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Biogas Utilization in Addressing West Africa's Energy Problems: Opportunities and Challenges

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Abstract
Background: *As energy poverty pervades across West Africa, the demand for access to modern energy is on a steady rise. However, this demand is not matched with adequate supply, as successive West African governments have continued to rely on fossil fuel and traditional biomass which do not only degrade the environment but are unsustainable, inadequate, and have been a perennial source of political conflicts.*
Objectives: *To explore the opportunities and challenges associated with the use of biogas in West Africa, and to investigate how biogas utilization may address West Africa's energy problems.*
Methods: *This study is a qualitative research involving a total of 70 participants drawn from three West African countries, namely Ghana, Liberia and Nigeria. Semi-structured interviews were conducted by the researcher on all study participants who were selected using the purposive sampling technique; 40 percent (n=28) were drawn from Nigeria; 28.6 percent (n=20) from Liberia, and 31.4 percent (n=22) from Ghana. Transcript of the interviews were coded and analysed by identifying recurrent themes.*
Results: *The study finds thatbiogas technology in West Africa remains underdeveloped and underutilized. It identifies the potential for biogas utilization to include West Africa's high production of animal and solid wastes, cassava leaves, dungs as well as urban waste. With a population of about 362 million, the study finds that West Africa has the capacity to produce as much as two billion cubic metres of biogas annually, a quantity that is capable of enhancing electricity generation with over two million megawatts hour added to the sub-regional grid. With regards to the challenges associated with the development of biogas technology in West Africa, the following themes were identified, and these include: corruption, illiteracy, inadequate funding, poor research as well as poorly implemented policy frameworks.*
Conclusion: *There is need to develop West Africa's biogas technology. This will not only improve access to modern energy, but will boost the country's economy by creating employment opportunities, improving overall quality of life (QOL), and reducing over-reliance on fossil fuels. Biogas utilization will also help to address the menace of environmental pollution as it provides a platform for the recycling of wastes.*
Keywords: *Biogas, energy, fossil fuel, biomass, technology.*

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I. Background

Available research evidence have sufficiently underscored the role of energy as a crucial enabler; this is because energy is fundamental to improving access to quality healthcare, increasing productivity, reducing poverty and generally improving overall quality of life.[1] Nevertheless, the demand for access to modern energy in West Africa is not matched with adequate supply as the region continues to rank low in terms of access to energy. This is in spite of the plethora of promises, policies, and reforms from successive West African governments, which have mostly failed to translate into improved access to energy among West Africans.

Whereas several factors can be associated with West Africa's pervading energy poverty, one common denominator which this paper chooses to emphasize is the region's excessive reliance on fossil fuel and traditional biomass, with little or no attention for alternative sources such as biogas. Rather than explore new and alternative sources of energy, reliance on coal, oil, firewood, crop residue as well as animal dungs has continued to hamper Africa's access to adequate and sustainable energy. Moreover, the use of these traditional sources of energy is associated with adverse environmental, social and health challenges. Moreover, the non-

[1]Sovacool, B. K., &Drupady, I. M. (2016). *Energy access, poverty, and development: the governance of small-scale renewable energy in developing Asia*. London: Routledge; Miller, C. A., Altamirano-Allende, C., Johnson, N., &Agyemang, M. (2015). The social value of mid-scale energy in Africa: Redefining value and redesigning energy to reduce poverty. *Energy Research & Social Science, 5*, 67-69.

renewable nature of fossil fuels and biomass makes it unsustainable, and inadequate for addressing the energy needs of a fast growing region such as West Africa.

Conversely, biogas simply refers to gas produced during the decomposition of organic matter under anaerobic conditions.[2] It is a renewable source of energy with proven usefulness for power generation, heating, transportation, as well combined heat and power (CHP).[3] Also, biogas is an acclaimed source of clean and affordable energy, whose utilization contributes significantly to the preservation of the environment. The production of biogas is usually a long process which involves series of metabolic stages, and a consortium of micro-organisms.[4] Hydrolysis or liquefaction is usually the first stage in the biogas production process, and this involves the conversion of complex organic compounds such as proteins, lipids and polysaccharides into soluble oligomers or monomers such as long chain fatty acids or glycerol. This stage is usually facilitated by the activities of fermentative bacteria which facilitates the release of extracellular enzymes.[5]

At the next stage known as acidogenesis, acidogenic bacteria is introduced to aid the fermentation of the compound into a mixture of alcohol, carbon dioxide (CO_2), hydrogen (H_2), as well as lowmolecular weight volatile fatty acids (VFAs). Acetogenesis is the third stage of the production process and this involves anaerobically oxidizing alcohols and VFAs into acetate, hydrogen and carbon dioxide. The last stage which is known as methanogenesis involves the use of acetotrophic and hydrogenotrophic methanogens to transform acetate, hydrogen and carbon dioxide into a mixture of uncontrolled methane (CH_4) and carbon dioxide (CO_2)**.**[6]

Thoughmethane and carbon dioxide are the chief components of biogas, there are usually traces of other components including ammonia, water vapour as well as hydrogen sulphide. The composition of biogas is hugely dependent on the type of feedstock as well as the condition of the digester. Nonetheless, CH_4 is often the dominant component as it is the chief contributor to the heating value of biogas, and usually makes up an average 60 percent of the composition of biogas.[7]

Globally, the use of biogas as an alternative source of energy is on a steady rise, and one of its most common uses is electricity generation. Though biogas can be converted directly into electricity through the use of fuel cells, the huge costs involved in the use of fuel cells have negatively affected the direct conversion of biogas into electricity. Therefore, what is more practical with regards to electricity generation is the use of biogas as fuel for generator sets.[8] Biogas works for all types of engine including in internal and external combustion engines such as diesel engines, gas engines, gas turbines as well as Stirling motors.

Also, the use of biogas as fuel for transportation is fast gaining acceptance around the globe. Light duty and heavy duty vehicles have been observed to run normally on biogas and natural gas with little or no modifications. However, upgrading biogas to biomethane by removing components of CO_2 and other gases is considered as a preferred option as this does not only save the environment but also saves cost since biomethane is associated with lower fuel consumption than conventional diesel or petrol.[9] Perhaps, this explains the increasing frequency of cars that operate on biogas and biomethane across the globe. In Sweden alone, biogas-

[2]Mukumba, P., Makaka, G., &Mamphweli, S. (2016). Biogas technology in South Africa, problems, challenges and solutions. *International Journal of Sustainable Energy and Environmental Research*, *5*(4), 58-69.

[3]Surendra, K.C., Takara, D., Hashimoto, A. G., &Khanal, S. K. (2014). Biogas as a sustainable energy source for developing countries: Opportunities and challenges. *Renewable and Sustainable Energy Reviews*, *31*, 846-859.

[4]Torrijos, M. (2016).State of development of biogas production in Europe. *Procedia Environmental Sciences*, *35*, 881-889.

[5]Manyi-Loh, C., Mamphweli, S., Meyer, E., Okoh, A., Makaka, G., & Simon, M. (2013).Microbial anaerobic digestion (bio-digesters) as an approach to the decontamination of animal wastes in pollution control and the generation of renewable energy. *International journal of environmental research and public health*, *10*(9), 4390-4417.

[6]*Ibid.* p.4391

[7]*Ibid.* p.4391

[8]dos Santos, I. F. S., Barros, R. M., & Tiago Filho, G. L. (2016). Electricity generation from biogas of anaerobic wastewater treatment plants in Brazil: an assessment of feasibility and potential. *Journal of cleaner production*, *126*, 504-514.

[9]Subramanian, K. A., Mathad, V. C., Vijay, V. K., &Subbarao, P. M. V. (2013). Comparative evaluation of emission and fuel economy of an automotive spark ignition vehicle fuelled with methane enriched biogas and CNG using chassis dynamometer. *Applied Energy*, *105*, 17-29.

operated cars make up majority of the fleets in areas such as Linköping, Uppsala, Kristianstad.[10] Recent estimates suggest that as at 2015, nearly 23 million vehicles were operating on biomethane or natural gas.[11]

Finally, on a very small scale, biogas can be used for cooking and heating purposes. In this case, hydrogen sulfide is extracted from the biogas so that the resultant mixture can be burned for cooking and heating.[12] In comparison, biogas provides a cleaner and more reliable source of energy than traditional biomass; also, it is cheaper than the use of electricity for cooking and heating.[13] Therefore, in the light of West Africa's energy poverty vis-à-vis the opportunities embedded in biogas utilization, this paper seeks to explore the opportunities and challenges associated with the use of biogas in West Africa.

II. Methods

The paper will benefit from the review of secondary materials as well as qualitative interviews involving a total of 70 participants drawn from Ghana, Liberia and Nigeria. These three States have been selected as case studies for assessing opportunities and challenges relating to biogas utilization in West Africa as a result of their distinctive features. Liberia is West Africa's only State that was not colonised during the infamous 19th Century scramble for Africa; Ghana was the first West African State to gain independence after years of colonial rule; Nigeria is West Africa's most populous states with an estimated population of over 200 million persons.

Using the purposive sampling technique, a total of 22 respondents (31.4 percent) were drawn from Ghana, 20 respondents (28.6 percent) from Liberia, and 28 respondents (40 percent) from Nigeria. Among the 70 respondents, 19 (27.1%) participants were selected from the academia, 21 participants (30%) were drawn from among politicians and policymakers, while 30 participants (42.9%) were selected from the energy sector of the three respective States. Semi-structured interviews were conducted by the researcher on all study participants, after which transcript of the interviews were analysed and coded based on recurrent themes. The recurrent themes will be analysed using materials obtained from secondary sources.

III. Results and Discussion

The results obtained from the qualitative study are categorized into the following themes: awareness and utilization of biogas in West Africa, opportunities associated with biogas utilization in West Africa, and challenges facing the use of biogas in West Africa.

Biogas Utilization in West Africa: Current Status

Majority of the respondents (n=19, 67.8%) from Nigeria were unaware of the existence of policies or technology aimed at encouraging the development of biogas in Nigeria . Similarly, most participants from Liberia (n=19, 95%) suggested that there were little or no efforts from the government towards developing biogas technology in Liberia. A different line of response was obtained from respondents from Ghana, as a slight majority (n=12, 54.5%) reported that there were some considerable efforts from the Ghanaian authorities to encourage biogas utilization across the country. According to one of the respondents, "…there is some degree of commitment on the part of the government to develop biogas technology, though this is still in its embryonic stage."[14]

Therefore, findings of this study suggest that policies relating to the development of biogas technology in West Africa are mostly inadequate, and that there is a knowledge gap with regards to the usefulness of biogas in addressing West Africa's energy poverty. These findings agree with the study by Yusuf et al[15] which stresses that the biogas sector in Nigeria is seriously underdeveloped and lacking in engineering infrastructure as well as policy framework. In the same vein, Fashina et al[16] note that in Liberia, despite a robust National Energy Policy which identifies the need to explore alternative sources of energy, biogas continues to be severely

[10]Andersson, S., & Joseph, S. (2011). Are biogas buses socially beneficial?: A cost-benefit analysis from Örebro-a medium-sized Swedish city. Dissertation submitted at Orebro University, Sweden.

[11]Hakawati, R., Smyth, B. M., McCullough, G., De Rosa, F., & Rooney, D. (2017). What is the most energy efficient route for biogas utilization: Heat, electricity or transport?. *Applied energy*, *206*, 1076-1087.

[12]Pradhan, B. B., &Limmeechokchai, B. (2017).Electric and biogas stoves as options for cooking in Nepal and Thailand. *Energy Procedia*, *138*, 470-475.

[13]*Ibid.* 471

[14]Personal Interview with Tony Abeiku, energy consultant at Accra, Ghana. July 9, 2019.

[15]Yusuf, R. O., Adeniran, J. A., Mustapha, S. I., &Sonibare, J. A. (2019). Energy recovery from municipal solid waste in Nigeria and its economic and environmental implications. *Environmental Quality Management*, *28*(3), 33-43.

[16]Fashina, A. A., Akiyode, O. O., &Sanni, D. M. (2018). The Status Quo of Rural and Renewable Energy Development in Liberia: Policy and Implementation. *Journal of Energy, 1(1),* 9-20.

neglected, as there is little or no government effort to encourage the use of biogas in Liberia. Also, Yousuf et al[17] note that though Ghana has recorded some progress with regards to biogas utilization, lack of awareness as well as inadequate funding has been the bane on the development of biogas technology in Ghana and other neighbouring sub-Saharan countries.

Nevertheless, there are a number of examples with regards to the efforts of individual groups, organizations and institutions towards developing and encouraging the utilization of biogas technology in West Africa. For instance, Oloche et al[18] note that in Nigeria, there are over thirty biogas digesters, most of which are dome-type biogas digesters with an average installed capacity of $10m^3$. However, each of these digesters only has the capacity to cater for the energy needs of one family, as not much has been done to enhance the capacity of the available biogas digesters. Also, quite a number of small-scale biogas digesters have been installed in Ghana, some of which had failed shortly after establishment due to poor management, lack of technical knowledge as regards its operation, as well as the absence of government support.[19]

Potentials and Opportunities for Biogas Utilization in West Africa

On the potentials and opportunities for biogas utilization as an alternative source of energy in West Africa, what comes to mind is the availability of resources coupled with West Africa's pervading energy poverty. The feedstock for biogas usually consists of animal wastes, crop residue, and sewage as well as urban and industrial wastes. Animal wastes essentially consist of droppings, urine, cage wash water, organic matter from slaughterhouses, as well as waste water from the sanitation of slaughterhouses. Though statistical data on the quantity of animal waste generated annually across West Africa is currently unavailable or scanty at best, a rough estimate can be obtained from the number of livestock being cultivated across the sub-region.

A recent study by the Food and Agriculture Organization (FAO) suggests that there are about 199,550,000 livestock in Nigeria alone.[20] Based on this figure, chickens account for the highest set of livestock with 41.3% of the total number, followed by goats which make up 17.3%, while giant rats are the least cultivated livestock as they comprise of 0.03 percent of the total number of livestock cultivated in Nigeria. It is estimated that these livestock produce an average of 932.5 metric tonnes of solid waste annually[21], and this figure excludes urine, waste generated from spoilt feed, cage wash water as well as wastewater from slaughterhouses.

[17]Yousuf, A., Khan, M. R., Pirozzi, D., &Ab Wahid, Z. (2016). Financial sustainability of biogas technology: Barriers, opportunities, and solutions. *Energy Sources, Part B: Economics, Planning, and Policy*, *11*(9), 841-848.

[18]Oloche, B., Ozigi, I. I., Adeyemi, K., &Ikpe, E. (2017).Construction and Leakage Detection of a Dome-Type Biogas Digester in a Village at Abuja, Nigeria. *FUOYE Journal of Engineering and Technology*, *2*(1), 27-31.

[19]Arthur, R., Baidoo, M. F., &Antwi, E. (2011). Biogas as a potential renewable energy source: A Ghanaian case study. *Renewable Energy*, *36*(5), 1510-1516.

[20] Bourn, D., Wint, W., Blench, R., and Woolley, E. (2016). Nigerian Livestock Resources Survey.Food and Agriculture Organization.http://www.fao.org/livestock/agap/frg/FEEDback/War/t1300b/t1300b0g.htm#livestock%20distribution%20and%20abundance Accessed July 24, 2019.

[21]Adewumi, A. A., Adewumi, I. K., &Olaleye, V. F. (2011). Livestock waste-menace: Fish wealth-solution. *African Journal of Environmental Science and Technology*, *5*(3), 149-154.

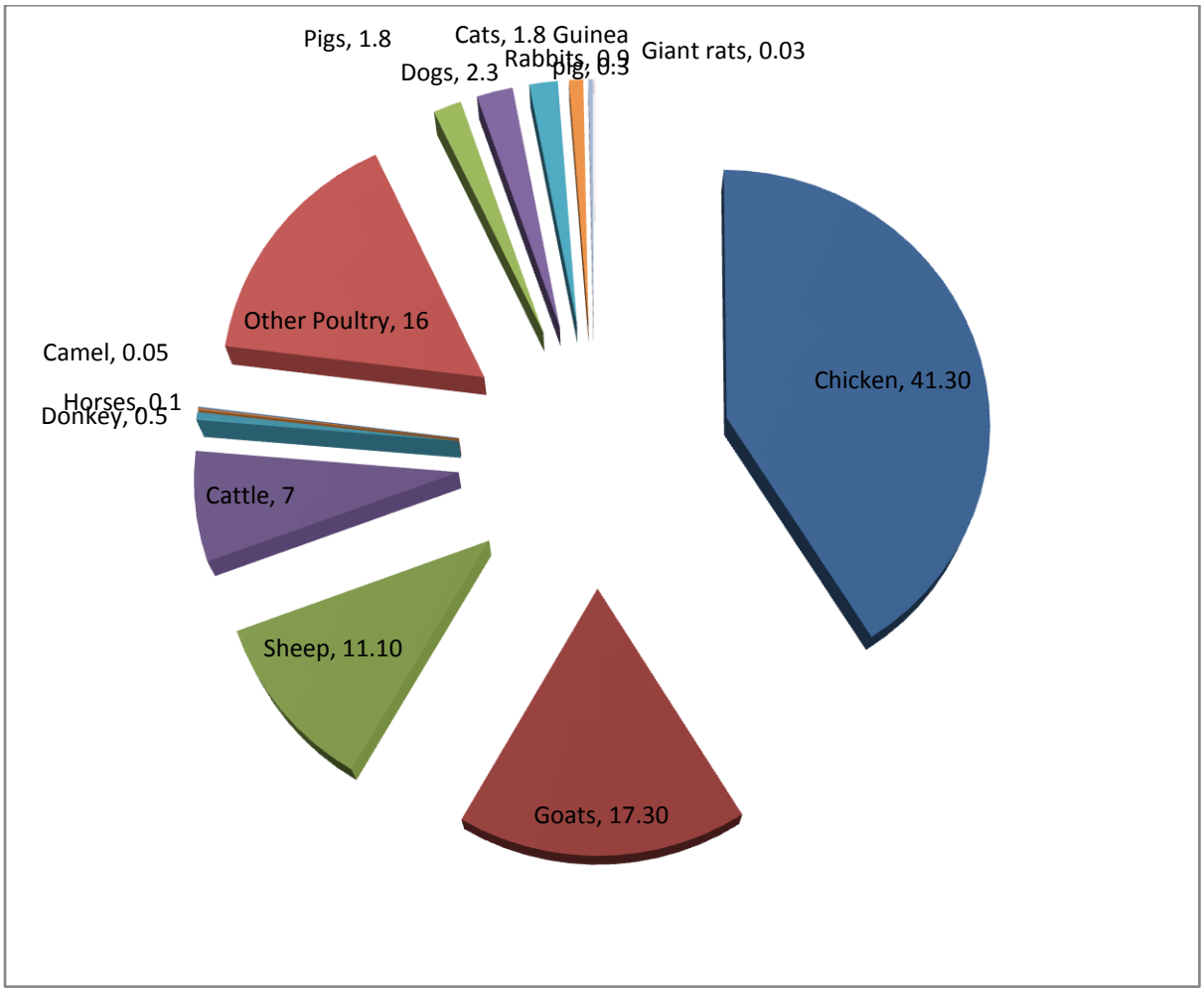

Fig 1: Percentage (%) distribution of livestock in Nigeria

Thus, with an estimate of 1 tonne for an average of 250m^3 of biogas, 932.5 metric tonnes of organic matter from animal dropping has the potential of producing as much as 233,125 cubic metres of gas annually. This equals a daily average of 638.7m^3 of biogas which when measured in terms of electricity can generate as much as 1.3MWh, where one cubic metre is capable of producing 2KWh of electricity. Thus, data from Nigeria identifies the potentials of converting animal waste into a sustainable and clean source of energy. While there are no sufficient data with regards to the number of livestock in Ghana and Liberia, data from Nigeria offers adequate insight into the untapped potentials of converting wastes and by-products of livestock farming into alternative sources of energy.

Similarly, crop residue is identified as another useful source of alternative energy that is mostly untapped across West Africa. Recent documents from Food and Agriculture Organization (FAO) suggest that a combination of all West African countries produce an average of 80 million tonnes of cereal straws annually, where most of the straws emanate from the cultivation of millet and sorghum; similarly, it is estimated that the average annual residue of root and tuber crops in West Africa amount to about 6 million tonnes, with most of the residue emanating from cassava and yam peels.[22]

Based on the data above, the West African sub-region produces a combined figure of 86 million metric tonnes (MMT) from cereal straws as well as cassava and yam peels. Therefore, if 1 kilogram of crop residue is capable of producing 0.65 cubic metres of biogas, 1 metric tonne of crop residue will produce 650 m^3 of biogas.[23] Thus, as much as 55,900m^3 of biogas can be produced annually from cassava and yam peels as well as cereal straws across West Africa. These figures do not include other crop residues such as banana and plantain

[22]Food and Agriculture Organization (2014). Crop residues and agro-industrial by-products in West Africa: Situation and way forward for livestock production. Accra: FAO Regional Office.

[23]Jekayinfa, S. O., Linke, B., &Pecenka, R. (2015).Biogas production from selected crop residues in Nigeria and estimation of its electricity value. *International Journal of Renewable Energy Technology*, *6*(2), 101-118.

peels, oil palm kernel and shells which have equally been shown to be of immense relevance when it comes to biogas production.[24]

Sewage and wastewater are also potential sources of feedstock for biogas digesters. However, there are no available data on how much sewage and wastewater is generated daily, monthly or annually in West Africa. This is mostly as a result of poor collection methods, as there are very few governmental arrangements for central sewage collection across West African cities. According to one of the respondents, "…there is no such thing as central collection of sewage in Liberia. In fact, I did not know of such a thing until I visited Abuja (Nigeria). In Liberia, every house owner builds an underground septic tank for the collection of sewage."[25]

Statistical data on per capita sewage generation in West Africa is mostly speculative and scanty. Consequently, this paper will rely on data relating to per capita solid waste generation across West Africa, as this will offer insight on how much waste is generated annually across the sub-region. According to the World Bank Group, a total of about 2.01 billion tonnes of solid waste was generated globally in 2016.[26] This suggests that each person generates approximately 0.74 kilograms of solid waste daily.

Therefore, with an estimated population of 362 million persons in West Africa,[27] the daily waste generation in West Africa is approximately 268,000 tonnes, and an average annual generation of 98 million tonnes. As such, with an average yield of 20 cubic metres per tonne of solid waste, depending on the nature of waste as well as digester used, West Africa is capable of producing as much as 1.9 billion cubic metres of biogas annually from solid waste alone.[28] With one cubic metre of biogas to 2KWh of electricity,[29] the figures above suggest that as much as 3.8MWh of electricity can be derived from West Africa's solid waste generation which is tipped to triple in quantity by 2050.

Table 1: Waste type and biogas potential

Waste type	**Quantity of Waste (Million Metric Tonne)**	**Biogas production potential (m^3)**	**Electricity equivalent (MWh)**
Solid Waste	98	1,900,000,000	3,800,000
Crop Residue	86	55,900	111.8
Animal waste	0.932	233,125	466.3
Total		1,900,289,025	3,800,578.1

As seen in Table 1 above, solid waste produces the highest amount of biogas, and is capable of generating as much as 3.8 million megawatt hour of electricity. This is followed by animal waste and crop residue which can generate as much as 466.5 and 111.8 megawatts hour of electricity annually. However, it is needful to note that due to the paucity of data, the figures on animal waste are limited to the livestock in Nigeria, and cannot be an actual representation of animal waste data in West Africa. Nevertheless, based on the findings from this study, it is evident that West Africa has the capacity of generating nearly two billion cubic metres of biogas annually. These figures do not include wastewater which is reportedly rich in compounds needed for the production of methane, the active component in biogas.[30]

[24]Sokan-Adeaga, A. A., & Ana, G. R. (2015). A comprehensive review of biomass resources and biofuel production in Nigeria: potential and prospects. *Reviews on environmental health*, *30*(3), 143-162.

[25]Personal Interview with Christian Brooks, a civil servant at Monrovia, Liberia on June 19, 2019.

[26]The World Bank (2019).Solid Waste Management.https://www.worldbank.org/en/topic/urbandevelopment/brief/solid-waste-management Accessed July 19, 2019.

[27]Scerri, E. M., Thomas, M. G., Manica, A., Gunz, P., Stock, J. T., Stringer, C., ...&d'Errico, F. (2018). Did our species evolve in subdivided populations across Africa, and why does it matter?. *Trends in ecology & evolution*.

[28]De Mes, T. Z. D., Stams, A. J. M., Reith, J. H., & Zeeman, G. (2003). Methane production by anaerobic digestion of wastewater and solid wastes. *Bio-methane & Bio-hydrogen*, 58-102.

[29]Islam, M. R., & Rashid, T. S. (2012). Prospects and potential analysis of solar and biomass energy at Pabna District, Bangladesh: A Realistic Way to Mitigate District Energy Demand. *International Journal of Engineering*, *2*.

[30]Montalvo, S., Huiliñir, C., Borja, R., Castillo, A., &Pereda, I. (2019). Anaerobic digestion of wastewater rich in sulfate and sulfide: effects of metallic waste addition and micro-aeration on process performance and methane production. *Journal of Environmental Science and Health, Part A*, 1-9.

Challenges facing Biogas Utilization in West Africa

One notable challenge that may be encountered in biogas utilization in Africa is the poor management of wastes across the sub-region. As pointed out by Boateng et al[31] waste management has, over the years, proven to be a major challenge in urban areas, especially within third world countries. West Africa is not an exemption as wastes littered across streets and public spaces is a common phenomenon across the major cities in the sub-region. This is in spite of varied government policies targeted at enhancing the management of waste. The inability of available policies to effectively address the challenge of waste management in West Africa is partly attributed to the non-inclusion of persons involved in informal waste management in the policymaking process.[32]Mbah and Nzeadibe[33] note that although informal waste management occupies the lowest ebb in the value chain of waste management, it is very vital as it reduces the cost of waste management.

The poor management of wastes in West Africa is associated with a number of negative consequences. First, poor waste management means that not all wastes are evacuated. This does not only have a negative impact on the environment, but means that statistical data on waste generation cannot be accurate. Also, poor management of wastes will discourage investors as the collection of feedstock for biogas digesters may be challenging. Lastly, poor waste management systems will discourage the use of biogas as an alternative source of energy. This is especially because the cost of gathering wastes before digestion may make biogas a more expensive source of energy than fossil fuel and traditional biomass

Aside poor waste management, corruption and nepotism are other notable challenges that may confront the utilization of biogas as an alternative source of energy in West Africa. Generally, Africa is renowned for high level corruption and this usually manifests in the allocation of contracts to companies with no track records or prior experience in the field.[34] According to Adinyira et al[35] construction contracts in Ghana are often awarded on the basis of political affiliation and the amount of kickbacks rather than the merits of a proposed bid and the competitiveness of cost. Brumskine[36] argues that in Liberia, government officials simply allocate contracts as a form of reward for political allies, and compensation for family members. In Nigeria, there are endless accounts of politicians who allocate contracts to themselves using fictitious company names.[37] "The negative consequence of endemic corruption in West Africa," according to one of the study participants, "is that contracts for the installation of biogas digesters may be given to inexperienced firms, and this may lead to failure."[38]

Other challenges to the utilization of biogas as an alternative source of energy in West Africa include the low quality of research being carried out in West Africa's tertiary institutions. Morhason-Bello et al[39] argue that one of the challenges facing the African society is the low quality of research emanating from tertiary institutions within the continent. This claim is supported by Fedderke et al[40] who argue that the low quality of research output from African institutions is responsible for the technological backwardness being experienced across the continent.

IV. Recommendations

Having demonstrated the opportunities and challenges associated with biogas utilization in West Africa, it is pertinent to consider ways to mitigate some of these identified challenges. First, there is need for

[31]Boateng, K. S., Agyei-Baffour, P., Boateng, D., Rockson, G. N. K., Mensah, K. A., &Edusei, A. K. (2019). Household Willingness-to-Pay for Improved Solid Waste Management Services in Four Major Metropolitan Cities in Ghana. *Journal of environmental and public health*, *2019*.

[32]Mbah, P. O., &Nzeadibe, T. C. (2017). Inclusive municipal solid waste management policy in Nigeria: engaging the informal economy in post-2015 development agenda. *Local Environment*, *22*(2), 203-224.

[33] Ibid. p. 205

[34]Dykes, B. J., & Jones, C. D. (2016). Public-private partnerships in Africa: Challenges and opportunities for future management research. *Africa Journal of Management*, *2*(3), 381-393.

[35]Adinyira, E., Manu, P., Mahamadu, A. M., Olomolaiye, P., &Agyekum, K. (2018). Curbing unethical practices associated with preferential allocation of construction contracts in Ghana: Survey professionals' perception of who should lead the way. Paper presented at International Conference on Professionalism and Ethics in Construction. November 21, 2018.

[36]Personal interview with Peter Brumskine, a staff of the Liberian Ministry of Energy at Monrovia, on June 19, 2019.

[37]Personal Interview with Osuigwe Charles, a newspaper reporter at Lagos, Nigeria on July 1, 2019.

[38]Personal Interview with AdemolaAdedoyin, public affairs analyst at Lagos, Nigeria on July 1, 2019.

[39]Morhason-Bello, I. O., Odedina, F., Rebbeck, T. R., Harford, J., Dangou, J. M., Denny, L., &Adewole, I. F. (2013). Challenges and opportunities in cancer control in Africa: a perspective from the African Organisation for Research and Training in Cancer. *The lancet oncology*, *14*(4), e142-e151.

[40]Fedderke, J., De Kadt, R., &Luiz, J. (2003).Capstone or deadweight?Inefficiency, duplication and inequity in South Africa's tertiary education system, 1910–93. *Cambridge Journal of Economics*, *27*(3), 377-400.

better waste management systems across West Africa. Ofoata[41] stresses that "until there are improved waste management systems in West Africa, the use of biogas as an alternative source of energy will remain a mirage." This is because improved waste management systems will not only help in ensuring accurate data on waste generation, but will also enhance the availability of wastes which will serve as feedstock for biogas digesters.

Also, there is need for genuine and non-partisan anti-corruption campaign across West Africa in order to discourage the menace of corruption and nepotism which have been identified as hurdles to successful utilization of biogas as an alternative source of energy in West Africa. Adazi[42] adds that strong legislations stipulating stricter punishment for corrupt political leaders will be necessary for curbing the menace of corruption in West Africa. Therefore, drawing from the submission above, there is need for legal and administrative reforms across West African states with the primary objective of addressing the region's perennial problems of corruption and abuse of power. Finally, there will also be need for reforms in the education sector, as this will enhance the quality of research from West Africa's tertiary institutions. As succinctly put by Moniba[43]"…so long as education remains the gateway for development and technological advancements, Africa needs to invest in education in order to solve its multiple challenges, including perennial energy poverty."

V. Conclusion

This paper has examined the opportunities and challenges associated with biogas utilization in West Africa. The essay notes that based on the human and material endowments in the sub-region, West Africa has the capacity to produce sufficient biogas which could serve as an alternative source of energy. The paper identifies West Africa's pervading energy poverty as a key factor signalling the need to explore alternative sources of energy such as biogas. Nevertheless, certain factors are identified as possible challenges that may face the utilization of biogas as an alternative source of energy in West Africa. Some of these challenges include poor waste management systems, endemic corruption as well as low quality of research output from the region's tertiary institutions.

Endnotes

Chinedu Ogwus. " Biogas Utilization in Addressing West Africa's Energy Problems: Opportunities and Challenges ." IOSR Journal of Biotechnology and Biochemistry (IOSR-JBB) 5.4 (2019): 49-56.

[41] Personal Interview with Johnson Ofoata, Energy consultant at Accra, Ghana on June 16, 2019.

[42] Personal Interview with Raymond Adazi, Staff of Eko Electricity Distribution Company, Lagos, Nigeria on June 7, 2019.

[43] Personal Interview with Peter Moniba, Researcher at the University of Liberia at Monrovia, Liberia on June 19, 2019.