International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 12, December-2020

Evaluation of Biogas Energy System as Source of Sustainable Electricity Generation. A Case of Kaduna Polytechnic Students' Hostel

G. Abdulhakeem[1], T. O. Zubairu[2] & Sanni Muinat[1]
[1]Department of Quantity Surveying, College of Environmental Studies, Kaduna polytechnic, Kaduna, Nigeria.
[2] Department of Building, College of Environmental Studies, Kaduna polytechnic, Kaduna, Nigeria

Abstract*:- Fossil fuel has become unpopular as fuel for energy supply because of its negative consequences on the environnment on account of the high carbon emmission.The search for alternative has made modern renewable energy sources popular. Nigeria is facing acute dwindling supply of commercial electricity. Due to this problem the country has been involved in self-generation electricity beyond the gridline capacity, and it has cost the country billion dollars annually. The academic institutions are not exempted from this problem. As an offshoot of the previous work done and presented as a conference paper, this paper presents the outcomes of further works on the use of biogas as an alternative fuel for running ICE electricity generators in Kaduna Polytechnic students' hostels. The study experimented with biological wastes sourced from students'hostels but compensated with addition of chicken drop and cow dung bought from farmers due to low biogas obtained from the previous study. The combination of wastes were allowed to decompose for between 13-28 days. Further, the original carburretor that comes with ICE generator was changed to dual used carburretor due to inability of the initial one to use biogas fuel. The findings reveal that after several attempts it became clear that we now have a promising outcome that can be pursued further to perfection as we have some element of intermittent electricity for up to 2 minutes and subsequently went on and off severally. The improvements in the electricity supply proved rewarding and worthy of the efforts thus far acceptable result. Given the game change experienced as a result of application of cow dung and chicken drop in producing biogas, the study recommends the establishment of ancillary livestock side business in most educational institutions to provide the needed livestock refuse. Suffice it to say that more work still need to be done to take this to a mega energy supply level.

Keywords: Biogas, ICEs electricity, generatioin

INTRODUCTION

The issue of alternative energy in Nigeria is beyond the challenges associated with the use of fossil fuel pose to the environment, it is more out of the existing insufficiency in the energy generation and supply from the beginning(Garba, 2017; Ohunakin, et al. 2012). It is against this backdrop that the need to explore other ways to enhance energy supply that the use of modern renewable energy sources like biomas (biogas) is being evaluated to provide basis for reducing the cost of providing fuel for the generating sets that have become so common in Nigeria. Suffice it to say that the use of this fuel type will invariably reduce the production of carbon (Evans et al., 2010). As previously enunciated in our previous papers Garba, Zubairu and Ryal-net, (2019) first in this series, it bears repeating the context within which alternative energy supply in Nigeria is situated.

The fact that energy supply in Nigeria is abysmal has been well document, part of the reasons as posited by several authors include amongst others high gridlines network loses of around 40% especially in Nigeria, investment imbalance of energy infrastructures (Garba, 2017; World bank 2005; Garba and Kishk 2014) and the electricity generation cost using fossil fuel (FF) sources in the country is in excess of US$ 1,000/kW (Eberhard and Gratwick 2012). Also, there is a high investment cost factor in extending the gridline network to rural communities as they are low income earners, have low capacity utilisation and are typically a long distance from load centres, making it unattractive to investors in providing electricity to these communities (Garba, Kishk and Moore 2016; Sambo 2009).

It is on record that Nigerian electricity generation and supply hover around 4,000MW or less for a population of approximately 180 million despite completion of the privatisation of power sector in 2013 (Garba, Kishk and Moore 2016; CIA 2017). Furthermore, the existing practice in the country reveals that Nigeria's government ministries; departments and agencies (MDA) are not exempted from this dwindling electricity generation and supply problem.

As buttressed by Eberhard and Gratwick (2012), self-generation electricity in Nigeria is generally common and exceeds the gridline capacity source, representing up to 8,000 mega-watt (MW). The businesses in the country spend approximately N5 trillion annually to generate their own electricity; while around 14 billion dollars is being spent annually on small-scale generators generally (Obioji, 2019; Olowosejeje, 2019). The MDA including academic institutions in the country also embark in this practice with significant amounts of their budget annually for electricity provision through fossil fuel based generators. Although, renewable electricity technologies (such as solar PV) have been used for electricity in some buildings (not hostels), street lightings among others in these institutions (Sambo,2009). However, the biological wastes that emanate from the students' hostels remains untapped for energy purpose (particularly electricity). Biological wastes can be used for electricity generation through biogas system, as it remains the option among BES with the lowest CO_2 over its life cycle (Rahman et al. 2013). Although Nigeria has experience of biogas utilization for laboratories and cooking gas in the secondary schools and prison respectively, however, it has no single case of biogas to electricity (Garba; 2017, ECN, 2005; Garba & Kishk 2014). Given the situation that students use kerosene lantern and candles for study purpose, with resulting eyes' infection problems; and

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 12, December-2020

considering the reasonable amount of biomass wastes (direct and process) coming from these hostels; hence, this study aims to examine biogas energy technology in providing sustainable electricity to students' hostel in Kaduna Polytechnic.

We had emphasized that students' electricity deficiency can be met through the renewable energy technologies (RETs) particularly its decentralized system (with less or no gridlines network and without fossil fuel sources). This is because RETs have been used in providing sustainable electricity to similar institutions in other developing countries cases (Mahapatra and Dasappa 2012). Also, decentralized RETs has merits in determining when and where power energy is truly required; helps in mitigating greenhouse gas (GHG) emission associated with FF and creates more employment especially biomass source (Evans et al., 2010). The most used in this respect includes solar PV, biomass and small hydropower systems (Mahapatra and Dasappa 2012).
Dasappa (2011) reported that biomass is among the optimal alternative energy sources for sustainable electricity provision in Sub-Saharan Africa (SSA) given the universal availability of the resources. Demirbas (2001) argued that biomass energy technologies (BETs) are cost competitive with fossil fuel sources. This paper is second in series to the previous ones, this time with the addition of chicken drops and cow dung to the existing biological wastes from students' hostels for the generation of biogas.

LITERATURE

The literature reviewed still provide the background for this evaluation:

Biomass resources and energy system
The majority of biomass resources is located close to rural areas and includes agricultural crops and their residues, animal dung, forestry residues, other energy crops, and municipal solid waste (IRENA 2012). Biomass is mostly plant derived materials, capable of being transformed to different forms of energy (electricity, heat and fuel) and can quickly be regenerated in different environments (Evans et al.,2010).

Martinot (2015) reported that biomass is the fourth largest energy source after oil, coal and natural gas. By the end of 2014 bio-power global capacity was around 93 Gigawatt (GW) and 75% of electricity generated from biomass was from solid biomass fuel, biogas (17%), MSW (7%) and biofuel (1%). Also, by the end of 2014, all the existing bio-power systems together produced around 1.8% of global electricity.

Nigerian biomass resources potential
According to ECN (2005) Nigeria's estimated biomass resources consumption perannum is around 144 million tonnes. Dasappa (2011) projected Nigeria's biomass resources (30% forest and agricultural residues) availability is capable of resulting into a 15,000MW capacity. It is possible to generate up to 68,000 GWh/year using only one-third of biomass resources for the country's rural communities (Garba and Kishk 2014). The forest resource is the largest biomass utilized in Nigeria for energy purposes. Biomass resources can be used to provide electricity in Nigerian rural areas without a supply chain issue; however, its supply chain should be given emphasis before adoption in these communities as it determines its cost (IRENA 2012).

Biomass energy conversion technologies
Biomass Energy Technology conversion systems are classified under two main sections: thermochemical (Direct Combustion, gasification and pyrolysis) and biological (anaerobic digester).

Direct Combustion (DC) converts biomass materials to heat and electricity through production of steam in a furnace or boiler and use to drive steam turbine for electricity generation (Demirbas et al., 2009). Miguez et al., (2012) classification based on system capacity includes: fixed bed (less than 40kW), moving grate (between 40-150kW) and retorts system (greater than 150kW).

Gasification system (GAS) converts biomass through partial oxidation into a gaseous mixture of syngas/product gas consisting of hydrogen, carbon monoxide, methane and carbon dioxide (Wang et al., 2008). The producer gas (PG) is of low caloric value containing from 4-6 MJ/kg compared to natural gas having 35-50 MJ/kg due to high nitrogen presence in excess of 50%. The electricity generation from a small scale GAS plant is exclusively via Internal Combustion Engines (ICE), at the moment (Bocci et al., 2014). GAS is mainly classified into fixed bed, fluidised bed and entrained flow gasifier.

Anaerobic digestion (AD) is a biological process of generating electricity viaconversion of biomass resources with moderate moisture content into biogas. IRENA (2012) opined that multiple feed stock co-digestions is the best and generally practiced strategy in achieving good biogas. Biogas is a mixture of methane and carbon dioxide with other constituents, and is mostly burned in ICE or gas turbine for electricity generation at a capacities range between 10kW - several MW (IRENA 2012).

Biogas System
Biogas system is one of the methods of converting waste (particularly biodegradable) to energy. Biogas is created from decomposition of organic matter through the process of anaerobic respiration (in the absence of air) (Shaaban & Petinrin 2014; Mohammed et al. 2013; Poschl et al. 2010). Continuous electricity provision is realizable through biogas systems but it requires a constant supply of feedstock (IRENA 2012). IRENA (2012) reported that multiple feedstock co-digestions is the best method generally practiced in attaining good biogas. Biogas is suitable for various energy purposes such as heating, electricity and fuel (Martinot 2013).
Bio-power global capacity was around 106,000 MW by the end of 2015 and around 20% of this capacity is from biogas, and represent the second largest system after solid biomass (71%) (IRENA 2016). Over the period of 2015, all the existing bio-power systems together produced approximately 2% of global electricity.
Thus, the use of biogas system will resolve many environmental pollution issues noticeable in developing country cities, and offer better alternative for replacement of application of fossil fuel energy system (Sambo 2009). Utilization of green fertiliser

from biogas energy can reduce Nitrogen fertiliser and subsequently reduce CO_2 emissions (Moriarty &Honnery 2011). Also, suitable for redirecting waste designated for landfill (Evans et al., 2010).

From the Nigeria's livestock in 2001, it was possible to generate over 3 billion m^3 of biogas annually (equivalent to over 1.25 million tonnes of fuel oil equivalent per annum) (ECN 2005). Also, Shaaban & Petinrin (2014) reported that every 1 kg of fresh animal waste can generate around 0.03m3 of gas, hence Nigeria can generate multi-millions m3 of biogas/day. The major constraints identified in the utilisation of these pilot biogas plants utilised for cooking gas reported above, were lack of planned maintenance, inadequate feedstock sources, lack of budgetary allocation, lack of appropriate records of these pilot biogas projects (Garba & Kishk 2014).

Nigeria generate multi million tonnes of solid waste annually, at a rate of 0.66 to 0.44 kg/capital /day from urban to rural dwellers respectively (Ogwueleka 2009). Hoornweg et al., (1999) reported that over 50% of waste stream from developing countries are organic material; hence this is opportunity to produce electricity from biogas system. Similarly, Mohammed et al., (2013) stated that the kilograms of dry dung/head/day of cattle (1.8), sheep (0.4), pigs (0.8), goats (0.4), and chicken (0.06).

METHODOLOGY

As a successor to the previous research outcomes from our earlier study - Garba, Zubairu and Ryal-net (2019), which, for the purpose of recall is summed up in the following paragraph; The collection, weighing, and depositing of refuse in the airtight chamber presented no challenge during the course of the research, the volume and consistency of the gas emission (a central component of the biomass energy generation system) turned out to be the area of the research that falls below expectation/anticipation in the previous study. The converter to use to replace the fossil fuel carburetor in tandem with our purpose is yet to be obtained to draw a final conclusion from the earlier study.

The biological wastes were collected directly from the students' hostels with the help of research assistance; while chicken drop and cow dungs were collected by direct purchase from poultry and livestock farmers. The wastes were fed into the digester. The digester, an airtight chamber that is largely anaerobic, releases gas emanating from the biodegradation. Like done in the previous experiments we have a repeat of the following:

- The physical and chemical characteristics of the wastes are relied upon for their gas emitting capability for electricity generation via biogas system. The biodegradable refuse deposited in the airtight chamber (biogas digester - 500 litre Plastic Tank) are left to decompose for a varying period. The valve-controlled connection from the decomposing chamber allow for gas to leave through a non-return valve to the gas collection cylinder. The cylinder collects gas and store under pressure. The gas from the cylinder is then released through the pipe to the Internal Combustion Engine (ICE) generator to turn for electricity.

- The waste collected are presented using the table below:

Table 1 - Waste Collection 1

S/No.	Bin No.	Hostel	Floor	Date	Weight (Kg)
1.	001m	Male	1	12-04-2019	4
2.	002m	"	2	12-04-2019	6
3.	003m	"	3	12-04-2019	6
4.	004m	"	4	12-04-2019	6
5.	001f	Female	1	12-04-2019	7
6.	002f	"	2	12-04-2019	8
7.	003f	"	3	12-04-2019	9
8.	004f	"	4	12-04-2019	10

Table 2 - Waste Collection 2

S/No.	Bin No.	Hostel	Floor	Date	Weight (Kg)
1.	001m	Male	1	18-04-2019	4
2.	002m	"	2	18-04-2019	6
3.	003m	"	3	18-04-2019	5
4.	004m	"	4	18-04-2019	6
5.	001f	Female	1	18-04-2019	7
6.	002f	"	2	18-04-2019	5
7.	003f	"	3	18-04-2019	9
8.	004f	"	4	18-04-2019	10

Table 3 - Waste Collection 3

S/No.	Bin No.	Hostel	Floor	Date	Weight (Kg)
1.	001m	Male	1	26-04-2019	6
2.	002m	"	2	26-04-2019	5
3.	003m	"	3	26-04-2019	5
4.	004m	"	4	26-04-2019	7
5.	001f	Female	1	26-04-2019	9
6.	002f	"	2	26-04-2019	9
7.	003f	"	3	26-04-2019	7
8.	004f	"	4	26-04-2019	11

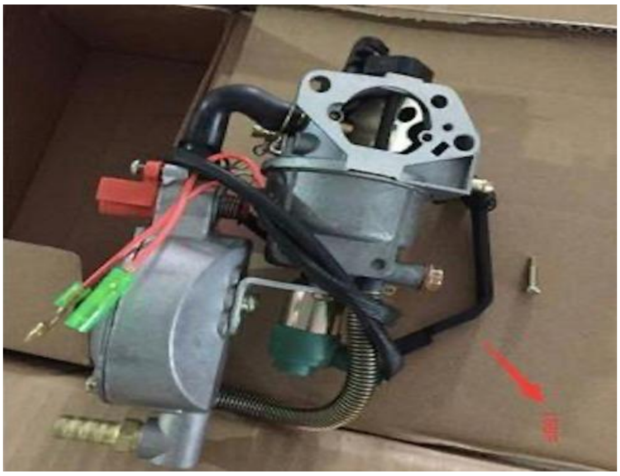
Table 4 - Waste Collection 4

S/No	Bin No.	Hostel	Floor	Date	Weight (Kg)
1.	001m	Male	1	26-05-2019	5
2.	002m	"	2	26-05-2019	5.5
3.	003m	"	3	26-05-2019	7
4.	004m	"	4	26-05-2019	5.6
5.	001f	Female	1	26-05-2019	8.4
6.	002f	"	2	26-05-2019	8.3
7.	003f	"	3	26-05-2019	8.1
8.	004f	"	4	26-05-2019	9

It was established from the foregoing that the gas emanating from the biogas harvest and ICE generator used for electricity generation proved insufficient for this purpose. To improve on the outcomes, we had to improve the gas emission by adding other sources of waste such as chicken drops and cow dung to obtain adequate gas. Further assessment revealed that not only is efficiency being affected by the nature and volume of gas obtained from our current research efforts. The insufficiency of the biological waste appear key to the limitations but also by the carburettor used to generate electricity.

These factors combined to present varied limitations to the results. We decided to try out several alternative carburettors from different manufacturers, it became evident that there existed a new purpose made dual Carburettor that can use gas and fossil fuel based (petrol and liquid gas).

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 12, December-2020



Dual use carburettor

The Improved approach

The**e** improved approach to our experiments started out with the addition of the wastes mentioned above;

The chicken drops and cow dung were added to the existing biological wastes from the students' hostels, to the digester in a programmed manner to ensure a renewal of digestion in the chamber. The waste so added rev up the biodegradable activities in the tank. In table 5, we have shown the cumulative total waste in kilogram that we had in the renewed digestion process that resulted in the improved outcomes.

Table 5 - Waste Collection Additional Wastes

S/No	Biological waste	Chicken drop waste	Cow dung	Total [kg]	Remark
1.	224	19	31	274	OK

The continual addition of the very active chicken drop and cow dung led to the production of adequate gas to feed into the converter as fuel. The reservoir tank provided sustained gas supply no matter how slow the activities in the digester get.

Parametric Factors

As we have in the previous exercise, the average outputs related to the size of facilities used for the research remain the same as and arising from the established constants and in tandem with the previous work done which is associated with food waste volume/weight with the additional wastes added the level of gas as they relate to the expected standards indicated below can be said to be adequate when compared to the parameters stated as follows:

(i) 1000 litres capacity digester (air tight chamber) yields between 20m3 – 800m3 of gas per tonne of waste. This is the expected range. (It is worthy of note that by general standards, the amount of biogas you can extract from your organic waste depends on the waste itself and design of the digester system. Some can yield up to the maximum.

From the research, the following situation prevailed:

(i) Digester size (airtight chamber) – 500 litres (0.5m3)

(ii) Gas expected (from a standard of 1 tonne of waste giving 1m3 of gas) is between 10 - 400m3 of gas.

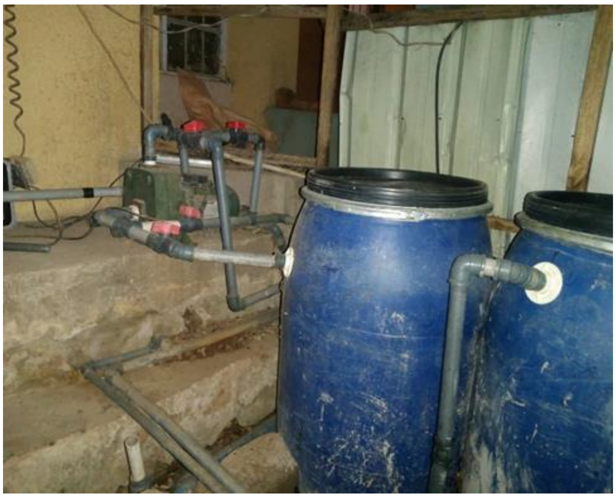
(iii) The electricity deliverable, m3 (biogas) = 2kWh/m3

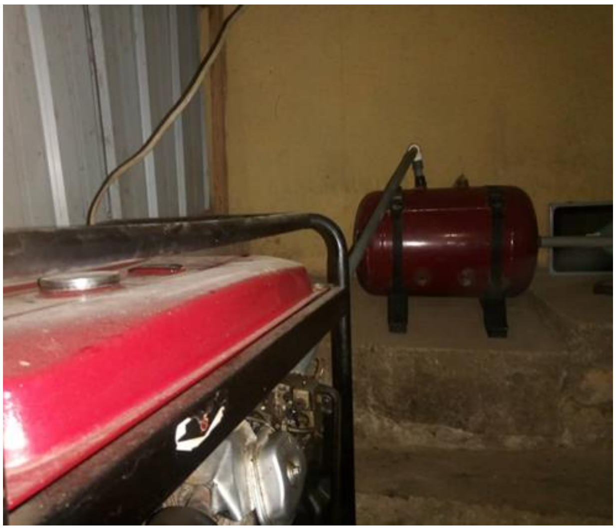
(iv) The obtained volume of gas in reality from the experiment amounted to 0.12m3, an amount considered inadequate for the level of electricity expected.

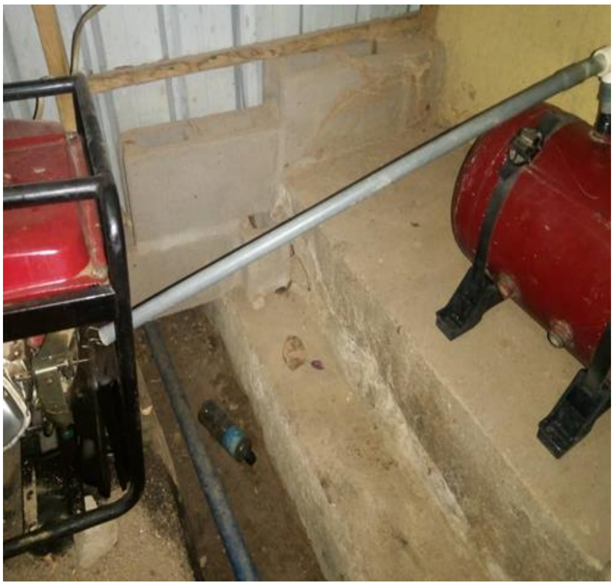
RESULTS

After carrying out changes in the parameters as mentioned above a repeat of near continuation of the process was embarked upon. It entails depositing the additional waste in the existing biological waste in our biogas digester and again allowed to decompose for between 13-28 days. By which time the gas valve is again released to allow for the flow of air/gas to the holding tank (cylinder). The gas obtained from the digester filled the cylinder time high enough to fill the pressured cylinder, from where the consistent fuel is derived for the internal combustion engine (ICE) generator. After several attempts it became clear that we now have a promising outcome that can be pursued further to perfection (as we have some element of intermittent electricity for up to 2 minutes and subsequently went on and off). The significant improvements in the electricity supply proved rewarding and worthy of the efforts thus far acceptable result. obvious that the level of gas emission from the digester is largely inadequate to produce the expected gas level to sustain the right amount of consistency of gas in terms of volume and pressure to run power general for adequate and sizeable power supply.

We can conclude here that the adjustments carried out during this research point to the right direction that lay the basis for future expansion of this research.







CONCLUSION AND THE WAY FORWARD

The energy crises in Nigerian have hindered the progress of the nation in all facets. Educational institutions are not left out of the crises. We tried, in this study to look at the situation and explore the options that are available to reduce cost, expanding access and helping in the eliminating carbon emission. Part of the solutions apart from cost reduction is the Decentralisation of BETs. Relying on the most suitable means of electricity provision is central to achieving the needed goals. The biomass resources availability in Nigeria partly motivates its choice as the means to bringing about the needed changes.

This research, which started out to provide alternative and sustainable electricity to students' hostel as was established promising from the beginning, but the level of gas was found inadequate, at that point it was revealed that the quality, quantum and consistency does not support our expectations. Our recourse to using other biodegradable sources like chicken drops and cow dung changed all the lost hope, it became clear that the use of the gas emanating from the digester as expected is adequate to run the ICE generator. It has been argued that that cows and chicken was are promising as alternative resources, which are readily available. This is in tandem with the various schools of thoughts such as that of IRENA (2012), which concluded that the more the diversity of biomass wastes the better, the biogas production.

The utilization of livestock waste as we have as chicken drops and cow dungs provide two prong benefits of waste management/recycling and cheap energy fuel source. This idea is seen as assisting in mitigating the effect of fossil fuel price increase. The recommend the establishment of ancillary livestock side business in most establishment such as educational institutions to provide the needed livestock refuse. This is to sustain the availability of the primary feed to generate the gas needed to serve as fuel for ICE generators. While we used a small sized generator for the study we are confident that big size generators fit into this method of fuelling. We call for the production of the converter in Nigeria to ensure availability and low price.

Suffice it to say that more work still need to be done to take this to a mega energy supply level, especially in institutions or cities with central solid waste disposal system. We are therefore suggesting further research to explore standalone gas turbine energy sources with/without the presence of ICE generator. This is to avoid the limiting factors inherent in the use of this type of generator. A direct gas propelled turbine is the ultimate goal.

REFERENCES

[1] Bocci, E, Sisinni, M, Moneti, M, Vecchione, L, Di Carlo, A and Villarini, M. (2014). State of art of small scale biomass gasification power systems: A review of the different typologies. Energy Procedia, 45, 247-256.

[2] Central Intelligence Agency (2017) https://www.cia.gov/library/publications/resources/the-world-factbook/rankorder/rankorderguide.html : Accessed 29-08-17.

[3] Dasappa, S. (2011) Potential of biomass energy for electricity generation in sub-Saharan Africa. Energy for Sustainable Development, 15(3), 203-213.

[4] Eberhard, A and Gratwick, K N (2012) Light Inside: The Experience of Independent Power Projects in Nigeria. University of Cape Town: The Infrastructure Consortium for Africa.

[5] Energy Commission of Nigeria and United Nations Development Programme (ECN– UNDP) (2005) Renewable Energy Master Plan: Final Draft Report. Available from: ⟨http://www.iceednigeria.org/REMP%20Final%20Report.pdf⟩ (accessed 22.02.14).

[6] Evans, A, Strezov, V and Evans, T J (2010) Sustainability considerations for electricity generation from biomass. Renewable and Sustainable Energy Reviews, 14(5), 1419-1427.

[7] Garba, A and Kishk, M (2014) Renewable energy technology means of providing sustainable electricity in Nigerian rural areas: A review. In: A Raiden and E Aboagye-Nimo (Eds)Proceedings 30th Annual ARCOM Conference, 1-3 September 2014, Portsmouth, UK. Association of Researchers in Construction Management, 143–51.

[8] Garba, A and Kishk, M (2015) Economic assessment of biomass gasification technology in Providing Sustainable Electricity in Nigerian Rural Areas. In: C Gorse and M Dastbaz (Eds.) International Sustainable Ecological Engineering Design for Society Conference (SEEDS) Conference, 17-18 September 2015. Leeds Sustainability Institute, Leeds Beckett University: Leeds, 554-565.

[9] Garba, A., Kishk, M and Moore, D. R., (2016). A Comparative Study of Biomass Energy Technologies for Sustainable Electricity in Nigerian Rural Areas.*In*: P W Chan and C J Neilson (Eds.) *Proceedings of the 32nd Annual ARCOM Conference*, 5-7 September 2016, Manchester, UK, Association of Researchers in Construction Management, Vol 2, 1209-1218.

[10] Garba, A. (2017). Renewable energy technologies assessment in providing sustainable electricity to Nigeria rural areas. *Robert Gordon University, PhD Thesis, held on OpenAIR (online)* available from: https://openair.rgu.ac.uk

[11] Garba, A., Zubairu, T. and Ryal-net, B., (2019). Biogas System, an alternative Source of Sustainable Electricity for Students' Hostel. A Paper Presented at CES 13th Annual National Conference; Title Catching up with Technological Advancements and Innovations in Developing Economies. Dated: 08-10th October, 2019.
[12] Hoornweg, D. and Thomas, L., (1999). *What a waste: solid waste management in Asia.* The World Bank.
[13] International Renewable Energy Agency (IRENA) (2012) Renewable energy technologies: Cost analysis series.
[14] MacDonald, M (2011), Costs of Low-Carbon Generation Technologies. London: Committee on Climate Change.
[15] Mahapatra, S and Dasappa, S (2012) Rural electrification: optimising the choice between decentralised renewable energy sources and grid extension. Energy for Sustainable Development, 16(2), 146-154.
[16] Martinot, E (2015) Renewables 2015 Global Status Report. Paris: Worldwatch Institute.
[17] Martinot, E., (2013) Renewables 2013 global status report.*Worldwatch Institute, Paris,*
[18] Mohammed, Y.S. et al. (2013) Renewable energy resources for distributed power generation in Nigeria: A review of the potential. *Renewable and Sustainable Energy Reviews,* 22(0), pp. 257-268
[19] Moriarrty, P. and Honnery, D. (2011) Renewable Energy: Too Little, Too Late? *Rise and Fall of the Carbon Civilisation: Resolving Global Environmental and Resource Problems,* , pp. 79-101
[20] Ohunakin, S.O. et al., (2012) Analysis of cost estimation and wind energy evaluation using wind energy conversion systems (WECS) for electricity 259 generation in six selected high altitude locations in Nigeria. *Energy Policy,* 48, pp. 594-600
[21] Ogwueleka, T. (2009) Municipal solid waste characteristics and management in Nigeria. *Iranian Journal of Environmental Health Science & Engineering,* 6(3),
[22] Poschl, M., Ward, S. and Owence, P. (2010) Evaluation of energy efficiency of various biogas production and utilization pathways. *Applied Energy,* 87(11), pp. 3305-3321
[23] Rahman, M.M., Paaterro, J.V. and Lahdelma, R., (2013). Evaluation of choices for sustainable rural electrification in developing countries: A multicriteria approach. *Energy Policy,* 59, pp. 589-599
[24] Sambo, A.S. (2009) Strategic developments in renewable energy in Nigeria. *International Association for Energy Economics,* 16
[25] Shaaban, M. and Petinrin, J.O. (2014) Renewable energy potentials in Nigeria: Meeting rural energy needs. *Renewable and Sustainable Energy Reviews,* 29(0), pp.
[26] Wang, L, Curtis, L W, Jones, D D and Hanna, M A (2008) Contemporary issues in thermalgasification of biomass and its application to electricity and fuel production. Biomassand Bioenergy, 32(7), 573-581.
[27] World Bank (2005) World Resource Indicators, Washington DC. Available fromhttp://www.worldbank.org/afr/findings (Accessed 13th May 2014)