methanogen or other anaerobic microbes, causing decomposition and production of methane gas (CH_4) and Carbon di oxide (CO_2) and small amounts of other gases such as hydrogen sulfide, (H_2S) methane gas (CH_4), through a liquid replacement system (Mahmoodi, et al., 2018). The manure and waste are injected into the receiving tank which mixes the organic material before being heated to 38-52°C/100-125.6°F and pumped into the digester in which the biogas is produced. The biomass stays in the digester for 2-3 weeks and the fermented slurry can subsequently be used as crop fertilizer (Bonten et.al, 2014). .

After the removal of trace contaminations consisting of hydrogen sulfide, xyloxanes, and water, it can be burnt to generate heat or can be used as fuel in gas engines, coupled to a generator to produce electricity and heat. If the CO2 is also eliminated from the biogas, the remaining gas, often called biomethane, has the properties of purified natural gas and can be utilized in every application to replace fossil natural gas as transportation fuel, raw material for the chemical industry, or in fuel cells, which convert it to electricity with high efficiency. (Ahring 2003.)

With this technique of renewable waste management, biogas can displace use of kerosine, at least 357-60,952 tons of carbon dioxide emission will be avoided. (Akinbami et.al., 2001). Also, FAO (2010) reported that Nigeria has the highest rate of deforestation in the world with 55.7% of her primary forest lost between 2000 and 2005. Records also shows that fifty million tons of wood fuel is consumed per annum in Nigeria which makes Nigeria rank 8 in the world methane emission where 60% of emission is from bass flaring. Biogas technology can avert the problems of low power supply due to inadequate gas, lack of fertilizers for agriculture and also high burning of fossil fuel.
Nigeria has a lot of potential for the effective creation of extensive and environmentally sound biogas anaerobic digester projects with a projected bio potential energy of 610,350 Tj per year from organic waste, which is roughly comparable to 169,541.66 megawatts and capable of displace kerosene and coal as a major fuel. (Ngumah et.al., 2013).

3.1.1 Biogas Composition

The composition of biogas depends on the feedstock and this affect the production of other gasses. The main biogas produced is methane (CH_4) gas and carbon dioxide (CO_2) which the quantity produced is dependent on the type of feedstock used as shown in Table.1, other gases are generated alongside methane and carbon dioxide. According to Jönsson et. al (2003) Biogas from sewage digesters usually contains from 55 to 65 % methane, 35 to 45 % carbon dioxide and < 1 % nitrogen, biogas from organic waste digesters usually contains from 60 to 70 % methane, 30 to 40 % carbon dioxide and < 1 % nitrogen, while in landfills methane content is usually from 45 to 55 %, carbon dioxide from 30 to 40 % and nitrogen from 5 to 15 %. Hydrogen sulfide and other sulfide compounds, siloxanes, and aromatic and halogenated compounds are generated in small amounts compared to methane (CH_4).

Table 1. Percentage Composition of methane in different feed stock (Adapted from Sasse 1988).

Feedstock	Methane Percentage
Cattle manure	65
Poultry manure	60
Pig manure	52
Farmyard manure	55
Straw	59
Grass	70
Leaves	50
Kitchen waste	60
Algae	63
Water hyacinths	67

The presence of several trace compounds in raw biogas produced from anaerobic digestion as shown in Table 2 may have adverse effects on beneficial uses but can be removed through pretreatment (or conditioning). The most significant components targeted in biogas conditioning/pretreatment are hydrogen sulfide (H2S), siloxanes, moisture, PM, ammonia, and CO_2. Hydrogen sulfide is a toxic product formed from sulfates and organic sulfur compounds in the feedstock under anaerobic conditions. During combustion, H_2S will react with oxygen to form SO_2, then sulfurous acid (H_2SO_3) and sulfuric acid (H_2SO_4). These acids are corrosive to downstream equipment such as IC engines (Razbani et al., 2011). Stringent H2S limits are usually imposed by regulatory agencies. Gas treatments for H_2S removal include adsorption, chemical scrubbing, and biological scrubbing using bio trickling filters (Huertas et al., 2011).

Table 2. Percentage production of biogas component (Adapted from Zhang, R. 1999 and Kali et.al 2002)

Constituent	Percentage composition
Methane (CH_4)	55-65
Carbon (CO_2)	35-45
Hydrogen Sulphide (H2S)	0-1
Nitrogen (N_2)	0-1
Hydrogen (H)	0-1
Carbon Monoxide (CO)	0-3
Oxygen (O_2)	0-2

Higher amount of biogas is dependent on the digestibility of the feedstock. The more digestible the feedstock is, the higher is the gas yield potential. The biogas or methane yield is measured by the amount of biogas or methane that can be produced per unit mass of volatile solids (VS) contained in the feedstock after a given amount of time under a given temperature (Banks et al., 2011; Zhang et al., 2007).

3.1.2 Monitoring produced gas

The most important measurement for biogas plant operators is the volume biogas produced which is also referred to as methane yield. A low recorded yield will give an indication that fermentation was disturbed, while a high yield will indicate accuracy in production process. A perm-selective gas sensor for determining the composition of carbon dioxide and methane mixture on a range of 0-100% has been described by Rogo and Mendes (2014) with a time response of 1 minute would help optimise possible operating conditions. The ration of carbon dioxide and methane production is usually stable but can be altered during fermentation processes. It is advisable that biogas plant should be properly checked for possible cause of shortage, low production and flaring. During monitoring, optimum condition which includes the pH and temperature should be highly considered as they influence every stages of fermentation and microbial activity. Surpassing the defined optimum temperatures of $37^{0}C$ may lead to inhibition of enzymatic reactions. (Streitwieser, D.A 2017). Every biogas operator should put into consideration, monitoring of the quality and quantity of feedstock for the target production, making sure that there are no harmful materials or non-soluble materials that are not good for the digester walls. Although there are no technologies that are put in place to monitor every stage and aspect of biogas except for analysing every single output of production. Monitoring of biogas plant parameter can be achieved by grouping them under three categories which are parameters characterizing the process (feedstock type and quantity, biogas production amount and its quality, reactor temperature, dry matter concentration, ammonia concentration, and pH), parameters supplying early detection of instability (alkalinity, hydrogen concentration, redox potential, and other complex monitoring parameters), and variable process parameters defined by plant operators (Drosg 2013) which implies that monitory should be done at every stage.

3.2 Anaerobic Digester

Anaerobic digestion is the breakdown of organic matter by bacteria, such as animal manure., wastewater bio solids, and food waste—in the absence of oxygen. Anaerobic digestion for biogas production takes place in a sealed vessel called a reactor, which is designed and constructed in various shapes and sizes specific to the site and feedstock conditions. Anaerobic microorganisms digest the organic materials, in the absence of oxygen to produce methane and carbon dioxide as end products under ideal conditions. The biogas produced in anaerobic digestion plant usually contains small amount of hydrogen sulphide (H_2S) and ammonia (NH_3), as well as trace amount of other gases (Monnet, 2003).

The anaerobic process undergoes four states which are hydrolysis, acidogenesis, acetogenesis and methanogenesis. The first stage of the process is the bacterial hydrolysis of the input feedstock. Insoluble organic polymers, such as carbohydrates, are broken down to soluble monomers and proteins are broken down into amino acids, lipids into long- and short-chain fatty acids, starch into glucose, and carbohydrates into sugars that become available for other bacteria. This process is immediately followed by Acidogenesis which will breakdown certain substrates, such as lignin, cellulose, and hemicellulose. Acidogenesis converts volatile fatty acids into acetic acid, carbon dioxide, and hydrogen. As opposed to other stages, acidogenesis is generally believed to proceed at a faster rate than all other stages of anaerobic digestion, with acidogenic bacteria having a regeneration time of fewer than 36 h (Dublin et.al, 2008). The following process involves the acidogenic bacteria converting these resulting organic acids into acetic acid, along with additional ammonia, hydrogen, and carbon dioxide amongst other compounds. Acetogenesis occurs through carbohydrate fermentation, in which acetate is the main product, and other metabolic processes (Themelis and Verma, 2004). The presence of Hydrogen Scavenging Bacteria (HMBs) consume hydrogen, thus lowering the partial pressure, is necessary to ensure thermodynamic feasibility and thus the conversion of all the acids (Siddhart.S 2006)

The final stage of methanogenesis convert these products to methane and carbon dioxide. The process of formation of methane by some microorganisms commonly known as methanogens under anaerobic conditions (Venkata Mohanet al. 2011,2013). Methanogens utilizes the waste products of different bacteria to produce methane and carbon dioxide under anaerobic conditions (Kumar et al.2014). The breakdown of the organic compounds is facilitated by a cascade of bacterial degradation enzymes by various groups of bacteria such as acidogens, acetogens, methanogens. These set of bacteria thrives in the absence of oxygen and water bodies. Methane production is higher from reduction of carbon dioxide but limited hydrogen concentration in digesters results in that the acetate reaction is the primary producer of methane (Monnet, 2003). The methanogenic bacteria include methano bacterium, methano bacillus, methano coccus and methano sarcina. Methanogens can also be divided into two groups: acetate and H_2/CO_2 consumers. Methanosarcina spp. and methanothrix spp. (also, methanosaeta) are considered to be important in anaerobic digestion both as acetate and H_2/CO_2 consumers (Monnet,2003).

3.2.1 Components of the Anaerobic digestive system

Anaerobic digester system as shown in Figure 2 constitute different components which has been used for decades and most recently for municipal wastewater facilities and in the processing of industrial and agricultural wastes (Burke, 2001). These system uses organic wastes as the major input, which produces biogas that contains 55% to 70% CH_4 and 30% to 45% CO_2. On dairy farms, the overall process includes the following:

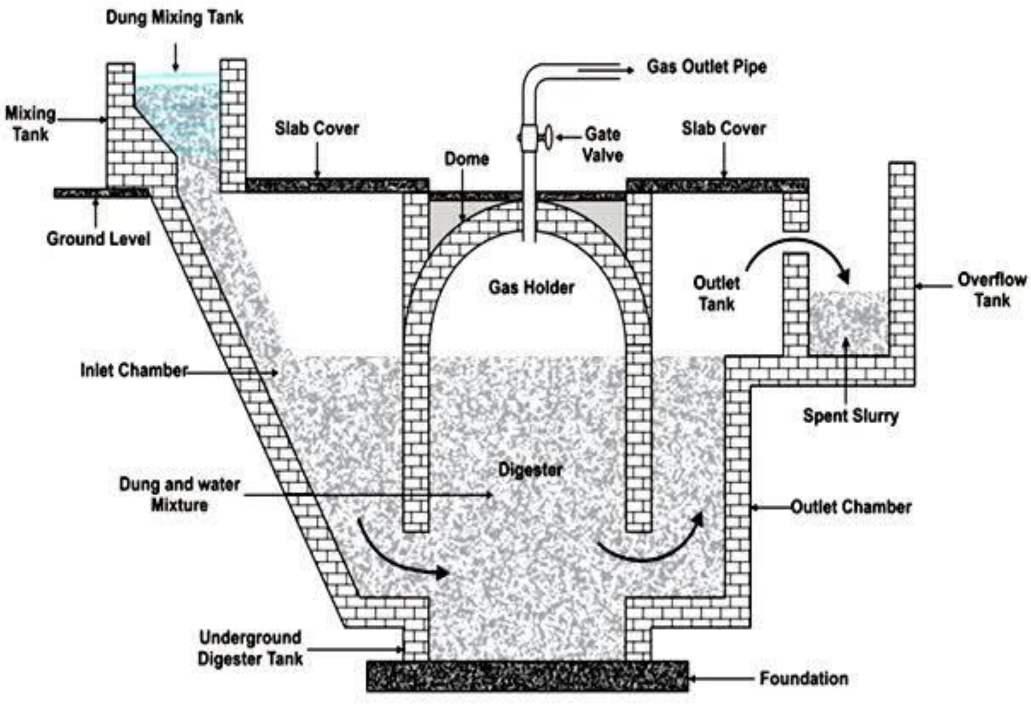
Manure collection and handling**:** The major materials needed in the system is organic manure. During collection, inorganic material is crushed and mixed with adequate amount of water and organic manure, to form a slur.

Pretreatment: Collected manure may undergo pretreatment prior to introduction in an anaerobic digester. Pretreatment—which may include screening, grit removal, mixing, and/or flow equalization—is used to adjust the manure or slurry water content to meet process requirements of the selected digestion technology.

Anaerobic digestion: An anaerobic digester designed to exclude air and promote the growth of methane bacteria. The digester may be a tank, or a covered lagoon designed in a way that will support bacterial growth. In anaerobic habitats, methanogens keep fermentative pathways energetically favorable by maintaining an extremely low partial pressure of H_2. The methanogens are a highly specialized group of microbes that produce CH_4, which is both a useful energy source and a powerful greenhouse gas (Hendrickson et.al., 2004).

Biogas recovery. Biogas formed in the anaerobic digester bubbles to the surface and accumulate at the collection/storage facility, depending on the design of the digester. The collection system, typically plastic piping, then directs the biogas to gas handling subsystem. The generated biogas is pumped or compressed to the operating pressure required by specific applications and then metered to the gas use equipment. Collected biogas is processed by removing other impurities.

Figure 2. Components of an anaerobic digester (Sooch.S and Gautam.A 2013).



3.2.2 Bio plant management and maintenance

In maintaining the biogas plant which includes the anaerobic digester and every pipe, fittings and components, a regular service repair is needed to prevent leakage, breaks and malfunctioning of any equipment needed in the process. The anaerobic digester plant have to be frequently managed to prevent flaring and loss of gas. Frequent control and documentation of motor settings and frequent maintenance and control of methane concentrations can help to minimize these flare emissions (Jan et.al 2017). Every pipes, outlet and fittings should be monitored for leakage and repaired immediately upon identification and the biogas plant should be serviced regularly within a period of 1-2 years. (Holm-Nielsen and Oleskowicz-Popiel 2013). The use water or urine contaminated with pesticides should be avoided in the mixing tank, impurity free substrate and dung from slaughter houses should not be used and the mixing chambers should be left clean. This will prevent impurities which will result to low metabolism and fermentation from entering into the fermentation chambers of the tank. (UDBP 2011). Every measuring instrument such as pressure guide should be adequately calibrated and pipes well hose well fitted. Failed in proper management and maintenance of biogas plant can result to low production, biogas filled with impurities, damage of digester plant and operator accident.

4 HISTORICAL DEVELOPMENT OF BIO-DIGESTER SYSTEM

Historical evidence indicates that the anaerobic digestion process is one of the oldest technologies (Monnet, 2003). Jan Baptita Van Helmont was the first to determine in 17th century that flammable gases could evolve from decaying organic matter. Count Alessandro Volta concluded in 1776 that there was a direct correlation between the amount of decaying organic matter and the amount of flammable gas produced. In 1808, Sir Humphry Davy determined that methane was present in the gases produced during the anaerobic digestion of cattle manure (Monnet, 2003) .

The first digestion plant was built at a leper colony in Bombay, India in 1859 (Meynell, P-J 1976). anaerobic digester (AD) reached England in 1895 when biogas was recovered from a "carefully designed" sewage treatment facility and used to fuel street lamps in Exeter (McCabe & Eckenfelder 1957) . The development of microbiology as a science led to research by Buswell and others in the 1930s to identify anaerobic bacteria and the conditions that promote methane production (Meynell, P-J 1976) .

China is one of the countries in the world where the use of biogas started at a very early stage (Ahmadu, 2009). In 1920, Mr. Luo Guorui built a biogas digester called “Chinese Guorui Natural Gas store”, which was the first hydraulic digester in China, (Ahmadu, 2009). This marked the beginning of rural biogas systems development in China (Fulford, 2011). In 1978, 7 million plants were built, but only 3 million were working. In 2009, about 17 million biogas plants which mainly use underground masonry plants of size 4 to 10 m3 but less than 50% success was recorded (Fulford, 2011).

The fixed dome plant was originally developed in China, which consists of a cylindrical digester with a round top and flat or curved bottom. Other variations of the fixed dome plant include the Deenbandhu and Deenbandhu 2000 model biogas plants developed in India, which have a dome at the top and a curved base (Kudaravelli, 2013). Another type is the CAMARTEC model designed by GIZ for use in Tanzania, which is built as a series of brick rings in the shape of a dome on top of a flat base (Sasse et al, 1991). The digester in a fixed dome plant consists of an underground pit lined with concrete or brick, with an inlet pipe that is used to add feed to the digester. Gas is produced under pressure and is stored under the dome at the top of the digester. Biogas is removed from the digester using a pipe attached to the top of the dome. As biogas is produced, slurry is pushed out from the digester through the outlet pipe

into a displacement tank. When the biogas is used, this slurry flows back into the digester. Some designs may also include an additional gas storage tank connected to the gas outlet pipe .
The floating drum plant was designed and developed in India. It comprises a brick lined pit that is often partly underground (the digester) and a drum above ground is used as the gas collector. A popular design is the Khadi and Village Industries Commission (KVIC) digester. The drum is typically made of steel although some newer designs use fiber glass reinforced plastic. Water and feedstocks are combined in a mixing pit which then flows into the underground digester through the inlet pipe. As gas is produced, it is collected in the drum, which moves up and down a central guide pipe depending on the amount of gas being stored. The gas is held under pressure from the weight of the drum, which can be increased with the addition of weights. As more feedstocks are added, slurry flows out through the outlet pipe. A gas outlet pipe is also attached to the drum to remove gas from the plant. A variation of this design is the small-scale above ground floating drum plant developed in India by the Appropriate Rural Technology Institute (ARTI). The ARTI biogas plant is made for the digestion of household food waste and is made from two plastic water tanks with their tops removed and the smaller tank placed upside down inside the larger one. Pipes are added to the outer tank to add feedstocks and remove the slurry and a gas outlet pipe is added to the top of the inner tank (AIDG, 2009).

While Chains and India uses the fix dome plant and floating dome plant respectively, Latin Americans uses the Ballon digester. This type of digester is usually made from a large, strong plastic bag connected to a piece of drainpipe at either end, with these pipes being used to add feedstocks and remove slurry. To avoid damage to the bag, the digester is usually placed in a trench and the trench is slightly deeper at the slurry outlet so that the slurry will settle there. As gas is produced the top of the bag inflates and the gas can be removed through an outlet pipe in the top of the bag. Gas pressure can be increased by placing weights on top of the bag (Vögeli et al, 2014).

The use of biogas of recent centuries were effective in Sweden, Switzerland, and Germany where a biogas-powered train, named Biogaståget Amanda (The Biogas Train Amanda), has been in service in Sweden since 2005 (New Strait Times 2015). In 2007, an estimated 12,000 vehicles were being fueled with upgraded biogas worldwide, mostly in Europe (U.S department of Energy, 2010).

4.1 Biogas Development in Africa

The development of biogas in Africa is more on a developing scale than it ought to be with Africa being the largest continent with the highest fossil burning rate and the second largest continent in the world after Asia making up 10% of the world’s population which is equivalent to about 80% of the population in India sub-continent Amigun et al., 2008) as such, biofuels especially biogas, biodiesel, and bioethanol are being considered as the most potent alternatives to fossil fuels in the continental energy mix (Adeniyi et al., 2007; Ayhan, 2008).

In 2005, the Biogas Africa initiative was launched in Nairobi. Africa is one of the regions with high potentials in biogas production, though it has achieved little in developing the sector. While the continent has made progress in small-scale or household biogas systems (Kinyua et.al., 2016), commercial bio- (Amigun et al., 2008) as such, biofuels especially biogas, biodiesel, and bioethanol are being considered as the most potent alternatives to fossil fuels in the continental energy mix (Adeniyi et al., 2007; Ayhan, 2008).

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Table 3. African Country into Biogas production (Adapted from Mshandete and Parawira 2009, Ocwieja 2010)

Country	**Small to Medium digester**	**Large Digester**	**Region**
Bostwana	Several	1	South Africa
Bokina Faso	>30	-	West Africa
Burundi	279	-	East Africa
Egypt	Several	Few	North Africa
Ethiopia	Several	>1	East Africa
Ghana	Several	-	West Africa
Cote D'Ivoire	Several	1	West Africa
Kenya	500	-	East Africa
Lethoso	40	-	South Africa
Malawi	-	1	South Africa
Moroko	Several	-	North Africa
Nigeria	Few	-	West Africa
Rwanda	Several	Several	East Africa
Senegal	Several	-	West Africa
Sudan	>200	-	North Africa
South Africa	Several	Sveral	South Africa
Swaziland	Several	-	South Africa
Tanzania	>1000	1	East Africa
Tunisia	40	-	North Africa
Uganda	Few	-	East Africa
Zambia	Few		East Africa
Zimbabwe	>100	1	South Africa

4.2 Biogas Development in Nigeria

Biogas technology's adoption and operation in Nigeria is still at the developing stage. This slow development rate of biogas system in Nigeria could be caused by unfavorable government policies, inadequate funding of technology and individual's unwillingness (Sokoto Energy Research Centre Information Brochure, 2004). Nigeria has every bio material which are economically suitable for the generation of biogas in Nigeria; these include aquatic plants like water lettuce and water hyacinth; agricultural wastes like cow and piggery dung, poultry droppings, cassava leaves and processing waste; industrial wastes like municipal solid wastes and sewage (Okagbue, 1988; Akinbami et al., 1996, 2001). Also, the continuous assessment of other locally available materials for their use in biogas production has been made (Ubalua, 2008). The use of succulent plants has been limited to water lettuce, water hyacinth, cassava leaves, Eupatorium odoratum and Cymbopogon citratus (Odeyemi, 1983; Alfa et al., 2012). Similarly, the potential of poultry droppings, cow dung and kitchen/food wastes for biogas generation has been experimented upon (Lawal et al.,1995; Ojolo et al., 2007).

In Nigeria, some biogas projects have been executed, including construction of biogas plants at Zaria prison in Kaduna, Ojokoro in Lagos, Mayflower School Ikene in Ogun State, and a biogas plant at Usman Danfodiyo University in Sokoto with capacity of the digesters ranges between 10 and 20 m3 (Abubakar 1990; Adeyanju 2008; Atuanya and Aigbirior 2002; Dangogo and Fernando 1986; Igoni et al. 2008; Ilori et al. 2007; Lawal et al. 1995; Odeyemi 1983; Ojolo et al. 2007; Sambo 2005). However, the biogas projects in Nigeria are yet to be commercialized, since most of them are either non-operational or still at the research stage.

According to the feedstock available in Nigeria as shown in table 4, there could be a development of a large plants and different regions of the country and also in acting a policies of ranching so animal dunk can be easily collected. Nigeria can generate a total of 0.83 million tonnes abattoir waste could be annually, which could be harnessed using biogas technology to produce about 0.34 billion cubic metres of methane gas (Akinbomi et.al 2014).

Table 4. Shows the feedstock production potentials (Adapted from Ostrom 2004)

Biomass Feedstock	**Total potential biomass feedsctock (tonnes x10^8)**	**Quality of available biomass feedsctock (tonnes x10^8**	**BMP of biogass based on 0.7m^3/kg VS at 350oC (m^{3}x10^9)**	**Potential electricity production based on 3.73 KWh/m^3 CH_4 (kWh x 10^9)t**	**Electricity Production (Terawatt hour, TWh)**
Agricultural crop waste	171.86	51.56	20.77	77.47	77.47
Livestock Manure	32.40	9.79	3.69	13.76	13.76
Livestock abattoir waste		0.83	0.34	1.27	1.27
Organic municipal solid waste	0.83	33.12	13.27	49.50	49.50
Human waste	33.12	86.12	34.29	127.90	127.90
Total	324.33	181.42	72.36	270	270

4.3 Constraints to Biogas production in Nigeria

In as much as Nigeria has a high potential of producing large amount of biogas that could solve Nigeria's problem of electricity and availability of biofertilizers, Nigeria still has a great constraint, limiting the production of biogas for consumption (Akinbami et al, 2001).

According to Akimbomi et.al, in 2014 it was noted that government policies is a major constraints of biogas production in Nigeria. The government has a role in stimulating the market penetration of biogas technology for easy penetration of biogas energy into energy market, the government needs to play an active role in ensuring that the biogas energy is sufficient, efficient, affordable, steady, and dependable (Winkler et al. 2011). Also knowing that the production biogas needs good funding, government interventions through subsidy provisions and tax holidays are needed to reduce the initial cost of investing in biogas technology.

Low awareness on biogas is also a major constraint to biogas production in Nigeria. The level of awareness of the benefits of biogas technology needs to be raised, as many people are not acquainted with benefits associated with biogas technology. In the rural area, for example, some people still have the notion that food cooked using fuel wood tastes better than food cooked using other energy source. Furthermore, many people lack the technical know-how in operating and maintaining biogas plants. People should be trained to construct, operate, and maintain biogas plants for efficient and optimum production. It would also be wise to make use of locally available materials in Nigeria for biogas projects in order to reduce the difficulty involved in getting spare parts of plants and thereby ensure the sustainability of the biogas programme (Akinbomi et.al 2014).

5 RESEARCH METHODOLOGY

This study is composed of a theoretical and practical framework which involves reviews from previous research findings, articles, journals, reports, and books in relations to the study. These reviews were used for better understanding of the study and investigation on the subject matter.

A questionnaire of 24 questions which are divided into three segments for different categories of individuals was developed for the collection of data for the study. The questionnaire comprised both closed and open-end questions. This questionnaire was distributed to 5 geopolitical zones of the country (Nigeria) for better survey and result,upon the study data was analyzed, showing difference and relations between the category of individuals in relations to biogas production in Nigeria.

5.1 Quantitative Research Method

Quantitative research method involves the utilization and analysis of numerical data using specific statistical techniques to answer questions like who, how much, what, where, when, how many, and how (Oberiri, 2017). Aliaga, and Gunderson (2002) further describes quantitative research methods as a research method that involves explaining of an issue or phenomenon through gathering data in numerical form and analyzing with the aid of mathematical methods; in particular statistics. Quantitative research can be used to find patterns, means, make predictions, test relationships, and generalize results to wider populations. Quantitative research method involves various ways of data collection such as experimental group sampling, interviews, Surveys, observations, reports and reviews. These research methods can be used for experimental research, descriptive research and correlation research and on the basis of this research, quantitative research method presented better result on the different group of individuals involved in the research, better explanations on the different approach to biogas and its production in Nigeria.

5.2 Relevance of study

This study would provide proper information on the status of biogas production in Nigeria. Information on the potential biogas production capacity was generated for proper and better decision on policies that would promote biogas production in the country as recommended by Akhator *et.al* in 2016 who studied the potential for commercial biogas production from domestic food waste generated in Benin metropolis in Nigeria. The research indicated that about 305.075 tonnes/day of food waste is generated in Benin metropolis. This is sufficient for the production of about 28,836.91m3 of biogas per day in Benin metropolis which would satisfy family energy need for cooking. He further recommended that anaerobic digestion technology should be viewed as a waste management practice that should be incorporated in the waste management system in Benin metropolis.

Also, this study would be used to create awareness on biogas as a potential source of energy in Nigeria. Several reports have shown Nigerians high potential of producing biogas and solving Nigeria's problem of electricity and biofertilizers for agriculture. Chima et al 2013 on organic waste and biogas production, conclude that Nigeria will be able to generate about 88.19 million tons of dry biofertilizer from biogas technology per annum. This is about 13 times the tonnage of synthetic fertilizer consumed in Nigeria between 2001 and 2010, for which the Federal Government of Nigeria spent N 64.5 billion ($ 410, 828, 025.48) on fertilizer subsidy. This potential amount of dry biofertilizer obtainable is valued at N3.53 trillion ($ 22.77 billion) per annum.

6 FINDINGS AND ANALYSIS

The research objective was to evaluate the potentials of biogas as a viable source of energy in Nigeria. Literature has shown Nigerians major problem of lack of electricity and burning of fossil fuel which in turn is expensive and harmful for the Nigerian citizens. In other to meet these objectives and others as stated, a set of questionnaires was generated with questions for three categories of potential Biogas users in Nigeria. These sets on individuals include; private individuals and agricultural firms, government agencies, energy producers.The survey questions was shared across the 6 geopolitical zones on the nation which are; north central region, north eastern region,north western region,south eastern region,south south region,south western region.

6.1 RESULT

Despite Nigerians large population and quest for stable electricity, there has notable awareness on bio recycling in to natural gas which can be used for cooking but not been much knowledge and awareness on its production other uses in term of power supply that could be helpful and cost effective for both household and commercial users. From the information gotten by interviews and survey questionnaires, Nigerians uses solar as a source of energy for electricity more than even think of biogas. Figure 3 below shows the percentage biogas awareness across the country.

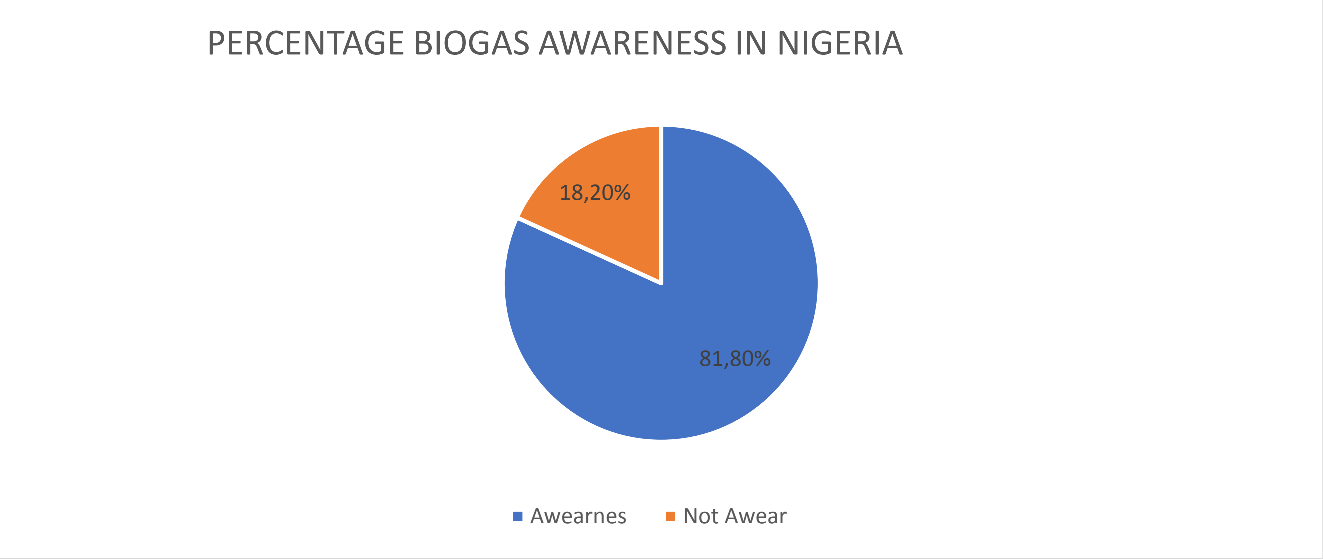

Figure 3. Biogas awareness in Nigeria

From the figure 3 above, 81.80%n of Nigerian's population are aware of biogas which involves both the rural and urban settings, and 18.20% of the population have not heard of biogas and how it could be recycled from plants and animal remains to solve electricity and cooking problems. This indicates that with the level of biogas awareness, there is possible shift to biogas use and purchase if the products are made notable and available to these citizens for use and purchase from commercial biogas plants at a more affordable rates compared to other gases and means of energy supply.

6.1.1 Use of Biogas in Nigeria

Result obtained shows that Nigerian citizens find it difficult to run their homes and business freely without much stress due to the lack of constant electricity and as such they always run the cost of spending more to make power available for both businesses and household consumption. According to the result obtained which is displayed in Figure 4, Nigeria is only interested in solving the problem of power supply and cooking which will help reduce the falling of forest trees and emission of greenhouse gases due to high level of combustion and coal burnings activities in the nation.

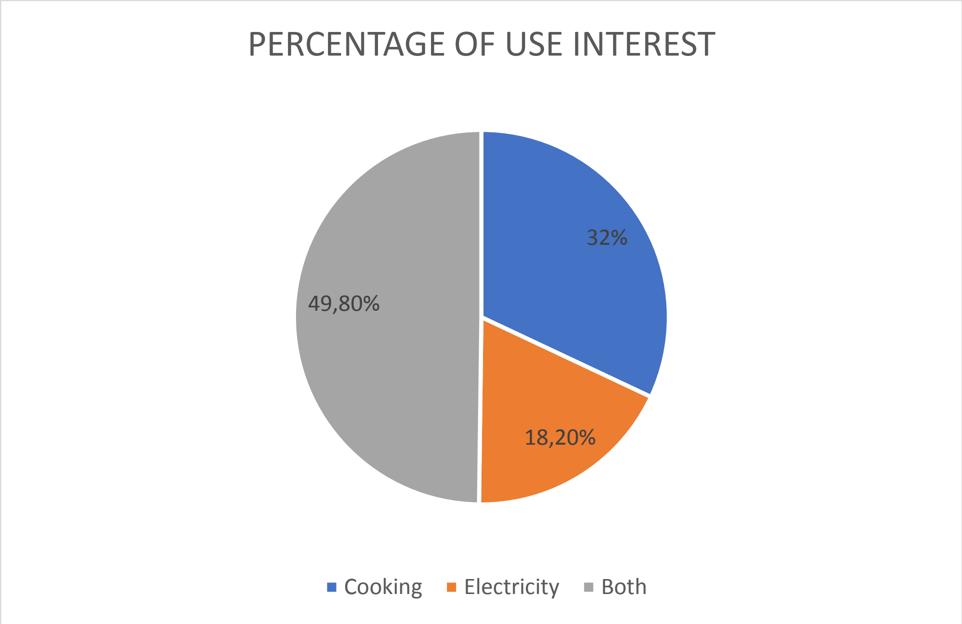

Figure 4. Biogas use potential

Figure 4 shows that 49.80% of individuals need biogas for cooking while 18.20% needs it for electricity and 32% for both electricity and cooking. This is related to the high cost of plant installation and labor involved in gathering feedstock for production and they may opt for the conversion of house hold latrines which can solve problems of purchase of cooking gas and reduce use of firewood. Some individuals who may be able to convert their latrines indicated that they could purchase the gas if there is a central sales point, since biogas is eco-friendly and would be much cheaper than the conventional cooking gas. Although some fraction of rural citizens need biogas for electricity which would serve as a source of light at night for students who require it for reading and also brighten the environment. A bright street, in their opinion, reduces crimes such as stealing because many individuals in the act would find it difficult to carry out their criminal activities.Business owners also indicated their need in electricity as this will reduce cost incurred on electricity and also double production and services.

The 18.20% of individuals who needs it for both services consist of mostly agricultural firms and few private household users. In terms of agriculture, they indicated that available electricity will provide power which would enhance healthy rearing of animals and lighting for proper monitoring of animal activities at night and also double production. biogas would aid processing of agricultural products which would be readily available since the challenge faced mostly depend on electricity and cooking need. Hatcheries also welcomed the use of biogas as this will reduce mortality rate at incubation and hatching as well as reduce cost of chicks for farmers.

6.1.2 Current use of Biogas in Nigeria

The use of biogas in Nigeria is still at the development stage as only few individuals use biogas as shown in figure 5 below. Only a fraction of 14.60% individuals is actually using the biogas, where 5.50% are of small agricultural food processing farms and farms, 9.10% are house hold individuals who generated biogas from their household latrines and are used mostly for cooking. 85.40% of individuals do not use biogas and still spend dearly for electricity and the challenge of availability. This can be related to the low awareness and unavailability of biogas plants in Nigeria. With the increasing population and large business opportunities in Nigeria, biogas awareness ought to be at the maximum as this will reduce electricity demands on the government and also regulate power supply to every individual and businesses in the country.

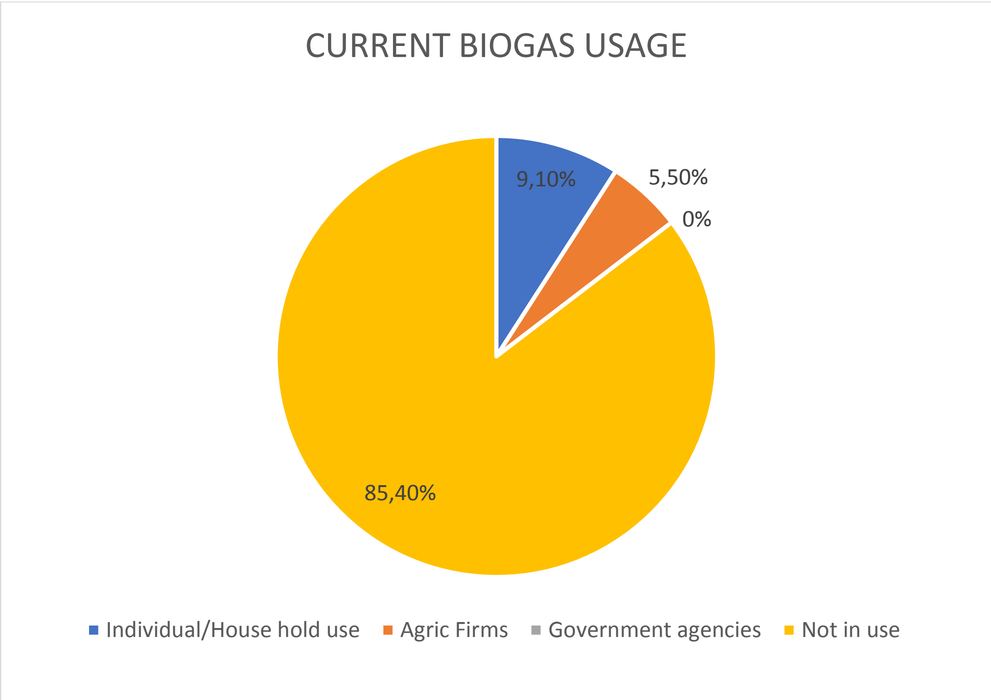

Figure 5. Categories of biogas users

From this result generated, it can be said that biogas production and use in Nigeria will create a shift from the old normal and project a limelight for easy lifestyle and pave way for more investment, new businesses and job creation.

6.1.3 Available anaerobic digester plant in Nigeria

Due to the stage of biogas production in Nigeria, Nigeria has a few numbers of installed anaerobic digester plant. Most of these plants are owned by small farms and agricultural processing firms and household individuals who converted their latrines to serve the purpose and provide gas for cooking.

From the survey, Nigeria has < 200 Biogas production system as shown in Table 5 below and distributed across regions in figure 6.

Table 5 Total number of biogas plants in Nigeria

Firms using Biogas	Number of plants
Agric firms	75
Individuals	45
Government Agencies	0
Total	120

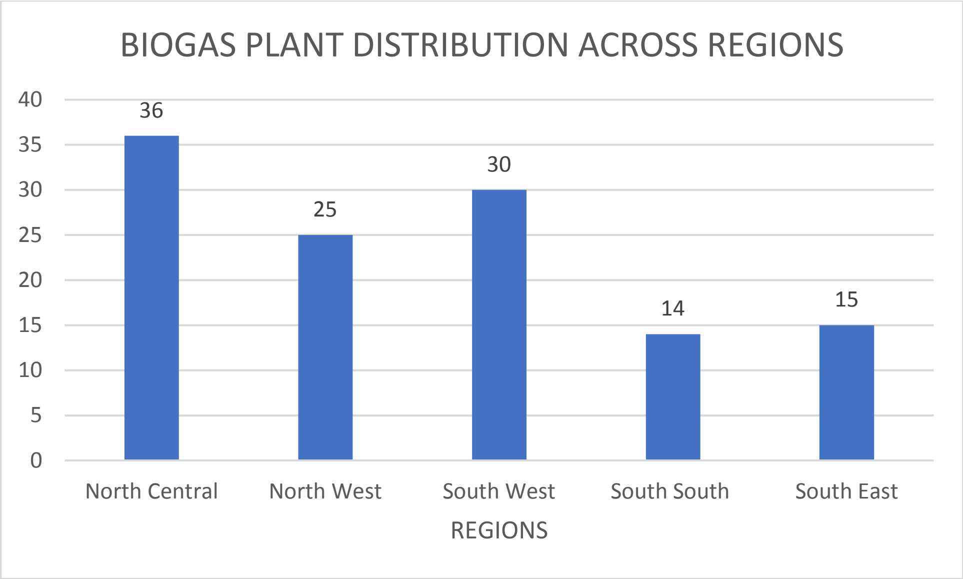

Figure 6. Distribution of biogas plant across regions in Nigeria

6.1.4 Limitations of biogas plants in Nigeria

Result shows positive response from the use of biogas. Respondents indicated that the system is less expensive to maintain and has reduce cost of electricity use and commercial gas expenses in farm and at home, however they complain of the foul smell arising due to the decomposed materials involved and also the high cost of installation which can be related to the limited skilled hands in the field. Response is presented in figure 7 below.

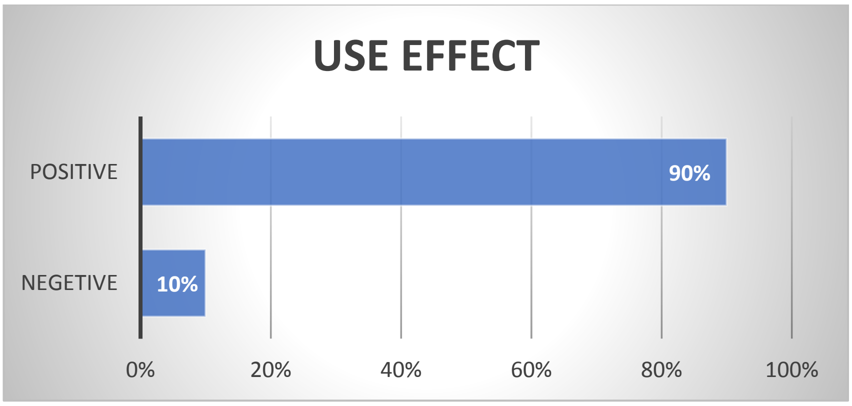

Figure 7. Limitations arising from use of biogas

Despite the positive response on the biogas, there are some limitations to the use of the system which are mostly high installation cost, availability and bad smell. 72% response indicated that the anaerobic digester plant is expensive at installation, 18% indicated it is not available. This can be related to the less available AD plants and lack of skilled persons in the field. 9.10% responded that the bad smell arising from the AD plant is a great limitation to them. Percentage responses are shown in figure 8 below.
These limitations only come at a stage and can be handled as they are not fixed.

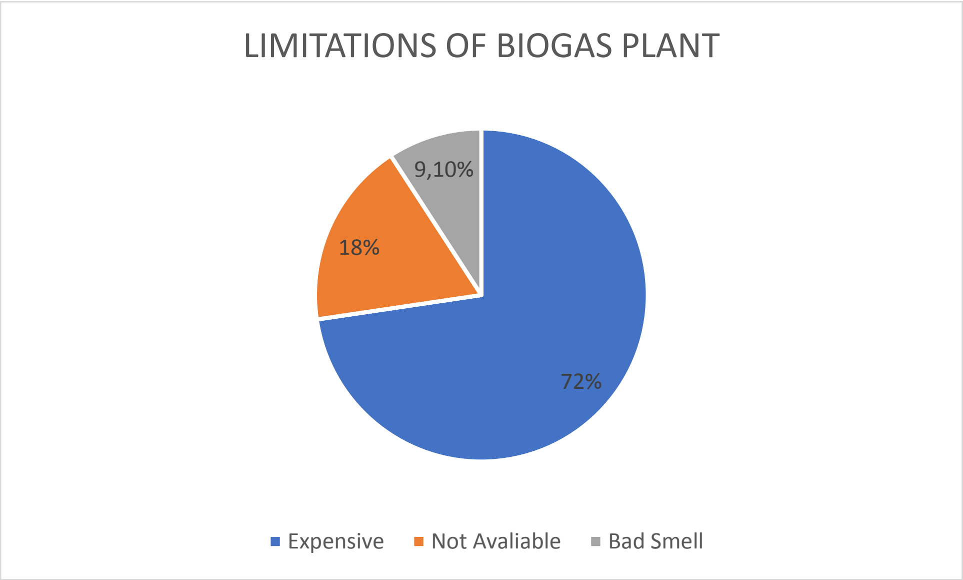

Figure 8. Limitations of biogas plant.

The high installation cost of biogas plant can be attributed to the low frequency on installation and unavailable individuals with the technical skill of biogas installation. With higher installation request and more skilled personnel, there would be an increase in biogas plant and available biogas and a drop in high installation cost due to available skilled personnel and demand., High installation cost can also be reduced if two individuals living closely jointly own a plant. With proper installation, offensive smell can be controlled.

7 CONCLUSION AND RECOMMENDATION

Nigeria, with its large population and abundant feedstock for production, has a great potential for biogas production and use. However, biogas production is hampered by a lack of awareness and skilled personnel in the field. In order to address the inconsistency of electricity in Nigeria, Biogas can provide a solution that will increase business while also attracting the attention of investors.
In a bid to make biogas an accepted and appreciable means of cobbing electricity challenges, the government should regulate good policies that will support the use of biogas, practical study area should also be made available which will train individuals on the technicality in anerobic plant installation and biogas production and storage. There is an expected positive output in Nigerian's economy if biogas is considered as a second source of power generation in Nigeria.

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SURVEY QUESTIONAIRE

Please read:

Dear Sir/ Madam, I am carrying out a research on Biogas use and production in Nigeria, please your contributions are needed by providing the accurate information needed. Thanks

Geopolitical Zone.....,......................................,...............
Category of user (a) Individual (b) Biogas production firm (c) Industries / Government Agencies

CATEGORY A (INDIVIDUAL)

1. Have you heard of Biogas (a) Yes (b) No
2. Have you used Biofuels for any thing??? (a) Yes, (b) No.
If yes State your Experience...
........,..,...
3. Which of these activities would you love to use biogas for? (a)Cooking (b) Power (c) Both
4. Would you like to install a small bio production plant for home use ?............. (a) Yes (b) No
5. Would you prefers buying bio product for home and agricultural use (a) Yes (b) No
6. What are you limitations to Biogas plant (a) Not readily available (b) Expensive (3) Bad small
Please state others..
................................,..

CATEGORY B (BIO PRODUCTION FIRM)

Name of your Firm ....

1. How old is your firm ....

2. How many tons / kg could a digester provide daily?...........................

3. How many digester plant have you installed? ....

4. Which set of individuals make use of bio products??
(a) Agricultural Firms (b) Industries (c) house hold use

5. How many Industries use the bio digester plant...............

6. What services do they get from the plant?...............

7. How many government agencies use the bio digester plat???............................

8. What service do they get from the plant?............................

9. How many watts of electricity can the bio digester produce daily..................

10. What are the economic benefit, if 70% of Nigherians use this plant.

CATEGORY C (GOVERMENT AGENCY)

Name of your Agency ....
1. Do you use any bio product? ....
2. What services do you get from the producer? (a) Bio Fuel (b) Electricity (C) Bio Fertilizer.
3. Does the Agency have the digester plant for generation of its products?..............

4. How effective is bio product (a) Not effective (b) Effective (c) Very effective
5. If 70% of Nigeriansown thedigester plant, how will it cub Nigerian's present economic issue.

6. What have the agency benefted since you started using the digester plant.

7. How many government agencies use the bio digester plat???............................

8. What would you suggest to the Nigerian government on use of biofuels and its products.