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Impact of Biogas Fuel on Energy Diversification and Sustainable Development in Nigeria

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Abstract

This study investigates the impact of biogas fuel on energy diversification and sustainable development in Nigeria. Biogas is a renewable fuel, and it seems to have a very important role in the energy mix for Africa, and Nigeria in particular. Energy is being used on daily basis throughout the value chain: from farming, processing, manufacturing, packaging, storage, marketing, transportation and distribution to consumption. This research comes in a right time when the world has high attention on climate and emissions caused mainly by energy demand and use. Nigeria also faces the challenge on how to find sustainable energy solution to reduce poverty in Nigeria and Africa as a continent. In the literature review, examples of countries like China, Denmark and Germany that have achieved remarkable success in biogas and renewable energy, respectively, were reviewed. There was no official data on biogas funding and development in Nigeria that was found in the course of this study. The methodology adopted is therefore a combination of primary data, using descriptive statistics, linkert scale, simple percentages and logit-probit regression analysis. A sample of 382 questionnaires was distributed to respondents in local communities and university students in the North Central states of Plateau, Nasarawa and Benue. The responses were verified, sorted, classified and analyzed. Biogas development (BIOD) is a qualitative dependent variable; hence, the model for the estimation of the binary logistic dependent variable is adopted. The study finds that Nigeria suffers from energy poverty, and that biogas is not well developed to diversify Nigeria's energy supply. All around our rural settlements, communities, cities and urban slums, there are untapped heaps of stinking refuses. These include sewage slurry, kitchen wastes, food waste from restaurants and industries, farm residues of grains, fruits and vegetables, manure, abattoir refuse and by-products from livestock and forestry, suitable as raw materials for biogas. The study recommends that the production process from waste to biogas will help to reduce the Refuse Mountains and securing renewable energy supplies with positive impact on the environment. Students in tertiary institutions can engage in industrial training (IT) by constructing biogas stations to innovate home-made energy solutions

Background to the Study

Biogas is a renewable fuel, and it seems to have a very important role in the energy mix for Africa. Energy is being used on daily basis throughout the value chain: from farming, processing, manufacturing, packaging, storage, marketing, transportation and distribution to consumption. Africa suffers from energy poverty and energy access in both rural and urban areas which need to be redressed in order to achieve sustainable development. Nigeria's slow industrialization is connected to power failure, weak systems and institutions which have in turn hindered the creation of jobs, slowed down economic and social development. The majority of the poor have not sufficiently benefited from steady electricity and a robust social investment program, vocational and skills acquisition initiatives that will translate to self-employment, wealth creation and poverty reduction. There is need for pulling together national and community resources for risk sharing and alleviating the suffering of the poor. This capacity building can be achieved through inclusive entrepreneurship that is possible only with constant power supply. Although the government is doing something on social investment schemes, it has not made profound impact on the core poor, women and youth. Infrastructure, especially electricity is yet to be inclusive.

Statement of the Research Problem

The year 2020 has begun, where Nigeria proposed to generate 40,000 Megawatt (MGW) of electricity. South Africa with less than 60 million people generates 50,000 MGW. Nigeria is yet to move close to half of this target, though it is richly endowed with potentials for several energy-mix. Energy poverty and lack of energy diversification seems to have been responsible for this delay and has caused sluggish performance of social and economic indices in Nigeria. Over reliance on fossil fuel has rather generated so much environmental problems. The 2020 climate summit will be held in Glasgow in November, with climate strike all over the world in 2019, the dangers of climate changes seem not to be unconnected to energy poverty, industrial pollution, deforestation and desertification. Everything we use, eat and wear comes from the environment, and in turn pollutes the environment. The transport sector currently accounts for one third of total global emissions of greenhouse gases, especially heavy goods vehicles emissions (HGVE). Water sources are increasingly contaminated by refuse dumps, human and animal pressures. There is air pollution, ecosystem degradation and climate change, a threat to human health and livestock safety. Climate change causes about$ 436 Trillion losses to the global economy.

More so, there is energy poverty and lack of energy access in developing countries leading to poor output of small and medium scale enterprises and other economic agents. Poor household's energy demands have led to indiscriminate cutting down of trees, resulting to deforestation and desertification which is unsustainable. Energy poverty seems to fuel unemployment. Nigeria has become a dumping ground for obsolete technology. Generators that use petrol and diesel are examples of such obsolete technology dumped in Nigeria by China and other countries. Many households have lost their lives due to emission of poisonous gas (carbon monoxide) from generators. However, a survey of

households using generators in China, by this study, shows the number of households using generator at absolutely zero percent. Besides, increase in fuel prices in Nigeria has negative multiplier effects on all sectors of the economy resulting to cost-push inflation. Nigeria needs energy diversification and energy entrepreneurs, especially revolution in the renewable energy. There is need to search for alternative, renewable and sustainable energy-mix for Nigeria and Africa as a whole. It is in the light of these that this study is initiated. Biogas fuel research seems to fill the gap and provide the solution. It is a high-class alternative to petrol and diesel.

Objective of the Study

This study sets out to find solution to energy poverty in Nigeria by investigating the causal relationship between biogas fuel, energy diversification and sustainable development in Nigeria. It provides an overview of how biogas is developing around the world, and the potential for biogas fuel production to diversify energy sources in Nigeria. Converting waste to huge wealth and employment opportunities through recycling, re-using, a value chain that goes back into the production system is the main objective of this renewable energy (biogas) research. The role of environment in the quality of life of the people cannot be overemphasized. Environmental health is tied to economic health. There is need for more industries that convert waste into wealth in Nigeria.

Significance of the Study

This research comes in a right time when the world has high attention on climate and emissions. Nigeria also faces the challenge on how to find sustainable energy solution to reduce poverty in Nigeria and Africa as a continent. All around our rural settlements, communities, cities and urban slums, there are heaps of stinking refuses. These include sewage slurry, kitchen wastes, food waste from restaurants and industries, farm residues of grains, fruits and vegetables, manure, abattoir refuse and by-products from livestock and forestry. The production process from waste to biogas will help to reduce the Refuse Mountains and securing energy supplies with positive impact on the environment. The gas can serve as transportation fuel and also as a clean replacement for biomass for indoor cooking and lightning, to improve the air quality and maintain a cleaner environment. Besides, biogas plays an important role in creating a sustainable society and reducing dependence on oil. It promotes the development of SMEs through meeting their energy demands. Industry and agriculture can be self-sufficient within heating and electricity by using their own biogas produced from the decomposition of various kinds of refuse, (Heltberg, 2014; Gabriel et al.,2018).

Literature Review

The 50th World Economic Forum, Davos 2020, with the theme: "Stakeholders for a Cohesive and Sustainable World", had its topical issue on Climate Change which seems not to be unconnected with the use of fossil fuels. According to the Center for Biogas Research (2019), Nigeria produces 32 million tons of waste annually. These huge wastes can be converted into inorganic manure and biomass electricity, generating millions of employment in the SMEs sector. Rwanda is rated as the cleanest state in Africa because

they hunt their waste and convert them to biogas. The use of biodegradable waste generates huge environmental and economic benefits globally. The EU is investing a lot of money in replacing oil dependency with liquid natural gas (LNG) and in the longer term, with liquid biogas (LBG), (ECOWAS, 2019).

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.

Globally, Sweden has over 5000 biogas plants, many of these have been built with state investment subsidies over a ten-year period. Different countries have invested in different types of biogas systems depending on widely different environment and energy programmes. The USA also has ambitious plans for biogas production expansion. President Obama's "Climate Action Plan" from 2013 called for biogas production to become a means of reducing methane emissions and increasing energy security. The UK and South Korea for example gain most of their biogas from landfill sites, whilst Switzerland and Sweden have built up systems for decomposition at sewage plants, (Lijo et.al, 2014). Denmark uses manure to a large extent as this has been a means of dealing with the overproduction of manure there. Germany, the UK and Sweden are examples of countries where biogas production comes from collecting food waste, (Francis, Muyiwa and Morken, 2018).

Germany for example has developed a largely agriculturally-based biogas production system through subsidizing production. China and Germany are world leaders within farm-based biogas production. There are no less than 24,000 small farm plants in China, and almost 8,000 agricultural plants in Germany of various sizes. The German plants contribute 10,500 GWh of heat and 25,000 GWh of electricity per annum, corresponding to 3% of the country's electricity consumption. France, Holland, India, Austria and Italy also produce large amounts of farm-based biogas, (Deubleun & Steinhauser, 2008).

Infrastructure development in China has impacted significantly on security, industrialization and rapid poverty reduction. This has attracted the attention of many African countries who want to emulate the China model in a China-Africa Cooperation for Development, leaving some infrastructure footprint. China's footprint in Africa is also remarkable in the energy sector. Rapid economic development and urbanization across China have brought major changes to the rural setting and have made a significant impact on household biogas production. Following a decade of expansion aided by heavy government investment, around 200 million people in China's rural households now benefit from biogas digesters to provide clean cooking fuel and organic fertilizer, (Sun et.

al, 2014). However, the challenge China has, which may work favorably for Africa is that fewer animals are kept as livestock in rural households, meaning less manure to feed into biogas digesters, and migration to cities means less available labour to operate them. African biogas development difficulties include inadequate technical services for post-installation maintenance and repair, and the biogas digesters, which we could learn from China.

Biogas is one of the world's cleanest fuels, (IGU, 2015). Biogas technology has clear economic, social and environmental benefits for rural households, such as reducing environmental pollution by safely recycling manure and providing households with a clean cooking fuel alternative to fossil fuels or firewood. It is one of the fuels with the absolute lowest impact on climate and the environment. One of its major advantages is that it can be used as a fuel for vehicles. The transport sector currently accounts for one third of total global emissions of greenhouse gases. Biogas is a high-class alternative to petrol and diesel. It does not contribute to higher CO2 emissions and is therefore one of the most climate-friendly vehicle fuels. Gas-powered vehicles also give reduced emissions of nitrogen oxide and particles, thus contributing to lower environmental impact.

The African government's promotion of biogas technology is motivated by the need to address the following problems in rural areas across Africa: lack of clean cooking fuels; indoor air pollution from burning solid biomass (such as firewood) in poor cooking stoves; water pollution and water-borne infection from human and animal waste; soil degradation due to the wide application of inorganic fertilizers; and forest deterioration caused by the over-collection of firewood, among others. The national biogas program will provide two effective solutions to the problems described above: 1) it minimizes environmental pollution in rural areas through the appropriate disposal and recycling of animal waste and agricultural residues, and 2) Providing rural households with a clean cooking fuel alternative. These challenges of energy poverty are common in Africa from Nigeria to Ghana, South Africa to Zambia, Egypt to Algeria, in fact across West, North, East and Central Africa.

Most African countries, especially Nigeria, with solar endowment have suitable temperature in promoting biogas production. Data sources from the China Ministry of Agriculture show that the annual production of biogas in China is currently more than 15 billion cubic meters, roughly corresponding to 25 million tons of coal or 11.4 per cent of the country's total natural gas consumption. These biogas digesters each year produce 410 million tones of organic fertilizers, reduce carbon dioxide emissions by 61 million tones, and generate benefits worth CNY 47 billion from cost savings and income growth, (Tang et.al.2010). Efforts to pioneer biogas in China can be traced back to the 1930s, with a few companies trying to commercialize biogas as an alternative to imported kerosene for lighting, (Liu et al., 2008). In order to achieve this at home, a biogas digester has to be constructed. Biogas digesters allow rural households with livestock to convert manure and other organic waste into 'biogas' for cooking fuel and 'bio-slurry' as fertilizer.

Digesters tend to be underground, airtight containers with a capacity of four to 20 cubic metres. 'Feedstock' (the organic waste) is emptied into the digester, where a consortium of bacteria act on it anaerobically, breaking down the waste into gas and slurry. Pipes convey the biogas directly to the household kitchen, and the bio-slurry can be discharged regularly for use as a fertilizer. One cubic metre of biogas will provide about two hours' cooking time. Rural households deemed suitable for biogas installation must meet the following four criteria: 1) enough animal waste to feed the digester – minimum three pigs or one cow in stock; 2) enough ground space in the home yard for biogas construction; 3) adequate management capacity – minimum one adult labourer at home; and 4) appropriate self-financing capacity, (Wang, Zhang and Yin, 2011). The traditional design of domestic biogas digesters with a fixed dome and a hydraulic chamber are now commonly referred to as the Chinese fixed-dome type and it is promoted in developing countries by many organizations worldwide, with some modifications. The improved design and construction materials use are bricks and cement or concrete.

Different uses of biogas and bio-slurry were explored and advanced biogas cooking and lighting appliances were developed. In addition to the conventional use of biogas, experiments were carried out using biogas for small-scale power generation and atmosphere control for grains or citrus storage. Bio-slurry was tested for effectiveness in seed soaking (germinating rice seeds by soaking them in bio-slurry), mushroom cultivation, fish food, and fruit and vegetable fertilizing.

2003 was a turning point for China's domestic biogas development thanks to a significant increase in government investment. With funding from treasury bonds, annual investment in the national rural biogas programme reached a historical high of over one billion Chinese Yuan (CNY), roughly corresponding to USD 124 million (at 2003 exchange rates). The government investment in biogas sector kept growing until it reached CNY 6 billion (USD 863 million) a year in 2008, (Feng et.al., 2012). Meanwhile, large and medium scale biogas plants for cattle farms started growing rapidly. Greater investment in the biogas sector also stimulated the active involvement of both public and private sectors. As of 2011, there were more than 40,000 people working at around 13,000 biogas promotional institutions at provincial, county, and township levels. Over 2000 biogas enterprises across the country employed more than 30,000 people and achieved a total output value of CNY 8 billion (CAREI, 2012).

Funding for biogas development in China comes from a range of public and private sector sources, including central government, provincial government, government agencies, and international players such as the World Bank and the Asian Development Bank. Investment in domestic biogas is mainly via subsidies such as cash grants to households, construction materials, biogas appliances, and technician services. Biogas is still an appropriate technology for rural areas of China, Jun et.al., (2017). As Nigeria's population is growing with increased economic activities and energy demands, there is need to adjust strategy to meet changing circumstances, accommodate more poor rural households. The experience of China can also help in understanding some of the challenges and opportunities offered by the biogas sector in Africa and other developing

and emerging economies across the world. If the majority of these rural populations were to shift their primary energy supply from local renewable energy sources to commercial fossil fuels, it would have a huge economic and environmental impact, affecting the security of energy supplies at a national or even global level. For this reason, due efforts should be made, in Nigeria as elsewhere, to overcome the various barriers to a robust and sustainable development of the biogas sector.

Research Methodology

There was no official data on biogas funding in Nigeria that was found in the course of this study. The methodology adopted is therefore a combination of primary data, using descriptive statistics and probit-logit regression. A sample of 382 questionnaires were distributed to respondents in local communities and university students in the North Central states of Plateau, Nasarawa and Benue. The responses were verified, sorted, classified and summarized in the tables below. Biogas development (BIOD) is a qualitative dependent variable, hence, the model for the estimation of the binary logistic dependent variable is adopted. This is in line with Mulatie and Andualeuun (2019), who used the logistic regression to investigate the effect of gender on poverty status of female-headed households in South West Ethiopia. Variables such as sex, dependency ratio, credits access, occupation and place of residence were used as key determinants of poverty. This methodology is also in consonant with Aassve, Sironi and Goisis (2009), who studied the effect of happiness on child bearing across Europe. According to the formulation of the research problem, binary dummies can take zero (0) or one (1) as values to be considered, (Maddala, 2001; 1983). The data analysis considers a dichotomous characteristic of biogas development (BIOD), being developed as one (1) and also not being developed as zero (0), true or false, yes or no respectively, are the attributes.

$$BIODi = f(AWSTS, TE, GSBIO, ED) \text{----------(1)}$$

$$BOIDi = \beta_1 + \beta_2 AWSTS + \beta_3 TE + \beta_4 GSBIO + \beta_5 ED + \mu i \text{----------(2)}$$

Where:
BIODi = Biogas Development
AWSTS= Aggregate Wastes
TE = Technical Efficiency
GSBIO = Government Support of Biogas
ED = Energy Diversity
BIODi = 1 if it is well developed and 0 if otherwise.

The cross section data necessary to estimate the parameters of the probit-logit regression model were collected by getting feedback on questionnaires. Technical efficiency is also a qualitative variable, ranks as zero for no efficiency and one for the presence of efficiency. The variable BOIDi does not have a normal distribution, hence does not have a normal discrete regression model.

$BOIDi = \beta_1 + \beta_2 X_{i2} + \mu i$----------(3)
$E(BIODi) = \beta_1 + \beta_2 X_{i2}$----------(4)

Equation (4) represents the expected value of the qualitative variable (BOIDi) Expanding the expected value through probability gives the logit model:

$1/\ 1 + e^{-\beta 1 - \beta 2 Xi2} = 1/\ 1 + \exp(-\beta_1 - \beta_2 X_{i2})$----------(5)

The parameters of equation (5) were estimated by the logistic regression method with the following results obtained.

Table 1.

Method: ML-Binary Logit
Dependent Variable: BIODi
Date: 10/01/20 Time: 06:58
Sample(adjusted): 1 30
Convergence achieved after 7 iteratios
Included observations: 30

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	15.90143	5.227405	3.041936	0.0074
AWSTS	-4.641446	4.410404	1.052386	0.3074
TE	0.007512	0.003516	2.136674	0.0475
GSBIO	-137.9678	90.33749	-1.527249	0.1441
ED	5.10.001	24.84071	8.091558	0.0000

R-squared	0.781281	Mean dependent var	18.10550
Adjusted R-squared	0.708491	S.D. dependent var	5.963624
S.E. of regression	4.959172	Akaike info criterion	6.177836
Sum squared resid	418.0876	Schwarz criterion	6.327196
Log likelihood	-58.77836	Hannan-Quinn criter.	6.206992
F-statistic	5.238072	Durbin-Watson stat	0.810878
Prob(F-statistic)	0.016892		

Obs with Dep=0	12	Total Obs	30
Obs with Dep=1	18		

Source: Authors' computation using Eviews-10

The linkert scale was used to interpret items in the questionnaire. These responses were based on the respondents' assessment of the impact of biogas on energy supply and sustainable development in Nigeria. The results are presented in table 2 below:

Table 2: Development and impact of Biogas fuel and other renewable energy

Item	SA	%	A	%	DA	%	SD	%
Africa suffers from energy poverty and energy access in both rural and urban areas	137	35.9	225	58.0	15	3.9	5	1.3
Would you agree that Nigeria needs energy technology and diversification of energy sources?	153	40.1	199	52.1	10	2.6	20	5.2
Is there any causal relationship between energy poverty and sustainable development in Nigeria?	139	36.3	218	57.7	10	2.6	15	3.9
Would you agree that there is a direct positive relationship between unemployment and energy poverty in Nigeria	180	47.1	178	46.3	11	2.8	13	3.4
Biogas is one of the world's cleanest fuels, a high class alternative to petrol and diesel	117	30.6	230	60.2	15	3.9	20	5.2
Government, universities and industries should synergize in energy research and development	130	34.0	230	60.2	7	1.8	15	3.9
Do you have students from your institutions working on biogas construction during their industrial training (IT)	199	52.1	180	47.1	3	0.7	0	0.0
Biogas innovation will boost SMEs and create more jobs in Nigeria?	163	42.6	199	52.1	10	2.6	10	2.6
Diversification of energy mix is key to output growth, the development of industries and manufacturing	142	37.1	215	56.2	20	5.2	5	1.3
Nigeria has inherent potentials in the Mambilla hydropower, solar energy and other sources of renewable energy	139	36.3	215	56.2	10	2.6	18	4.6
Nigeria's current power supply in KLW is insufficient and inadequate for sustainable development	143	37.4	220	57.5	10	2.6	9	2.3
Biogas fuel has clear economic, social and environmental benefits for SMEs and rural households	200	52.3	161	42.1	20	5.2	11	2.8
Energy supply is both the engine and the wheel of progress	230	60.2	134	35.1	10	2.6	8	2.1
Energy efficiency is a precondition for entrepreneurship and industrial development	149	39.0	210	54.4	5	1.3	18	4.7
Energy supply is a veritable tool for raising the productive capacity of African economies	129	33.7	229	59.9	10	2.6	14	4.3
Diversifying energy sources away from fossil fuels is key to poverty reduction and sustainable environment in Africa	119	31.1	227	59.6	15	3.4	28	7.3
Diversifying energy sources will help diversify the Nigerian economy with positive financial returns on investment & improved standard of living	129	33.7	230	60.2	10	2.6	23	6.0
Low levels of productivity, low levels of income and lack of competitiveness are attributable to energy poverty in Africa	127	33.2	209	54.7	22	5.7	24	6.2
The rise in the transaction costs of SMEs in Nigeria and most African countries is attributable to power failure and energy poverty	170	44.5	198	51.8	9	2.3	5	1.3
The presence or absence of energy supply has positive or negative multiplier effects on other infrastructures such as transport, water supply, security, communication, education and health infrastructures	150	39.2	230	60.2	12	3.1	0	0.0

Energy supply for households and businesses in urban slums and rural areas can help minimize the risks of criminality	163	42.6	200	52.3	11	2.8	8	0.2
Government investment in Biogas and other renewable energy mix, roads, water supply and communication will reduce production costs for agricultural and manufacturing industries	120	31.4	234	61.2	18	4.7	10	2.6
Biogas production and energy supply increases private sector investment and profitability of firms, thus fostering sustainable economic development in Nigeria	145	37.9	199	52.1	16	4.2	18	4.7
Energy supply in Africa has been either not available or not reliable	149	39.1	221	57.6	10	2.6	4	1.0
Nigeria needs energy indigenous technology and diversification of energy sources	200	52.4	159	41.6	18	4.7	5	1.3
There is a causal relationship between energy poverty and sustainable development in Nigeria	153	40.1	204	53.4	15	3.9	10	2.6
There is a direct positive relationship between unemployment and energy poverty	159	41.6	200	52.3	10	2.6	13	3.5
Biogas innovation will reduce energy poverty, benefit SMEs and create more jobs in Nigeria	313	34.3	235	61.5	11	2.9	5	1.4
There is a direct causality between energy infrastructure supply and economic prosperity in Nigeria	145	39.9	220	57.5	5	1.3	12	3.1

Source: Field Survey, 2019

Fig 1: The Root Causes of Nigeria's Energy Problem

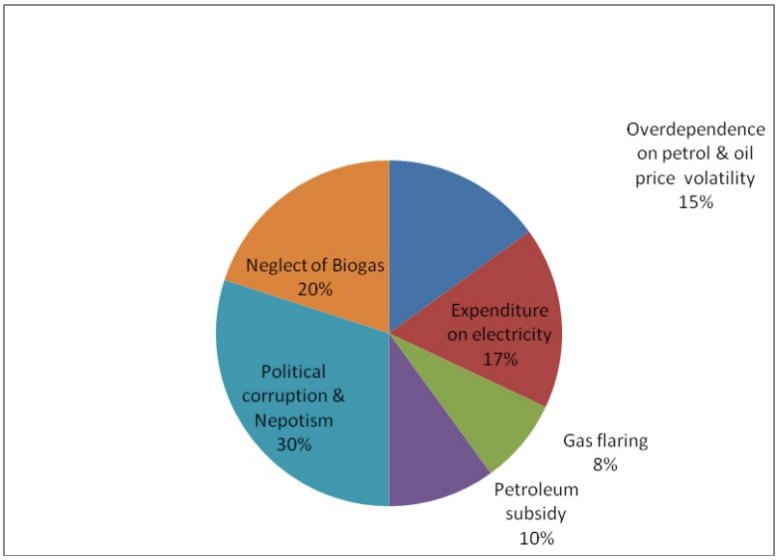
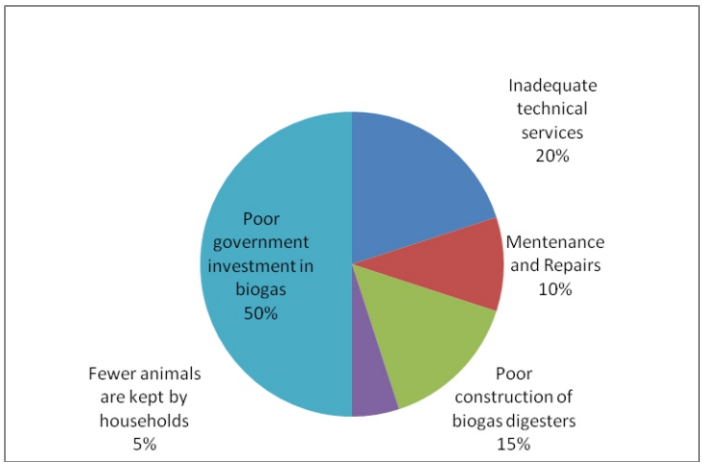


Fig. 2: Nigeria's biogas development challenges



Energy poverty comes with heavy costs. Some of the costs of energy poverty in Nigeria identified by this study include:

Fig. 3: Cost of Energy Poverty in Nigeria

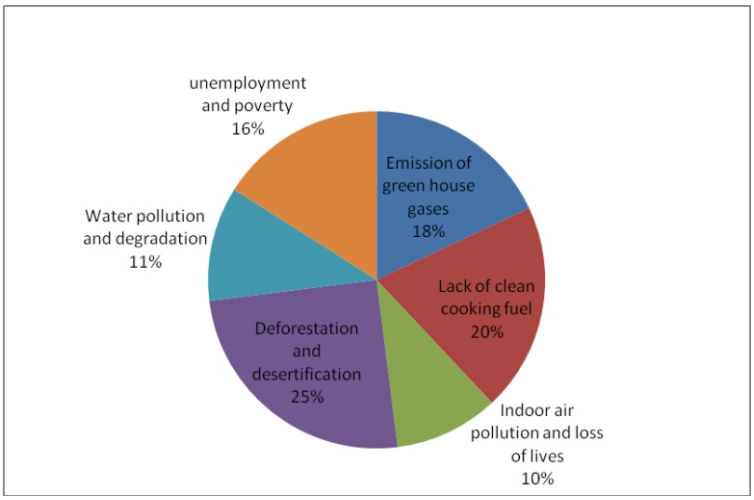
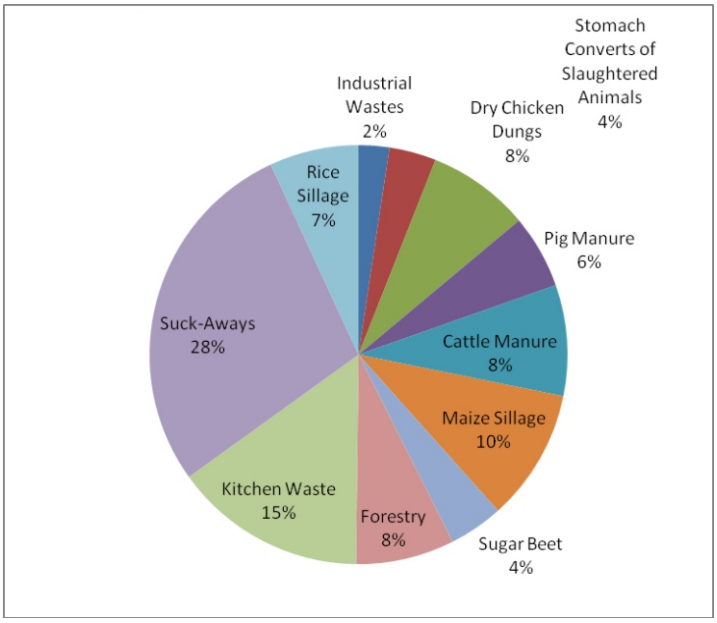


Fig. 4: Pie Chart Showing Typology of Wastes as Raw Materials for Biogas in Nigeria

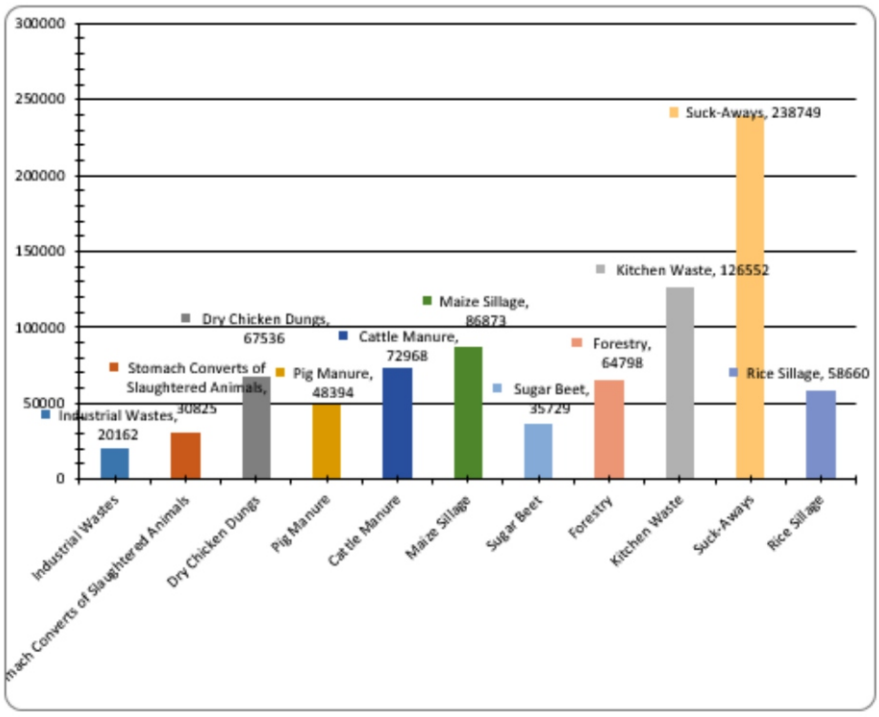


The development of domestic biogas in China has had some ups and downs in its 80-year history. Efforts to pioneer biogas in China can be traced back to the 1930s, with a few companies trying to commercialize biogas as an alternative to imported kerosene for lighting. In order to achieve this at home, a biogas digester has to be constructed. Biogas digesters allow rural households with livestock to convert manure and other organic waste into 'biogas' for cooking fuel and 'bio-slurry' as fertilizer. Digesters tend to be underground, airtight containers with a capacity of four to 20 cubic meters. 'Feedstock' (the organic waste) is emptied into the digester, where a consortium of bacteria act on it anaerobically, breaking down the waste into gas and slurry. Pipes convey the biogas directly to the household kitchen, and the bio-slurry can be discharged regularly for use as a fertilizer. One cubic meter of biogas will provide about two hours' cooking time. Rural households deemed suitable for biogas installation must meet the following four criteria: 1) enough animal waste to feed the digester – minimum three pigs or one cow in stock; 2) enough ground space in the home yard for biogas construction; 3) adequate management capacity – minimum one adult laborer at home; and 4) appropriate self-financing capacity. The traditional design of domestic biogas digesters with a fixed dome and a hydraulic chamber are now commonly referred to as the Chinese fixed-dome type, and it is promoted in developing countries by many organizations worldwide, with some modifications. The improved design and construction materials use are bricks and cement or concrete

Table 3: Typology of Waste for Biogas

Typology of Waste For Biogas	Tonnes
Industrial Wastes	20162
Stomach Converts of Slaughtered Animals	30825
Dry Chicken Dung	67536
Pig Manure	48394
Cattle Manure	72968
Maize Silage	86873
Sugar Beet	35729
Forestry	64798
Kitchen Wastes	126552
Suck Away	238749
Rice Sillage	58660

Fig. 5: Graph Showing Typology of Wastes as Raw Materials for Biogas in Tonnes/Nigeria



Different uses of biogas and bio-slurry were explored and advanced biogas cooking and lighting appliances were developed. In addition to the conventional use of biogas, experiments were carried out using biogas for small-scale power generation (a few KW) and atmosphere control for grains or citrus storage. Bio-slurry was tested for effectiveness in seed soaking (germinating rice seeds by soaking them in bio-slurry), mushroom cultivation, fish food, and fruit and vegetable fertilizing.

2003 was a turning point for China's domestic biogas development thanks to a significant increase in government investment. With funding from treasury bonds, annual investment in the national rural biogas programme reached a historical high of over one billion Chinese Yuan (CNY), roughly corresponding to USD 124 million (at 2003 exchange rates). The government investment in biogas sector kept growing until it reached CNY 6 billion (USD 863 million) a year in 2008. Meanwhile, large and medium scale biogas plants for cattle farms started growing rapidly. Greater investment in the biogas sector also stimulated the active involvement of both public and private sectors. As of 2011, there were more than 40,000 people working at around 13,000 biogas promotional institutions at provincial, county, and township levels. Over 2000 biogas enterprises across the country employed more than 30,000 people and achieved a total output value of CNY 8 billion (CAREI, 2012). Funding for biogas development in China comes from a range of public and private sector sources, including central government, provincial government, government agencies, and international players such as the World Bank and the Asian Development Bank. Investment in domestic biogas is mainly via subsidies such as cash grants to households, construction materials, biogas appliances, and technician services.

Biogas is still an appropriate technology for rural areas of China, though the sector needs a review and a shake-up. There is need to adjust strategy to meet changing circumstances, accommodate more poor rural households. The experience of China can also help in understanding some of the challenges and opportunities offered by the biogas sector in Africa and other developing and emerging economies across the world. If the majority of these rural populations were to shift their primary energy supply from local renewable energy sources to commercial fossil fuels, it would have a huge economic and environmental impact, affecting the security of energy supplies at a national or even global level. For this reason, due efforts should be made-in China as elsewhere to overcome the various barriers to a robust and sustainable development of the biogas sector globally.

Figures from the China Ministry of Agriculture showed that biogas users in China had reached 41.68 million households by the end of 2011, including 39.96 million households with domestic biogas digesters. Biogas households accounted for 23 per cent of total households in rural China or about one third of the rural households suitable for biogas installation.1 With the financial support of the government, 24,000 small biogasplants and 3690 medium and large biogas plants2 had been installed (MoA, 2012).

The direct outputs of domestic biogas digesters are biogas and bio-slurry. The main *direct* benefits are the fertilising properties of biogas slurry, better waste management, and the killing of pathogens during the anaerobic fermentation process. Commonly quoted *indirect* benefits of biogas technology include better environmental hygiene; fewer occurrences of respiratory and intestinal diseases; improved soil fertility and agricultural productivity; less pressure on forest ecosystems due to less demand for firewood; less time used collecting firewood and cooking; better energy security due to using diverse energy sources and relying less on fossil fuels; and less greenhouse gas emissions.These indirect benefits are important and should be included in any economic analysis. There are clear indications of time saved by needing less firewood, and easier cooking, which disproportionately benefits women.

The productive use of bio-slurry; the partial displacement of firewood, crop residues, and chemical fertilizers as a result of adopting biogas are parts of the benefits. Biogas and bio-slurry are useful in multiple ways such as cooking in a kitchen, vegetable plot, mushroom cultivation area, orchard, or fish pond. It destroys pathogens from human and livestock waste through the anaerobic fermentation process.

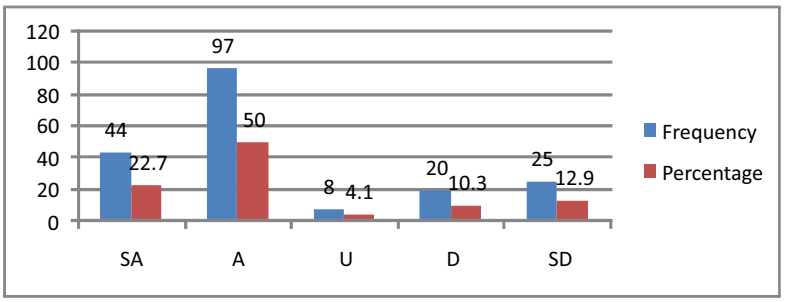
In the analysis that follows from table 4, the valid responses were further sorted and the sample reduced to a total of 194.

Table 4: Energy diversity will revitalize strategic industrial subsectors in Nigeria

Responses	Frequency	Percentage (%)
SA	44	22.7
A	97	50.0
U	8	4.1
D	20	10.3
SD	25	12.9

Source: Field Survey, 2019.

Figure 6: Energy diversity will revitalize strategic industrial subsectors in Nigeria



Source: Field Survey, 2019.

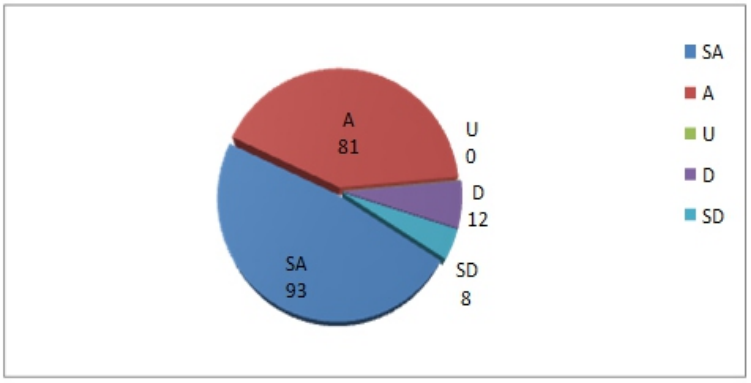
Table 4 and figure 6 above show that 22.7% (44) and 50% (97) of the respondents strongly agreed and agreed respectively that energy diversity will revitalize strategic industrial subsectors in Nigeria, 8 respondents representing 4.1% of the respondents were undecided. Similarly, 10.03% (20) and 12.9% (25) of the respondents disagreed and strongly disagreed respectively to the statement. In all, 72.7% (141) of the respondents are of the view that energy diversity will revitalize strategic industrial subsectors in Nigeria.

Table 5: Nigeria can use established highly profitable efficiency techniques to save half of the projected 2030 use of natural gas.

Responses	Frequency	Percentage (%)
SA	93	47.9
A	81	41.8
U	0	0
D	12	6.2
SD	8	4.1

Source: Field Survey, 2019.

Figure 7: Nigeria, Efficiency in the use of natural gas by 2030 is achievable.



Source: Field Survey, 2019.

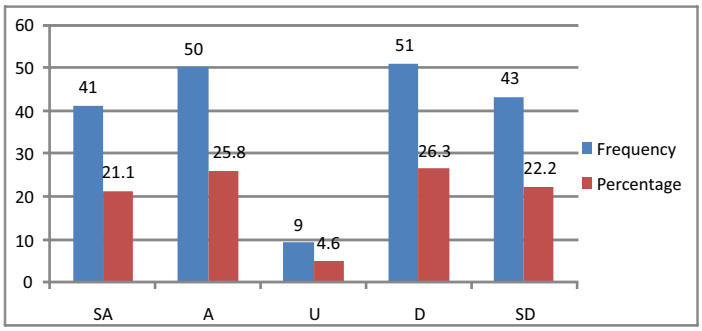
The table 5 and figure 7 (pie chart) above show that 93 (47.9%) and 81 (41.8%) of the respondents strongly agreed and agreed respectively that Nigeria can use established highly profitable efficiency techniques to save half of the projected 2030 use of natural gas. None of the respondents was undecided, while 12 (6.2%) disagreed, and 8 (4.1%) strongly disagreed. Thus, a total of 89.7% (174) of the respondents were of the view Nigeria can use established highly profitable efficiency techniques to save half of the projected 2030 use of natural gas.

Table 6: The lack of biogas development and other sustainable energy sources has made Nigeria a dumping ground for obsolete generators, inefficient trucks, cars and other engines that consume so much petrol and pollute the environment.

Responses	Frequency	Percentage (%)
SA	41	21.1
A	50	25.8
U	9	4.6
D	51	26.3
SD	43	22.2

Source: Field Survey, 2019.

Figure 8: The lack of biogas development and other sustainable energy sources has made Nigeria a dumping ground for obsolete generators, inefficient trucks, cars and other engines that consume so much petrol and pollute the environment.



Source: Field Survey, 2019

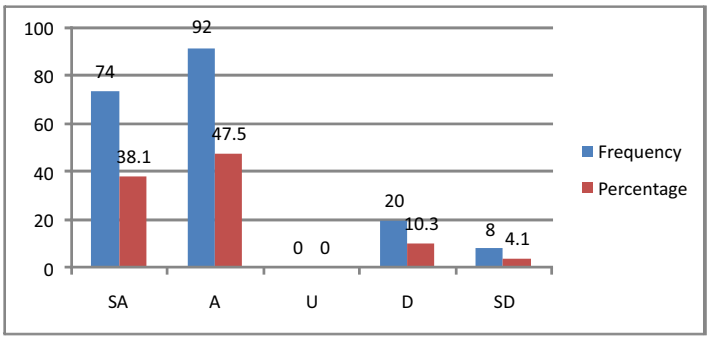
The table 6 and figure 8 (graph) above show that 41 (21.1%) and 50 (25.8%) of the respondents strongly agreed and agreed respectively that the lack of biogas development and the absent of other sustainable energy sources has made Nigeria a dumping ground for obsolete generators, inefficient trucks, cars and other engines that consume so much petrol and pollute the environment. 9 respondents representing 4.6% of the respondents were undecided while 51 (26.3%) of the respondents disagreed, and 43 (22.2%) strongly disagreed to the statement.

Table 7: Nigeria can no longer be a dumping ground for obsolete generators, inefficient trucks, cars and other engines that consume so much petrol and pollute the environment

Responses	Frequency	Percentage (%)
SA	74	38.1
A	92	47.5
U	0	0
D	20	10.3
SD	8	4.1

Source: Field Survey, 2019.

Figure 9: Nigeria can no longer be a dumping ground for obsolete machines



Source: Field Survey, 2019

Table 7 and figure 9 above reveal that 38.1% (74) and 47.5% (92) of the respondents strongly agreed and agreed respectively that Nigeria can no longer be a dumping ground for obsolete generators, inefficient trucks, cars and other engines that consume so much petrol and pollute the environment. Furthermore, 10.3% (20) of the respondents disagreed while 4.1% (8) strongly disagreed to the statement. In a nutshell, 85.6% (166) of the respondents are of the view that Nigeria can no longer be a dumping ground for obsolete generators, inefficient trucks, cars and other engines that consume so much petrol and pollute the environment.

Which of these renewable energy sources would you recommend for Nigeria to be economical, cheaper and rural-inclusive?

Fig. 10a: Choice of Renewable Energy for Nigeria

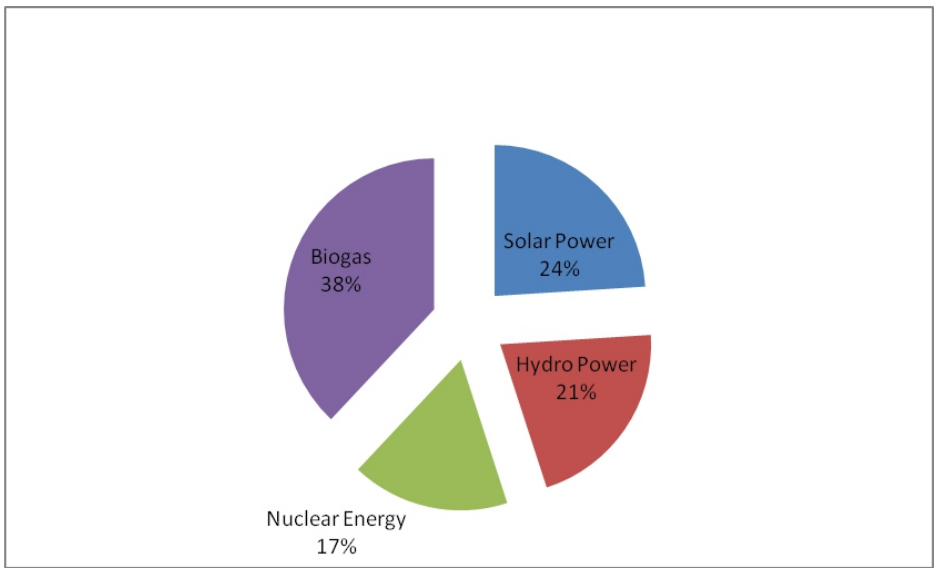


Fig. 10b: Choice of Renewable Energy for Nigeria

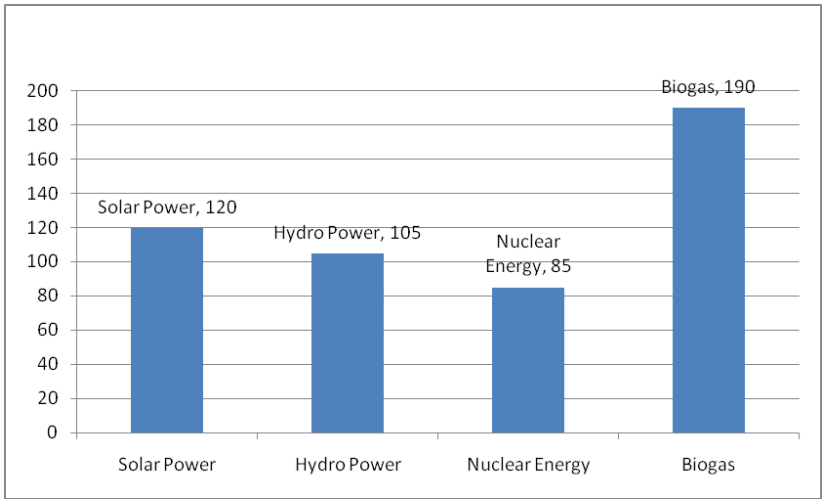
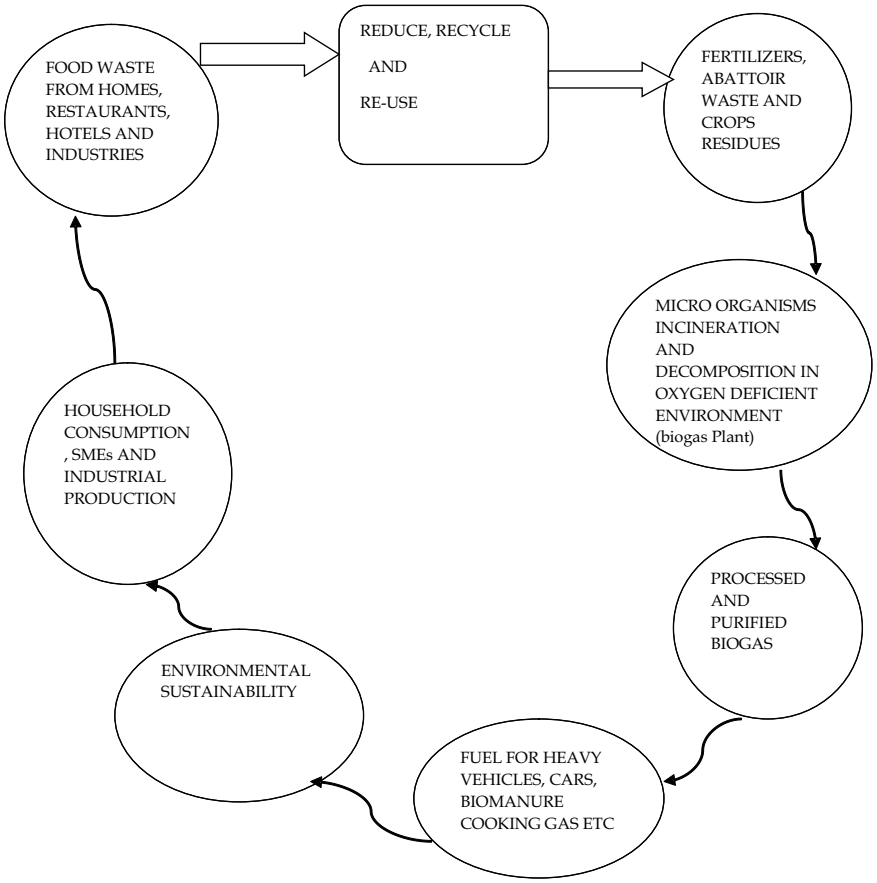


Fig. 11: Biogas Production Life Cycle



The biggest potential for biogas production in Nigeria and Africa as a whole lie in agriculture. In the literature, the energy content of 1m3 biogas (97% methane) is 9.67 KWH, higher than that of I litre of petrol which is 9.06KWH. Biogas reduces energy poverty by increasing energy access by poor households and small and medium scale enterprises. Women and children in Nigeria would have to spend less time and energy collecting firewood. This in turn saves the environment from the danger of desertification and climate change.

From an economic perspective, the public benefits of biogas digesters' various impacts should all be considered. These may cover the impact on health of less indoor air pollution and improved sanitation; the impact on the environment locally (improving living conditions in the immediate vicinity), nationally (forest conservation) and globally (reduced greenhouse gas emissions). They may also include increased agricultural outputs due to improved soil conditions and the alleviation of poverty through access to alternative cooking and lighting solutions. Most of these benefits are yet to be quantified. Both direct and indirect economic benefits are critical to the cost-effectiveness evaluation, and for justifying investment in the national biogas programs in Africa.

Discussion of Findings

Nigeria can free itself of oil and end its oil dependence within the next decade. It will cost less to diversify energy sources than it costs to maintain petroleum subsidy and cleaning up of oil spillage in the Niger-Delta. Nigeria's shift from petrol dependence can be led sustainably and profitably by business at a net savings to the economy of 200 billion dollars a year by 2030. Oil's market price leaves out many of its true economic, military and environmental costs/burdens. Livelihoods should regenerate the environment and not to destroy the ecosystem. We are already in the year 2020, where Nigeria proposed to generate 40000MGW of electricity to meet the Vision 2020. However, Nigeria is yet to move close to half of this target. There is need to diversify energy mix. There are inherent potentials in the Mambilla hydropower project, the Kanji Dam, solar energy, nuclear energy and biogas. The Nigeria's leather industry for instance, has the potential of growing and generating about $2billion by 2030, contributing about 25% of agricultural GDP, employing about 10 million workers including women and youths. A lot of leather entrepreneurs are presently importing their raw materials from China, Italy, Spain, India etc. This is because the quality needed cannot be guaranteed at home, and one of the negating factors is lack of constant power supply. The first step to building an export-driven economy in Nigeria is by providing reliable, accessible and affordable energy mix.

In an assessment of the root causes of Nigeria's energy poverty, political corruption and nepotism top the list of six with 30 percent. Apart from the Abacha loots in the military era, since 1999 that Nigeria's democratic rule returned, huge public funds have been spent on the power sector. However, the ministers of power and contract awards in the sector have not been based on purely merit. Nepotism, party affiliation and religion have been a major part of Nigeria's development problem. There are more churches and mosques in Nigeria than in the 1960s, but so are the problems and national challenges: corruption and

poverty. There is no nation in the world that has become developed through miracles but deliberate planning for development intervention. There is need for transformation of citizenship perception of nationality through civic education and national identity, not just religious, ethnic or party identities. Public officers must look at their representation from a patriotic perspective.

Nigeria's government has laid so much emphasis on petroleum and its subsidy with little or no funding of biogas project. Smart government financing of biogas plants will accelerate energy diversity. Farm subsidies can be trimmed as profit-making biogas fuels and biomaterials supplant loss-making crops. Within a few years, farm net income could triple with biogas-supported agricultural vale-chain. Biogas fuels will be a new product line that will leverage recycle wastes in Nigeria. Petroleum subsidy is not inclusive of the poor, the chunk of the benefits goes to the rich who own many cars and also industrial wheel power. However, if such subsidy is invested in biogas, energy supply for poor households will step up to meet their energy demands. This is inclusive of the rural poor.

The direct outputs of domestic biogas digesters are biogas and bio-slurry. The main direct benefits are the fertilizing properties of bioslurry, better waste management, and the killing of pathogens during the anaerobic fermentation process. Commonly quoted *indirect* benefits of biogas technology include better environmental hygiene; fewer occurrences of respiratory and intestinal diseases; improved soil fertility and agricultural productivity; less pressure on forest ecosystems due to less demand for firewood; less time used collecting firewood and cooking; better energy security due to using diverse energy sources and relying less on fossil fuels; and less greenhouse gas emissions. These indirect benefits are important and should be included in any economic analysis. There are clear indications of time saved by needing less firewood, and easier cooking, which disproportionately benefits women. The productive use of bio-slurry; the partial displacement of firewood, crop residues, and chemical fertilizers as a result of adopting biogas are parts of the benefits. Biogas and bio-slurry are useful in multiple ways such as cooking in a kitchen, vegetable farm, mushroom cultivation area, orchard, or fish pond. It destroys pathogens from human and livestock waste through the anaerobic fermentation process. From an economic perspective, the public benefits of biogas digesters' various impacts should all be considered. These may cover the impact on health of less indoor air pollution and improved sanitation; the impact on the environment locally (improving living conditions in the immediate vicinity), nationally (forest conservation) and globally (reduced greenhouse gas emissions). They may also include increased agricultural outputs due to improved soil conditions and the alleviation of poverty through access to alternative cooking and lighting solutions. Most of these benefits are yet to be quantified. Both direct and indirect economic benefits are critical to the cost-effectiveness evaluation, and for justifying investment in the national biogas programs in Africa. In Nigeria, petroleum subsidy has raised street protests because it is not inclusive of the poor, it is wasteful and it encourages corruption. Petroleum subsidy could rather be used to build biogas stations in rural areas boost industrial activities.

True value lies in processing and there is no processing without infrastructure. Energy supply is key to output growth and the development of SMEs as well as manufacturing. Nigeria should develop its value chain beginning with constant and accessible power supply. The government, industries, universities and polytechnics should synergize in research to bring about indigenous technology as a solution to Nigeria's energy poverty. Nigeria needs home-made energy solutions, power stations, biogas development, solar panels and hydro dams. It is noteworthy to reemphasize the urgent need for the establishment of industrial, science and technology parks across the country for the incubation and hatching of home-made technologies. Some of the costs of energy poverty identified by this study include: green house gas emission, lack of clean cooking fuels, indoor air pollution from burning solid biomass such as firewood, poor cooking stoves, loss of man-hours, water pollution and water borne infections, environmental degradation, economic wastages and financial costs.

Conclusion and Recommendations

1. Nigeria can use established highly profitable efficiency techniques to save half of the projected 2030 use of natural gas. This is simply by using electricity efficiently, especially at periods of peak energy demand. By diversifying energy sources, Nigeria can save eighty trillion cubic feet of gas a year. Gas efficiency will make this fuel abundant and affordable, cut gas and power bills by 150 billion Naira a year and free 10 trillion cubic feet a year to substitute for petrol. Nigeria can free itself of oil and end its oil dependence within the next two decades, precisely by 2040. It will cost less to diversify energy sources than it costs to maintain the controversial petroleum subsidy and cleaning up of oil spillage in the Niger-Delta. Nigeria's shift from petrol dependence can be led sustainably and profitably by business at a net savings to the economy of 200 billion dollars a year by 2030. Oil's market price leaves out many of its true economic, military, social and environmental costs or burdens that are not sustainable. Nigeria needs to use advanced technology and ultra-light materials to engineer advanced versions of vehicles and factory plants/materials, replacement of inefficient trucks and cars and generators which consume 40 percent of petrol and pollute the environment. Nigeria can no longer afford to be dumping ground for these obsolete technologies. There is need to improve both safety and performance. The Nigerian Customs, Federal Road Safety Corps, the Nigerian Police Force and the Civil Defense should be involved in a national scrap-and-replace program for cars, trucks, generators and other kinds of machines coming into Nigeria. If energy source is diversified and stable, it will encourage domestic and foreign investment in Nigeria's automobile industry, and production with local content to end dumping. Nigeria can actually coordinate public policies and business strategies to speed up biogas production in order to end energy poverty in Nigeria, combined with efficient buildings and factories. This shift can revitalize strategic industrial sectors that will make the key oil-saving technologies.

2. This study recommends inclusive approach to poverty reduction and sustainable development through the revamping of infrastructure and modernization of agricultural value chain to completely eliminate wastages, the provision of quality and inclusive health care services, functional rail and road transport networks, electricity, water and sanitation that reduce rural-urban divide. Biogas has a role in providing electricity, sanitation, improving agricultural value chain and industrialization. This will enable the poor to explore their creativity, resourcefulness and resilience. They would therefore engage in economic activities that will half poverty in Nigeria. Energy poverty increases absolute poverty and the provision of alternative renewable energy will lead to a miracle of rapid poverty reduction in Nigeria
3. Double efficiency of using fuel, advanced technology ultra light materials to engineer advanced versions of vehicles and factory plants/machines, replacement of inefficient trucks and cars, generators, which consume 40% of petrol, and pollute the environment. Nigeria can no longer afford to be a dumping ground for these obsolete technologies. There is need to improve both safety and performance.
4. Coordinate public policies and business strategies to speed up biogas production, and other sources of renewable energy such as hydro, wind and solar energy in order to end energy poverty in Nigeria, combined with efficient buildings and factories. This shift can revitalize strategic industrial subsectors that will make the key oil-saving technologies in Nigeria. Students in tertiary institutions can engage in industrial training(IT) by constructing biogas stations to innovate home-made energy solutions.
5. Turn to modern biofuels to replace another 30 percent of Nigeria oil needs is highly recommended. New ways to convert forestry plants like switch grass and poplar into ethanol can yield twice as much fuel as today's corn-int0-ethanol processes, yet it costs less in both capital and energy. Replacing fossil fuels with these plant-derived carbon hydrates will strengthen rural Nigeria too. It will boost the farm income by tens of billions of Naira a year and create 1000000(one million) jobs. Huge funding in this sector is required.
6. Improvement in infrastructure, security, health and economic indices through diversification of energy mix. Nigeria has rich development potentials, but the issue of infrastructure, especially electricity and transport infrastructure is limiting these potentials. Nigeria is fit potentially to become the SMEs and manufacturing power house of Africa with supply chain all over the continent and beyond if the enabling environment is created. There are inherent potentials in the Mambilla hydropower project, the Kanji Dam, solar energy, nuclear energy and biogas.
7. This study also recommends the use of established highly profitable efficiency technologies to save half the projected 2030 use of natural gas. Simply by using electricity efficiently, especially at periods of peak demand, Nigeria can save eight trillion cubic feet of gas a year. Gas efficiency will make this fuel abundant and affordable too, cut gas and power bills by 150 billion Naira a year and free 10

trillion cubic feet a year to substitute for petrol. These recommendations are shifts from oil dependency in the 21st century. They are fundamentally disruptive technologies to current oil business models which the big oil giants like Shell BP, Mobil etc should be proactive by investing in them. Nigeria needs to build an alternative energy economy and it starts now, this should be innovation-driven.

8. Smart government financing of biogas plants will accelerate energy diversity. Farm subsidies can be trimmed as profit-making biofuels and biomaterials supplant loss-making crops. Within a few years, farm net income could triple. Biofuels are a new product line that leverages recycled wastes and the burdens of petrol dependence., and at the same time conserve our biodiversity. Besides, petroleum subsidy is not inclusive of the absolute poor, the chunk of the subsidy goes to the rich who drive cars and own industrial wheel-power. However, if such subsidy is invested in constructing thousands of functional community-level biogas plants, it is inclusive of the rural poor.
9. Finally, it is highly recommended that Nigeria should turn to biofuels to replace another 30 percent of her oil needs. New ways to convert forestry plants like switch grass and poplar into ethanol can yield twice as much fuel as today's corn-into-ethanol processing. Yet, it costs less in both capital and energy. Substituting fossil fuels with these plant-derived carbohydrates will strengthen rural Nigeria too. It will boost the farm income by tens of billions of Naira and create one million jobs per year. These recommendations are shifting from oil dependency in the 21st century. They are fundamentally disruptive to the current oil business models. Nigeria needs to build an alternative energy economy and it starts from now, this should be innovation-driven. Nigeria should double efficiency of using fuel.

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