ISSN No:-2456-2165

Energy Prospect of Nigeria's Municipal Solid Waste

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Abstract:- Waste is an indispensable part of human life. Biological, Medical, Agricultural, Industrial, Domestic wastes are generated continuously across races and places on the planet. It certainly cannot be eliminated but can be profitably managed.

As a by-product of human and economic activities, waste could be in the form of Gas (Vented gas/Flare), liquid (Effluent/leachate) or Solid (Municipal Solid Waste/particulates).

Waste (which typical has large content of Solid part) which might have seemingly been of no significance a while ago is now being recognised as a wealth. By research and technological innovations, heap of waste is presently sought in the modern world as a valuable resource for energy derivation. Countries like Norway and Germany import waste for energy generation[6].

Nigeria recent population estimate hovers around 203 Million[10]. This populace generates an annual solid waste of more than 32 million tonnes of which only about 20% -30 % is collected for treatment/management; the remaining proportion is recklessly disposed[12].

Nigeria can minimize waste by intensely exploring waste control measures such as Reducing, Reusing, Recycling or the Nation can maximally tap from the enormous energy potential of waste via multiscale/ large-scale recovery mechanism & systems.

This paper evaluates the power resource value of Nigeria's Municipal Solid Waste. It also captures Solid Waste recovery strategies in place in Nigeria and how the country could optimally exploit the man-made 'filth' for her economic gains by emulating benchmarked practices.

I. INTRODUCTION

Municipal solid waste is defined as household waste, commercial solid waste, non-hazardous sludge, conditionally exempt, small quantity hazardous waste, and industrial solid waste (EPA-530-R-95-023 1995). MSW includes food waste, rubbish from residential areas, commercial and industrial wastes, and construction and demolition debris[3].

Though Solid waste have been traditional landfilled or combusted, modern techniques of waste management now includes reduction, reuse, recycling and recovery.

Reduction of Waste, Reuse of Waste and Recycling of Waste are basically waste management techniques aimed at reducing energy consumption level. However, realities have emerged that Energy can be derived directly from waste via controlled Recovery method.

For a Standard Waste Management practice, after primary resource recovery from Waste, a secondary energy resource recovery would be carried out during combustion/incineration.

Below is a flow chart diagram illustrating the overall Waste Management process.

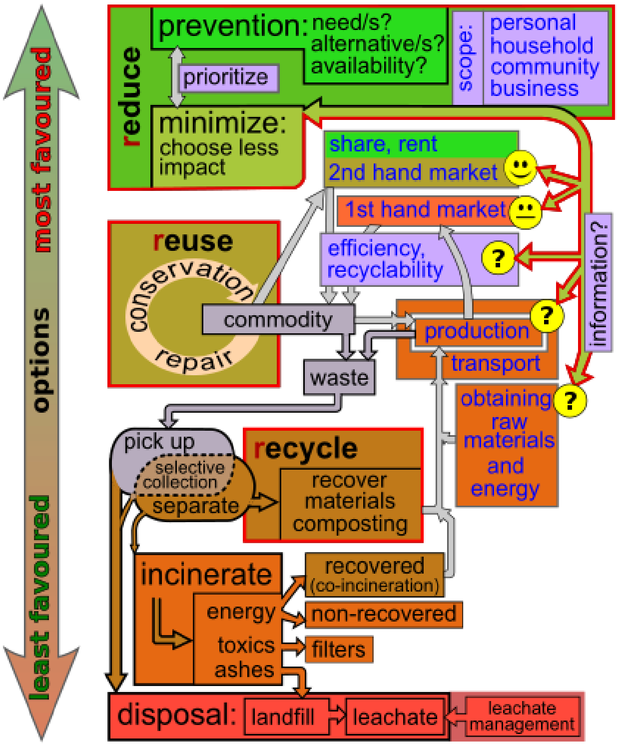

Fig 1:- Diagram of Waste Hierarchy
(Source: Wikipedia[14])

The diagram indicates recovery of material and Energy could be achieved after separation (or segregation) of waste and incineration/composting respectively. At that point, a Waste-to-Energy Installation is vital for recovery of Energy form Waste via incineration.

➢ *Waste-to-Energy*

Waste-to-Energy (WTE) or energy-from-waste is the process of generating energy in the form of electricity and/or heat from the incineration of waste[11].

Below is the Schematic diagram on the Process involved in harnessing Energy from Waste.

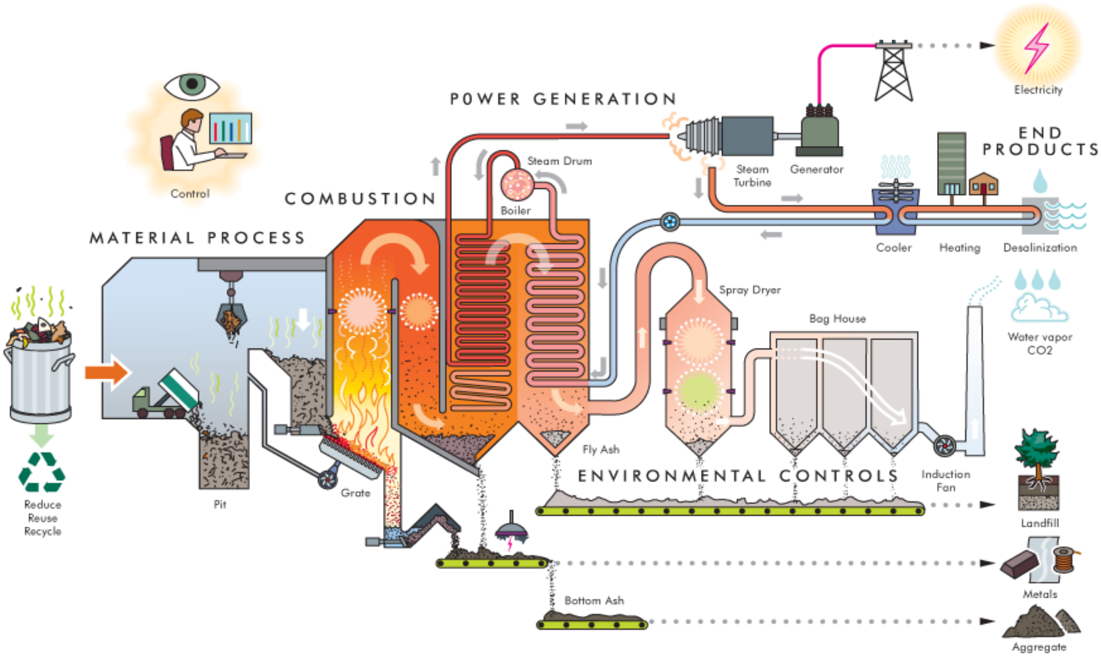

Fig 2:- Waste to Energy Incineration Plant Diagram
(Source: Green Living Answers[5])

➢ *Waste-To-Energy Technology*

Proven technologies used for Derivation of Energy from Waste consists:

- Thermal Technology (Direct Combustion): Mass Burn & Refuse Derived Fuel
- Pyrolysis
- Gasification: Conventional and Plasma Arc types

Tabulated below are short descriptions of the technologies

Technology	Description
Thermal Technology: Mass Burn and Refuse Derive Fuel	Mass Burn is the process of completely burning the waste while getting a residue of non-combustible material. Useful Heat energy is generated during the burning
	Refuse Derived Fuel (RDF) is the process of removing the recyclable and non-combustible from the municipal solid waste (MSW) and producing a combustible material, by shredding or pelletizing the remaining waste[11].
Pyrolysis	Thermo-chemical decomposition of organic material, at elevated temperatures without the participation of oxygen[11]. The process involves the simultaneous change of chemical composition and physical phase that is irreversible[11]. Pyrolysis occurs at temperatures >750°F (400°C) in a complete lack of oxygen atmosphere[11]. The syn-gas that is produced during the reaction is generally converted to liquid hydrocarbons, such as biodiesel[11]. By-products from the process are generally unconverted carbon and/or charcoal and ash[11].
Gasification	Conventional Gasification is the thermal conversion of organic materials at temperature of 1,000 °F – 2,800 °F (540 °C – 1,540 °C), with a limited supply of air or oxygen (sub-stoichiometric atmosphere)[11]. This is not combustion and therefore there is no burning[11]. Gasification uses a fraction of the air/oxygen that is generally needed to combust a given material and thus creates a low to medium Btu syn-gas[11].
	Plasma Arc Gasification is the process that utilizes a plasma torch or plasma arc using carbon electrodes, copper, tungsten, hafnium, or zirconium to initiate the temperature resulting in the gasification reaction[11]. Plasma temperature temperatures range from 4,000 °F – 20,000 °F (2,200 °C – 11,000 °C), creating not only a high value syn-gas but also high value sensible heat[11].

Table 1:- Description of WTE Technologies

Another Waste-to-Energy Technology which is not common compared to the Thermal/Composting technology is Landfill Gas Collection

The Landfill Gas, which is mostly Methane, is collected from Landfill Sites for applicable energy use.

Of all the technologies listed above, the thermal process(incineration/combustion) is most popular.

With the concept of Waste-to-Energy Process extensively outlined above, let us X-ray Nigeria's Initiatives/Models put in place to recover Energy from Waste

II. BACKGOUND

Solid waste management in Nigeria is characterized by inefficient collection methods, insufficient coverage of the collection system and improper disposal[9]. Disposal in most Nigeria cities include, co-disposal of hazardous and municipal waste in open, unlined dumps, open burning of municipal solid wastes, dumping on water bodies and in other unauthorized places[9].

The Federal Ministry of Environment of Nigeria has over the years embarked on intervention programmes to assist the state and local governments manage their municipal solid waste in environmentally sound and sustainable manner[9].

Public private partnership Project to build an Integrated Waste Management Facility with various components such as Sanitary Landfill, Scrap Metal Recovery & Recycling Plant, Material Recovery Facility, Plastic Recycling Plant, Compost Plant, Leachate Treatment Plant, Biomedical Waste Incinerator etc., is slowly underway in Nigeria due to inadequate funding[9].

Eight incinerators have been installed and commissioned at eight federal medical institutions spread across the country while Installation is on-going in about other fifteen federal institutions[9].

Despite the efforts/initiatives, the Nation's Waste-to -Energy conversion rate is currently insignificant compared to the tonnes of waste routinely generated.

Based on current realities such as poor collection efficiencies, Nigeria's exploitable Waste-to-Energy capacity from Municipal Solid Waste is below 3800 GWh/year, with all the states having less than 50 MW capacity.

ISSN No:-2456-2165

Nigeria is expected to launch unto the full Energy prospect of her annually generated waste via aggressive approaches & Mechanisms. Details of the Method/Derivations subheading below gives a hint at the Quantity of Energy derivable from Nigeria's Solid Waste.

III. METHOD/DERIVATIONS

Energy content of Waste is calculated by determining the calorific value (CV) of the composition of referenced waste.

The table below shows the heat content (or calorific value) of different material a waste could be composed of.

Type of material	**CV (MJ / kg)**	**CV (kCal / kg)**
Medical waste	19 - 24	4540 - 5735
Industrial & hazardous waste	22 - 40	5257 - 9558
Domestic waste (without recycling)	7 - 16	1673 - 3823
Domestic waste (after recycling)	10 - 14	2389 - 3345
PVC	41	9797
Dry wood	14,4	3441
Paper	13,5	3226

Table 2:- Calorific Value of Waste Composition
(Source: Igniss Energy[7])

Based on trend of generated waste composition along with corresponding Calorific content, some National/international energy organizations have valued the energy content of specific Municipal Solid Waste Volume.

Source(s) of Data that are used for computing the Energy content of Nigeria's yearly waste are highlighted next.

➢ *Data Sources*

According to a US Department of Energy Document, 138 Million short tons of Municipal Solid Waste has about 1.4×10^{15} British Thermal Unit (1.4 quadrillion Btu) fuel value associated with it[3].

Also, an Energy Information Administration May 2007 Publication indicates one (1) Ton of Municipal Solid Waste has an average range value of 10 -11 Million British Thermal Unit[4].

➢ *Computation*

By making proportionate computations, Nigeria can extract up to 358 trillion Btu fuel Value from more than 32 Million tons of Waste generated annually by her populace if managed properly.

The following table shows source/factor(s) used to calculate the British Thermal Unit (Btu) Fuel Value of Nigeria's Waste produced yearly.

	Waste Volume (in tons)	Waste Volume (in short tons)	British Thermal Unit (BTU) Fuel Value of Waste	Factor(s)
US Data		138 Million	$1.4 * 10^{15}$	
Nigeria	32 Million	35.28 Million	$358 * 10^{12}$	[1 short ton = 0.907 ton]

Table 3:- Nigeria's Waste British Thermal Unit Fuel Value; including Computation Factors

In terms of Electricity, an electric energy worth 105 Terawatt-Hour (Twh) could be obtained from Nigeria's annual waste generated. However, considering 25% conversion installation inefficiency, about 26 TWh of energy could be realized from the load of Waste shunned out yearly.

Highlighted in the table below are the factors considered for arriving at the 26 TWh Energy value.

British Thermal Unit (BTU) Fuel Value of Waste	Waste Energy Content equivalent in Watt-Hour Unit	Waste Energy Content (considering average Waste-to-Energy Installation efficiency)	Factor
$358 * 10^{12}$	105 Terawatt-Hour (Twh)	26 Terawatt-Hour	[1BTU = $293.07 * 10^{-6}$ Kwh]
Factor *Incineration conversion efficiency for Electricity generation[1]: 15-27% (21% average)* *Gasification Efficiency[1]: 30%* *Hence, 25% typical average efficiency of WTE Plant (Incineration & Gasification combined) used*			

Table 4:- Nigeria's Waste Electrical Energy Equivalent (in Watt-Hour unit); including Computation Factors

Considering a population of 203 Million[10], Nigeria could generate an annual Energy per Capita value of 128 Kwh from Waste alone via engagement of modern/efficient waste management techniques.

IV. DISCUSSION/RECOMMENDATION

Energy available to an individual determines to what extent such individual would contribute to the economic wellbeing of his/her society or Nation. Consequently, a country's Energy per Capita Index largely depicts the prosperity of the Country.

Currently, Nigeria has less than 150 Kwh per capita index while countries or regions that have developed robust & sustainable energy mix (waste inclusive) such as Europe has about 5,000 Kwh per capita mean value.

To develop a robust Energy base and partly achieve Energy Security, Nigerian should invest in and sustain widespread Waste-to-Energy technologies; especially the commonly used modern thermal technology(incinerators).

Policies and Regulations that have potentials to bolster efficient Waste Management and Waste-to-Energy implementations at domestic and industrial levels should be formulated and enforced.

V. CONCLUSION

Nigeria stands a chance of generating up to 3 GW of Electricity power per year from waste turned out via domestic/economic activities.

By exploiting modern & world-class waste management principles & technologies, the Country's ambition of generating 20,000 Mega-Watts (20 GW) of power and securing uninterrupted power supply for the citizens would be integrally achieved.

REFERENCES

[1]. Anu Antony (October 2017), *What are some of the latest waste-to-energy technologies available?;* available at https://www.prescouter.com/2017/10/waste-to-energy-technologies-available [Accessed online on January 07,2020]

[2]. Babayemi J.O., Dauda K.T. (2009); *Evaluation of Solid Waste Generation, Categories and Disposal Options in Developing Countries: A Case Study of Nigeria;* J. Appl. Sci. Environ. Manage. September 2009 Vol. 13(3) 83 - 88, Available Online at www.bioline.org.br/ja

[3]. C Valkenburg, CW Walton BL Thompson, MA Gerber, SB Jones, DJ Stevens (December 2008), *Municipal Solid Waste (MSW) to Liquid Fuels Synthesis, Volume 1: Availability of Feedstock and Technology*; Prepared for the U.S. Department of Energy under Contract DE-AC05-76RL01830 [PNNL-18144]

[4]. Energy Information Administration (May 2007), *Methodology for Allocating Municipal Solid Waste to Biogenic and Non-Biogenic Energy*; published by Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, U.S. Department of Energy, Washington DC 20585; Pg 6

[5]. Green Living Answers (@2020 Green Living Answers), *Is Waste to Energy Incineration a Viable Option*: available at https://www.greenlivinganswers.com/archives/138 [Accessed online on January 06,2020]

[6]. Helen Russell (June 2013), *Trash to cash: Norway leads the way in turning waste into energy*: available at https://www.theguardian.com/environment/2013/jun/14/norway-waste-energy [Accessed online on January 06,2020]

[7]. Igniss Energy Incineration Technology, *Calorific Value (CV) of Waste*, available at www.igniss.com/calorific-value-waste [Accessed online on January 06,2020]

[8]. Maduka Nweke (December 28,2016), *Waste management: Lagos unveils new strategies:* available at https://www.sunnewsonline.com/waste-management-lagos-unveils-new-strategies [Accessed online on January 06,2020]

[9]. Olori Olufunke Babade, *Status of Solid Waste Management in Nigeria (Including Plastic);* UNEP-POPS-CW.2-CP06.En

[10]. PopulationStat world statistical data(@Population Stat, 2017-2020), *Nigeria Population*: available at https://populationstat.com/nigeria [Accessed online on January 06,2020]
[11]. Thomas Stringfellow(2014), *An Independent Engineering Evaluation of Waste-to-Energy Technologies:* available at https://www.renewableenergyworld.com/2014/01/13/an-independent-engineering-evaluation-of-waste-to-energy-technologies [Accessed online on January 06,2020]
[12]. Wale Bakare (April 04,2019), *Solid Waste Management in Nigeria*: available at https://www.bioenergyconsult.com/solid-waste-nigeria [Accessed online on January 06,2020]
[13]. Wikipedia(December 16, 2019), *List of Countries by Electricity Consumption*; available at https://en.m.wikipedia.org/wiki/List_of_countries_by_electricity_consumption [Accessed online on January 16, 2020.
[14]. Wikipedia (January 06, 2020), *Waste Management*: available at https://en.wikipedia.org/wiki/Waste_management [Accessed online on January 06,2020]