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A Review: Repositioning Biogas as an Alternative Energy Biotechnology in Nigeria - Realities and Challenges

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Abstract
The negative impact of fossil fuel on the environment and public health has necessitated the need for an alternative source of energy that is cheap and renewable. Presently the high demand on oil and natural gas caused by high consumption levels is one of the current major problems faced by the world population. There is need for a new energy generation that could challenge the present energy system which is highly dependent on fossil fuel across the globe. The economic and environmental concerns have resulted in research on renewable source of energy to replace the present fossil fuel. Burning fossil fuel such as coal and oil release carbon dioxide (CO_2), which is a major cause of global warming. It is expected that not a single source of energy but a combination of various energy sources and carriers will contribute to the energy system of the future. Hence, Biogas which is the anaerobic digestion of organic wastes to produce primarily methane a colorless hydrocarbon and carbon dioxide which can be used for heating, drying, lightening and other farm operations. Biogas offers one of the best alternative energy sources as it presents a viable option for improving sustainable development through energy security, poverty reduction and low emission of greenhouse gases. This paper highlights the potential benefits of biogas generation as a renewable source of energy using livestock waste (cow dung), poultry waste, human waste, crop residue and solid waste at dump sites. It equally elucidates the importance of Biogas utilization as a means of solving problem of power generation, climate change, rural-urban migration, poverty reduction as well as decrease in environmental pollution caused by emission of fumes from cars, motorcycles, industrial activities and burning of woods, kerosene and charcoals for cooking.

Keyword: *Biogas, renewable energy, Anaerobic digestion, Fossil fuel, Bio-digester*

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I. Introduction

Energy is a substantial tool for man to meet its basic essentials in life[1]. This energy has been utilized by man through modifying and manipulating lands, water, plant and animals to obtain food, clothing and shelter[2]. However, heavy exploration of natural resources without appropriate and economically feasible technologies that could salvage the waste has posed challenges to the ecosystem and humanity[2]. Ani (2017) divulged that Nigeria generates about 542.5 million tons of organic waste such as livestock wastes, cattle excreta, sheep and goat excreta, pig excreta, poultry excreta, abattoir waste, human excreta, crop residue and municipal solid waste per annum[3]. This in turn has the potential of producing about 25.53 billion cubic meter of biogas (about 169 541.66 MWh of electricity) and 88.19 million tons of bio-fertilizer per annum[4]. Agbogu (2006) noted that over the centuries various sources of energy have been used by man in order to meet his basic life essentials[1]. Man has utilized energy in modifying and manipulating land, water, plant and animals to obtain food, clothing and shelter[2]. Ani (2014) described Nigeria as a country endowed with huge resources of conventional energy resources (crude oil, natural gas and coal) as well as reasonable amount of renewable energy resources example hydro, solar, wind and biomass[3]. According to Ani, the Organization of Petroleum Exporting Countries (OPEC) annual statistical bulletin 2009 revealed that Nigeria proven crude oil reserve and natural gas are 37.2 billion barrels and 5292 million standard cubic metres respectively[4]. In addition, the estimated reserve of tar sands and proven reserves of coals are about 30 billion barrels of oil equivalent and 639 million tons respectively[5]. Sequel to the above, Nwadike *et al.,* (2022) states that most of the developing nations are facing serious shortage of fuels, the most commonly used fuel being wood fuel[8]. The social statistics presented by the Nigeria Bureau of Statistics (NBS) revealed that Nigeria as at 2006 had a total of about 28 900 492 households. 79.6% of these households still depend on wood fuel for cooking as at 2008[7]. In some states like Adamawa, Nasarawa, Zamfara, Sokoto States in Nigeria, the percentage of household depending on wood fuel for cooking is over 90 (NBS, 2009)[6]. Ahmadu outlined that even though sizeable proportions of urban and semi-urban dwellers use fuel wood, the majority of users of this fuel are rural dwellers, who constitute between 65-70 % of the population in Nigeria and with the recent hike in the pumping price of kerosene in Nigeria, the dependence on wood for domestic cooking has significantly increased[2]. The main challenge of the present world is to harness the energy source that will be environmentally friendly and ecologically balanced[1]. This need has forced African countries to search for alternative source of energy[9]. According to Anyadiegwu *et al* (2021) these new alternative energy sources like solar, hydro, wind, nuclear and so on require huge economic investment and technical know-how to operate, which seem to be very difficult for the developing nations like African countries[9]. Kerosene and other oil-based sources of fuel are scarce and costly to be easily available for small marginal and medium farmers residing in rural areas[6]. Furthermore, frequent alarming hike in prices of imported fuel has serious economic threat to the poor rural dwellers[10]. The World Energy Council (WEC, 2000) estimated that 1.6 billion of the world's populations do not have access to commercial energy. Many of these are in Africa, and they are located primarily in the rural areas[10]. It is expected that policy makers and implementers will be able to promote the use of biogas as an alternative source of energy.

What is biogas technology

Biogas refers to the mixture of different gases produced by the breakdown of organic matter in the absence of oxygen. Biogas can be produced from raw materials such as agricultural waste, animal waste, municipal waste, plant materials, sewage, green waste or food waste[7]. Ani (2017) defined biogas technology as an alternative energy source which utilizes various organic wastes in order to produce biogas, mineralized water and organic fertilizers[3]. Leshach (2013) revealed that Biogas is produced under anaerobic conditions; the process is denominated as anaerobic digestion[10]. Leshach further described biogas technology as the use of biological processes in the absence of oxygen for the breakdown of organic matter as the stabilization of this material by conversion to biogas and nearly stable residue (digestate)[10]. Biogas is a mixture of methane (45-75%) and carbon dioxide (25-55%), the actual proportion depending on the feedstock (substrate) used and processes employed[3]. Ani 2017 opined that biogas technology is the use of biological process in the absence of oxygen for the breakdown of organic matter into biogas and a high-quality fertilizer and further noted that biogas technology is a 'carbon neutral process', meaning it neither adds nor removes carbon dioxide from the atmosphere[4].

Biogas production and composition

Niesner *et al* (2013) When organic wastes decompose, it does so in the presence or absence of air and is referred to as aerobic or anaerobic decomposition respectively and this decomposition could be natural occurring or maybe artificially induced under controlled conditions[11]. One of the end-products of anaerobic decomposition is biogas which produced naturally from decomposition under water or in the guts of animals and artificially in air tight digesters[11]. Ani (2017) stated that Biogas is generated when bacteria degrade biological material in the absence of oxygen, in a process known as anaerobic digestion[3]. Meshach (2013) elucidated that biogas is produced from anaerobic decay (decay that occurs without oxygen) and its composition varies depending upon the substrate as well as the conditions within the anaerobic reactor (temperature, pH and substrate concentration)[10]. Biogas is primarily composed of 50-75% Methane (CH_4) and 30-40% Carbon dioxide (CO_2) with smaller amounts of Hydrogen Sulphide (H_2S) and ammonia (NH_3)[1]. Trace amounts of hydrogen (H_2) Nitrogen (N_2) Carbon monoxide (CO) and Oxygen are present in the biogas (Monnet, 2003). Methane CH_4 (50-75%), Carbondioxide CO_2 (25-50%), Hydrogen H_2 (0-1%), Nitrogen N_2 (0-10%), Water Vapour H_2O (0.3%), Hydrogen Sulphid H_2S (0.1-.5%), Oxygen O_2 (0-0.5%)[3]. This composition of biogas is different from that of natural gas but it is quite similar to landfill gas which often contains significant amounts of halogenated compounds and occasionally oxygen content when too much air is sucked during the collection[3]. The calorific value is 36.14 MJ/m^3 for natural gas and 21.48 MJ/m^3 for biogas[6].

Percentage of Methane Content in Biogas from Different Feed Materials

Ahmadu (2009) described that methane content also depends on the feed material. Some typical values of methanol content for different feed materials include cattle/Cow dung 65%, Poultry dung 60%, Pig dung 52%, Farm waste 55%, Algae 63%, and 59% of Straw[2].

II. Biogas System

A biogas plant converts biodegradable waste to useable gas under anaerobic conditions. This gas consists mainly of methane and carbon dioxide as well as other traces elements[4]. Organic material is added to the digester where under anaerobic conditions bacteria convert the material to two products which are biogas and slurry[11]. The system consists of a digester which provides an area for the material to be digested by bacteria in an environment devoid of oxygen[7]. Material is added to the system via an inlet tube and the digested material is then removed from a separate opening[8].

Classification of biogas plants

Leenawat *et al.*, (2016) listed that there is a wide range of facility types which differ in location, size of feedstock and process employed and the characteristics of the facility have to be carefully chosen in each specific case[5]. Ahmadu (2009) noted a typical biogas plant to consists of two main parts; a digester (where fermentation occurs) and a gas holder (where the gas produced is stored)[2]. Other parts include an inlet mixing tank and an outlet tank. Various kinds of biogas plants, e.g., the Indian, Chinese, Taiwanese and Philippine plants are in used. He further opined that the classification of biogas plants is based on several criteria such as method of feeding the digester, orientation, geometry as well as the gas storage system[7].

Types of biogas technology

There are two major types of Biogas Technology for the production of Biogas. They are briefly highlighted as;

1. Fixed Dome type

This consists of an airtight container or fixed non-movable gas space constructed of brick, stone or concrete, the top and bottom being hemispherical. Sealing is achieved by building up several layers of mortar on the digesters inner surface of brick is used for construction[7]. The gas is stored in the upper part of the digester. When gas production commences, the slurry is displaced into the compensating tank. It is relatively cheaper to construct the fixed dome digester than the floating gasholder type. It has longer life; there is no problem of corrosion or rusting. However, the amount of biogas present cannot be known, problem of gas leakage is there; gas production is lesser and requires skilled labour[7].

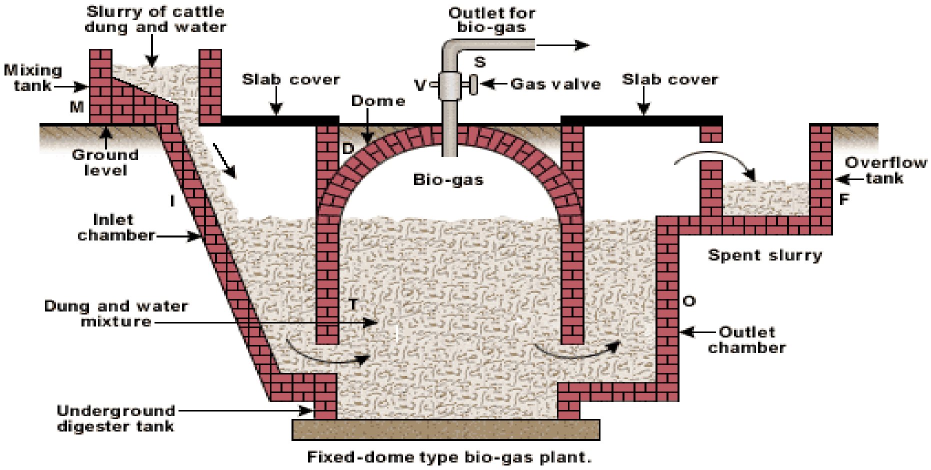

Fig1: Fixed Dome Biogas Type

2. Floating Gas-holder Type

The design of this type consists of a dome shaped gas holder made of steel for collecting biogas. The dome shaped gas holder is not fixed but is moveable and floats over the slurry present in the digester tank[7]. Due to this reason the biogas plant is called Floating gas holder type biogas plant[7]. The cover is usually constructed of mild steel. The level of biogas present inside the gas plant can be known, it runs at constant gas pressure, No gas leakage problem due high pressure and high gas production. Though, it is expensive due to steel gas holder, corrosion or rusting of gas holder may lead to leakage of the gas, also maintenance cost is higher and the cover have been the main problem of this design[7]. However, the mild steel cover is gradually been replaced by plastic gas holder[4].

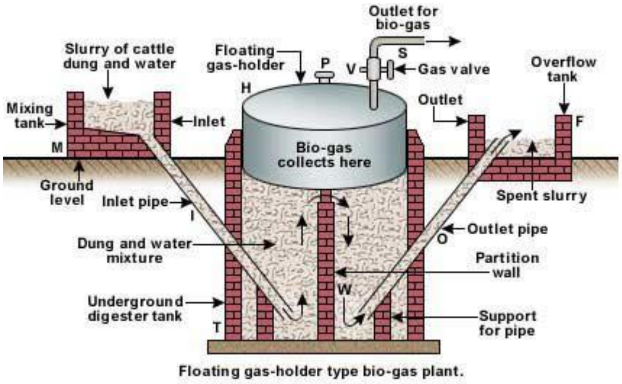

Fig 2: Floating Gas Holder Type

III. Global production and utilization of biogas

Ani suggested that biogas has provided an economically viable and sustainable means of meeting the thermal energy needs in China (7.5 million), India (3 million) and Nepal, where over 37000 biogas digesters were installed from 1992 to 1998[7]. Ani states that 900 small scale digesters in Germany, 10 000 000 in China, 5 000 000 in India, 40 000 in Cambodia, 5000 in Vietnam and 500 in Costa Rica[3]. Their use is not limited to these countries, but extends throughout the developing world. More recently, developed countries have been making increasing use of gas generated from both wastewater and landfill sites[1]. Fuel produced may be used for direct firing of boilers or to fue1 a CHP (combined heat and power) plant. Alternatively, the gas can be upgraded by extracting the trace gases and carbon dioxide to produce a vehicle-grade fue1[5]. According to Niesner *et al.*, (2013), France, in 1987 the streets lamps of Exeter started running on biogas produced from wastewater[11]. Germany, agricultural products were used to produce biogas in 1945. Today, China is credited as having the largest biogas programme in the world with over 20 million biogas plants installed[7]. Ducellier and Isman started building simple biogas machine in Algeria to supply farmhouses with energy. The most recent Anaerobic Digestion plant in Belgium can handle 58000 tons of waste per year[7]. A plant in Freiburg in Germany processes 36000 tons of waste per year producing 3 million cubic meters of gas and 15000 tons of compost[7].

Benefits of Biogas

Biogas is eco- friendly, biogas generation reduces soil and water pollution, it's a simple and low-cost technology that encourages a circular economy, biogas generation produces organic fertilizer and healthy cooking alternative for developing areas[6].

A. Benefits to the energy sector

i. Source of renewable (green) energy, which leads to a lesser dependency on the finite fossil fuels.
ii. The use of the digestive decreases the use of fossil fuels in the manufacturing of synthetic fertilizer.
iii. It is carbon dioxide neutral.

B. Benefits to agricultural sector

i. Transformation of organic waste to very high-quality fertilizer.
ii. Improved utilization of nitrogen (by plants) from animal manure.
iii. Balanced phosphorus / potassium ratio in digestate.
iv. Homogenous and light fluid slurry.

C. Benefits to the environment

i. Reduces emission of greenhouse gas
ii. Reduces nitrogen leaching into ground and surface waters
iii. Improves hygiene through the reduction of pathogens, worm eggs and flies.
iv. Reduces odour by 80%
v. Controlled recycling/ reduction of waste.
vi. Reduces deforestation by providing renewable alternative to wood fuel and char coal.

D. Benefits to the economy

i. Provides cheaper energy and fertilizer.
ii. Provides additional income to farmers.
iii. Creates job opportunities.
iv. Decentralizes energy generation and environmental protection.

Fig 3: Biogas used as Gas Cooker

IV. Prospects and Challenges

4.1 Prospects

Ani (2014) described Nigeria to be Africa's energy giant and it is the continent's most prolific oil producing country, which along with Libya, accounts for two-thirds of Africa's crude oil reserves[3]. Nigeria has warm, stable climate and easy availability of plant material and animal wastes (cow dung, poultry droppings, and pig excreta among others) is at an advantageous position for adopting and popularizing biogas[2]. According to Ahmadu (2009), at present much of the dung producing about millions of herds of cattle in Nigeria is either wasting or burnt among as wasteful cooking fuel[2]. Assuming an average production of 10kg of dung per animal per day and a collection rate of 60 per cent, the amount of dung available in the country in a year may work suit to about 300 million tons which can generate a staggering millions of tons of humus-rich manure[2]. As it is 30 million m^3 of biogas equals 20 million tons of kerosene oil, nearly three times the animal consumption of the commodity in the country[3]. Biogas is not popular in Nigeria as well as most countries in Africa[2]. Most of the materials available on biogas in Nigeria are reports of scientific researches into the technical aspects and basic factors of biogas production, especially on raw materials[6]. Presently biogas production is beginning to catch attention in Nigeria[3]. At Ibadan a local NGO and a community-based organization has joined with Technology Innovators from Thailand, to build a sustainable Ibadan project in Nigeria to Install a biogas plant that will run on abattoir effluents to create a source of domestic energy, abate pollution and mitigate gas emissions[11]. Also, another abattoir biogas project in Enugu with a proposed plant capacity of $8500m^3$ 2000 number of cows slaughtered daily, quantity of solid organic waste, 120 tons parlay, volumes of waste water generation, with electricity generation of 1.9 MWL per day at 35 percent generation efficiency, savory application of solid organic fertilizer production[3]. Ani (2014) also described another project which needs biogas production is a Toilet/ Kitchen waste linked biogas (Urine reactor) plant located in Abuja with a plant capacity of $10m^3$, biogas production of $6m^3$ with biogas application for cooking gas and electricity 1.5kw biogas gen[3]. Another biogas plant uses cassava and cow dung as feed stock for Biogas and solar food dryer in project location in Oyo state with capacity of $20m^3$ system[6]. The biogas plant if implemented through Public-Private Partnership, in addition to the production of a cheap source of domestic cooking gas and organic fertilizer is expected to generate employment[3]. It is a known fact that health is wealth and the synergy between poverty and ill wealth has long been established[9]. Biogas utilization will turn environmental and human health hazards into valuation energy resource and revenue source[8]. A supply piped gas for cooking will reduce deforestation and the daily drudgery of collecting firewood. The introduction of biogas stoves will reduce or eliminate health hazards like respiratory disorders associated with wood fires[3]. The hygienic state of settlements will also improve when sewages, channeling slaughter house wastes, a major sources of local water pollution and greenhouse gas emission into biogas production, clean burning domestic gas for urban poor families and cheap organic fertilizers to low-income farmers[3]. Biogas production and utilization will eliminate methane, the highly destructive greenhouse gas, so it does not go into the environment and contribute to global warming. Environmentally, biogas has some advantages over fossil fuels such as coal and petroleum[4]. Growing plants for use as biomass fuel helps to keep global warming in check Biogas production and utilization will also boost livestock keeping in Africa and helps to meet the ever-growing demand for meat in Africa. The result would be more income for families[3].

4.2 Challenges

However, there is always a strong inertia against change in every human society. The following are some of the challenges;

1. **Planning and Construction**:
2. **Lack of financial capabilities**:
3. **Lack of public support**

4. **Lack of effective and clear policies**
5. **Technical challenges**:

V. Conclusion

Based on the study it is evident that biogas can serve as an alternative source of energy not only in Nigeria but in all African countries, since what is required in its production are readily available ranging from animal wastes (cow dung), organic waste solid waste which could be converted to renewable energy through the use of bio digesters biogas can replace fossil fuels as well as reduce disposed waste volume to dump sites. Hence it generates high quality renewable fuel proven to be useful in a number of end-user applications. Also, it can create employment and can produce organic fertilizer and many more environmental benefits.

VI. Recommendations

The following are recommended for biogas production as an alternative source of energy in African countries;

a. An immediate shift in government policies to encourage the adoption and promotion of biogas energy in Nigeria.

b. Provision of subsidies to individuals and companies that would want to build and run biogas production plants.

c. Training and deployment of extension officer or trained personnel that would provide the technical know- how on building and managing biogas plants.

d. Introduction of a biogas programme that would lead to the evolution of inexpensive and locally adaptable technology.

e. Reprogramming the agricultural sector to produce daily cow wastes, poultry wastes as well as regular production of fodder grass.

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