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Estimating MSW Energy as Alternative Fuel Support for Sustainable Power Generation in Nigeria

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ABSTRACT

One of the challenges facing power industries in Nigeria today is shortage of gas supply to power thermal and steam turbine in electricity generating stations which has resulted in low generating capacity relative to installed capacity by most of these companies. This paper attempt to estimate capacity of energy value that could be realized from domestic waste using geometrical model and 2006 population data in the country. With per capita waste generation and specific value of waste to energy conversion through waste to energy technologies, the findings revealed that, municipal solid waste (MSW) could be an alternative fuel to thermal stations and enhance sustainable electricity production if properly managed. For projected population of over 255millions by the year 2025, an estimated 60 534 742 tons of domestic waste, 9 240MW of energy, over U\$2.9billion in the same period could be realized. This power value is estimated to be around 136%, 264-205%, 93% and 37% of present installed capacity; present electricity generation capacity; current potential demand and long term power demands of the country respectively. The significance of this study shows that huge amount of energy in the form of electricity, gas, and heat locked in organic part of MSW is been wasted on daily basis that could have being used in power generating industries. One of the recommendations is to engage professional waste management agencies by investing in waste to energy technologies.

Keywords: Electric energy, Electric power, Municipal solid waste, per capital waste generation, Population projection and Thermal technology.

1.0 INTRODUCTION

United Nation (2012) reported that the 2013 world population was about 7.2 billion and is projected to increase by 1 billion by the year 2025 with an average growth rate of 1% per year. It further revealed that the growth will be mainly in developing countries, with more than half in Africa. Urban population increases at a higher rate than population growth where the

world urban population is expected to grow roughly 1.5% per year in the same period (Omar & Syed, 2014). The increase in urban population will be mainly in developing countries, with majority in Asia, where industrialization has caused population shift from villages to cities.

Comparatively, Nigeria is the most populous country in Africa (UN, 2012). Nigeria 1963,

1991 and 2006 Population and housing Census placed the country's population at 55.7, 88.9 and 140.4 million with a national growth rate estimated at 3.2% per annum (Nigeria, 2013).

In this present work, application of geometrical model projected Nigeria population to be around 242million by the year 2025 at annual growth rate of 3% in the same period and is expected to be around 428million by the year 2050 which would be a significant amount in Africa and World population.

The above implication as reported by Sharholy *et al*, (2008) and Ouda, (2013) is that Population growth, urbanization, and the increase in the standards of living are the three ingredients that govern the increase of municipal solid waste (MSW) generation. Current global MSW generation level is 1.3 billion tons per year, and is expected to increase to approximately 2.2 billion tons per year by 2025(Urban Development Series-Knowledge Papers 2012). MSW generation, in terms of kg/capita/day, has shown a positive correlation with economic development at world scale (Rajendra *et al*, 2012).

Therefore, Management of MSW resulting from rapid urbanization has become a serious concern for government departments, pollution control agencies, regulatory bodies and public in most of the developing countries (Glawe *et al*, 2005; Erdogan *et al*, 2008).

High standards of living and ever increasing population have resulted in an increase in the quantity of wastes generated (Rajkumar *et al*, 2010, Anoop *et al*, 2016 and Rajasekhar *et al*, (2015).

Waste generation has been observed to increase annually in proportion to the rise in population and urbanization (Rajendra *et al*, 2012; Sharholy *et al*, 2008 and Ouda, 2013).

To this end estimation on the quantity and characteristics of MSW and its forecasting over the planning period is the key to a successful management plan (Rajendra *et al*, 2012).

However, it is important to realize that MSW contains organic as well as inorganic matter. The latent energy present in its organic fraction can be recovered for gainful utilization through application of suitable Waste Processing and Treatment technologies. This technology includes Thermo-chemical and Bio-chemical conversion (Tsunatu *et al*, 2015).

Currently many countries are exploring the potential of waste to energy (WtE) technologies to export electricity to their national grids. For instance, Malaysia with MSW projection of 36,165tones per day by the year 2022 (Alireza *et al*, 2016) produces 7Million tones in 2010 due to its growing economy and GDP (Alireza *et al*, 2016). It also generated 5.5MW of electricity from MSW in 2009 and is expected to rise to 360MW by 2022 (Alireza *et al*, 2016).

Also, in a period of less than twenty years, China has become a major actor in the implementation of WtE technologies for managing MSW, at the present time, an estimated 15% (23 million tons of MSW) are processed in over 100 WtE plants furthermore, in Lujiashan incineration plant (Asia's largest MSW incineration power generation project) underwent trial operation and eventually supplied 320 million kWh of electricity to the grid per year (Alireza *et al*, 2016).

Similarly in Dakar city, Bangladesh electricity generation potential estimation was 456,900MWh in 1995 which increases to 1,894,400MW in 2025. Mohammad and Kenneth, (2012) report indicates that, the rate of production of MSW in Jordan has been estimated at about 1,960,000 tons annually with an average generation rate of 0.95 kg/cap/day in urban and 0.85 kg/cap/day in rural areas. The electricity generated was around 2.62GWh.

Using WtE technologies, analysis of MSW to energy generation in India and calculation of state-wise potential and tariff comparison with EU shows that India has potential to generate close to over 3000MW of energy from MSW by 2020 (Rajendra *et al*, 2012).

Renewable power generation opportunity from MSW has been studied for Lagos metropolis (Nigeria). Anupam *et al*, (2010) is of the view that estimation and prediction of municipal solid waste generation play an important role in municipal solid waste management. It is then evident to present WtE technologies as an attractive option to solve not only the pressing waste disposal problems, but several other challenges simultaneously: shortages in gas require for power generation, limited space for landfills, and greenhouse gas emissions from inappropriate waste disposal. The objectives of this research work therefore, is to estimate the amount of energy that could be generated through WtE technology.

2.0 METHODOLOGY

Data pertaining to estimating potential energy of municipal solid waste in this study were secondary data from 1991 and 2006 house to house population censuses for each state of Nigeria. The state wise potential of MSW to Energy has been calculated using value of MSW to WTE technology taken from literature reviews of several papers. With projected population census figures for the years 2025 computed through empirical relation of Ayman (2012) with average of 0.65kg/capita/day for sub-Sahara Africa (World Bank, 2015) and a ton of MSW to 550kwh (ASME, 2008) an estimated amount of waste and equivalent energy values were computed for each state per year. The empirical relations used for population projection is:

$$P_t = P_0 (1 + r)^t$$

P₀ = base population,
 P = projected population,
 P_t = recent population,
 t = time after the last census and
 r = growth rate.

2.1 Energy Conversion Processes of MSW

Gasification is an old technology used for the production of energy from solid materials. Generally, gasification has been used for the conversion of carbonaceous materials into a gaseous product for the production of energy products and byproducts in an oxygen starved environment. The carbonaceous material, whether from Municipal Solid Waste (MSW) or other sources, is processed in an oxygen deficient environment with heat to produce a Syngas comprised mostly of Carbon monoxide (CO) and Hydrogen (H₂). Chemical bonds of the carbonaceous materials (complex chemical compounds) break down with heat to produce the simpler and thermodynamically stable gaseous molecules of Carbon monoxide (CO) and Hydrogen (H₂). The inorganic or “mineral” materials are converted to a solid rock like material, called slag or vitrified slag or ash. A typical process for the gasification of Municipal Solid Waste (MSW) to Syngas, energy, products and byproducts is illustrated in Figure 1. The organic components of MSW are converted into Syngas, primary product, and the mineral components are converted into slag or vitrified slag or Ash, a byproduct. For some gasification processes, some (limited) amount of oxygen is supplied to the gasification reactor to provide heat in the form of combustion heat necessary for the oxygen deficient reactions to produce Syngas, which are endothermic reactions. Sufficient steam/water is supplied to the gasification reactor to promote some Syngas reactions.

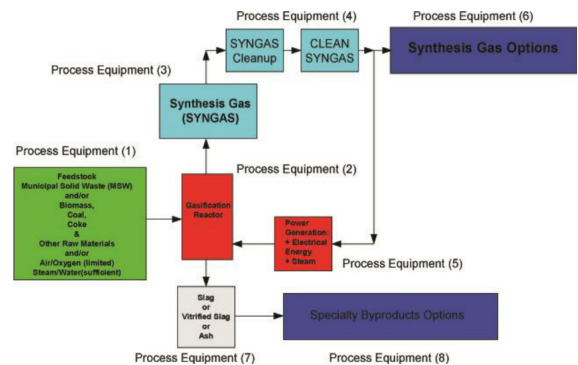


Figure 1: Syngas (CO & H₂) Process Options adapted from (Gary C.Y, 2010).

For energy conversion processes, several basic process approaches (options) exist for the Syngas produced from the management of Municipal Solid Waste (MSW). These Basic process approaches are as follows: Power Options, Chemistry Options and Bio-chemistry Options.

Options denote the various uses of the Syngas such as the production of electricity and/or steam in the “Power Option.” Process Options for Syngas are shown in Figure 2.

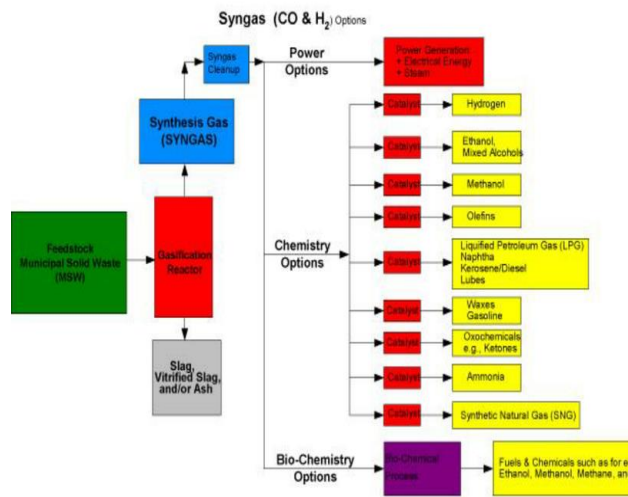


Figure 2: Syngas (CO & H₂) Process Options adapted from (Gary C.Y, 2010).

MSW energy demand projections rose from 5 140MW in the base year to 9 240MW by the year 2025. This projected value is 11.9% of electricity projected demand by 2025 with reference (7%) GDP growth rate as computed by Sambo (2008) using IAEA modeling tools.

The country’s electricity consumption per capita as measured by world bank at 149kwh (Agusto, 2014), implies that if all the estimated MSW by 2025 were to be processed by waste to energy plant of capacity 550kwh per ton (ASME, 2008), without loss due to generation, transmission and distribution, the projected 9 240MW electric power could generate enough electricity to supply close to 225 365 884million Nigerians.

Nickolas *et al.* (2014) reported that every ton of MSW combusted for electricity generation in recently built WTE plants replaces an estimated 0.4 tons of coal. Therefore an estimated 60 534 742 tons of MSW in the country by 2025 will save the mining of 242 13 897 tons of coal that would be used in thermal turbine plants for the generation of electricity.

With electric power tariff of ₦31.58 per Kwh (Okechukwu, 2017) projected 9 240MW by 2025 with estimated cost of this energy will be over US\$2.9billions at exchange rate of a USD to 360 Naira.

Analysis by world energy council (2010) shows that average household electricity used per year in Nigeria stands at 570kwh which is lower than world average of 3500kwh. With this projected power of 9 240MW, 58 357 894 million households would be powered per year.

Kano and Lagos are two states showing an escalated growth in population having projected populations of 18 007 745 and 16 519 813million by 2025 with same future potential waste projection of 4272337 and 3919326 tons having potential power generation potential from MSW as 653MW and 599MW. Each projected

3.0 RESULTS AND DISCUSSION

Table 1: Compacted table of Secondary and Generated Data

State Names	**Base Population Census (millions)	Current Available Data as of 2006		Energy Value Per year (MW)	Growth Rate (%)	Projected Population (Millions)	Projections for 2025		Energy Value Per year (MW)
		Waste Generation Per Capita (Kg/Capita/day)	Total (tons/year)				Projected Waste Per Capita (Kg/Capita/day)	Total (tons/year)	
Abia	2,845,380	1,849,497	675,066	103	1.45	3,740,497	2,431,323	887,433	136
Adamawa	3,178,950	2,066,318	754,206	115	2.74	5,312,946	3,453,415	1,260,496	193
Akwalbom	3,902,051	2,536,333	925,762	141	3.39	7,351,655	4,778,576	1,744,180	267
Anambra	4,177,828	2,715,588	991,190	151	0.028	7,034,192	4,572,225	1,668,862	255
*Bauchi	7,018,106	4,561,769	1,665,046	254	3.31	13,029,411	8,469,117	3,091,228	473
Benue	4,253,641	2,764,867	1,009,176	154	2.88	7,295,398	4,742,009	1,730,833	264
Borno	4,171,104	2,711,281	989,618	151	3.23	7,630,687	4,959,947	1,810,381	277
Cross river	2,892,988	1,880,442	686,361	105	2.97	5,044,872	3,279,167	1,196,896	183
Delta	4,112,445	2,673,089	975,677	149	0.025	6,574,361	4,273,335	1,559,767	238
Edo	3,233,366	2,101,688	767,116	171	2.74	5,403,890	3,512,529	1,282,073	196
*Enugu	5,444,784	3,539,110	1,291,775	197	3.68	10,818,958	7,032,323	2,566,798	392
Imo	3,927,563	2,552,916	931,814	142	3.10	7,015,293	4,559,941	1,664,379	254
Jigawa	4,361,002	2,834,651	1,034,648	158	2.92	7,534,979	4,897,736	1,787,674	273
Kaduna	6,113,503	3,973,777	1,450,429	222	2.92	10,562,967	6,865,929	2,506,064	383
Kano	9,401,288	6,110,837	2,230,456	341	3.48	18,007,745	11,705,034	4,272,337	653
Katsina	5,801,584	3,771,030	1,376,426	210	2.74	9,696,126	6,302,482	2,300,406	351
Kebbi	3,256,541	2,11,6752	772,615	118	3.10	5,816,627	3,780,808	1,379,994	211
Kogi	3,314,043	2,154,128	786,257	120	3.10	5,919,333	3,847,567	1,404,362	215
Kawara	2,365,353	1,537,480	561,180	86	2.78	3,982,535	2,588,648	944,857	144
Lagos	9,113,605	5,923,843	2,162,203	330	3.18	16,519,813	10,737,878	3,919,326	599
Niger	3,954,772	2,570,602	938,270	143	3.14	7,116,015	4,625,410	1,688,275	258
Ogun	3,751,140	2,438,241	889,958	136	3.18	6,799,520	4,419,688	1,613,186	247

Table 1 Continuation

State Names	Current Available Data as of 2006				Growth Rate (%)	Projected Population (Millions)	Projections for 2025		Energy Value Per year (MW)
	**Base Population Census (millions)	Waste Generation		Energy Value Per year (MW)			Projected Waste		
		Per Capita (Kg/Capita/day)	Total (tons/year)			Per Capita (Kg/Capita/day)	Total (tons/year)		
*Ondo	5,859,834	3,808,892	1,390,246	212	2.78	9,866,179	6,413,016	2,340,756	358
Osun	3,416,959	2,221,023	810,673	124	2.97	5,958,587	3,873,082	1,413,674	214
Oyo	5,580,894	3,627,581	1,324,067	202	3.18	10,116,231	6,575,550	2,400,076	367
*Plateau	5,075,908	3,299,340	1,204,259	184	2.97	8,851,508	5,753,480	2,100,020	321
*River	6,903,231	4,487,100	1,637,792	250	3.72	13,817,837	8,981,594	3,278,282	501
*Sokoto	6,981,549	4,538,007	1,656,373	253	3.14	12,562,243	8,165,458	2,980,392	445
Taraba	2,294,800	1,491,620	544,441	83	2.97	4,001,736	2,601,128	949,412	145
Yobe	2,321,339	1,508,870	550,738	84	3.39	4,373,516	2,842,785	1,037,617	159
Abuja	1,406,239	9,14055	333,630	51	1.09	7,396,020	4,807,413	1,754,706	268
TOTAL	140,431,790		33,317,468	5140		255,151,677	60,534,742	9240	

*State Splited and **Secondary data obtained from NPC, 2006

Table 2: Nigeria Energy Status

PRESENT ENERGY STATUS	ENERGY CAPACITY (MW)
Present Electricity Generation	6,803
Available Energy	4,500
Installed Electricity Generation	12,522
Average Daily Power Generation	Below 2,700
Electricity Peak Load Forecast	8,876
Current Range of Electricity Generation	3,500 – 4,500
Long Term Power Demand	25,000

Source: Adebayo *et al*, 2017 and Prime Time

Table 3: Secondary Data of Some Selected State and Projected Waste, Energy, Percentage And Energy Cost

NIPP Project in Nigeria			Projection for 2025			
Name	Location	***Installed capacity (MW)	Waste (ton/year)	Energy (MW)	Percentage in NIPP	Energy Cost (M)
Aloji	Abia state	1074	887,433	136	Over 12%	US\$42.9
Calabar	Calabar, Cross River	634.5	1,196,896	183	Over 28%	US\$57.8
Egbema	Near Oweri, Imo state	380.7	1,664,379	254	Over 6%	US\$80.2
Gbarain	Near Yenogoa, Bayelsa state	253.8	-	-	-	-
Geregu II	Ajaokuta, Kogi state	506.1	1,404,362	215	Over 42%	US\$67.9
Ihovbor	Benin city, Edo state	507.6	1,282,073	196	Over 38%	US\$61.9
Olorunsogo	Olorunsogo, Ogun state	754.0	1,613,186	247	Over 32%	US\$78.0
Omoku II	Near port Harcourt, River state	264.7	3,278,282	501	Over 189%	US\$158.2
Omolosho	Okitipupa, Ondo state	512.8	2,340,756	358	Over 69%	US\$113.1
Sapele	Sapele, Delta state	507.6	1,559,767	238	Over 46%	US\$75.2

***Source: www.nipptransactions.com, United Capital

power generation from MSW of these two states could support energy demand of the two growing economies with capacity bigger than any installed capacity of independent power plant in the country (United capital, 2017) but with few exceptions as indicated in table 3. Projected powers are over 4.7% and 13% of installed electricity generation in table 2.

Bauchi, River and Sokoto with projected population counts as indicated in the table 1 above with potential power projections of 473, 501(equivalent to US\$158.2M) and 455MW respectively above capacity of Gborain and Omoku II power plants in Yenagoa, Bayelsa state and River state (United capital, 2017) which are over 3.6 and 10% of installed electricity generation and available energy in table 2. The electricity projection capacity from MSW in River state is bigger than Omoku II independent power plant of installed capacity of 264.7MW as put in table 3.

Kaduna, Enugu, Kastina, Ondo, Oyo and Plateau, each with estimated electric powers generation for these states are 383, 392, 358, 367(equivalent to US\$113.1M) and 321MW by the end of 2025. These powers are over 2.5% and 7% of installed electricity generation and available energy as reported in table 2. MSW electricity potentials capacities for these states are greater than in Gborain and Omoku II (United capital, 2017). The same value of power from MSW for Ondo state is lower than installed capacity of omoloshio independent power plant at Ondo by around 72% (United capital, 2017).

Anambra, Akwa Ibom, Benue, Borno, Delta, Imo, Jigawa and Niger, electric power projections are 255, 267, 264, 277, 238(US\$75.2), 254 (US\$74.7M), 273 and 258MW by the year 2025. These powers are over 1.9% and 5.2% installed electricity generation and available energy as shown in table 2. With exception of Delta state all the projected powers have capacities greater than Gborain independent power plant (United capital, 2017). The projected power generations from MSW for Delta and Imo state are 47% and 67% of independent power plants in sapele II and Egbemo (Table 3).

Adamawa, Edo, Kebbi, Kogi, Ogun, and Osun each would have the potential projections of 1260496, 1282073, 1379994, 1404362, 1613 and 1413674 tons of MSW by the year 2025 with estimated electric power generation potentials of 193, 196 (US\$57.6M), 211 (US\$63.2M), 247 (US\$72.6M) and 214MW. These are over 1.5% and 4.2% of installed electricity generation and available energy (Table 2). The projections electric power from MSW from the two states Edo, Kogi and Ogun are around 39%, 49% and 33% of Ehovbor, Geregu II and Olorunsogo independent power plants (United capital, 2017).

Abia and Cross River state, each could generate 887433 and 1196896 tons from its MSW with power generation projection of 136MW (US\$40.0M) and 183MW (US\$53.8M) by 2025. These projected output power from MSW is over 1% each of the installed electricity generation and available energy (Table 2). The same MSW electricity projection for Abia state is greater than installed capacity power plant at Alaojo by over 126%. MSW power estimation for cross river state is lower than installed capacity of independent power plant at calabar by approximately 29% (Table 3).

Yobe, Taraba, and Kwara each would produce 1037617, 949412 and 944857 tons of MSW. This could generate 159, 145 and 144MW of power by the year 2025. The value of these powers is over 1% and 3.2% of installed electricity generation and available energy (Table 2). All these values of projected power by 2025 are less than installed capacity independent power plants as recorded in table 3 above.

Abuja the present seat of governance with tendency for continuous increase in population would produce 1754706tons of the MSW is projected to generate from MSW 268MW by 2025. This value of power is over 2.1 and 5.9% of installed electricity generation and available energy (Table 2).

5.0 CONCLUSION

MSW energy demand projection estimations in these studies indicated that huge amount of energy that could enhance in the production of electricity, gas, and heat is locked in MSW is being wasted on daily basis due to our population explosion which could have been transformed into millions of dollar investment of over US\$2.9billion though waste to energy technologies. With over 60million tons per year of MSW and over 9000MW of power per year and, since energy is the key for any economic drive, diversification and sustainable economic development one can confidently put forward that Nigeria is losing prospective organic resource by way of improper MSW management system which include separation, disposal, recycling and use of application of waste to energy technologies. It is therefore necessary to harness the locked energy resource from the organic fraction of MSW to reduce not only volume of waste in the community, but pressing waste disposal problems.

6.0 RECOMMENDATIONS

There is need to privatize waste management system in the country by engaging professional firm in waste to energy technologies. Also, studies should be carried out on characterization and composition of Nigeria waste and its calorific value for potential of generating energy. Ministry of environment through National orientation agency should sensitize the public on proper way to waste disposal practice.

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