



## SUSTAINABLE ENERGY IN NIGERIA: AN INTEGRATED WOMEN-FRIENDLY ENERGY SUPPLY APPROACH

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### ABSTRACT

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Sustainable energy is at the center of pursuit of sustainable development goals (SDGs). Gender inequality, fueled by religious and cultural beliefs, has hampered the achievement of sustainable energy supply in Nigeria. Women, who are major consumers of energy, are largely excluded from energy production due to a relative deficiency in technical training. The paper focuses on integrating women in sustainable energy supply in Nigeria through the adoption of women-friendly energy production methods such as biogas production. The importance of installing household biogas plants in rural communities, providing relevant technical training for women, as well as cheap labor for servicing the biogas plants, and establishing accessible markets for sale of excess biogas were discussed. The economic potentials of well-packaged biogas feedstock, and bio-slurry (a by-product of biogas production) were highlighted to portray the win-win characteristics of biogas production.

**Contribution/Originality:** This review exposes the energy crisis in Nigeria as an effect of non-integration of women in energy production/supply systems, and proposed a woman-friendly energy resource that is capable of supporting a sustainable environmentally friendly energy supply in Nigeria.

### 1. INTRODUCTION

Sustainable energy can be said to be synonymous with sustainable development since energy is arguably the single most important prerequisite for success of the three pillars

of sustainable development – economic, environmental and social development (Purvis, Mao, & Robinson, 2019). Access to energy is very vital to achieving many development goals such as eradicating poverty, increasing food production, providing clean water, improving public health, providing reliable and efficient lighting, heating, cooking services, enhancing education, creating economic opportunity, and empowering women (International Energy Agency (IEA), 2010). Consequently, the high level of poverty and underdevelopment witnessed in most developing countries are linked with energy crisis arising from energy demand and supply gradient. In Nigeria, energy crisis has continued unabated up till now despite the heavy investment by the government in the energy sector. This is evidenced on the energy per capita of Nigeria in comparison with that of other peer countries. The people in the rural communities are not able to access the energy produced either due to unaffordability or unavailability which result in energy poverty. The rural dwellers resort to the readily available or affordable energy

sources which are mostly biomass and fossil fuels to meet their energy needs. The use of fossil fuels as source of energy has been implicated for greenhouse gas (GHG) emissions that have negatively impacted on the environment inducing the extant climate change. Most people in the rural communities who cannot afford fossil fuels energy resource have resorted to the use of fuelwoods and cow dungs etc. who's direct burning for provision of heat or light also add to greenhouse-effect on the environment. For instance, about 90% of the energy used by rural dwellers in Nigeria comes from fuelwood which is derived from non-nuclear and non-fossil sources (Shaaban & Petinrin, 2014). In Nigeria, it is reported that the highest amount of energy is consumed in residential homes and through cooking. The implication of this in a patriarchal society like Nigeria where women are believed to own the kitchen is that women are the consumers of energy. These women who consume the energy should be better energy managers and actively involved in energy production. However, gender inequality has eschewed Nigerian women from participation in the production of clean energy in Nigeria due to their ignorance of how energy is produced and because the greater percentage of the women were either stack illiterates (did not go to school at all) or avoided science-based subjects/courses at tertiary institution. The issues of gender inequality and how it has impacted negatively on sustainable energy production in Nigeria is part of the discourse of this review. Although there are indications that Nigerian women are beginning to participate in sustainable energy productions evidenced on the number of women who are CEOs of companies dealing with solar energy supply, it is not yet apparent how this will meet the energy demands of rural communities due to cost. A better alternative energy supply which is considered women-friendly, and which has no importation attachments as is obtainable in solar energy supply is biogas production. Both the digester and feedstock for biogas production are sourced locally and the process technology is quite simple. Also, there are reports of the potentials of food waste generated by women in the kitchen and other bio-wastes, that constitute environmental pollution and consequently climate change, for biogas production (Akhatior, Igbinomwanhia, & Obanor, 2016; Chibueze, Okorie, Oriaku, Isu, & Peters, 2017). For instance, about 305.075 tones/day of food waste is generated in Benin metropolis which is sufficient for the production of about 28,836.91 m<sup>3</sup> of biogas per day in Benin and can satisfy the cooking energy needs of about 24,076.1 families per day (Akhatior et al., 2016). It is apparently more robust to equip Nigerian women with the knowledge of biogas production since the feedstock are abundantly and readily available in Nigeria especially in rural communities where the energy poverty is more pronounced. This review also captures the integration of women in the production of biogas as an alternative cost effective renewable energy supply in comparison with solar energy supply where meaningful Nigerian women are beginning to contribute to sustainable energy production in Nigeria. There are also some recommendations as to how to integrate women in the biogas renewable energy supply as a means of ensuring a sustainable clean energy supply in Nigeria.

## 2. GENDER INEQUALITY AND ITS NEGATIVE IMPACT IN NIGERIA

The religious and cultural belief system in Nigeria uphold the superiority of male child over female child from birth which transcends into schooling and even inheritance (Adeyemi & Akpotu, 2004). Also, the concept of gender represents the woman as one who is superficial with interest mainly in fashion, beauty and little love for deep thinking" (Awajiusuk, 2015). Women are believed to be made for the kitchen and child rearing, and as such are not involved in matters considered very crucial and of impact on family and nation building. In the rural communities, for instance, the male children are sent to school, while the females are engaged in money-making ventures to help train the males in school. This sense of patriarchy brings high level of restrictions against the women in terms of job opportunities, courses/subjects studied in schools, owning lands as well as types of crops farmed for agriculture (Eniola, 2018). Nwajiuba (2011) acknowledged gender imbalance in students' enrolment in different disciplines and programs especially at the tertiary level. According to Agu and Omenyi (2013) who studied gender enrolment status in higher institution, the male/female disparity is witnessed in most science and technology courses and pure arts courses with the former favoring males and the latter favoring females.

The result of this gender inequality has impacted negatively on Nigerian women in particular, and sustainable development and nation building in general. The resultant high level of illiteracy among women is captured by the statistical report on women and men in Nigeria which reveals that the literacy rate among young women and men age 15-24 years in 2016 was 59.3% and 70.9% respectively, and the completion rate for girls in primary, junior secondary and senior secondary were 64.8%, 38.8% and 33.2 percent respectively. According to NUC's report on university annual review, from 2001-2005, males who obtained master's degree were 44,337 (72.79%) while females were 16,567 (27.20%). For graduates with doctoral degrees for the same period, males were 2,587 (64.01%) and females were 798 (23.57%) (Agu & Omenyi, 2013). Furthermore, gender stereotyping has led to some courses labeled as masculine and feminine and as such, females pursuing a male-labelled course and vice-versa are viewed abnormal (Agu & Omenyi, 2013). This is probably why most pure science courses such as engineering, mathematics, physics, etc. which are perceived to be difficult are left to be studied by men mainly while women take to pure arts courses. The impact of gender-labelled courses is still strongly felt in Nigeria today as women staff are found to be few in science departments and in other science-related jobs such as power/energy companies, oil companies, construction companies, science-based research institutes, etc. The women in Nigeria appear to have been partially eschewed from science and technology.

### *2.1. Energy Crisis*

The imbalance between the energy demand and supply occasioned by the disparity in gender commitment to energy production has thrown Nigeria into an energy crisis which remains the bane of her poor economic growth. The electricity demand in Nigeria is far higher than the supply and worse still the supply is epileptic in nature. World Bank in their 2015 edition of its Doing Business report ranked Nigeria 187 of 189 countries in terms of ease of getting electricity (World Bank, 2011). The World Economic Forum's Global Competitiveness Report 2014-2015 ranked Nigeria 141 out of 148 countries in terms of the quality of electricity supply (Rapu et al., 2015). The frequency of power outage is so undefinably erratic that firms of all sizes, and residential in all states and sectors have myriads of report on its devastating effect. The claims by an average firm of outage related losses equivalent to more than 4% of sales is second to none in the world (Giuseppe & Clarke, 2011).

Although the report from Energy Information Administration (EIA) showed improved electricity generation over the years, that resulted in significant increase in electricity power consumption per capita of 140.6 percent (World Bank, 2011), yet Nigeria still lag behind some peer economies such as South Africa, India and Brazil in meeting the energy demand in the country (Rapu et al., 2015). This development was attributable to huge demand by the steadily-growing population for electricity requirements at residential and firms (Rapu et al., 2015). According to report by International Energy Agency (IEA) (2010) the residential sector accounts for the highest energy consumption, and cooking accounts for about 91% of the residential energy consumption (Shaaban & Petinrin, 2014). The implication of this report is that women, who by Nigerian culture, are made for the kitchen are the energy consumers. The women are grossly involved in energy consumption much more than they are involved in contribution to sustainable energy supply. This is as a result of women not being adequately integrated in the energy sector due to lack of knowledge and technical know-how of energy production and distribution – an outcome of gender inequality. The women who mostly are either not graduates or graduates of Arts courses are found unfit in the energy sector where science and technology knowledge are indispensable. Consequently, the women are much more involved in energy consumption with only an insignificant number involved in energy supply.

#### *2.1.1. Women and Sustainable Energy Supply in Nigeria*

The women are known as the energy consumers because of their attachments to the kitchen as demanded by some cultural and religious beliefs in Nigeria. However, their energy demand is not met by the current energy

supply resulting in energy poverty. Around the world, women face the largest burden of not having access to modern energy (IRENA, 2018). Nigerian women in the rural communities are affected most in terms of access to clean energy as about 90 percent of them resort to solid cooking fuels such as fuel wood, cow dungs etc. while the remaining 10 per cent access non-solid cooking fuels which are fossil fuels (Figure 2) (World Bank; International Energy Agency, 2014). These cooking fuels are not sustainable due to some associated adverse effects such as house hold indoor air pollution, and climate change.

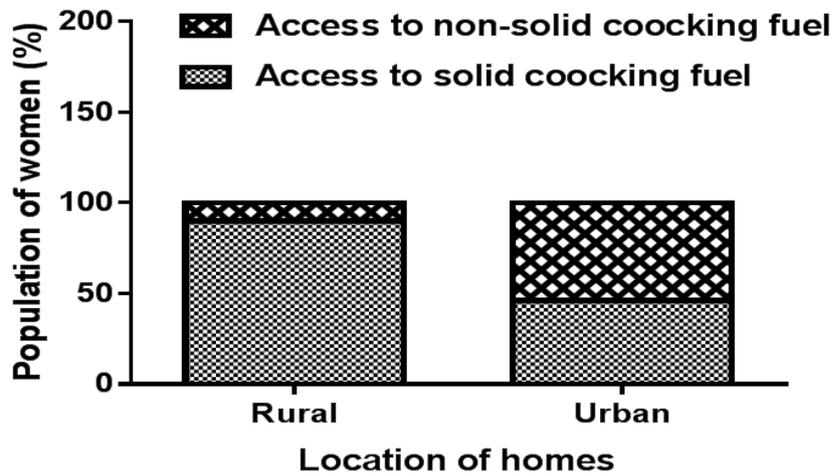


Figure-1. Access to cooking fuels in rural and urban areas in 2010 (in %) (World Bank; International Energy Agency, 2014).

The following deductions can be made from the Figure 1 above: (a). At least half the population of Nigeria (both in urban and rural areas) still depends on solid cooking fuels. (b). women consume the highest amount of energy through cooking and using solid-based fuels which positioned them potentially as better energy managers than men. (c). women receive the direct consequences of use of solid cooking fuels and will be more eager to adopt a healthy and better environmentally friendly option. In view of the deductions above, there is no gainsaying the fact that women should champion the global move for renewable energy. Unfortunately, Nigerian women are facing challenges that obviously impede their involvement in the actualization of renewable energy dream. The high level of poverty resulting in lack of affordability of electricity from the national grid, poor electrification rate in the rural communities as well as epileptic power supply may be the underlining reason for the use of fuel woods or fossil fuels in both rural and urban communities (Akorede, Ibrahim, Amuda, Otuoze, & Olufeagba, 2017).

## 2.2. Women in Energy Sector

Recently, women are beginning to be noticed in sustainable energy supply in Nigeria but not yet significantly. Habib Ali and Salimata is both solar energy women entrepreneur who are currently providing solar energy sources to rural communities in Nigeria. Smarter Grid International (SGI) limited is a renewable energy finance company and service provider whose Managing Director/CEO is a women- Heather Onoh. SGI collaborates with international bodies such as GSMA to provide affordable solar energy solutions using the Pay-As-You-Go or Lease to Own system. Hannah Kabir is the Managing Director of Creeds Energy established in 2012, and which has installed 250 kilowatts (KW) of renewable energy solutions that has positively affected over 2,000 lives (Onehi & Echewofun, 2019). The increasing number of women as CEOs of renewable energy companies in Nigeria gives hope of women integration into the energy sector as a means of providing sustainable energy in Nigeria. However, the concentration on solar renewable energy supply by women may not help to alleviate the current energy crisis as the solar gadgets are mostly imported and thus cost intensive due to import duties and other costs associated with importation. Hence, the need for a cost effective women-friendly alternative.

### 3. BIOGAS – A SUSTAINABLE WOMEN-FRIENDLY ENERGY SUPPLY

Amidst the high level of poverty occasioned by unsustainable power supply, Nigeria has potentials for provision of sustainable energy to her citizens for sustainable developments. Her abundant endowments with renewable energy sources such as solar photovoltaics, solar thermal, wind, small hydropower and efficient biomass has already been reviewed in literature (Akorede et al., 2017; Energy Commission of Nigeria (ECN), 2014). From Table 1, it is obvious that the most abundant renewable energy resource in Nigeria is biomass which include but not limited to fuel wood, municipal waste, animal waste, energy crops and Agricultural residues. Biomass has been widely recognized with the potential to meet the global energy demand (Ben-Iwo, Manovic, & Longhurst, 2016; Berndes, Hoogwijk, & Van den Broek, 2003). The wastes considered an environmental nuisance and of great contribution to greenhouse effect before have become the wealth of many nations due to the emergence of technologies that converts waste to energy and other value-added products. A well-known energy derived from bio-waste is biogas.

**Table-1.** Renewable energy potential in Nigeria (Energy Commission of Nigeria (ECN), 2014).

Energy Resources	Estimated Reserve
Large Hydropower	11,250 MW
Small Hydropower (<30 MW)	3500
Fuel Wood	11 million hectares of forest and woodland
Municipal Waste	30 million tonnes/year
Animal Waste	245 million assorted animals in 2001
Energy Crops and Agricultural Residue	72 million hectares of agricultural land
Solar Radiation	3.5-7.0 kW h/m <sup>2</sup> /day
Wind	2-4 m/s at 10 m height. Wind speeds in Nigeria range from a low 1.4 to 3.0 m/s in Southern areas, except for coastal line and 4.0 to 5.1 m/s in the North. The Plateau areas particularly interesting.

Source: Energy Commission of Nigeria (ECN) (2014).

#### 3.1. Biogas as a Sustainable Fuel for Heat, Power and Transport

Biogas is a renewable fuel that could be used to produce electricity, heat or as vehicle fuel (Scarlat, Dallemand, & Fahl, 2018). The technology is very simple and involves anaerobic digestion (using anaerobic digester) that converts organic waste/biomass into biogas. The technology has dual advantage of economic and environmental benefits. Anaerobic digesters are mostly connected to gas-fired engines for heat and electric power generation. The heat generated can also be used to meet the local heat demand on families and farm, or delivered to external users. Biogas can be upgraded to bio-methane and injected into natural gas network or used in transport vehicles, with proper purification to remove trace gases such as H<sub>2</sub>S and water and CO<sub>2</sub> (Scarlat et al., 2018). Biogas is produced in small, domestic-scale digesters, in developing countries, to provide fuel for either cooking or lighting. This is very critical in meeting the energy demand of a country as the highest energy consumption is by residential homes through cooking (Shaaban & Petinrin, 2014). This is probably why different biogas support programs have been carried out to develop household biogas systems to provide people with biogas for cooking, as an alternative energy source. For instance, several countries in Asia (China, Thailand, India, Nepal, Vietnam, Bangladesh, Sri Lanka and Pakistan) have large programs for domestic biogas production (Vögeli, Lohri, Gallardo, Diener, & Zurbrugg, 2014). The use of biogas for cooking is a sustainable energy development as it reduces firewood consumption and avoid deforestation, decrease indoor air pollution and improve soil fertility.

#### 3.2. Biogas Production Technology

The technology for production of biogas is simple though evolving as there are emergent technologies for the fourth-generation biofuels. For instance, there are emergent technologies for pretreatment of recalcitrant biomass and purification/upgrading of biogas for improved biogas yield, and bio-methane production (Aryal, Kvist, Amman, Pant, & Ottosen, 2018; Scarlat et al., 2018). Most of these emergent technologies involve integrated systems that

may be complex but often times are targeted at industrial/commercial production level either for electricity generation or transportation fuel. However, biogas technology does not require advanced technology for producing energy, nor is it complex or monopolistic (Chibueze et al., 2017). The production of biogas involves a very simple device called a bio digester (or simply a 'digester') which is an airtight container made with concrete, metal or plastic (Figure 3). It digests biodegradable waste (raw materials) with the help of indigenous bacteria in the absence of oxygen (anaerobic digestion) to produce biogas (methane gas). The methane gas that is produced usually rises and builds up at the top of the digester. A gas pipe is attached to the top of the digester to channel the produced gas into the house (usually the kitchen) where it is used as fuel for cooking and heating Figure 2.

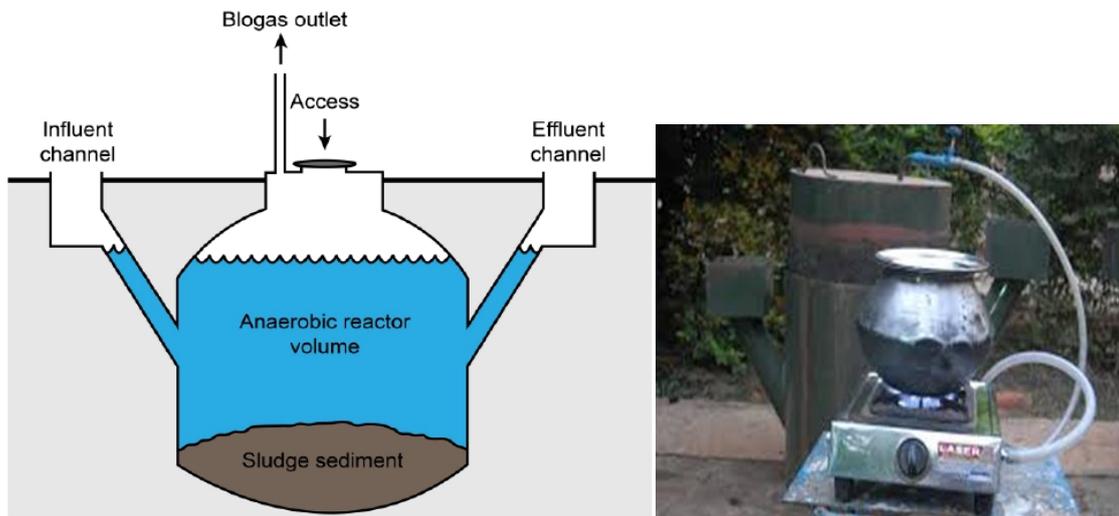


Figure-2. A schematic diagram of a bio-digester for biogas production and connected to a burner for heating (Rennuit & Sommer, 2013).

#### 4. BIOGAS FEEDSTOCK

The biological substrates, usually wastes, that are fed into bio digesters for production of biogas are called biogas feedstock. The availability of the feedstock determines the success of biogas production. In Nigeria, biological wastes are in abundance (Table 1) and in some places constitute environmental as well as health hazard due to lack/poor management. For instance, the abattoir sites in Nigeria are disgusting and characterized with foul smell and flies. The food wastes are found littered the dump sites both in the cities temporarily and in the rural communities where they are permanently dumped.

##### 4.1. Abattoir Waste

Abattoir waste comprises animal feces, blood, fat, animal trimmings, paunch content and urine (Bandaw & Herago, 2017). These solid and liquid waste products are generated from the approximately 132 slaughterhouses spread across Nigeria (Nwanta, Onunkwo, Ezenduka, Phil-Eze, & Egege, 2008); and pose a high risk to the environment and public health due to lack of proper management. For instance, the analysis of the Nsukka metropolitan abattoir solid waste in South Eastern Nigeria showed that a total of 194 kg of solid (rumen/stomach) wastes were generated daily in its municipal abattoir without any clearly defined system of disposal and management (Chukwuma, Chukwuma, & Orakwe, 2016). Abattoir waste can be managed by channeling them towards biogas production. This can be achieved by properly separating and packaging the waste at specific locations from where they can be dispensed to families and restaurants as biogas feedstock for biogas production. (Rabah, Baki, Hassan, Musa, & Ibrahim, 2010) have recorded the production of 2240 cm<sup>3</sup> of biogas from abattoir waste in 2 weeks. Klintenberg, Jamieson, Kinyaga, and Odlare (2014) also reported the production of over 600 mL of biogas from abattoir waste. The bones and blood components of the abattoir waste can also be separated to

produce high protein meals for poultry production. As local poultry production in Nigeria is run largely by women in rural communities, this application of abattoir waste would facilitate women empowerment.

#### 4.2. Food Waste

Nigeria is among the world's largest producers of various foods, such as yam, cassava, cocoyam/taro, beans/cowpea, egusi/melon seed, groundnut/peanut, plantain, corn/maize and ugu/pumpkin leaves (Longjan & Dehouche, 2018). Due to poor storage facilities, however, the amount of food waste generated in Nigeria is alarming.

According to Orhorhoro, Ebunilo, and Sadjere (2017) food waste accounts for 75% percentage of household-generated solid waste; and consists mainly of left-over cooked food, as well as vegetables, fish/meat, and fruits, either wholly or in part. A study of the potentials for commercial production of biogas from domestic food waste generated in Benin Metropolis, Nigeria, found that food waste accounted for 78.49% of the solid waste generated, corresponding to about 0.281 kg/person/day (ppd.), and a total of 305.075 tonne/day of food waste generation (Akhator et al., 2016).

The reckless disposal of food waste has caused untold havoc to the environment, leading to blocked sewers and drainages, and choking water bodies. While it is widely accepted that the management of solid waste is a global problem, the problem is a major concern in developing countries like Nigeria (Amasuomo & Baird, 2016). However, the food waste generated in Nigeria can be effectively managed by channeling it to biogas production. Longjan and Dehouche (2018), after characterizing the nutrient quality of food waste, opined that the bio-methane potentials of the food waste samples collected from Nigeria varied widely -from 35-460 m<sup>3</sup> tonne<sup>-1</sup> (fresh) and (5.4-6.2) × 10<sup>5</sup> m<sup>3</sup> kg<sup>-1</sup> (volatile solid)- and have an energy potential of 31 TWh yr<sup>-1</sup>. This can make a substantial contribution to the bioenergy production of the country, helping meet the energy demand of 4.7 × 10<sup>7</sup> Nigerian households.

The obtainable biogas from food waste was estimated to be 28,836.91m<sup>3</sup> of biogas in Benin metropolis per day, which can provide cooking gas for about 24,076.91 families per month in Benin metropolis. Alternatively, such can be utilized to generate about 49.023MW of electricity/day (Akhator et al., 2016). Chibueze et al. (2017) has also demonstrated that food waste can be combined with other biogas feedstock, such as cow dung, for enhanced biogas production. Also, these food wastes can be properly packaged and dispensed to women as biogas feedstock for biogas production at homes and other places of need.

### 5. A PROPOSAL OF WOMEN-INTEGRATED BIOGAS SUPPLY IN NIGERIA

The integration of women in sustainable biogas energy supply has great potential in solving the Nigerian energy crisis as well as enhancing sustainable development. This is possible because of the enormous biogas resources available in Nigeria, most of which constitute environmental nuisance in the rural communities. When there is sustainable biogas supply in the rural communities, there will be access to off-grid clean energy, thus relieving the government of the burden of capital investment in grid extension into rural communities for electricity supply.

The on-grid power supply would be concentrated in the urban areas, thus helping to prevent the epileptic power supply. Interestingly, the women who are proposed to be at the center of this project for its success would be emancipated from the hazards associated with the use of firewood for cooking. Also, the time spent in gathering firewood can be channeled towards self-development ventures like schooling, skill acquisition, etc., making women more relevant and useful partners with men in sustainable nation building.

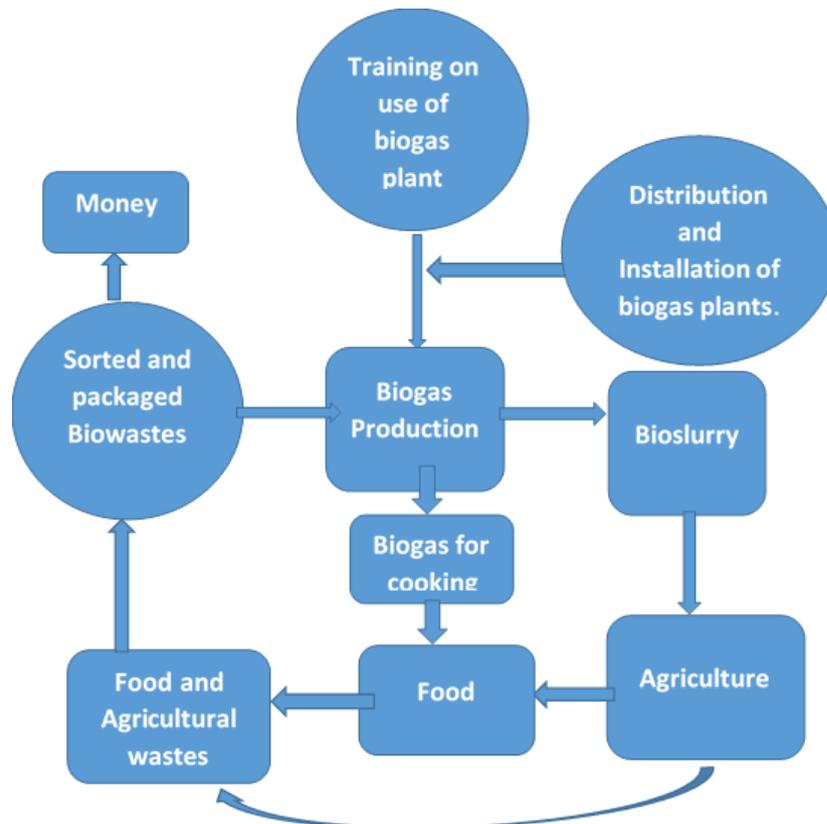


Figure-3. A schematic diagram of proposed women-friendly biogas production in the rural communities in Nigeria.

### 5.1. Personnel Training and Distribution of Biogas Plants

The very first step of women-integrated biogas supply in Nigeria would be to establish an organization such as Nigerian Domestic Biogas Plant Organization (NDBPO), as exists in Pakistan (Berhe, Tesfahuney, Desta, & Mekonnen, 2017) and with the following objectives:

1. Organizing and training women in the rural communities on the use of biogas plants, and its advantages.
2. Construction and distribution of biogas plants at the household level.
3. Provision of personnel for the purpose of servicing the biogas plants at no cost to the rural communities.
4. Seeking and establishing links/partnerships with similar international agencies, such as the African Biogas Partnership Program (ABPP).
5. Establishing a mini biogas-market where excess biogas generated from different homes can be sold for income generation by women.

The ABPP is currently being implemented in 5 African countries -Uganda, Kenya, Tanzania, Ethiopia, and Burkina Faso (Berhe et al., 2017). It facilitates the development of the biogas sector in these countries by promoting quality standards, results-based financial solutions, and awareness campaigns; and advocating for appropriate government support and policy (Berhe et al., 2017).

### 5.2. Separating and Packaging Biogas Feedstock for Sale

In the rural communities in Nigeria, the most common biogas feedstock includes Palm Oil mill Effluent (POME) and cassava processing wastes (peels, pulp and cassava mill effluent). Although these are generated by virtually every home, the amount generated by individual families varies. Depending on the size of farmland and number of palm trees owned by each family, some generate so much more than others. For efficient biogas production, therefore, the families that generate much waste need to properly separate and package them for easy dispensing to those who need to augment the little they have. As women in rural communities often supplement their family incomes by retail of firewood, they can also generate income by dispensing of sorted and packaged bio-

waste. In urban communities, there are other common waste products that can serve as biogas feedstock. These include abattoir and food wastes produced at abattoirs and food companies. Due to improper management and disposal of these wastes, they constitute a huge source of environmental nuisance. With appropriate management, however, they could help reduce the high energy burdens of those communities.

### 5.3. The Biogas Slurry

The production of biogas from bio wastes like abattoir and food wastes leave behind an eco-friendly waste by-product, called biogas slurry. Biogas slurry (or Bio-slurry) is an almost pathogen-free anaerobic digested organic material released from the biogas plant after production of combustible methane gas for cooking, lighting and running machinery (Debebe & Soromessa, 2016). Biogas feedstock and biogas slurry are two different kinds of wastes. Bio slurry is formed as a result of microbial transformation of bio-waste in a biogas plant. While bio-waste has odor, breeds flies and other disease vectors, bio slurry does not (Devarenjan, Herbert, & Amutha, 2009) and thus reduces the probability of diseases transmission (Al Seadi et al., 2008; Debebe & Soromessa, 2016).

Bioslurry can also be used to maintain soil fertility and enhance crop production. Bonten et al. (2014) reported that the nutrients in bio-slurry, especially nitrogen, are more readily available than in manure, leading to a larger short-term fertilization effect. Bioslurry is perceived as an ideal soil conditioner which adds humus and enriches the soil's ability in retention of water (Devarenjan et al., 2009). According to Malav, Khan, and Gupta (2015), the digested biogas slurry (DBGS) has been reported to be rich in micro- and macro-nutrients that provide essential plant nutrients for longer periods of time; and may thus be considered quality organic fertilizer for sustainable agriculture (Devarenjan et al., 2009; Malav et al., 2015). A study by Nyang'au, Gatebe, Nyagah, and Ahenda (2016) revealed that the mean percentage concentration of nitrogen, phosphorous and potassium were relatively high in bio slurry as compared to slurry compost and farmyard manure at  $2.14 \pm 0.6233$ ,  $1.37 \pm 0.888$  and  $0.70 \pm 0.3684$  respectively. Biogas slurry being rich in available nutrients, has the potential to lessen the use of expensive inorganic fertilizers and improves the soil health consequently enhancing the crop yields (Hussain et al., 2019).

It is estimated that the use of bio-slurry annually saves 39 kg of nitrogen, 19 kg phosphorus and 39 kg potash per household (East Consult, 2004). These attributes confer a 4-fold advantage on biogas production from bio-waste: waste management, energy production, GHG emission control, and bio fertilizer production.

## 6. CONCLUSION

Gender inequality has contributed immensely to the current energy crisis in Nigeria. As a substantial amount of the national energy load is used for domestic cooking, integration of women in household biogas production would greatly reduce the energy burden in Nigeria, and help avert the looming energy crisis. Distribution of properly packaged domestically sourced biogas feedstock, such as abattoir and food wastes, can also become a viable business venture for women in rural communities.

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