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A Review on Waste to Electricity Potential in Nigeria

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Abstract

Inadequate supply of electricity in a country can be a major setback to the development of its economy. The subject of electricity generation, distribution and transmission has been a major issue in Nigeria and has been the center of previous research over the years due to the inadequacy of supply to the citizens of the nation. Owing to the carbon footprints left by conventional source of electricity generation, other sustainable options are being explored. Biogas been generated from municipal solid waste is a current trend in renewable energy. In this review, considering all the factors stated above, a MSW stream has been identified as a consistent source and also a widely accessible and available source that can be utilised for energy generation. In addition, it is an unwanted resource in the state, as such, will easily be accessible. Waste management practice in Nigeria seems to be unsustainable, as a result of the steady increase in the amount of waste generated on daily basis. Although, building a biogas plant could handle huge amount of waste and provide electricity to household, however, the greatest challenge to setup such facility could be in-terms of capital investment, as well as operating and maintenance cost. The best suited technology for application is anaerobic digestion of food waste, the reason for this is that most of the non-biodegradable materials are recycled by scavengers, and a consideration of the fact that Nigeria imports a greater percentage (80%) of its fertilizer from abroad, thus, application of this technology is enormous, as the by-product of the digestion process will serve as fertilizer which will be sold to farmers.

Keywords: biogas, electricity, municipal solid waste

1. Introduction

In the new global economy, energy has become a major indicator of the economic growth of a nation. Poor access to electricity translates to increased poverty, depletion in biodiversity, deforestation, complicated prospects for institutional development, increase in waste management problems and so on (Mohammed *et al.*, 2013). Globally, the economy of conventional sources of energy (coal, oil and gas) is fluctuating due to an acute fear of shortage in the future. Also, the use of fossil fuels results in the emission of greenhouse gases such as carbon dioxide (CO_2) which pollutes the atmosphere, hence the reasons for exploration of renewable sources for power generation (Buragohain, Mahanta & Moholkar, 2010). The subject of electricity generation, distribution and transmission has been a major issue in Nigeria and has been the center of previous research over the years (Akinbulire *et al.*, 2008; Mohammed *et al.*, 2013; Ogujor & Orobor, 2010; Oseni, 2011; Mohammed *et al.*, 2020; Sambo 2009), due to the inadequacy of supply to the citizens of the nation. This has resulted in self-generation of electricity through the use of small personal generators that have low efficiencies and high CO_2 emissions. Self-generation of power is reported to exceed grid generation, ranging between 4000-8000MW (Reegle, 2014). This is very expensive to generate. Furthermore, it is harmful to the environment as a result of the high CO_2 emissions from the machines utilized for self-generation. Difficulty in doing business was attributed to electricity provision by 83% of firms. This was confirmed by a poll carried out by the Manufacturers Association of Nigeria (2011) which showed a close result of 76%. Sustainable development can therefore be achieved only through adequate transitioning to the emerging renewable energy (RE) technologies from over-dependence on traditional energy sources, thereby improving infrastructural development, enhancing clean energy provision and providing a better standard of living. In Nigeria, supply of electricity is less than demand; therefore, decentralized power generation through renewable resources could be a viable solution for meeting the needs of the local populace and will help in reducing the gap between supply and demand of energy (Buragohain, Mahanta & Moholkar, 2010; Mohammed *et al.*, 2013).

The use of biogas, produced from the processing of municipal solid waste as a renewable and sustainable energy source, could be the solution to the recurrent energy challenges of the country. Biogas is a gas composed of methane, carbon dioxide and other constituents; it is produced through the anaerobic digestion of biomass (including waste). Since the country has more waste generation capacity than it has the ability to handle, this could also be a feasible approach to power generation, as well as waste management (International Energy Agency, 2023). In this review, considering all the factors stated above, a MSW stream has been identified as a consistent source and also a widely accessible and available source that can be utilised for energy generation. In addition, it is an unwanted resource in the state, as such, will easily be accessible. Carbon Trust (2012), states that after identification of technologies, feasibility studies determining technical, environmental and economic performance should be carried out by assessing physical constraints, cost-benefit and risk associated with the project.

2. Background

Nigeria is the most populated country in Africa, located 3º and 14º East of Greenwich and latitude 4ºand 14º north of the equator. It has a population size of 173,615,345 and growth rate of 2.792% with a population density of 185.37 per square kilometre of land area. It has both rural and urban areas with population of 85,343,053 and 88,272,292 respectively, with each of these areas having a growth rate of 1.55 and 4.01 respectively (The World Bank, 2023). This large populace is spread over the 36 states of the nation with a total land size of approximately 937,052.16 square kilometres (NPC, 2006). Its total gross domestic product (GDP) is $522.6 billion (The World Bank, 2023) and average per capita waste generation ranges between 0.44 and 0.66kg/cap/day, leading to the generation of a very vast amount of municipal solid waste streams.

The electricity generating plants that are in operation in the electricity supply industry of Nigeria are mainly hydro, gas and oil power generating plants (Figure 1), with an installed capacity (the intended technical full-load sustained output of the plant) of 6500MW, but only about 3920MW. An independent study showed the system average interruption duration index figure to be greater 60,000 minutes per year, however, the Nigerian national electrical company claimed that it was only 900 minutes per year (Akinbulire *et al.*, 2008; Ogujor & Orobor, 2010). Figure 2 below shows locations of the world without access to electricity. A quick glimpse of the map shows that places with the least access to electricity are the developing countries of the world with Nigeria inclusive. This shows that there is a direct or indirect link between development and electricity, such that it is either the lack of development affects the supply of electricity or the inadequate supply of electricity results in underdevelopment of the economy of that nation.

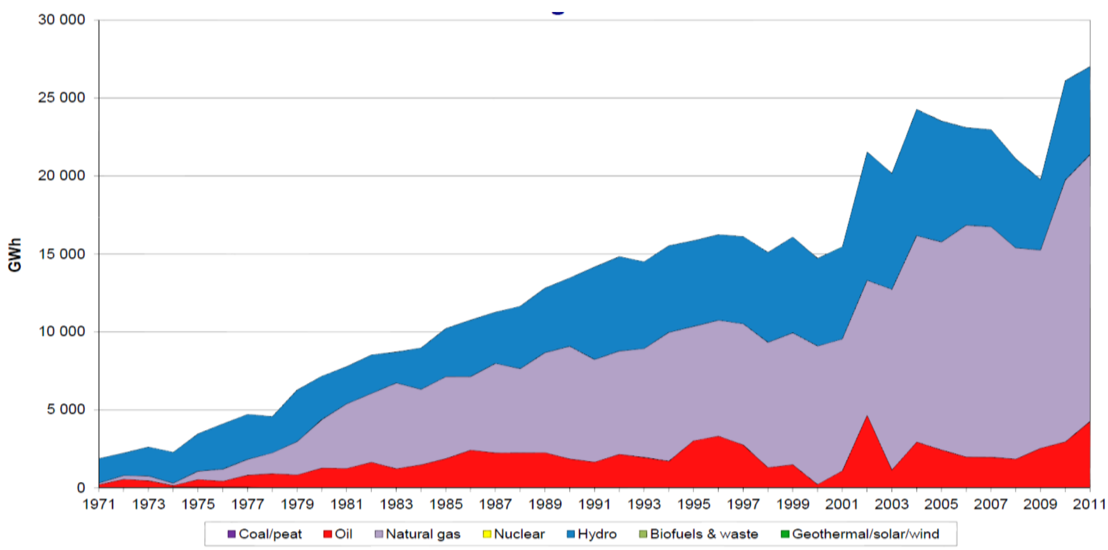

Figure 1. Electricity Generation by fuels (International Energy Agency, 2013)

The above mentioned issues have called for a major reform (privatisation) in the power sector of Nigeria. This is purported by Jamasb and Pollitt (2005) to be a major step towards improvement in the power sector through an increase in competition, thus allowing customers to choose their own power providers. The authors also opined that this would put the power companies "on their toes" thereby improving the efficiency of the system. The president of the Federal Republic of Nigeria, stated at the Nigerian power investors conference held in the nation's capital (Abuja) that a total investment of $900 billion would be required within the next 30 years (with a significant percentage expected from the private sector) to develop the country's energy sector. This would lead to the provision of an additional 5000MW of power to the country (Alohan, 2014). To enable the Nigerian power sector to be a priority destination for foreign direct investments (FDI), a "Power Sector Intervention Fund" has been set up by the government to enable access to cheap long-term funds. The investment portfolios of Nigerian banks in the power sector stood at N750 billion, furthermore, that of the African Development Bank stood at $380 million. Also, incentives are offered such as tax holidays, investment credits, free imports of equipment and so on, all geared towards encouraging private investment in the energy sector.

Nigeria is rich in energy resources, comprising of non-renewable and renewable sources, enabling a good platform for the development of an effective energy plan. Notwithstanding, it is yet to exploit its renewable resources focusing its main national energy supply on fossil fuels and firewood, which is fast depleting due to non-diversification of required energy sources (Iye & Bilsborrow, 2013), these concerns call for sustainable alternatives. Figure 3 below shows the trend in primary energy consumption based on availability in Nigeria from 1990 to 2008.

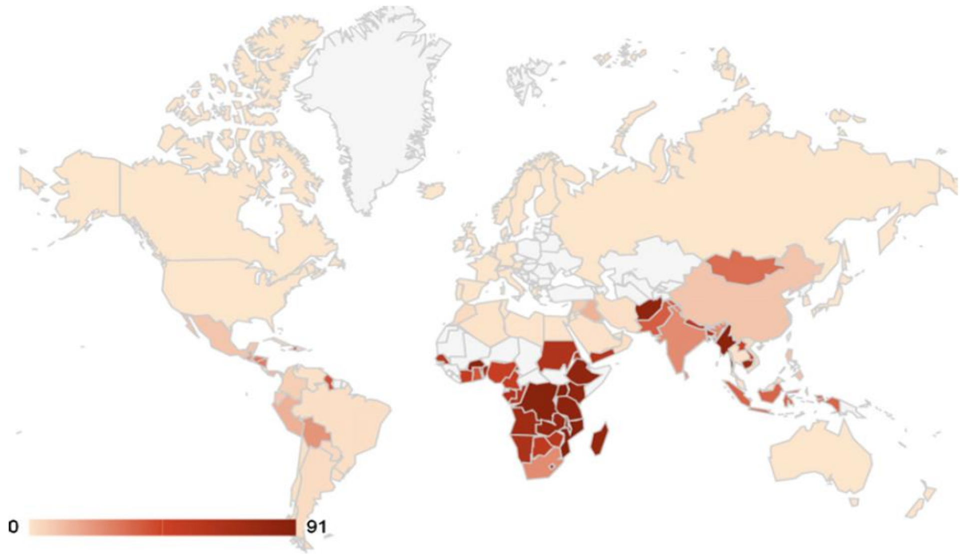

Figure 2. Locations of the World without access to Electricity (Mohammed *et al.*, 2013)

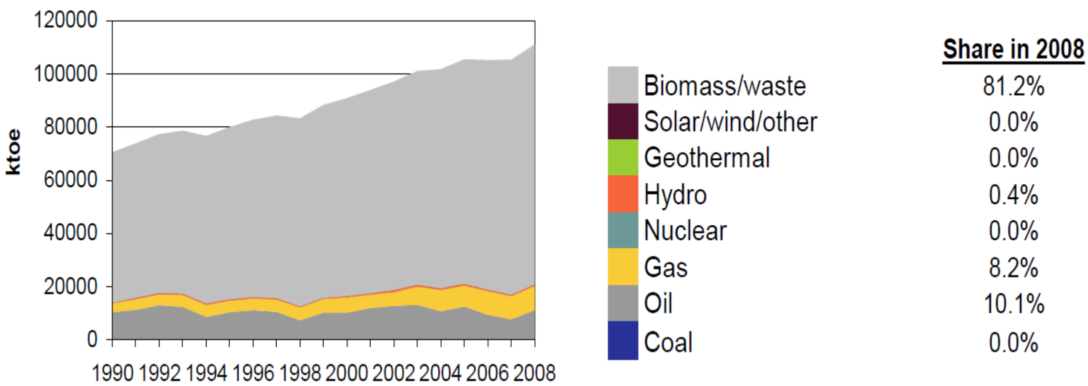

Figure 3. Primary Energy Consumption in Nigeria (Hagemann *et al.*, 2011)

Figure 4 shows the share of total primary energy supply in Nigeria. Biomass and waste forms a major part of this proportion with as high as 82.2%. However, the main focus for energy conversion to useful elements in the country are the hydro, natural gas and oil with respective percentage availability of 0.4%, 6.8% and 10.6%. This leaves the biomass and waste unharnessed, thus, causing this large streams to become an issue of concern to the country.

Waste management in Nigeria is an issue of major concern; with the government utilising incineration facilities (which failed due to the high moisture content of the waste generated, thus requiring more energy for its combustion), landfills (which is overstressed and also emits carbon dioxide to the atmosphere) and open dumpsites usage (which is has a negative environmental impact on the atmosphere, groundwater and others) (Ogwueleka, 2009). Coverting these large quantities of waste to energy, using the appropriate technology, will go a long way in improving the economy of the country through increased power supply, reduction in CO_2 emissions from landfills and others.

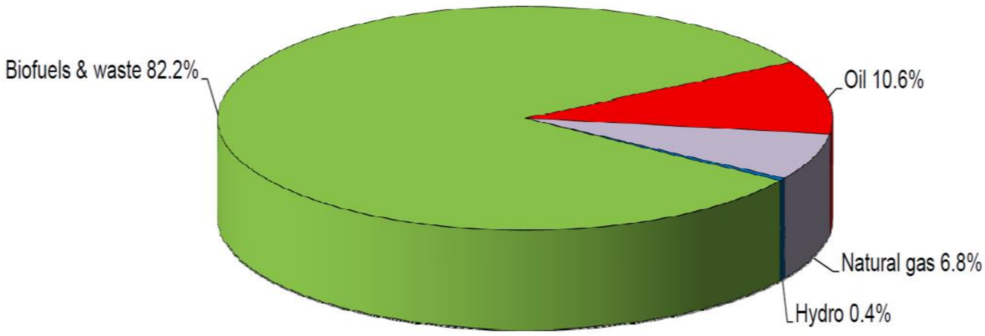

Figure 4. Share of Total Primary Energy Supply in Nigeria (International Energy Agency, 2013)

3. National Energy Policy and Renewable Energy Plan in Nigeria

The Nigerian government instituted a renewable energy master plan that focuses on increasing the access to electricity by households. It also drives a shift from fossil fuel based economy to a renewable energy driven economy and outlines the following targets for renewable technologies expected to be achieved by 2025.

- Solar-PV: 500MW
- Wind: 40MW
- Biomass: 50 MW by 2015 and 400MW by 2025
- Small Hydro: 600 MW by 2015 and 2000MW by 2025

It also aims to increase electrification from 42% (2005) to 60% (2015) to 75% (2020) to 95% (2025), thus raising minimum electricity demand to 315,113 MW by 2030, and consequently causing renewable energy to contribute 20% to the entire energy mix (Adebisi, 2013; Federal University of Applied Sciences, 2013). Means of encouraging private sector involvement include; a moratorium on import duties, design of further tax credits, capital incentives, preferential loan opportunities mainly focused on renewable energy projects, and feed-in Tariffs (Norton Rose Fulbright, 2012).

4. Biomass Energy

Biomass is simply the conversion of stored energy in the plant into energy that can be used. Burning wood is a method of producing biomass energy. Biomass is the most commonly used resources of rural energy in Nigeria because fuel wood is the cheapest and most accessible source of fuel even in the urban household. Fuel-wood is the traditional fuel source, which in spite of the availability of conventional domestic fuels, remains in high demand at the expense of Nigeria forest. Plant biomass can be utilized as fuel for small-scale industries. Biomass is a renewable energy resource, which can be converted through the use of different technologies, however, each of these technologies have their limitations. Table 1 shows different technologies that can be used in the conversion of biomass to different useful forms of energy, their applications and limitations.

Table 1. Biomass Conversion technologies

Technology	Applications	Limitation
Direct Combustion	Burning of biomass in a furnace to produce hot flue gases used for hot water, steam, electricity.	It is more suited to biofuels that has very low moisture contents, this is because a portion of the energy is utilised for water evaporation.

Gasification	Production of syngas (a combustible gas through a thermochemical process (a combustible gas).	It requires very low moisture content or even very dry fuels.
Fermentation	Converting sugar to ethanol	It makes use of sugar or corn, thereby competing with other uses such as food.
Pyrolysis	Similar to gasification, but bio-oil is produced and can be used for power plants' co-firing.	Requires only about 10% moisture content and as such requires drying. Its nature and efficiency is also dependent on the size of the feedstock as only a maximum of 2mm particle size can be processed by the technology.
Biodiesel	Chemical conversion to produce biodiesel fuels, a substitute for petroleum diesel.	Mainly oilseed feedstock can be utilised.
Anaerobic digestion	A natural process that converts organic matter to biogas that can be used for heat, and electrical generation as well as fuels for transport.	Requires biomass with high moisture content, however, it has been used for fuel with low moisture contents.

In selecting a suitable conversion technology, the balance of energy demand is very important, as the ability of the business to exploit the natural resources available in abundance within that locale is "key" to feasibility of that business. This can be achieved through assessing the energy mix, consistency of energy demand, ability to access materials such as waste needed, climate of the location (if it is windy, sunny, or constantly raining) and so on. These are factors to consider in determining the best renewable conversion technology that will make the best economic sense to the business and provide more environmental benefits to the chosen location.

5. Resources for Biogas Production in Nigeria

The resources available for biogas production in Nigeria are vast. They are MSW, animal manure, crop residues, and energy crops. The main focus in this research is MSW as it is a more consistent source stream and also unwanted, thus making it the optimal feedstock for an economic analysis.

5.1 Municipal Solid Waste as Feedstock for Anaerobic Digestion

MSW is inhomogeneous, thus requiring separation into sub fractions. These sub fractions are digestible organic fractions such as kitchen wastes, and inorganic fraction which can be further split into; combustible fractions such as wood and inert fractions such as stones. Theses vary in composition according to the locations and standard of living of the people, but typically, the digestible organic fraction takes the major part of the waste composition in Nigeria, ranging between 50-70% (Ogwueleka, 2009). In Europe, policies for waste management prioritize waste separation, recycling, composting and energy recovery, stating that landfills should only be used for pre-treated waste. These policies have led to the popularity and importance of mechanical-biological treatment of MSW for effective waste management. In literatures published by Adani *et al.* (1998) and Binner and Zach (1998), the production of biogas from the biodegradable organic fraction of MSW, was used as an alternative methodology for improving the biological stability wastes. The composition of the waste is important for the determination of appropriate treatment methods. Mechanical separation is the only other alternative for obtaining organic fraction of waste in places where separation of waste from source is not available, but this tends to be more contaminated than source separated waste. Therefore, in cases where the environmental quality of digestate is not acceptable, reduction in the volume and toxicity of waste may be regarded as a major reason for AD, rather than profit making. Table 2 shows the different treatment options of the different fractions of MSW which can be integrated into the MSW management of that particular state. Procedures for the treatment of MSW includes; pre-treatment, AD and Post-treatment.

Table 2. Fraction in MSW and Treatment Options (Adapted from Braber, 1995)

	Source Separation	**Mechanical Separation**	**No Separation (Integral MSW)**
Organic Fraction	• AD for biogas and digestate production. • Composting	• AD for biogas and digestate production • Incineration • Composting • Landfill	• Incineration • Landfill

Paper Fraction	• Recycling • AD	• AD	• Incineration • Landfill
Plastic Fraction	• Recycling Incineration	• Incineration • Recycling	• Incineration • Landfill
Metals	• Recycling	• Recycling	• Landfill • Recycling
Inert Fraction	• Recycling	• Landfill • Recycling	• Incineration as bottom ash • Landfill
Various non-organics	• Incineration • Landfill	• Incineration • Landfill	• Incineration • Landfill
Manure and other wastes	• Co-digestion	N/A*	N/A*

*Not Applicable.

5.2 Electricity Generation

Biogas can be converted to electricity using combined heat and power (CHP) generation, fuel cell technologies, Stirling engines, and micro gas turbines. The CHP generates electricity (which can be sold off or connected to the national grid) and heat (which can either be used in district heating networks or in the digestion process for pasteurisation of feedstock and process control). It has an electrical efficiency of about 33% and thermal efficiency of 50%, and a running input between 3-4.5%. The fuel cell technology is still in its development stages, it is considered most promising with electrical efficiency of 50% and thermal efficiency of 40%, however, investment cost is very high. The Stirling engines have a higher thermal efficiency of up to 72% and a low electrical efficiency of 24%, making this technology less reliable if electrical production is the main intent. The micro gas turbines have thermal and electrical conversion efficiencies of 54% and 28%, respectively, and about 10% energy input (Poschl, Ward & Owende, 2010).

6. Overview of Studies on Biogas-To-Electricity (BTE) Technology

Previous research has been carried out on BTE technologies, also, they have been installed in various locations, with proven success, therefore, indicating that it could be a profitable investment alternative. However, there are factors that hinder the success of these projects based on their locations such as socioeconomic, technical and other factors. A summary of an established project and some research studies on BTE are discussed below.

In the UK, the biggest BTE plant was completed in 2011 by a waste management company (Biffa). It was located at the landfill site and costs £24 million ($40.3 million) to install. The plant processes food waste of 120,000 Tonnes/year and produces biogas. The plant's operating capacity is 6 MW that can supply about 10,000 households with power. The economics of this plant is not available; therefore, it is uncertain if the intended aim of the plant is mainly for waste treatment or for profit. However, the lesson that can be learnt from this plant is that it is located near a landfill site, thus existing waste management infrastructure helps in improving the supply of feedstock and reducing cost. Also the heat generated is not sold but the digestate is sold to farms and gardening centres and about 15 percent of the electricity produced is used in-house (The Greenage, 2011).

Agrawal and Yadav (2012) used the earlier version (2000) of the MUDGI (2013:15) energy recovery potential to calculate for the energy recovery from MSW in Jabalpur, India. Using both the bio-chemical and thermochemical conversion methods, the authors arrived at a power generation potential of 5.8 MW based on organic fraction of MSW feedstock input of 396 Tonnes/day. This means that 1 Tonne/day of waste fed into the digester will lead to the generation of 0.0146 MW of power. Comparing this result, with that of Biffa, it shows a close relationship but varies by about one percent. This variation is because the properties of waste differ within these two regions.

Karellas, Boukis and Kontopoulos (2010) developed an investment decision tool for biogas production from agricultural waste (fresh pig manure, wheat straw and glycerol) with a total waste input of 45,000 Tonnes/year containing 93.83% volatile solids (VS) which yielded 16,452,581m^3 of biogas/year. Based on the information given above the key figures for the plant performance and economic analysis are shown in Table 3.

Table 3. Key Figures for Plant Performance (Karellas, Boukis & Kontopoulos, 2010)

Key Figures	Values
Capital Cost (€/Tonne)	199.30
Operation and Maintenance Cost (€)	5% of Capital Cost
Electrical Efficiency (%)	39.1
Net Electricity Generation (kWh_e/year)	33,698,284
Own Consumption (%)	15
Losses (%)	6
Heat Generation (kWh_{th}/year)	37,921,343
Percentage of digested biomass to separator	100
Separated Digestate (tons/year)	25,924
Dry Matter in Fibre Fraction (%)	35
Dry Matter in Liquid Fraction (%)	2.5
Nitrogen in Fibre Fraction (%)	20
Phosphorus in Fibre Fraction (%)	80
Potassium in Fibre Fraction (%)	10

The economic evaluation was carried out using Net Present Value (NPV), Internal Rate of Return (IRR) and Payback period (PP), and it was found to be a profitable investment. The Anderson Centre (2010) provided analysis of six case studies of anaerobic digestion plants in the UK and EU. The general analysis from these case studies proved not only that small farms processing 13,200 litres of slurry per day and producing 75MWhe per year can remain functional and still generate revenue for over 17 years, but that large Central Anaerobic Digestion (CAD) Systems are also established and proven systems that can process both farm and non-farm feedstock.

In regards for the adoption of biogas technology in Nigeria, Gajibo (2016) developing a frame work which key aspect is to construct and operate a pilot Biogas Plant within the Federal Capital Territory (Abuja). Moreover, the goal of the work was to compare the cost and benefit of constructing such plant, of which cost benefit analysis was used as the methodology for decision making. The proposed plant will have a capacity of approximately 450 tons per day of MSW and produces approximately 6MW of electricity which will serve more than six thousand homes. Important revenue from the plant comes from electricity sale, which will be equivalent to 22 Naira perK/W, = 8 pence per K/W, a tipping fee of 600 Naira per ton, and sale of digestate at70 Naira per Kilogram. The evidence from this study suggests that the proposed project should be undertaken, because the Net Present value of the project benefit out-weighs the Net Present Value of the expenses (Gajibo, 2016).

Mohammed *et al.* (2020) present an economic evaluation of the feasibility of investing in biogas-to electricity projects that can process MSW generated in Maiduguri and its environments, thereby improving the supply of electricity within the city. The assessment was carried out for energy generation by a biochemical process (Anaerobic Digestion) based on Primary and secondary data. It will also incorporate all the plants' output (digestate, recyclables, electricity and heat) as co-products which can be marketable, but heat was assumed to be used in-house. Results obtained indicates the investment would be feasible on wholesale and retail electricity distribution basis. However, trading directly to end users will pay back the investment cost of the project faster at 2 years and 361 days, at an NPV of $423,944,603.13 than having to distribute the electricity generated at wholesale prices to electricity suppliers which would pay back the investment after 3 years and 91 days. Thus, the project will help in increasing the amount of power available in the country, by 0.59%, which is an addition. Hence, the BTE project will have a positive effect on the power sector, thereby contributing to the improvement of the economy of the nation.

Legal perspective on the challenges and prospects of waste to electricity generation is not left out with another study that proposes a model for converting wastes to electricity to sustain the ever-intensifying demands for energy and to combat ecological issues in Nigeria. The research concludes with recommendations for the fusion of regulations and non-regulatory incentives for conversion of wastes to electricity in Nigeria's power sector and advocates coherent legal framework on sources of energy with stringent enforcement of energy laws for stable electricity generation and sustainability in Nigeria's power sector (Olujobi, 2021).

A life cycle assessment (LCA) as a primary analytical approach in order to undertake a comparative analysis from an environmental impact perspective of different Waste-to-Energy scenarios, along with diesel backup generators (DBGs) and grid electricity was carried out by Nubi (2023). The overall result indicated that anaerobic digestion (AD) had the highest energy generated per one tonne of MSW processed. It was concluded that additional electricity supply from AD to the grid, with its potential to reduce the reliance on DBGs (worst scenario overall), would be a positive action in environmental impact terms.

7. Benefits of BTE Technology

Apart from the production of biogas that can be used for energy generation, the AD technology has other benefits such as:

- Production of 0.45 tonnes of organic fertilizer per tonne of feedstock input into the digester which can be an added source of revenue.
- Reduction of methane that would have been emitted from landfills by harnessing of the biogas in the waste.
- Diversion of waste from the landfills, thereby reducing the rate at which the landfills get filled up.
- Volume reduction of waste aimed for aimed for landfilling.
- Reduction of odours and unpleasant sights of waste.
- In cases of onsite mechanically separated waste, extra added revenue from the sale of recyclables is also an added advantage (Hessami, Christensen & Gani, 1996).
- Reduction of reliance on fertiliser imports due to the production of soil improvers.

8. Drawbacks Associated with BTE Technology

Despite the fact that AD has a lot of benefits, it also has issues associated with its design, environmental impact, reception from the local populace and others. According to Jacobsson and Bergek (2004), the success or failure of transforming the energy system of a place to a new technology is not only determined by the characteristics of the technology but also on the social system which is responsible for whether that technology is accepted, rejected, implemented, diffused or developed on a large scale. The major issues associated with the technology that will determine whether it is successful in that area are outlined below;

8.1 Environmental

The environmental issues that can be encountered with the BTE technology are blockage of road networks by trucks transporting waste to treatment plants, emission of CO_2 during the transportation process, odour issues in cases of improper odour management and others.

8.2 Socioeconomic

The acceptance of the BTE plant installation by the local populace is critical to the success of the plant. According to (Jacobs, 2013) a critical factor that affects viable operations of facilities treating waste is the levels of odour incidence which occurs in the site of the plants' locations. Therefore, emphasis should be placed on proper use and monitoring of odour filters in all tanks and vessels, thus removing the impact of odour incidences in the environment, which would aid acceptance of the technology.

8.3 Financial

Lack of access to financing due to the high capital investment required is a major barrier to the growth and use of the technology. Also the procedures are rigid, which further limits access to financing (Ravindranath & Balachandra, 2009). Also, transportation costs of feedstock for municipal solid waste for distances in excess of 425km results in a negative energy balance of operational limits (Poshl, Ward & Owende, 2010).

8.4 Technical

The feedstock must be pre-treated to fit the design of the vessel to be used for treatment as the vessels can only function optimally when the solids content of feedstock is compatible with the vessel design. Also, it is difficult to determine the quantity of water required for wet systems (Braber, 1995; The Andersons Centre, 2010).

8.5 Spatial

The plants require considerable space for storage and post treatment of digestate output and other functions required to be carried out on the plant. The location of the plant is also important; if it is far away from the source of feedstock supply, it reduces the profit margin of the investment and also increases potential of CO_2 emissions into the atmosphere during transportation.

9. BTE Economics Perspectives

Revenue from AD could come from various sources which should be marketed as a co-product and not a by-product. These revenue sources include Sale of biogas, sale of fibre, sale of recyclables (in cases of non-segregated waste), sale of electricity, sale of heat or own use. The major costs are the capital and operation and maintenance (O&M) cost. There could also be other funding and incentives such as grants, tax holidays and so on (The Anderson Centre, 2010).

The Economic viability of a project is dependent on the financial sustainability and the economic efficiency of the project. Therefore, in the analysis of project alternatives, it is pertinent to analyse economic perspectives (Lassner, 2011). The use of financial discounted cash flows (DCF) aids in determining the change in the value of assets of the private sector when a biogas-to-electricity project is implemented, matching revenues and allocating costs and benefits by implementing all taxes and fees is very important in order to effectively determine the change in value of the assets (Lassner, 2011). It is almost impossible drawing up general economics of the technology as influencing factors vary widely from place to place, therefore, to get an idea of economics, there has to be a focus on a particular case study such that the influencing factors of that particular area is the focus of the study (Braber, 1995).

10. Conclusion

The purpose of this study was to review the status of electricity in Nigeria, as well as evaluating the potential of the waste management sector, with a view of finding solution to the dual problem facing the country. A greater percentage of the energy been utilized in the country are non-renewable, however, the renewable contribution comes from hydro and few solar-panel. Despite projections to the future status of non-renewable energy and its implications on the environment along with global warming and climate change, yet the available energy (non-renewables) is inadequately maintained and electricity supply seems to be insufficient. Waste management practice in Nigeria seems to be unsustainable, as a result of the steady increase in the amount of waste generated on daily basis. Although, building a biogas plant could handle huge amount of waste and provide electricity to household, however, the greatest challenge to setup such facility could be in-terms of capital investment, as well as operating and maintenance cost. However, the Federal Government has privatized the electricity sector to pave way for investment by independent power plant and other private sector participation. The best suited technology for application is anaerobic digestion of food waste, the reason for this is that most of the non-biodegradable materials are recycled by scavengers, and a consideration of the fact that Nigeria imports a greater percentage (80%) of its fertilizer from abroad, thus, application of this technology are enormous, as the by-product of the digestion process will serve as fertilizer which will be sold to farmers.

References

Adani, F., Tambone, F. and Gotti, A., (2004). Biostabilization of Municipal Solid Waste. *Waste management*, *24*(8), 775-783.

Adebisi, A., (2013). *Nigerian Renewable Energy Master Plan and Fit Mechanism*. '2nd edition of the ECOWAS Renewable Energy Investment and Business Forum'. Held 9 October at Accra. Ghana: Federal Ministry of Power.

Agrawal, P. C. and Yadav, V., (2012). Evaluation of Potential of Energy from Jabalpur Municipal Solid Waste (MSW) for Eco-Sustainability. *International Journal of Scientific Engineering and Technology, 1*(2), 197-202.

Akinbulire, P. O., Oluseyi, P. O., Awosope, C. O. A. and Okoro, O. O., (2008, June). Data-Based Analysis of Power System Crisis in Nigeria. ESPTAEE 2008 National Conference, University of Nigeria, Nsukka, 25-27, 190-195.

Alohan, J., (2014). Nigeria: FG Seeks N144 Trillion Investments for Power Sector Development. Available from <http://allafrica.com/stories/201402110207.html> [15/08/2014].

Binner, E. and Zach, A., (1998). 'Biological reactivity of residual wastes in dependence on the duration of pre-treatment' in *3rd Swedish Landfill Symposium*.

Braber, K., (1995). Anaerobic digestion of municipal solid waste: a modern waste disposal option on the verge of breakthrough. *Biomass and bioenergy, 9*(1), 365, 376.

Buragohain, B., Mahanta, P. and Moholkar, V.S., (2010). 'Biomass gasification for decentralized power generation: the Indian perspective'. *Renewable and Sustainable Energy Reviews*, *14*(1), 73-92.

Federal University of Applied Sciences, (2013). Nigeria and Renewable Energy. Available from http://www.laurea.fi/en/connect/results/Documents/Nigeria%20Fact%20Sheet.pdf [12/08/2014].

Gajibo, A. I., (2016). Developing a framework for generation of energy from waste through anaerobic digestion in Nigeria: Case study — Abuja. University of Abertay Dundee.

Hagemann, M., Moltmann, S., Escalante, D., Masidi, M., Höhne, N. and Busch, P., (2011). Factors underpinning future actions. United Kingdom: Ecofys.

International Energy Agency, (2013). Energy Statistics: Electricity Generation by Fuel. Available from http://www.iea.org/stats/WebGraphs/NIGERIA2.pdf [24/06/2014].

International Energy Agency, (2014). World energy balance. Available from <http://www.iea.org/statistics/resources/balancedefinitions/#biofuelsandwaste > [05/09/2023].

Iye, E.L. and Bilsborrow, P. E., (2013). Assessment of the availability of agricultural residues on a zonal basis for medium-to large-scale bioenergy production in Nigeria. *Biomass and Bioenergy*, *48*, 66-74.

Jacobs, J., (2013). Temlow and Goostrey no to waste plant. Available form http://tagnotowasteplant.wordpress.com/ad-smells/ [12/08/2014].

Jacobsson, S. and Bergek, A., (2004). Transforming the energy sector: the evolution of technological systems in renewable energy technology. *Industrial and Corporate Change*, *13*(5), 815-849.

Jamasb, T. and Pollitt, M., (2005). Electricity market reform in the European Union: Review of progress toward liberalization & integration. *The Energy Journal*, 1141.

Karellas, S., Boukis, I. and Kontopoulos, G., (2010). Development of an investment decision tool for biogas production from agricultural waste. *Renewable and Sustainable Energy Reviews*, *14*(4), 1273-1282.

Lassner, K., (2011). Financial and Economic Analyses of Biogas-to-Energy Projects in Brazil.

Manufacturers Association of Nigeria, (2011). Have your Say… Available from <http://www.manufacturersnigeria.org/polls.php?action=r&id=12> [01/07/2014].

Mohammed, U. Abubakar, S, Abubakar, A. B., I. N. Odia, and Jalingo, S. A., (2020). Evaluation of the Feasibility of Biogas-to-Electricity plant in Maiduguri, Borno State, Nigeria. *International Journal of Information, Engineering and Technology*, *11*(2), 48-56.

Mohammed, Y. S., Mustafa, M. W., Bashir, N. and Mokhtar, A. S., (2013). Renewable energy resources for distributed power generation in Nigeria: a review of the potential. *Renewable and Sustainable Energy Reviews*, *22*, 257-268.

National Population Commission, (2006). Population Distribution by sex, state, LGA and senatorial District. Federal Republic of Nigeria: Abuja.

Norton Rose Fulbright, (2012). Scaling-up Renewable energy in Africa: Nigeria. Available from http://www.nortonrosefulbright.com/knowledge/publications/59010/scaling-up-renewable-energy-in-africa-nigeria [13/08/2014].

Nubi, O., Morse, S., & Murphy, R. J., (2022). Electricity Generation from Municipal Solid Waste in Nigeria: A Prospective LCA Study. *Sustainability*, *14*(15), 9252.

Ogujor, E. A., and Orobor, N. P., (2010). 'SAIDI Minimisation through Non-Conventional Energy Resources: Opportunities and Challenges'. *Journal of Economics & Engineering*, 2.

Ogwueleka, T. C., (2009). Municipal solid waste characteristics and management in Nigeria. *Iranian Journal of Environmental Health Science & Engineering*, *6*(3), 173-180.

Olujobi, O. J., Ufua, D. E., Olokundun, M., & Olujobi, O. M., (2021). Conversion of organic wastes to electricity in Nigeria: legal perspective on the challenges and prospects. *International Journal of Environmental Science and Technology*, 1-12.

Oseni, M. O., (2011). An analysis of the power sector performance in Nigeria. *Renewable and Sustainable Energy Reviews*, *15*(9), 4765-4774.

Osueke, C. O., &Ezugwu, C. A. K., (2011). Study of Nigeria Energy resources and its consumption. *International Journal of Scientific & Engineering Research*, *2*(12), 121-130.

Pöschl, M., Ward, S. and Owende, P., (2010). Evaluation of energy efficiency of various biogas production and utilization pathways. *Applied Energy*, *87*(11), 3305-3321.

Pöschl, M., Ward, S. and Owende, P., (2010). Evaluation of energy efficiency of various biogas production and utilization pathways. *Applied Energy*, *87*(11), 3305-3321.

Ravindranath, N. H. and Balachandra, P., (2009). Sustainable bioenergy for India: technical, economic and policy analysis. *Energy*, *34*(8), 1003-1013.

Sambo, A. S., (2009). 'Strategic developments in renewable energy Nigeria'. *International Association for*

Energy Economics, 16.

The Andersons Centre, (2010). A Detailed Economic Assessment of Anaerobic Digestion Technology and Its Suitability to UK Farming and Waste Systems. 2nd edn. Leicestershire: Graham Redman. Available from <http://www.organics-recycling.org.uk/uploads/category1060/10-010%20FINAL_Andersons_NNFCC_AD 2010.pdf> [25/06/2014].

The World Bank, (2023). Data. Available from <http://data.worldbank.org/country/nigeria> [05/09/2023].