Production of Sustainable Renewable Energy from Biodegradable Wastes

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Abstract

Renewable energy from ISWM system plays a significant role in clean energy harvesting. SW containing 50% - 60% of methane (CH_4) gas, with 40% - 50% carbon dioxide (CO_2). CH_4 being a valuable resources for clean energy production has 18 - 22 MJm^{-3} of energy content. Nigeria depends on finite means of energy sources, and are generally non-renewable in nature. Hence, this poise a greater danger to environmental sustainability. Therefore, this research aimed at providing an effective and sustainable dependability from the use of non-renewable to renewable energy sources, leading a shift from oil resource based energy to biodegradable energy & W-t-E resources, all emanating from MSW. Quantitative and qualitative approaches have been adopted in-line with this research work, to effectively evaluate and to extract 100% of CH_4 gas (natural gas) available as LFG from SW to be used in domestic, industrial and power electricity generation plants. Technically this is achievable through passive or active gas management system, for an extensive extraction peak productivity period of 1 - 20 yrs. of available waste stream table 3, figure 4 and 7. Similarly an increased waste generated in 2020 from that of 2015, led to the extraction peak production period of 1 – 30 yrs. of continuous energy harvesting table 4, figure 5 and 7 respectively. Hence, there is the need for various stakeholders to invest in effective ISWM to boosting raw material sources for RRR.

Keywords: *MSW, Biodegradable, Waste-to-Energy, Landfill, CH_4, Gas, and Simulation.*

1.0 Background

Renewable energy from ISWM system plays a significant role in clean energy harvesting. (Tchobanoglous and Theisen, 1993) and (US EPA, 2008) However, chemical and biological processes are present in the disposed SW containing 50% - 60% of methane (CH_4) components and 40% - 50% carbon dioxide (CO_2). Both methane and carbon dioxide are the major greenhouse gases (GHGs) which poise a great threat and danger to our global environments. But, when effectively managed, it serves as valuable resources for clean energy production, with 18 - 22 MJm^{-3} of energy value resulting from methane content. In 2011 there were 734 and 551 active Landfill Gas to Energy existing across Europe and US respectively, with 11700 MW annual electricity design capacity for generation, having an estimated direct thermal use value of three billion m^3. (ATSDR, 2001); (Hwa T. J, et al 2005); (US EPA, 2005); (UNEP, 2005), (Spokas et al., 2006) and (US EPA 2010).

Continuous dependency on energies sources from oil based resources, will lead to serious problem in environmental sustainability (ElJrushi GS and Veziro Tglu., 1990). High volume of gas are available in disposed solid waste which is known as landfill gas (LFG). However, LFG is utilized as liquefied gas and are applicable for the production of power electricity. Researches has shown that it's an effective advancement in terms of energy conservation as well as aid in reducing water, soil and air pollutions. Recovering energy from solid waste represent a drastic procedure to reducing the immense of electrical energy to be consumed and produced from fossil fuels (non-renewable energy sources). Similarly, there are several benefits in the usage of LFG via waste-to-energy (W-t-E) process (World Energy Resources, 2016). These serves as alternative renewable energy resources, thorough utilization of LFG which leads to minimal global GHGs emission. There are available technological facilities utilized worldwide for operation and production of power electricity through LFG, includes; gas engines, gas turbines and steam turbines (Ho-Chul S. et al., 2005) and (Saleh, 2015)

According to World Energy Consumption by fuel type in 2013 reported that, less than 20% of energy is consumed from renewable energy and less than 10% is from nuclear energy while more than 70% is from fossil fuels (K. J. Krishnan et al., 2013). The problem associated to Nigerian ISWM for renewable energy is basically psychologically driven, lack of technological advancement, politically motivated with economical barriers. Leading to the combinations of; insufficient funding, week legislative system to promulgate effective policies and laws, scarcity of infrastructures and professional in the fields, enlightenment and awareness is lacking, ineffective disposal techniques and recovery process as the major source to ecological and carbon footprints leading to, among others in Nigeria also includes are:

- Environmental degradation, pollution, and subsequently constitutes out breaks of rampant cases of diseases and devastating health effects on both human and animals;
- Refuse dup sites had become an environment for indiscriminate defecation by all ages of humans and the dumping of animal carcass;
- Gross Leachate collections, which subsequently pollutes soil starter and underground aquifers (boreholes and open dug wells) hampered by noncompliance to managing and monitoring pollution of land, water and air quality;
- Global warming and the depletion of the Ozone layer, as a result of excessive release of toxic GHGs (CO_2, CH_4, VOCs etc.) in to the atmosphere;
- Sustainable management of both hazardous and non-hazardous wastes are lacking with little or no support for R&D on sustainable ISWM to generate power and energy in Nigeria;
- Absolute blockage of water channels and facilities due to the presence of unlawful disposal of MSW, does pave ways for over-flooding within host communities and its environs; thereby, causing loss of billions of dollars annually.

The quest for eliminating the disposed waste in Nigeria is by direct open burning, leading to the destruction of the Ozone layer and subsequently weakens the ambient strength of civil engineering structures such as bridges, culverts and other utility structures, [Authors personal industrial research and development (R&D)].

Recent energy conservation from solid wastes in Nigeria (2011) sturdy reveals that, about 17.2 MW of power electricity can be generated from each of Nigerian cities, equivalent to 619.36 MW of daily power generation from wastes. However, this is highly important in the quest for alternative energy sources to diversify Nigerians economy for energy production, jobs and wealth creation. Sweden pay for importing 8000 tons of garbage from other parts of Europe every year for use in the countries power plants. While, Norway is paying Sweden to collect the SW off the Norway's lands (Science, Tech & Environment, 2012).

1.2 Research Problems

1) Nigeria depends on finite resources (fossil fuels) energy sources, which are non-renewable in nature. Hence, this poises a great danger for the present and future environmental sustainability;
2) The gross volume of available present and future disposes of SW in Nigeria is detrimental to the environments, because ISWM system is lacking in Nigeria; and
3) Nigeria has no single renewable energy source for national utilization. Hence, the need to utilize our present and future vast solid wastes as resources among others for the recovery of renewable energy development. (Nations developments depends on effective & sustainable energy sources).

1.3 Research Impacts to the Nigeria Economy:

1) To providing an effective and sustainable dependability from the use of non-renewable to renewable energy sources (shift from oil resource energy to biodegradable energy & W-t-E resources);
2) To enhance on the scarcity and or epileptic energy production for infrastructural demand so as to meeting energy sufficiency for all citizenries.
3) To minimise the adverse environmental degradation causing global warming, pollution and the detrimental human, animal & plants health effects, resulting from indiscriminate deposes of wastes and the use of non-renewable energy (fossil source energy).
4) The oil and gas industry requires renewable energy technology to resolve problems of supplying electricity for offshore production and to supply the thermal energy required for the enhanced oil recovery (EOR) technique.
5) The use of renewable energy source for productions in the oil and gas industries, reduces risk and uncertainty, and hence increases the likelihood to attaining more Environmental Health & Safety (EHS) as well as reducing energy cost and the expected decrease in GHGs emissions.
6) This would also help in linking the oil and gas sector with the materials science and engineering sector through the commercial production of turboelectric generators (renewable energy harvesting devices) like offshore wind energy systems, wave energy from ocean, and other Renewable Energy sources using polymeric and non-polymeric materials.

2.0 Research Aim & Objective:

To come up with sustainably and viable clean technological advancement of harvesting renewable biogenic synthetic gas (CH_4), and W-t-E from MSW as major means for a shift from the use of fossil fuels to non-fossil fuels in Nigeria.

3.0 Major contributions of this research work to Knowledge will include among others majors are:

1) To promoting and providing bases for extensive R&D for researchers in alternative renewable energy sources from biodegradables, apart from the commonly used (oil, solar, wind, thermal power etc.);

2) This research work will serve as reference and as an effective tool in global institutions of learning via reputable national and international journals, conferences, seminars, workshops, training skills etc.;
3) It will also serve as suitable material and document for project development by various stakeholders of interest and concerns;
4) It will promote the development of technical knowledge and technical facilities nationwide; and
5) It will serve as baseline document to understanding the uses of SW materials (refuse dups) for energy harvesting in the quest to a shift from the consumption of finite resources (fossil fuels) energy sources, which are generally non-renewable etc.

4.0 Materials and Methods

4.1 Relevant Materials/Specification

The major relevant materials required for this research work is basically:

1) Solid Waste landfill site, and or controlled waste disposal site;
2) Landfill Gas Emissions Model (LandGEM software) Version 3.02;
3) Energy project landfill gas utilization software (E-PLUS) Version 1.0;
4) Info Works for Civil Engineering Simulation Model (CESM) CS V15.0;
5) 3D CAD Design Software; and
6) SOLIDWORKS among others.

4.2 Method(s) of Data Analysis

Generally, there are two (2) efficient and effective methodologies which are viable to undertaking this research work. A conglomerate of both quantitative and qualitative approaches has been chosen. (raw data collection from existing landfill site and or relevant authorities, analytical and numerical approach, computer base validation/simulations, current and relevant scholarly materials etc.). This will however increase the probability and the likelihood of exploring effectively with greater perfection to quantifying, extracting and harvesting biodegradable gas from disposed MSW for energy production on landfill and or controlled waste disposal site.

5.0 Results Analysis

5.1 Techniques/Method(s) used for data Collection/Modelling/Construction

This research work is exploring one of these two (2) or both techniques to evaluate and harvesting biogas from landfill and or a managed waste disposal site, namely: through passive or active system both of which consist of gas collection wells that provide a preferential migration route for the landfill gas *figure 1*, and the alternative measure *figure 2*, an incineration energy [Waste-to-Energy (W-t-E)] system for non-decomposable landfill wastes known as refuse drive fuel (RDF).

1) A Passive system LFG collection process consists of pipe wells similar to ground-water wells (boreholes), in which gas is being drawn upwards from the well as a result of differential pressure between the landfill and the atmosphere;
2) An active LFG collection system consist of an incorporated designed vacuum connected to the bored wells, so as to create higher potential within the wells, which allows for the gas extraction from landfill/managed waste disposal site, and subsequently, undergoes purification to illuminate CO_2 to produces LFG.
3) W-t-E plants operates on non-biodegradable SW stream known as refuse derived fuel (RDF), this influences efficient and effective generation of energy productions.

Composition of these RDF are combustible wastes having 15 – 20 MJ/kg of heat generation values. However, the capacity of energy production in the plant, depends on high heating values of the material comprising the waste stream.

5.1.1 Construction process of MSW LFG collection and utilization system

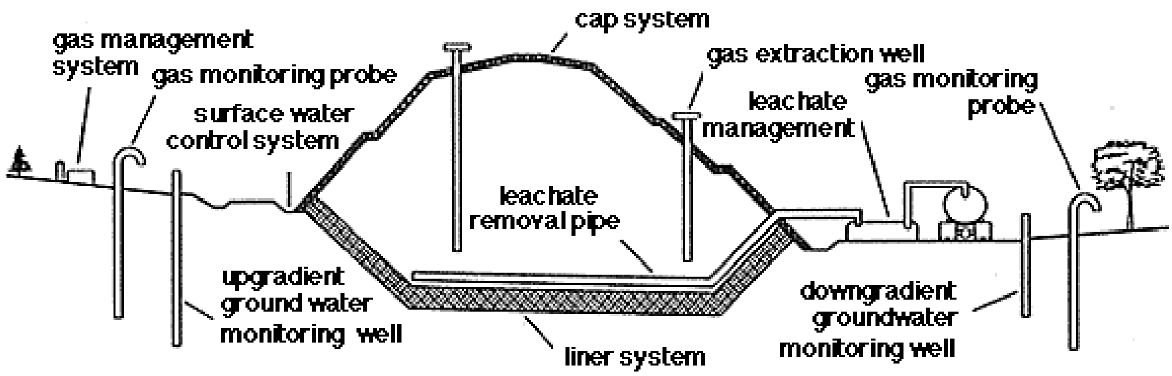


Figure 1: Cross section through MSW LFG management system.
Source: (Saleh Mamman Abdullahi, 2015)

5.1.2 Construction process of W-t-E collection management system

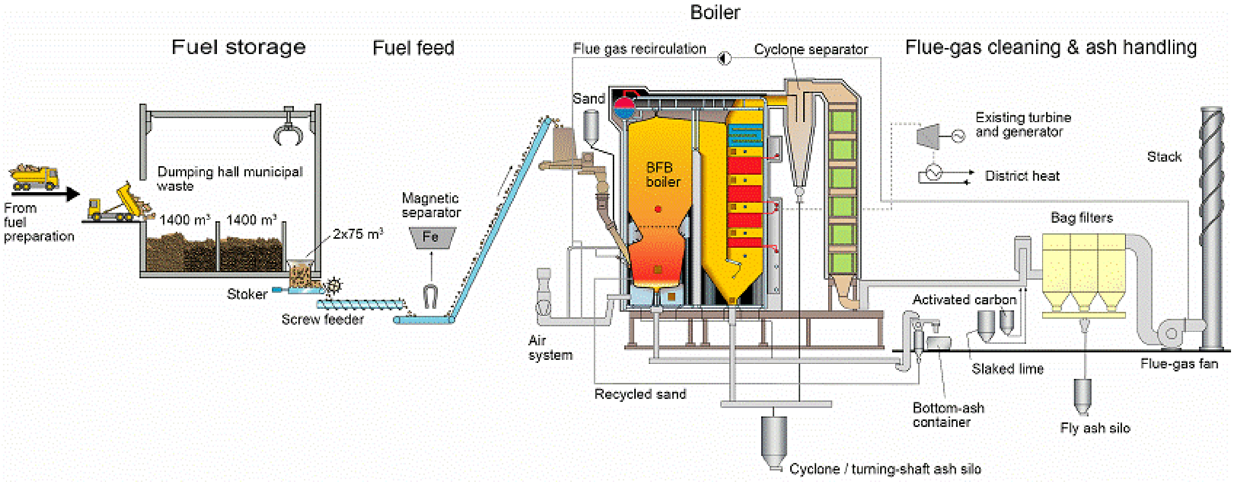


Figure 2: Incineration energy [Waste-to-Energy (W-t-E)] management system.
Source: (Prof. Mohammad Taherzadeh, 2015)

5.2 Result Preface

Renewable energy from MSW is an alternative prominent solution which may play essential role in resolving the global energy problems. Nowadays, the way the world thinks about renewable energy has changed, it is no longer just a concept but a global reality with priority to growing renewable energy for sustainability. With much of the world looking for fossil-free energy sources, renewable energy is becoming increasingly popular, and forward-looking countries and companies are adapting their oil and gas solutions for use in the renewables sector. The current global crisis and the hiking period in oil prices is not left out, worldwide interest in renewable energy technology has been on the incremental, with no future to declining. Some of the contributing factors are due to lingering problems associating to greenhouse gas emissions and conventional energy production technologies, which is threatening environmental safety, as it can be associated to the Paris Agreement.

Currently, eco-friendly renewable energy technologies that are sustainable, such as; Biomass & W-t-E, Tidal power, Wave power, Wind power, Hydropower, are being widely used in virtually all developed and some developing countries as well as their respective industries. However, Nigeria is having abundant MSW disposed all around its rural and urban areas, leading to environmental degradation, pollutions and with adverse health implications. Hence, these wastes are resources for renewable energy which can boost economic developments, but however it remained untapped in Nigeria.

Table 1: Average daily MSW generation through open dumps in six (6) Nigerian cities with its environmental footprint as at 2006 Population figures.

Research locations (cities)	2006 Population figure	Daily generated wastes (kg)	Kg. per Capital per day	Organic components (%)	Combustible Components (%)	Generated CH_4 (kg)	GHG (CO_2) equivalent emission (kg)
Abuja	1,406,239	322,107	0.57	56.4	36.4	191271.5	1399480.9
Kano	9,401,288	1,970,920	0.56	43.0	50.0	892469.4	6529953.6
Lagos	9,113,605	5,747,616	0.63	68.0	21.0	2885686.4	30114059.3
Maiduguri	4,171,104	222,044	0.25	25.8	29.5	60327.4	441399.1
Onitsha	4,177,828	530,530	0.53	30.7	53.9	171515.8	1254934.2
Port Harcourt	5,198,716	714,360	0.60	39.4	29.9	207809.7	2168632.7
Total	**33468780**	**9,507,577**	**3.14**	**63.22**	**36.8**	**5727761.4**	**41908459.7**

Source: (Beatrice A., et al., 2013; Abila, 2014; Nigerian National Bureau of Statistic, 2015 and Saleh Mamman Abdullahi, 2015)

Furthermore, wealth of alternative sources for energy such as biomass fuels, W-t-E exist in Nigeria for energy and power productions to be used in our industries, businesses, vehicles and homes, without the application of fossil fuels (coal, nuclear, crude oil products etc.), but it's not given the attention it deserves at the moment. It's important to note that, renewable energy sources can adversely contribute to reducing the daily amount of GHGs we emit into the atmosphere, as well as reduces the expensive cost and to eliminating the negative environmental impacts cause as a result of the use of finite resources (fossil fuels) which are naturally non-renewable.

Waste	Abuja	Kano	Lagos	Maiduguri	Onitsha	Port Harcourt
Glass	03.000	02.000	03.000	04.000	09.200	13.500
Metal	03.140	05.000	04.000	09.100	06.200	17.200
Paper	25.300	17.000	14.000	07.000	23.100	12.400
Plastic	03.400	04.000	04.000	18.000	09.200	09.900
Putrescible	42.600	43.000	56.000	25.800	30.700	31.000
Textile	03.300	07.000	-	03.900	06.200	07.600
Others	19.530	22.000	19.000	31.300	15.400	08.400
Total (%)	**100**	**100**	**100**	**100**	**100**	**100**

Source: Compositions of Nigerian wastes. (Igoni et al., 2007; Ogwueleka, 2009; Ayuba et al., 2013 and Saleh Mamman Abdullahi, 2015)

Table 2: Percentage Characteristic of MSW generation in six (6) Nigerian cities by 2015

Municipal Solid Waste (MSW) are generally known to be our domestic garbage generated over time from our everyday activities, some major characterisations of its waste streams are as depicted in *table 1* above. These wastes are disposed within our environments by residents. Classification shows that the major constituents of MSW in Nigeria are biomass deposits, in the forms of food waste, paper, and wood/vegetable wastes. The 6 selected Nigeria cities (Abuja, Kano, Lagos, Maiduguri, Onitsha and Port Harcourt) generate 9.51 million kg, this is an equivalence of 10,480.31tons of waste generated per daily consumptions *table 1 and 2*. SW disposal through intergraded solid waste management (ISWM), will bring about reductions in the adverse degradations, pollutions scenarios and the undesirable effects that are associated with human health as caused within the environment. ISWM in this case will provides for economical supports, tremendous developmental achievements and with an improvement to a qualitative ways of living. In view of these, the Science, Engineering and Technologies can however promotes to bring about the country's economical diversifications, for the propagation of effective ISWM to recovering reusable resources for the production of cost effective sustainable energies to supplement and enhances the regular national demand and consumption of energy requirements.

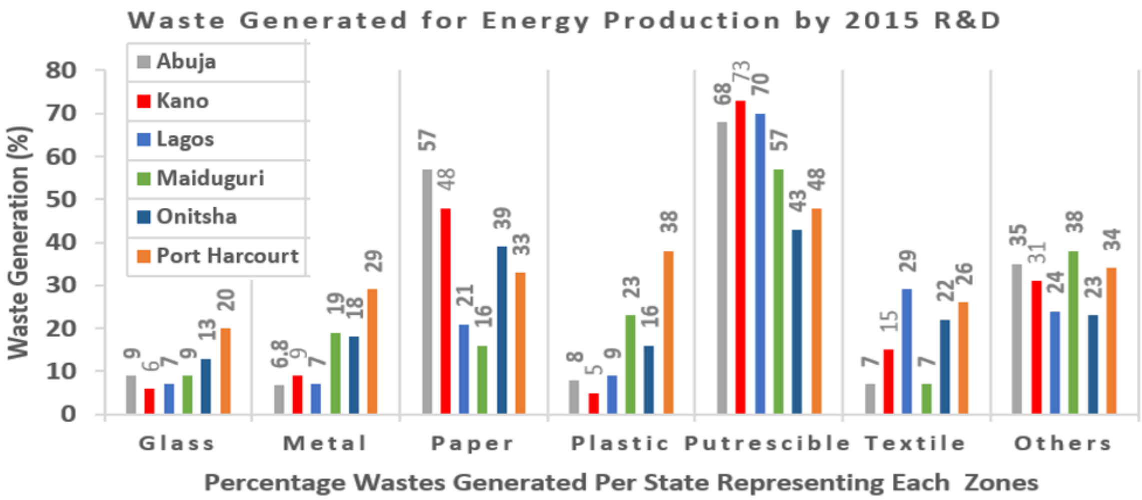
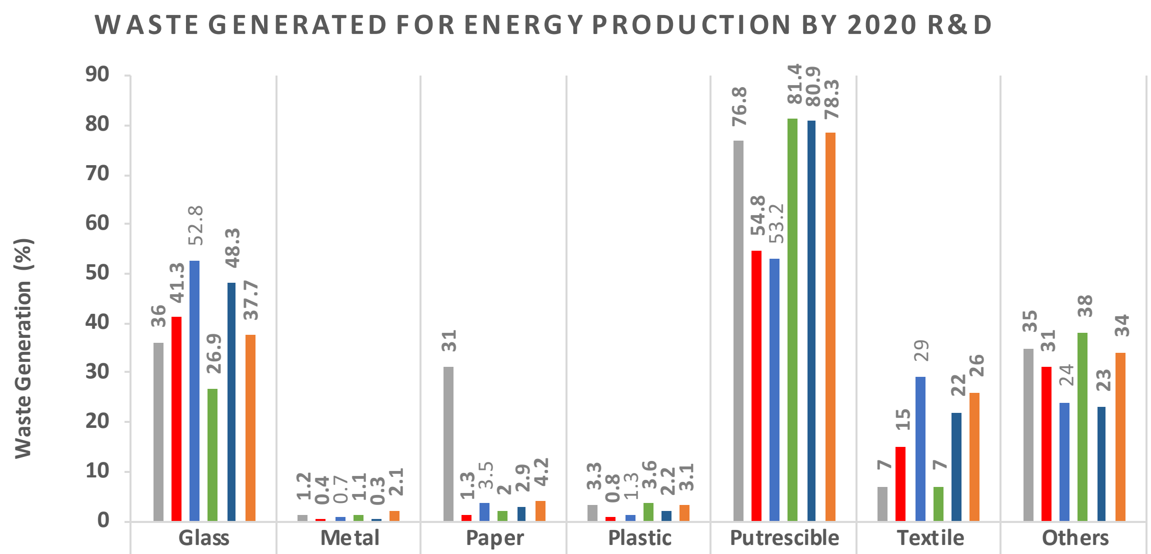


Figure 3: MSW Generated for Energy Production by 2015 R&D

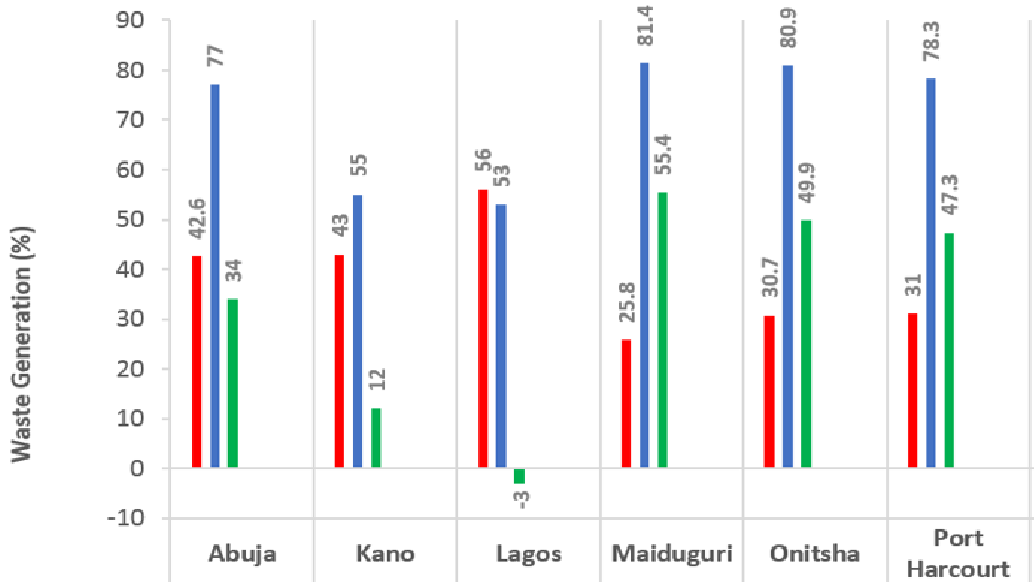


	Glass	Metal	Paper	Plastic	Putrescible	Textile	Others
Abuja	36	1.2	31	3.3	76.8	7	35
Kano	41.3	0.4	1.3	0.8	54.8	15	31
Lagos	52.8	0.7	3.5	1.3	53.2	29	24
Maiduguri	26.9	1.1	2	3.6	81.4	7	38
Onitsha	48.3	0.3	2.9	2.2	80.9	22	23
Port Harcourt	37.7	2.1	4.2	3.1	78.3	26	34

Table 3: Percentage Characteristic of MSW generation in six (6) Nigerian cities by 2020
Figure 4 of table3: Waste Generated for Energy Production by 2020.

Similarly, *table 2* and *figure 3*, depicts the characteristic trends of MSW deposits as an average percent disposal per person per day on six (6) disposal sites in each of the cities (states) representing each of the geological zone in Nigeria. However, it can be deduced that the bulk of waste streams seen on each dumpsites are the putrescible (biodegradable) materials for having the highest volume of 77.25% of the seven (7) categories of waste streams herein. Similarly, paper materials are second in terms mass volume of wastes disposed on sites with 16.42% total, while all the other five (5) categories of wastes put together are less than 30% of the total by mass volume of entire disposed wastes. Therefore, the 77.3% mass volume of biodegradable is a minimum volume of disposed wastes expected by the time of energy harvesting, this depict a positive indication for the amount and or volume of LFG to be generated as a result of CH4 deposits within the dumpsites.
Furthermore, analysing *table 4* and *figure 3* of the categorisations of waste stream generated on individual dumpsites, while taking an interval period of five (5) yrs. i.e from year 2015 to year 2020 *table 3*, *figure 4* and *5*, confirms herein that the trends of available disposed wastes had tremendously increased over the period of 5 years, with Maiduguri recording the highest volume of 55.4% increase, Onitsha 49.9%, Port Harcourt 47.3% Abuja has 34%, while Kano state is the least with a total of 12% increased deposits. The least of all volume of putrescible generated was recorded from Lagos state, with a decline in the volume of biodegradable waste available over this years in question to be -3% when compared with

that of the volume recorded in year 2015 (year 2015 = 56% and year 2020 = 53%) respectively.



	Abuja	Kano	Lagos	Maiduguri	Onitsha	Port Harcourt
2015 Waste (%)	42.6	43	56	25.8	30.7	31
2022 Waste (%)	77	55	53	81.4	80.9	78.3
Waste Growth (%)	34	12	-3	55.4	49.9	47.3

Figure 5: Differences in the Volume of Biodegradables Waste Generated for Energy Production between year 2015 – 2020 (5 years interval)

However the CH_4 gas deposited in these waste can be extracted and or collected through pipe networks to a gas management system as liquefied gas for commercial distributions for domestic heating & cooking, as well as for industrial uses, and more importantly CH_4 gas is used as fuel energy in gas turbine, thermal stations and steam engines for electricity generation at much lower cost. Similarly, CH_4 gas produces lesser CO_2 for each units of heat released. However, production of LFG from the above waste stream an d as seen in *figure 6* and *7*, shows a computer based simulation result for the extraction of CH_4 gas, which will be harvested from the first year and extraction reaches its peak at 3 - 20 years, then start to drops gradually at 20 - 30 years as in *figure 6* and *figure 7* below respectively. Similarly, the available 30% - 35% of combustible components [refuse derived fuel (RDF)] waste, is then utilised directly in W-t-E incinerator plant for the production of energy and heating in domestic, agro, steam and thermal plants for electricity generation

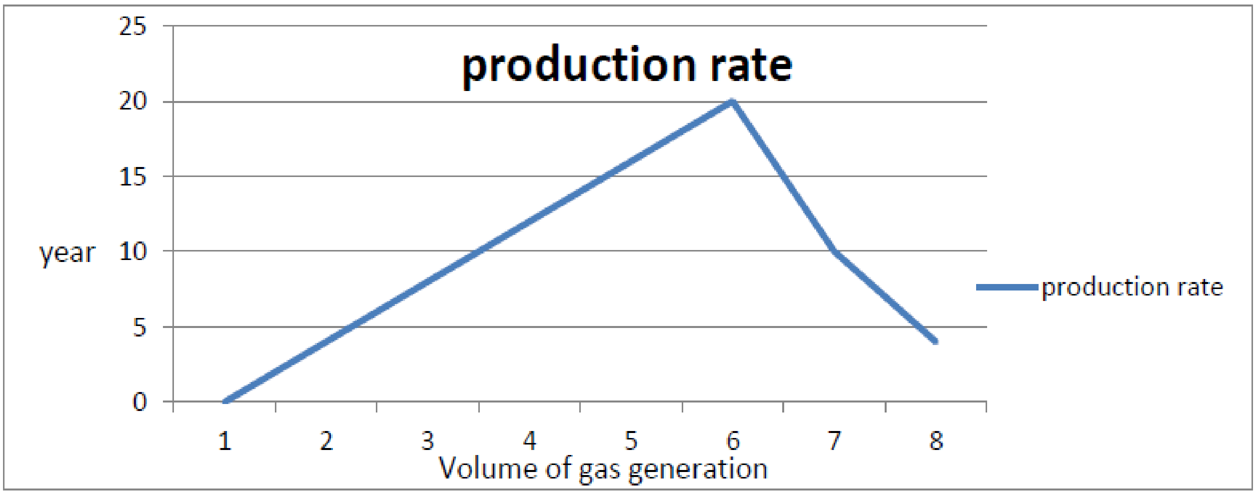


Figure 6: Simulation of gas extracted from *table 1, 2 and figure 3, from year 2015 data.*
Source: Authors simulated data

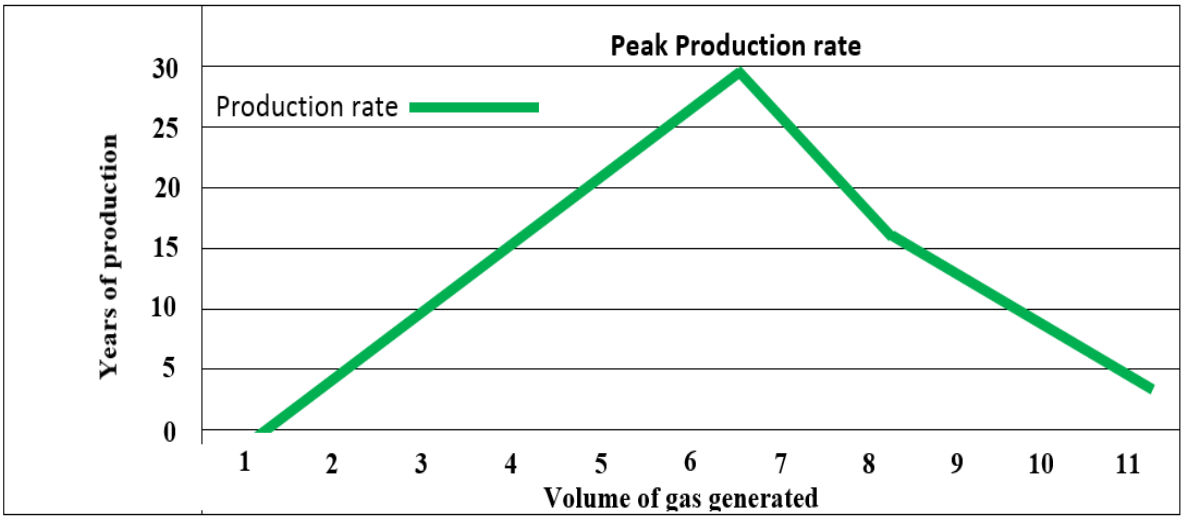


Figure 7: Computer based simulation of gas extraction *table 1* and *2* year 2020
Source: Authors simulated data

Furthermore, it's important to note that from *figure 4 of table 3* above, some of the waste volume are diminish gradually from the dump sites within a period of five (5) years (year 2015 to year 2020). However, the agent which is responsible for this singular act is through waste recovery, reuse and recycling (RRR). First of this on the list of these waste stream reduction index is metal, followed by paper materials, next to it is plastic materials.

6.0 Conclusion

Energy recovery from SW is economically cheaper and environmental friendly and serves as remediation measure to minimising the negative impact of SW disposal such as; environmental degradations and pollutions, health effects, emission of GHGs and global warming. SW disposal in Nigeria is an issue of great concern which needed to be dealt with serious effort. However, SW being a menace of concern, but highly economically profitable for national development, can serves as a source for renewable energy resources through ISWM to extract CH_4 gas. Eliminating SW in Nigeria means a future for greater economic developments and the educational systems, as well as a major shift from oil base energy resource to clean, sustainable and renewable biofuel energy resources. This is evident as a total of 1285 LFG extraction system are available in Europe and US, which produces 33% of their energy demands.

Similarly for an increased waste generated in 2020, its extraction peak production period is 1–30 yrs. of continuous energy harvesting *table 4, figure 5* and *7* respectively. It can be referenced in here that integrated dump sites will start to yield CH_4 gas for harvesting as LFG effective from 1-3 yrs. period. While the highest CH_4 gas production begins from 5-7 yrs. Once the wastes are completely being disposed on landfill sites. Virtually all required gases are generated for harvesting within 20 yrs. of waste disposal. Nevertheless, as from, 50 yrs. and above, landfills will continuously emit smaller quantity of available gas. However, the volume of gas production start to decline gradually after 20 to 30 yrs. depending on the quality of wastes nature available on the landfill. While for non-biodegradable wastes RDF, these wastes are collected from initial screening of waste and are utilized directly through, W-t-E plants for total conversion to produce heat in agro-farms, domestics, industries and for power electricity generation in power plants. This implies therefore, there's no waste in solid wastes but a complete resource for economical and national development of our Nations at large.

7.0 Recommendation

1) Looking at the current scarcity and the hike in energy demand, it's hereby recommended that LFG and RDF resources are sustainable alternative renewable energy source that requires prompt government and various stakeholder's investment to promoting cheap and clean energy source through MSW disposal;
2) It's equally important for the government and the various stakeholder's to holistically invest in RRR to boost raw material source for various businesses as well as the manufacturing industries;
3) Similarly, this research is calling on to the agricultural sectors to as well invest in MSW management to harvesting non-fuel and non-RDF compost putrescible waste as manure for agricultural developments;
4) It's also herby recommended that all the non-recyclables, no-fuel and non-RDF waste materials should be utilized by the construction industries for fillings in structural construction, or ecological reclamation of lands due to erosion, mining activities and or other menace; and
5) Finally, further R&D should be carried out to exploit the extracted leachate fluid for the development of bioremediation of contaminated hydrocarbon soils.

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