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WASTE TO ENERGY PROJECT IN CALABAR

School of Technology
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ABSTRACT

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Waste disposal has been a challenge to developing countries mostly in Africa which has caused problems to the inhabitants and the environment they live in. But with the impact of technology various methods to combat waste has been put in place ranging from recycling to waste to energy either through bio process or incineration process.

The aim of this project was to show how an effective waste incineration plant can help to tackle the issue of waste disposal in developing countries, especially Calabar in Cross River State of Nigeria, to improve access to electricity and reduce pollution and help to reduce the case of malaria as it will eliminate breeding grounds for the mosquitos which cause malaria.

The research was done to ascertain the amount of waste that could be gathered to ensure that the project will be profitable for the government to invest in. The findings obtained from the research proved that the project had benefits both financially and to the environment at large.

This project will serve as a wakeup call to other states in the country and they will follow this path to eliminate waste and have a pollution-free environment that is caused by an open waste site that exists within the cities.

Keywords Waste, energy, environment, incineration, electricity

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1 BACKGROUND

There has been an increasing need for electricity and cooling in some parts of the world recently due to the high rate of development. This has been a problem for developing countries in Africa but the focus of this project is for a municipality in Cross River State known as Calabar municipality in Nigeria. About 90% of the homes in this municipality make use of the air conditioning system due to the hot weather and this in turn consumes more electricity at a high cost, that is if available. This project is about building a waste-to- energy facility of 10MW in which the waste heat water will be connected to a reversible heat pump that will be used for district cooling to increase the access to electricity and address the heat issue.

The entire city of Calabar’s waste is collected by Zoom Lion in collaboration with the Calabar Urban Development Authority (CUDA) and the waste is being dumped in a landfill just some few kilometers from the municipality and the waste site has been generating severe stench, which affects the nearby residents. The waste in the waste site will serve as a fuel for Waste to Energy plant

The energy that can be harnessed from the waste will be an advantage to the in-habitants because it will give them electricity and reduces or even eliminates the stench that comes from the landfill. The state already has a contract in place to build three 30MW hydro power plants in three different local governments but still there is a need for more due to the increasing population of the state. The WTE energy plant will go in tune with the goal of the government which is generating clean energy and eliminating the waste in the City of Calabar.

1.1 The Design Objective

The WTE project is aimed towards the following:

- To eliminate the municipal solid waste by using it as a fuel for the WTE plant.
- To improve electricity production in the City of Calabar from the waste to energy plant.
- To create awareness about proper means for waste disposal in the state

1.2 Access to Electricity in Nigeria and Calabar in Cross River State

Because of high economic growth and demographic pressure, in 2008 the Energy Commission of Nigeria (ECN) together with the International Atomic Energy Agency (IAEA) projected a demand of 15,730 MW for 2010 and 119,200 MW for 2030 under the reference scenario (7% yearly economic growth). Other ac-tors, such as the defunct Power Holding Company of Nigeria (PHCN) or World Alliance for Decentralized Energy (WADE), have also developed scenarios. The results of these studies vary widely, but they all conclude that the current gap between supply and demand is already very substantial (1:3) and that it will be-come more entrenched under a business as usual scenario.

The installed capacity for on-grid power generation increased by 5,600 MW over the period 1968 to 1991 in Nigeria. However, the lack of significant investment in maintenance of the existing and in the construction of new infrastructure in the 1990s resulted in the decrease of capacity throughout the 1990s and 2000s. Other factors hindering on-grid power generation include shortage of gas supply, misaligned gas and infrastructural facilities, vandalisation and sabotage of generating facilities and power evacuation constraints. As of mid-2015, there were a total of 58 licenses for on-grid generation with a total on-grid generation capacity of 26,423.2 MW, mostly for thermal generation in the southern part of the country where the oil and gas fields are located. However, out of this figure, only 11,774 MW have been built. Due to poor maintenance, only 3,801.19 MW are currently generated as in June 2015.

Most of the generation capacity is based on natural gas. The share of large hydropower in the energy mix for power generation has decreased due to the Government’s focus on thermal energy. The thermal/hydro mix is 84%/16% for the installed capacity, 84%/16% for the available generation capacity and thermal/hydro mix is 80%/20% for actual generation capacity. Table 3 includes the list of on-grid generation companies and plants in Nigeria:

Table 1. Existing power plants in Nigeria./2/

Name	**Fuel type**	**Year com-pleted**	**Installed capacity MW**	**Installed available capacity MW**	**Actual generation capacity MW as of May 2015**
AES	Gas	2001	270	267	0
AFAM IV-V	Gas	1982	580	98	0
AFAM VI	Gas	2009	980	559	523
ALAOJI NIPP	Gas	2015	335	127	110
DELTA	Gas	1990	740	453	300
EGBIN	Gas	1985	1320	931	502
GEREGU	Gas	2007	414	282	138
GEREGU NIIP	Gas	2012	434	424	90
IBOM POWER	Gas	2009	142	115	92
IHOVBOR NIPP	Gas	2012	450	327	225
JEBBA	Hydro	1986	570	427	255
KAINJI	Hydro	1968	760	180	181
OKPAI	Gas	2005	480	424	391
OLO-RUNSOGO	Gas	2007	335	244	232

Name	**Fuel type**	**Year completed**	**Installed capacity MW**	**Installed available capacity MW**	**Actual generation capacity MW as of May 2015**
OLO-RUNSOGO NIPP	Gas	2012	675	356	87
OMOKU	Gas	2005	150	0	0
OMO-TOSHO	Gas	2005	335	242	178
OMO-TOSHO NIPP	Gas	2012	450	318	90
RIVER IPP	Gas	2009	136	166	0
SAPELE	Gas	1978	900	145	81
SAPELE NIPP	Gas	2012	450	205	116
SHIRORO	Hydro	1989	600	480	350
ODUK-PANI	Gas	2013	561	70	0
Total			12,067	6,840	3,941

Even with these power plants the energy generated is being sold out of the country, remaining little which covers about 30 percent of inhabitants in Calabar, which is even not enough for households not even counting on the small-scale industries in the metropolis.

Looking at the case of Cross River State which depends solely on the Odukpani power plant one would see clearly that access to electricity is very low, making it difficult for industries to flourish in the state.

1.3 About Cross River State

Cross River State is a coastal state in South Nigeria, named after the Cross River, which passes through the state. Located in the Niger Delta, Cross River State occupies 20,156 square kilometres. It shares boundaries with Benue State to the north, Ebonyi and Abia States to the west, to the east by Cameroon Republic and to the south by Akwa-Ibom and the Atlantic Ocean. The state comprises 18 local government areas but the project is to cover two main local government areas which are the Calabar Municipality and the Calabar South. The above mentioned local government is under the capital of Cross River State which is Calabar and they have a land space of 142 and 264 km² respectively population of about 180,000 and 190,000 respectively, according to the last census conducted in 2006. Below is figure 1.

1.4 Waste Management in Calabar

Before 1999 there was no agency in Cross River State that managed waste, hence waste produced by homes and businesses was buried in the ground at any nearby bush. By the 2000 the government at that time put up the agency called the Calabar Urban Development Authority to oversee cleaning, clearing and disposal of waste in the city. This agency worked with other waste collection companies, such as Zoom Lion and other locally established waste collection firms within the developed local government areas in the state.

Due to a bad road network at that time some areas which had a deplorable road could not be accessed for their waste to be disposed properly and that caused the residents to drop their waste in gutters and the nearest bush at sight. A few years later roads were constructed and the dumping of waste in the bush became a thing of the past as waste bins were distributed on every street and were collected daily by CUDA and other waste collecting agencies working with them to the landfill site that was designated. Below are figures 1 and 2.

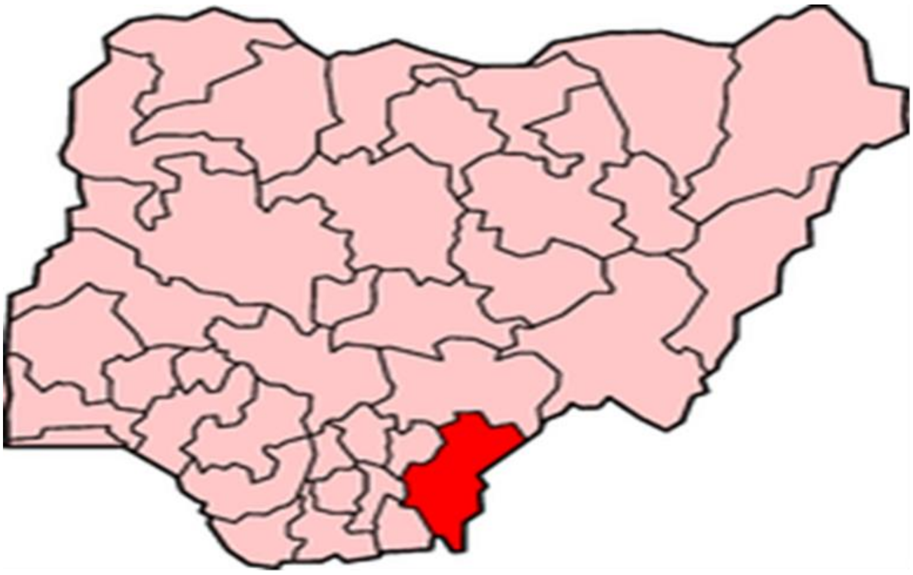

Figure 1. Map of Nigeria

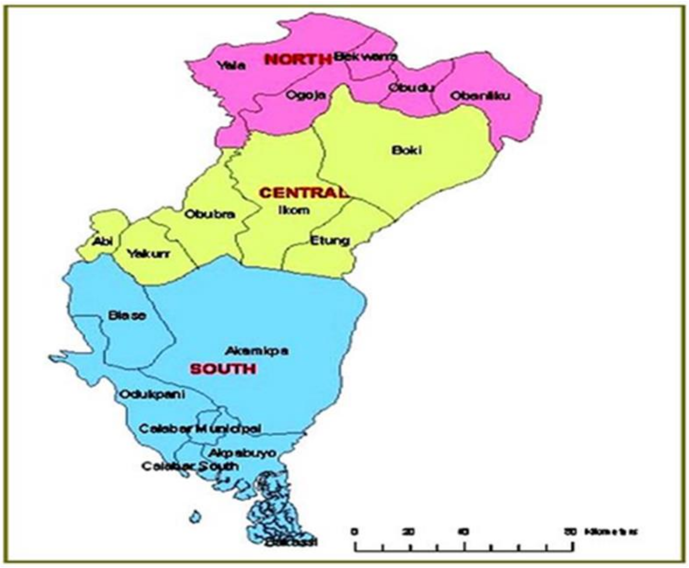

Figure 2. Map of Cross River State

2 WASTE AS FUEL

When considering a waste incineration plant, one must have accurate data concerning the amount of waste, the energy content in the waste to be used as fuel for the plant. The lower calorific value for the waste must be above the lowest level of waste required for the plant, the composition of the waste is also important and as well as a steady availability of waste in the location throughout the year to enable the plant run efficiently and at full capacity.

Waste composition varies in different countries due to cultural difference, socio- economic conditions, level of development and the financial stability. Considering Nigeria which is a developing country it generates more waste due to industrial and socio-economic activities going on in the country, not forgetting the population.

2.1 Waste Composition in Calabar

Municipal solid waste consists of different materials and can be classified into 4 groups:

1. Domestic waste
2. Commercial waste
3. Institutional waste
4. Constructional waste

2.1.1 Domestic Waste

This is waste resulting from home activities, such as waste from cooking process, home cleaning, clothes and furniture that are no longer needed, obsolete utensils and equipment and garden waste. Domestic waste in Calabar consist mostly of food waste, plastic and a little portion of paper, metal and glass.

2.1.2 Commercial Waste

Commercial waste comes from shops, offices, restaurant, hotels and commercial establishments. This type waste is closely related to domestic waste because it consists of almost the same materials. In Calabar, waste from food market takes a large share of commercial waste with the presence of other materials in smaller quantity. Some portion of commercial waste may be considered hazardous.

2.1.3 Institutional Waste

Institutional waste is accumulated from schools, hospital, clinics and pharmacies, government offices and such. The composition of this waste is a kind of the combination of domestic and commercial waste although it is made up of more packaging material than food. When considering a hospital one should take note because the waste from there might be infectious and hazardous so it is important to separate this type of waste.

2.1.4 Industrial Waste

This group of waste depends solely on the type of industries involved but it is dominated by packaging materials and by products from the company's production line, papers, plastics and metals, for example. Constructional waste is not suited for an incineration plant. Waste composition varies per season and cli-mate and the socio-economic state of the selected area for waste collection.

2.2 Heating Value

The ability of waste to sustain a combustion process without supplementary fuel lies on the number of physical and chemical parameters of which the lower calorific value (Hinf) is the most important factor to consider. This may also depend on the furnace design. Also, when working with low grade fuels, the design must be able to minimize heat loss and allow the waste to dry before ignition.

During the incineration process, the energy content of the water vapors accounts for the difference between the lower calorific value and upper calorific value (HSUP).

2.3 Calorific Value

The calorific value of a substance is the amount of heat released during the combustion of a specified amount of that substance. It is measured in unit of energy per unit of the substance, usually mass, such as KJ/kg, J/mol or Btu/m3.

The upper heating value is known by bringing the combusted material back to the original pre-combustion temperature and condensing any vapor produced. While the lower calorific value is known by subtracting the heat of vaporization of the water vapor from the higher heating value. This in turn treats any water formed as vapor. Table 2 below shows the waste calorific value per data from a World Bank re-search for waste to energy projects.

Table 2. Calorific values for waste./5/

Mass basis fraction	**% of waste**	**Moisture W%**	**Fraction based solids TS %**	**Ash A %**	**Combustible C %**	**Calorific values** H_{awf} **KJ/kg**	H_{inf} **KJ/kg**
Food and organic waste	45.0	66	34	13.3	20.7	17,000	1,912
Plastics	23.1	28	71	7.8	63.2	33,000	20,144
Textiles	3.5	33	67	4.0	63.0	20,000	11,789
Paper and cardboard	12.0	47	53	5.6	47.4	16,000	6,440
Leather and rubber	1.4	11	89	25.8	63.2	23,000	14,265

Mass basis fraction	**% of waste**	**Moisture W%**	**Fraction based solids TS %**	**Ash A %**	**Combustible C %**	**Calorific values** H_{awf} **KJ/kg**	H_{inf} **KJ/kg**
Wood	8.0	35	65	5.2	59.8	17,000	9,310
Metals	4.1	6	94	94.0	0.0	0	-147
Glass	1.3	3	97	97.0	0.0	0	-73
Inerts	1.0	10	90	90.0	0.0	0	-245
Fines	0.6	32	68	45.6	22.4	15,000	2,584
Weighted average	100.0	46.7	53.3	10.2	43.1		7,650

2.4 Waste Disposal Issue in Calabar

Waste is defined as a material, substance, or by-product eliminated or discarded as no longer useful or required after the completion of a process. The issue of waste disposal in the city of Calabar is classified into the following forms:

1. Peoples attitude
2. Means for proper waste disposal facility not available
3. Sorting of waste

2.4.1 Peoples Attitude

In Cross River State, some inhabitants have a care-free attitude towards waste disposal. These people consciously litter the city without regard to the effect that the waste could cause the environment. When they are approached to be told about the effect the waste might have on the environment, they will openly op-pose and in most cases, may not even listen. This set of individuals plays a passive role in the sanitation exercise and does not take part in cleaning up their immediate surrounding due to their negative attitude. As this continues some of the well-educated ones may even want to follow in the same direction.

2.4.2 Means for Proper Waste Disposal

Before talking about the means of disposing waste we first must look at the waste composition to enable us to come up with possible ideas to what should be called WASTE and also what will be due for disposal. Per a research carried out by professor Afangideh (2012) at University of Calabar, he found out the pro-portions for the waste generated in the City of Calabar of which 41.99% was organic waste, 15.33% metal, 14.68 plastic, 16% paper, and 12% wood.

Due to exhausted landfill sites, the Calabar urban development authority CUDA was unable to continue the waste collection from the bins by the road side. This made most residents of the city dump their waste in gutters, nearby bushes and some even dug their yards to bury waste. This is because a large number of those residing in the city had little knowledge about a proper waste disposal system and the effect it posed on the environment. Below is a chart showing the waste composition in Calabar and an image of an abandoned waste bin by CUDA.

Figure 3. Waste composition in Calabar

Figure 4. An overfilled waste bin abandoned by CUDA./3/

2.4.3 Sorting of Waste

The issue associated with sorting of municipal solid waste in the City of Calabar has been a long standing one. When the Calabar Urban Development Authority began waste management in Calabar, they provided different bins for different kinds of waste. This had little impact on the indigenes because they had not been made aware of what kind of waste was to be dumped in what kind of bin. Rather they saw it as an alternative to the other bin in which all kind of waste was dumped and that made the sorting of waste a failed project.

With proper awareness regarding the need to sort waste this problem can easily be solved and then different types of waste bins can be placed at vantage points on the streets and home owners.

2.5 Municipal Solid Waste Generation in Nigeria

Generating waste is an unavoidable process for a developing country like Nigeria due to human and industrial activities. This waste ranges from domestic waste, such as food waste, paper, plastic, polythene, metals, batteries and textiles, to waste associated to IT industries, such as mobile phones, computers and other electronic gadgets. In Nigeria, domestic waste constitutes a large fraction of the municipal solid waste followed by waste from markets and other businesses, as shown in Table 3 below. The World Bank data shows that the rate of municipal solid waste generation in Nigeria is at an average of 0.49kg/capita/day.

2.6 How Solid Waste Impacts on Climate Change

Even before a material or product becomes a solid waste, it goes through a long cycle that involves removing and processing materials, manufacturing the product, transporting the material to the markets, and using energy to operate the product. These processes have the potentials to generate greenhouse gases either energy consumption, methane emissions, or carbon storage./14/

Table 3. Waste composition in Nigeria./12/

Location	OW	M	G	P	WP	PP	RB	TX	W	D/C	D/S/A	OT	Rate	Source of waste	Source
Port Harcourt	38.6	10.8	23	–	–	–	–	6.4	7.6	2.1		5.6	0.6	Dump site	Abah and Ohimain (2010), Ogwueleka (2009)
Nsukka	47	4	4	4	11	6	–	3	–	–	–	21	0.39	Fresh from homes	Field work
Lagos	68.16	2.08	1.78	3.64	7.68	12.46	–	–	–	–	–	4.2	0.63	Homes	Oyelola and Babatunde (2012), Ogwueleka (2009)
Lasos	68.98	1.77	–	1.77	3.92	23.57	–	–	–	–	–	–	0.63	Business premises	Oyelola and Babatunde (2012), Ogwueleka (2009)
Makurdi	49.2	2.09	1.62	7.08	–	3.63	–	2.24	–	–	–	32.71		Homes	Sha'Ato *et al.* (2007)
Makurdi	27.9	3.4	6.9	10.2		10.9	–	1.2	–	–	36.4	3.1	0.54	Business premises	Sha'Ato *et al.* (2007)
Makurdi	44.8	0.9	1.2	5.9		8.9	–	0.3	–	–	36.4	3.1		Institutions	Sha'Ato *et al.* (2007)
Kano	57.48	3.9	2.53	17.55	–	6.72		4.48	1.8	–	–	5.58	0.31	Fresh from homes	Bichi and Amatobi (2013)
Umuahia	52.2	3	0.6	1.5	10.2	18.5	–	–	12	–	–	2			Onwughara *et al.* (2010)
Ibadan	64.9	2.9	1.7	9.9	–	14.2	–	–	–	–	6.5	–	0.71		Adewumi *et al.* (2005)
Ibadan	17.59	2.95	2.52	0.85	21.77	10.69	0.28	2.46	3.92	–	36.96	–		Business premises	Lade *et al.* (2012)
Iloriu	24.8	5.2	3.2	10.8	p/p	20	–	2	2.8	4.8	8.4	17.2	0.48	Waste trucks	Ibrahim *et al.* (2012)
Zaria	45.2	7	7.2	8	–	17.8	–	–	–	–	12	2.8	0.295		Ukoje (2011)
Abeokuta	26.3	5.26	5.75	24.95	–	25.57	–	9.48	–	2.69	–	–	0.66		
Maiduguri	25.8	9.1	43	18.1	–	7.5	–	3.9	–		21.5	9.8	0.25	Fresh from homes	Dauda and Osita (2003)
Delta	37	10	6	21		18	–	5	–	–	–	3	0.29		Egun (2012)
Minna	44.63	3.6	1.11	5.91	–	–	0.87	–	3.01	21.09	–	19.77	0.514	Fresh from homes	Adeoye *et al.* (2011)
Damaturu	76.3	2.7	–		21		–	–	–	–	–	–	0.32		Babalola *et al.* (2010)
Onitsha	49	8.7	4.5	17.9	–	8.1		10.1		–	–	3.7	0.53		Ogwueleka (2009)
Ogbomosho	56.4	1.5		10.4	–	15.7	3.7	2.5	–	–	9.8		0.13	Homes	Afon (2007)
Abuja	52	5	2	10		11		20 + paper			–	–	0.57	Homes	DFID (2004)
Abuja	8	2	4	7		68		11 + paper			–	–	0.57	Institutions	DFID (2004)
Gboko	17.3	10	8.7	–	19	12.7	–	11.3	–	–	12	9	0.44	Fresh from homes	Akpen and Aondoakaa (2009)
Oshogbo	58.2	1.4	0.6	12.1	–		–	–	–	15.3	9.9				
Benin	78	4	3	9	–	4	–	–	–	–	1	1	0.425	Waste trucks	Igbinomwanhia (2011)
Uyo	23.93	19.85	22.72	7.58		12.76	–	9.95	–	–	–	3.25		Homes	Ukpong and Udofia (2011)
Uyo	65	4	3	10	–	8	–	3	–	–	–	7	0.54		Okey *et al.*
Calabar	41.99	15.33	–	14.7	–	16	–	–	12	–	–	–		Dumpsite	Afangideh *et al.* (2012)
Jos	27.5	7.51	9.99	6.75	7.49	14.48	–	6.87	8.47	–	–	10.94		Dumpsite	Egbere *et al.* (2001)
Awka	33.17	14.4		19.57	32.84		–	–	–	–	–	–			Modebe *et al.* (2010)
Akure	59.5	7.2	6.3	1.7	–	15.1	–	–	–	–	11	–	0.54	–	Adewumi *et al.* (2005)
Okigwe	77	1	4	2	4	12	–	–	–	–	–	–	–	Market	Etusim *et al.* (2013)

Notes: OW, organic waste; M, metals; G, glass; P, plastic; WP, water proof/polythene; PP, paper; RB, rubber; TX, textile; W, wood; D/C, drugs/chemicals; D/S/A, dust/sand/ashes/fines; OT, others. Rate is kg/capita/day

Figure 5. Waste inspection officer at a landfill site in Calabar./3/

2.7 Amount of Waste Collected

Table 4 below shows the trend of population growth in Cross River State. The main concentration is in two local government areas s that make up the main city in the state. Where the plant will be located, the local government areas are Calabar Municipality and Calabar South.

Table 4. Population projection for Cross River State

The population development in Cross River.

Name	Status	Population Census 1991-11-26	Population Census 2006-03-21	Population Projection 2011-03-21
Cross River	**State**	**1,911,297**	**2,892,988**	**3,344,400**
Abi	Local Government Area	...	144,317	166,840
Akamkpa	Local Government Area	118,472	149,705	173,070
Akpabuyo	Local Government Area	103,952	272,262	314,750
Bakassi [→ Cameroon (2008)]	Local Government Area	...	31,641	...
Bekwara	Local Government Area	...	105,497	121,960
Biase	Local Government Area	101,121	168,113	194,350
Boki	Local Government Area	145,010	186,611	215,730
Calabar Municipal	Local Government Area	...	183,681	212,340
Calabar South	Local Government Area	...	191,515	221,400
Etung	Local Government Area	...	80,036	92,530
Ikom	Local Government Area	...	163,691	189,230
Obanliku	Local Government Area	48,611	109,633	126,740
Obubra	Local Government Area	134,225	172,543	199,470
Obudu	Local Government Area	84,799	161,457	186,650
Odukpani	Local Government Area	122,352	192,884	222,980
Ogoja	Local Government Area	...	171,574	198,350
Yakurr	Local Government Area	...	196,271	226,900
Yala	Local Government Area	156,627	211,557	244,570
Nigeria	**Federal Republic**	**88,992,220**	**140,431,790**	**164,728,600**

Waste per capita …… 0.49kg/capita/day

Population of the area……. 430000 people estimated as at 2011

To get the amount of waste collected daily... 0.49kg/capita/day*430000 = 210700kg/day

For a year

210700*365 =76905500kg/yr = 76905.5tonnes

To get the total composition of waste, one will have to multiply the waste percentage by the total amount of waste obtained.

For wood

12%*210700 =25284kg/day

For organic waste

42%*210700 =88494kg/day

For plastic

16%*210700 =33712kg/day

For paper

15*210700 =31605kg/day

2.8 Energy Content

To get the energy content you have to multiply the waste fraction by the calorific value.

For wood

25284kg*9310kJ/kg =235394040KJ60*60*24*0.84 =2724.5KW/h = 2.7MWh

For organic waste

88494kg*1912kJ/kg =169200528KJ/60*60*24 =1958.3KW/h = 1.9MWh

For plastic

33712kg*20144kJ/kg = 679094528KJ/60*60*24 = 7859.9KW/h = 7.8MWh

For paper

31605kg *6440kJ/kg =203536200KJ/60*60*24 =2355.7KW/h = 2.3MWh

To get the plant capacity

Efficiency = 0.84%

Total energy contained in waste = 14.7MWh*0.84% =12.3MW

Table 5. Energy content

waste	**Calorific value**	**Fraction(210700kg/day)**	**Total energy in waste**
Organic waste	1912kJ/kg	42%	1.9MWh
Plastic	20144kJ/kg	16%	7.8MWh
Paper	6440kJ/kg	15%	2.3MWh
wood	9310kJ/kg	12%	2.7MWh

3 WASTE TO ENERGY PLANT

3.1 Technology

The technologies associated with waste incineration can be divided into two broad parts: mass burning of inhomogeneous waste without pre-treatment and burning of pre-treated homogenous waste.

The mass burning of inhomogeneous waste needs little or no pre-treatment and this technology uses the moving grate./5/ It is commonly used and well tested to meet the demands for technical performance and can burn large variations of waste compositions and calorific value. The burning of pre-treated and homogeneous waste requires size reduction, manual sorting and even shredding, which makes the process complicated hence making this system limited. When thinking about the incineration plant, one must think of technology that would be feasible and consider the capability of the technology with regards to the type of waste and the quantity of waste available in the chosen location. Hence the type of technology that suits this is the mass burning incinerator with a moveable grate. Another thing to consider is suppliers with numerous reference plants in successful operation for several years and in low and middle income countries. The technology with regard to the combustion system must be made in a way that pollutants are not formed, especially organic compositions, such as dioxins. In this technology measures are there to ensure that an efficient combustion process occurs.

Below are the key components of waste incineration plant. Functions about the components listed below are explained on page 20.

1. Waste storage pit
2. Hopper
3. Grate
4. Forced draft fan
5. Furnace
6. Boiler
7. Bottom ash collector

8. Super heater
9. Economizer
10. Scrubber
11. Electrostatic precipitator (ESP)
12. Cyclone
13. Chimney

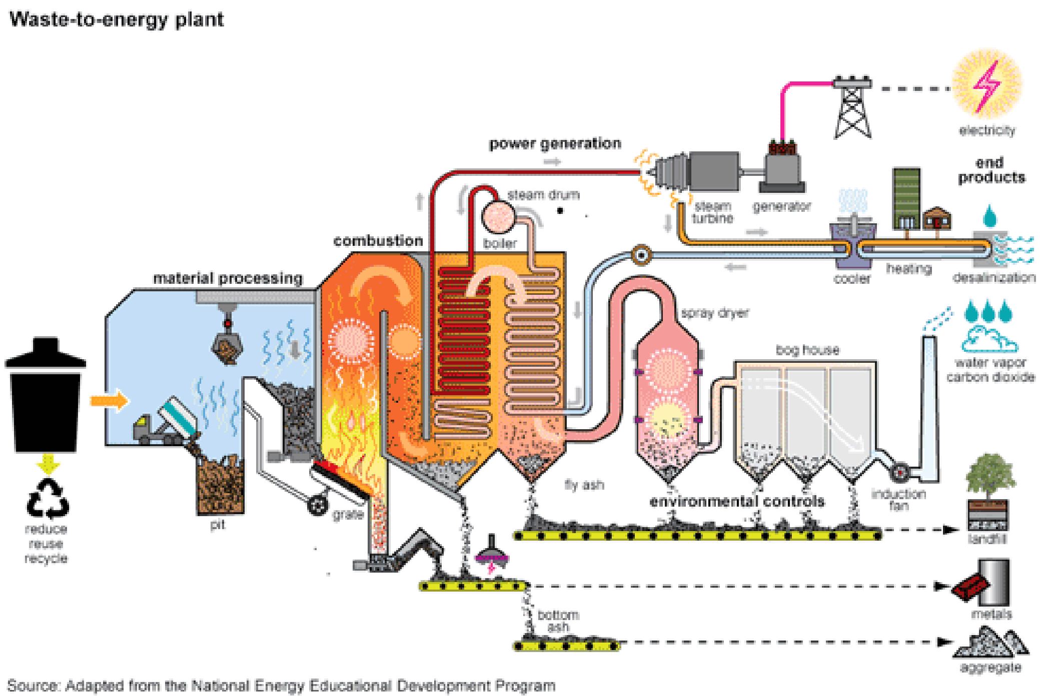

Figure 6. Waste to energy plant./4/

3.2 Moving Grate

There are four (4) types of moving grate for a WTE incinerator and they are listed below.

1. Horizontal grate
2. Reciprocating grate
3. Counter direction push over grate
4. Rotating drum grate

In the moving grate technology, municipal solid waste requires no pretreatment and allows for a large variation of waste to be combusted. The waste is first dried on the grate and then burned at a high temperature within the range of 850 to 950 degrees Celsius and then accompanied with a supply of air, while the left over then moves towards the ash pit and is treated with water, cleaning out the ash./1/

3.2.1 Horizontal or Travelling Grate

This type of grate is mostly used for high calorific fuels. A uniform load and the cooling of the grate bar can be achieved through the circulating grate layer. The travelling grate is like a conveyor with individual bars mounted to aid its movement horizontally as the fuel is being burnt. The burnt-out fuel is discharged at the end into an ash hopper that is beneath the grate. Figure 7 below shows a travelling grate which is also known as a horizontal grate.

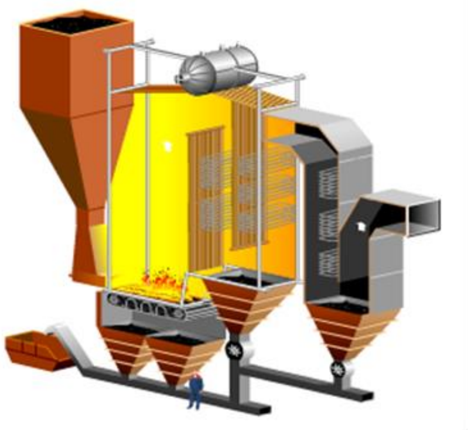

Figure 7. Horizontal grate

3.2.2 Reciprocating Grate

This type of grate is suitable for almost all kinds of fuels because of the closed feed motion of the grate series./10/ The speed can be set independently to cater for each cylinder and the under-grate air can also be regulated for different sections. This type of grate is structured like a staircase from fixed and moving grate bar series. The combustion doubles as a coolant for the grate layer and is fed through the wind zone under the grate. Below is figure 8, a picture of a reciprocating grate.

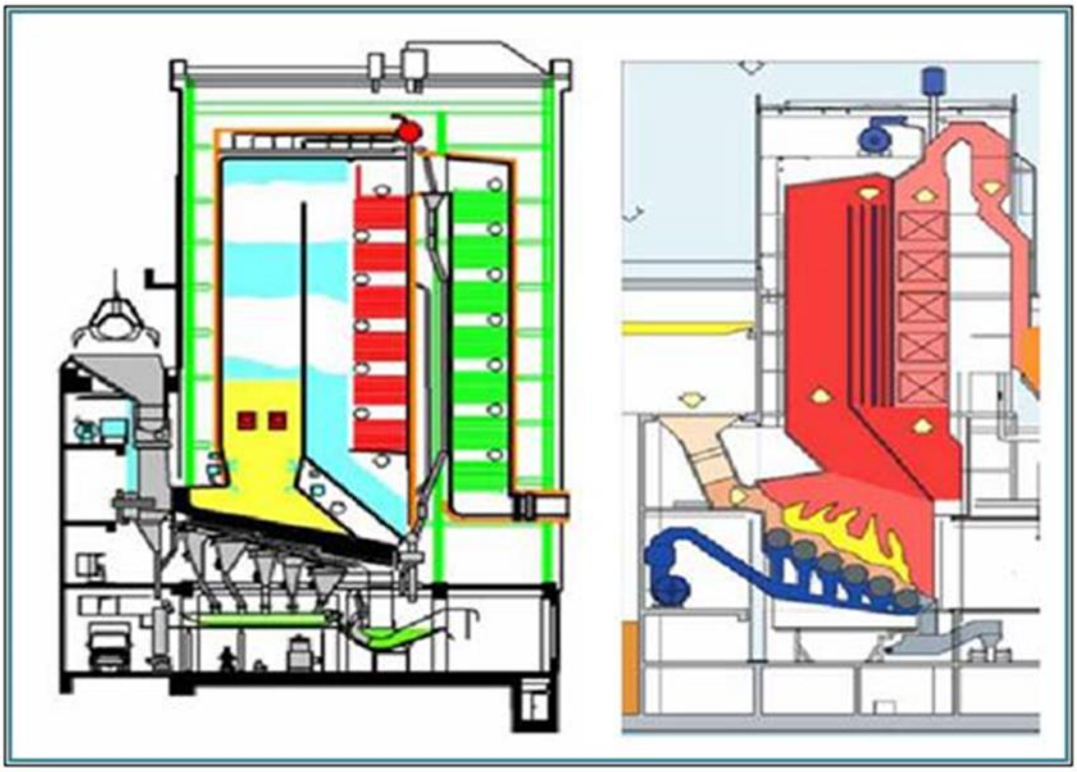

Figure 8. Reciprocating grate./8/

3.2.3 Counter Direction Grate

The counter direction grate has similar working principles as the traveling grate but it has another layer that pushes in the opposite direction which guarantees a better mixture of the fuel and enhances its stoking ability.

3.2.4 Rotating Drum Grate

The rotating drum grate provides a sloping fuel bed for the combustion of the waste. The roller grate rotates the wastes slowly at an adjustable speed of about three to six revolution per hour allowing efficient burning of waste to take place.

The counter direction grate and the rotating drum grate are not often used in waste incineration due to their low efficiency. Therefore, there was not much information available on them. Below is figure 9.

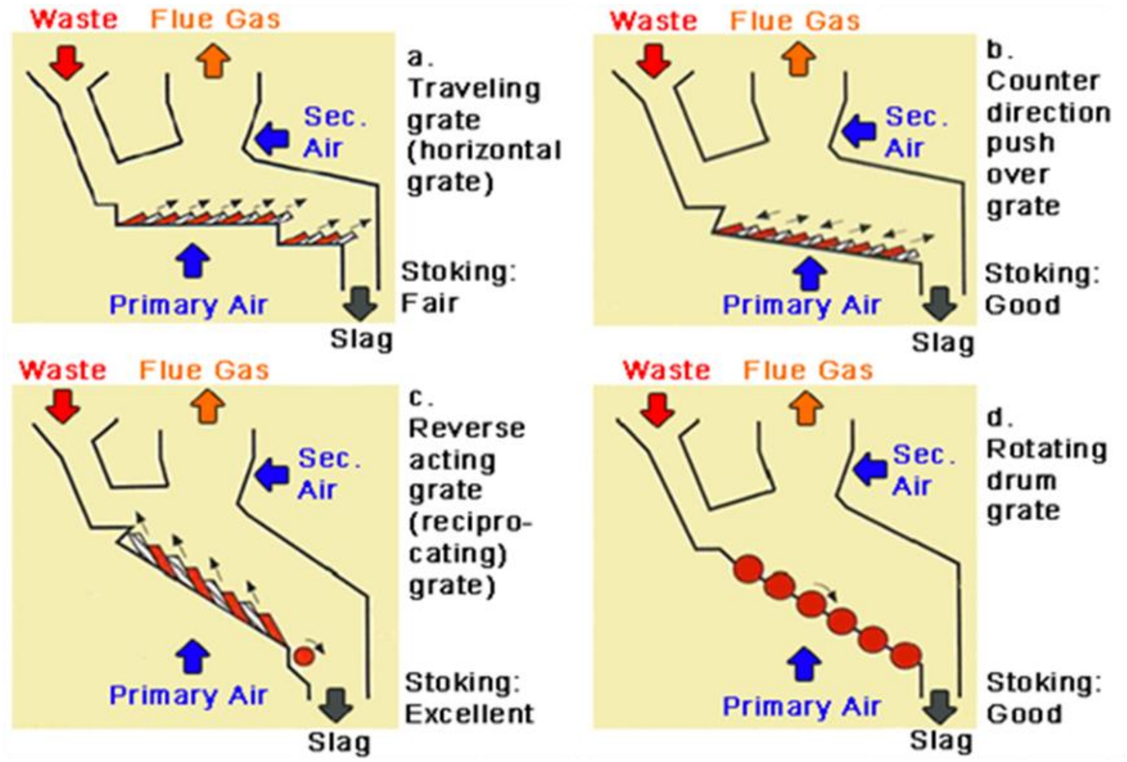

Figure 9. Types of grate for WTE plant./8/

3.3 Flue Gas Recirculation

Establishing a flue gas recirculation is part of the furnace design. After passing through the dust filter, part of the flue gas (20 to 30 percent) is limited and retained through an insulated duct to the furnace. The recirculated flue gas is injected through separate nozzles in the furnace and in the turbulence zone at the inlet to the secondary combustion chamber, the first pass of the boiler. The primary advantages of flue gas are:

1. Recirculates flue gas, which leads to a higher thermal efficiency, as the excess air and the oxygen content can be significantly reduced (efficiency can increase about 1 to 3 percent)
2. Reduces NOx (20 to 40 percent when recirculating 20 to 30 percent of the flue gas); reduces the dioxin generation (connected with a low amount of excess air and a low oxygen content)

3. Stabilizes or improves the flow and turbulence conditions—particularly at partial load
4. Minimizes the risk of "bursts" in the secondary combustion chamber, the first pass of the boiler
5. Decreases the amount of flue gas entering the flue gas cleaning system./5/

3.4 Combustion Systems and Fans

Special attention should be given to the design and regulation of the combustion air systems, which provide air in the flue gas, to ensure a high combustion efficiency and to avoid a reducing (corrosive) atmosphere, incomplete burnout of the flue gases, and related problems. The primary air should be drawn from above the crane slab in the waste pit and injected through the pressure side of the primary fan below the grate in at least four to six air zones regulated automatically by motorized dampers. Intakes for the secondary air are situated at the top of the furnace or boiler, possibly in the waste pit. Air should be supplied to the furnace and at the inlet to the first pass of the boiler (after-burning chamber) through three to five rows of nozzles (depending on the design). The amount of secondary air supplied to each of the rows of nozzles is regulated automatically by motorized dampers. An air preheater manufactured in a bare tube structure should preheat the primary air at low calorific values and with moist waste. It should be possible to heat the primary air from 10°C to approximately 145°C, depending on the waste composition and moisture content.

3.5 Air Pollution Control

Countries have different environment pollution standards that are put in place to curb the level of emission industries can release to the atmosphere and these standards range from air pollution to soil pollution and also the products produced by the industries. In 2004, the Harmful Waste Act was passed in Nigeria to enable companies fall in line with the requirement to have a healthy environment. Waste to energy plants have been progressing in terms of technology to curb pollution and flue gases that are released to the environment. The technologies minimize and almost eliminate flue gases, so it is not released into the environment. According to Directive 2000/76/EC, an incineration plants correspond to any stationary or mobile technical unit dedicated to the thermal treatment of wastes with or without recovery of the combustion heat generated. This includes the incineration by oxidation of waste as well as other thermal treatment processes, such as pyrolysis or gasification in so far as the substances resulting from the treatment are subsequently incinerated. This description comprises the site and the entire incineration plant including:

- Waste reception and handling (storage, on site pre-treatment facilities)
- Combustion chamber (waste-fuel and air-supply systems)
- Energy recovery (boiler, economizer, etc.)
- Facilities for clean-up gaseous emissions
- On-site facilities for treatment or storage of residues and waste water, stack
- Devices and systems for controlling incineration operations, recording and monitoring incineration conditions.

Below is figure 10.

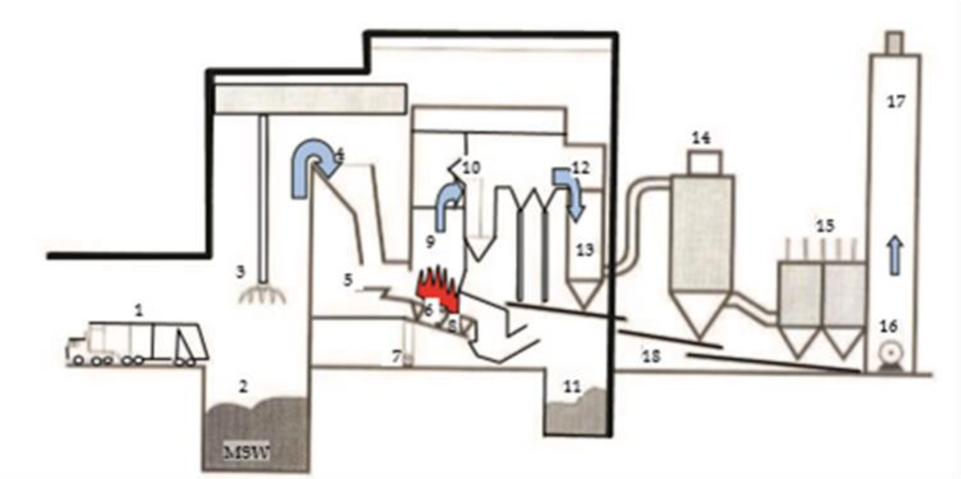

Figure 10. Mass flow in WTE plant.

The figure above shows the mass flow in the incineration plant. The truck with MSW (1) delivers the waste into the waste storage (2). The waste in the storage must be enough to ensure continuous fuel supply to the plant (3). The hopper picks the waste randomly and supplies it to the feeder (4), which then flows to the moving grate (5). The combustion takes place in the incinerator (6). At this point the plant has to be regulated to optimize the condition for combustion to take place and also ensure complete carbon burn-out (7). This usually can take up to 60mins. At this stage, the force draft fan forces the primary air through the under-grate air zone into the furnace (8) Air is drawn from the storage pit to supply to the furnace (9). This is done to ensure the turbulence of flue gases and to ensure complete combustion, during this time about 10 -20% of the flue gases are recirculated as secondary air. This is an exothermic reaction and it releases a high amount of energy that is carried as heat. The air taken from the storage pit is to lower the air pressure and eliminate stench emissions from the storage area. But this is not shown in the diagram. The boiler (10) where energy recovery occurs (11) is where the bottom ashes and metals are sorted out for possible recycling and improvement (12). The economizer (13) burned-out bottom ashes being drop to (11). The dry scrubber (14) cleans the pollutants (15). Here we have the fabric filter which is also used to clean pollutants in the flue gas before being disposed of monofills and lastly the cleaned flue gas is then let out the stack with the help of an induced fan./5/

3.5.1 Gas Cleaning System for Waste Incinerator

The three main components that must be removed and gotten rid of in the flue gases before it leaves the stack are:

1. Fly ash, which is composed by particles pneumatically transported by the gaseous flow;
2. Acids and acids precursors, such as Sulphur dioxide, nitrogen oxides, hydrochloric acid;
3. Dioxins and analogues that are compounds formed by radical recombination with structures such as polychlorodibenzodioxins and the respective furan analogues.

When the hot gas mixture is leaving the furnace, the heat exchangers exchange heat at the surface of the vertical tube where high or medium pressure steam is generated before it enters the cleaning system. Some of this gas is diverted through a booster and injected in the area below the moving grate. The remaining effluent gas is then cleaned by several units during the cleaning process. When the heat exchange takes place at the surface of the boiler tubes, the effluent gases are cooled and new additional solids are formed, which increases the particulate fraction. This also must be cleaned to meet the environmental standards in Nigeria. The table below gives mandatory limits for emission that is generally accepted and the calculated efficiency needed for cleaning each type of pollutant.

Table 6. Pollutants and removal efficiency./5/

Pollutants	**Concentration in the raw gas from boiler (mg/Nm^2)**	**Max admissible at exhaust (mg/Nm^2)**	**Removal efficiency required (%)**
Fly Ash	1500 – 2000	10	99.9
HCL	300 – 2000	10	>99
SO_2	200 – 1000	5	99.5
NO_x	200 – 500	70	86
HF	2 – 25	1	96
Hg	0.2 – 0.5	0.01	99
Cd + other metals	2 – 15	0.05	>99.5
Dioxins (ng I-TEQ/Nm^3)	0.5 - 5	0.1	98

3.5.2 Unit Operation for Gas Cleaning

Various numbers of unit operations based on primary separation process of gases can be used to clean the flue gases generated by a waste incineration plant. The table below provides a combination of unit operation for each type of pollutants with respect to a particular range of reduction.

Table 7. Steps to eliminate pollutants

Pollutants	**Process steps**	**Reductions**
SO_2	Wet scrubber or dry multi cyclone	50 – 90
HCL	Wet scrubber or semi-dry	75 – 95
NO_x	Selective catalytic reduc-tion	10 – 60
Heavy metals	Dry scrubber + electro-static precipitator	70 - 95
Fly ash	Electrostatic precipitator + fabric hose filter	95 – 99.9
Dioxins and furans	Activated carbon + fabric hose filter	50 – 99.9

3.5.3 Separation of Fly Ash and Activated Carbon

Fly ash is the by-product from the waste incineration plant as a result of burning of waste, they are collected and used as raw materials for various other products but they are usually contaminated with heavy metals and other harmful sub-stances and must be treated as hazardous waste.

Activated carbon in a powder form is used often used to absorb pollutants, such as l furans as well as dioxins. This powder is collected together with the fly ash during the cleaning process with the help of a cyclone, an electrostatic precipitator or fabric hose filter.

3.5.4 Cyclone

Cyclones are used in the incineration plant for the removal of solid particles with average diameter of 100 µm from gaseous flow, mostly constructed with stain-less steel and functions under a wide range of temperature. They are commonly used as primary separators in incineration plant.

3.5.5 Electrostatic Precipitators (ESP)

ESP is also used in an incineration plant to separate particles with the application of an electric field. The efficiency of this system depends on the design, material used and the size of the collection area. When constructing an ESP, the collection zones must be carefully designed to ensure that the laminar layer boundary is thick in other to avoid gases flowing back into the already collected particles. This is a more complicated system. Little information could be obtained for the fabric hose filter.

Table 8 below provides information on fly ash and activated carbon separation.

Table 8. Fly ash and activated carbon separation/5/

Equipment	Typical efficiency for fly ash	Typical efficiency for AC	Typical pressure drop range	Maximum operating temperature	Range of particles sizes
Cyclones	up to 80%	up to 50%	10 to 1000 Pa	1300 °C	≥ 20 µm
ESP	up to 99%	up to 80%	50 to 300 Pa	450 °C	0.08 to 20 µm
Fabric hose filters	up to 99%	up to 99%	500 to 2000 Pa usually with a booster fan	240 °C	0.04 to 50 µm

Table 9 below shows the most important techniques for the reduction of the main pollutants in an incineration plant.

Table 9. Standard reduction of gas techniques for WTE plant./5/

Pollutant	Techniques
Particles	Electrostatic precipitators Wet electrostatic precipitators Condensation electrostatic precipitators Ionization wet scrubbers Fabric filters Cyclones and multi-cyclones
Acid gases (HCl, HF, SO_x, …)	Wet-scrubber Semi-dray scrubber (e.g. suspension of lime) + bag filter Dry-scrubber (e.g. lime or sodium bicarbonate)
Direct desulphurisation	Injection of adsorbents (e.g. calcium compounds) directly into the incineration chamber
Oxides of nitrogen (NOx)	Primary techniques: air and temperature control, flue-gas recirculation, Secondary techniques: Selective Non- Catalytic Reduction (SNCR) and Selective Catalytic Reduction (SCR).
Hg	Primary techniques: separate collection, restrictions of receipt contaminated wastes Secondary techniques: scrubber by adding oxidants, activated carbon, furnace coke or zeolites
Other heavy metals	Converted into no-volatile oxides and deposited into fly ash, all techniques referred to remove particles can be applied. Activated carbon injection into scrubbing units.
Organic carbon compounds	Adsorption on activated carbon. SCR used for NOx. Catalytic bag filters Static bed filters Rapid quenching of flue-gas
Greenhouse gases (CO_2, N_2O)	All techniques used for NOx. Increase energy recovery efficiency
APC residues	Treated (e.g. solidification/stabilization and disposed of) Thermal treatment (vitrification, melting, sintering) Extraction and separation Chemical stabilisation
Bottom ash	Separation of metals Screening and crushing Treatment using ageing conditions High temperature slagging rotary kilns

3.6 Incineration Residues

During the combustion process in an incineration plant, most of the waste is converted to gases. These gases are treated and then released into the atmosphere with its potency reduced to avoid causing it being harmful to human and the environment.

However, some of the waste is incombustible and is removed from the incineration furnace as slag, which is a solid residue. Residues can also be gotten from the treatment of flue gases either directly or indirectly by using scrubbers or any cleaning mechanism that is used in the incineration plant. Landfill materials are exposed to precipitation, which means it must be deposited with consideration about the contents and its effects.

The main residues from an incineration plant are listed below and possible ways to remove and properly dispose this residue will be discussed. Slags, boiler and fly ashes, spent absorbent from filters and sludge from water treatment.

3.6.1 Slag

Slag is the major by-product of a waste incineration plant, it is also referred to as bottom ash. It makes up about 20 to 25 percent or even more depending on the content of the waste that has been incinerated. Slag is made up of some other noncombustible material, such as glass, metals. The grain size of slag ranges in size per the content of the waste that is fed to the combustion chamber.

3.6.2 Slag Removal and Disposal

After the waste has been burnt on the grate, the left-over drops by gravity through an opening just below the grate and into a water bath (de-slagger) that cools it down and dissolves and removes some salt from the unburnt materials. The water level in the de-slagger needs to be maintained as it evaporates during the process. Slags are being kept in landfills depending on its toxicity. If it contains much toxic elements, it must be treated before it is taken to the landfill.

3.6.3 Boiler Ash and Fly Ash

During combustion, some fine particles travel along with the flue gas to the boiler due to high velocity possessed by the flue gas when leaving the combustion chamber. At the boiler, the velocity is reduced and these fine particles settle as boiler ash. After the flue is cooled various compounds in gaseous state, such as lead, cadmium chloride and zinc, which are formed from the hydrogen chloride contained in the flue gas, then condense to form fly ash. Fly ash is mostly collected using electrostatic precipitators or together with the reaction products of dry or semi dry flue gas treatment processes.

3.6.4 Removal and Disposal

Since the boiler ash is collected and stored in the bottom of the ESP, it is then transported with the aid of a conveyor to silo. When the quantity collected is reasonable, then it is humidified by water or by fresh sludge from the scrubber after the treatment of flue gas. Disposing this has been a subject of intense research due to the high content of salt and heavy metals. The ash is disposed in a landfill under specific controlled conditions.

3.6.5 Spent Absorbent from Dioxins Filters

Usually this residue is fed back into the incinerator so that the dioxins can be destroyed, hence the incinerator serves as its best option for disposal and treatment.

3.6.6 Sludge from Water Treatment

During the process of cleaning the flu gas hydrochlorides and Sulphur dioxides are removed and a waste water stream is produced. This waste water must not be disposed as it contains elements that are harmful to the environment. This is normally done by the wet method of treating the flu gas.

3.6.7 Removal and Disposal

As earlier discussed in the removal and disposal of boiler and fly ash, sludge is used to humidify boiler and fly ashes and after that it is moved to a landfill. Since the sludge contains calcium chloride, additional chloride is added to the ash to improve its leaching property.

There are also other residues that should be removed from time and are listed below.

1. Damaged materials after maintenance.
2. Ions exchange resins from boiler water preparation.

3.7 Application for Waste Gotten from Waste Incineration Plant

There are various ways in which waste from an incineration plant can be used and below are some ways which we will look at:

1. Road construction.
2. Cement production.
3. Manure for agricultural produce.

3.7.1 Road Construction

Waste incineration residues do not always end up in landfills. Some countries for example USA, Denmark, Sweden, Japan and many others have used the fly ash and bottom ash in constructing durable road network. Boiler ash is one of the major by-product from waste incineration and it consists of grate ash and some-times grate shifting. Its contents are primarily glasses, ceramics organic carbons, ferrous and nonferrous metals, minerals. Before this residue is used for road construction, it is advised to treat it to reduce its leaching properties as it may have effect on the underground water bodies. After treating the boiler ash, it can serve as an alternative to the traditional material used for road construction.

3.7.2 Cement Production

Sludge from the waste plant has a composition of aluminum oxide, silicon oxide, calcium oxide, ferrous oxide, phosphorous pentoxide. In cement production, clinker, limestone and gypsum are the main components needed for production. When the sludge is dried, it can be used to produce mortar due to presence of silicon and calcium oxides. This makes it a good raw material for the cement production company and it comes with other side benefits as well. Some of these benefits are:

1. Less waste to landfills which may harm soil composition.
2. Reducing the cost of disposing waste.
3. Environmental conservation.

3.7.3 Manure for Agricultural Produce

The sludge water from the plant is rich in nutrients, such as potassium, phosphorous and nitrogen, which are essential in growing agricultural produce. These are key components in the production of manure so it can be extracted from the residue by the fertilizer company, which is owned by the government. This will in turn help the local farmers to increase yield in the farm produce yearly, the farmers are to be advised to apply this fertilizer sparingly as excessive application may have negative impact on the farm produce and possibly the soil composition.

3.8 Advantages and Disadvantages of Waste Incineration Plant

There are advantages as well as disadvantages to this technology but the ad-vantages far outweigh the disadvantages. The advantages are stated below.

1. This technology is widely used and has been thoroughly tested for waste incineration and meets the demands for technical performance.
2. This technology does not require sorting prior to shredding and burning.
3. It can accommodate large variations in waste compositions and calorific value.
4. It allows for an overall thermal efficiency of up to 85 percent.
5. The furnace can be built to accommodate waste up to 1200t/day.

So far, the only disadvantage associated with this technology is that the capital cost and maintenance cost are relatively high.

3.9 Operation of Waste Incineration Plant

The waste incineration plant will create job opportunities for skilled workers who have been trained in the field due to the level of competency required for the job. They operational structure will be one that allows flexibility in the day to day running of the plant. The government will oversee the setting up of the management board that will handle administrative and logistics procedure to ensure the well-being of the employees.

4 ECONOMICS OF THE PLANT

This aspect of waste incineration plant is the most important part which has to be considered because it varies in different countries due to economic factor, such as inflation, exchange rate and the policies of loan repayment by banks and other agencies involved in money lending. The government is expected to fund 100% of the investment cost. The capacity of the waste incineration plant is 4MW and will be a boost to the low power portion supplied to the state. The cost of the plant, including shipping, clearance and construction according to Mizun consultants and Engineers limited is ₦ 4,942,110,856.64 (14,760,000 euros) and additional ₦17394628 (50 000 euros) has been set aside for clearance with a proposal of 5000000 euros for installation, which is 1,673,616,000 naira

4.1 Feed in Tariff (FIT)

Feed in tariffs are regulations set aside by the Government to help investors in the energy sector to get the appropriate charge on the power generated. FIT is sometimes referred to as energy cash back because it is a scheme that was created for individuals who generate green electricity and offer to sell back to the grid. In developed countries, the FIT helps green energy producers in three ways.

1. It serves as a payment for the electricity generated.
2. It gives additional bonus payments for any amount of energy fed into the grid.
3. It reduces one’s electricity bill as individuals can generate for themselves.

4.2 Cost of Operating the Plant

The plant will require the services of qualified individuals whom have had the necessary training in automation and control system, waste management, plant engineering, two securities and additional staff to be charge of waste delivery trucks. So, in total 10 employees will be required to run the plant. The break-down of their salary is shown below.

Table 10. Administrative cost breakdown for the waste to energy plant in Calabar

Staff	**Salary (monthly)**
Automation engineer1	₦120000
Automation engineer2	₦120000
Plant engineer1	₦100000
Plant engineer2	₦100000
Waste manager1	₦75000
Waste manager2	₦75000
Security (2)	₦45000*2
Total administrative cost	₦680000

4.2.1 Maintenance of the Plant

The plant is expected to run for 8500 hours yearly and that will be followed by a shutdown maintenance to avoid wearing off some important component. The breakdown of maintenance cost for the plant is shown below.

Table 11. The breakdown of maintenance cost for the waste to energy plant

Maintenance cost	**Amount (₦)**
Cost of gas cleaning (15% of investment cost)	1200000
Cost of residual dispose (2% of investment cost)	160000
Overall maintenance (3 % of investment cost)	240000

Total maintenance cost	**1600000**

4.2.2 Sales of Electricity

The Nigerian Electricity Regulatory Commission (NERC) is responsible for set-ting the price of electricity in the country. Since the project belongs to the state government, the generating, transmission and distribution cost will set the same as the existing cost of electricity, which used to be ₦13.61kWh. But early in 2016 the NERC indicated that there will be an increase in the electricity tariff. Since there is an increasing energy demand in Calabar, the sales of electricity will surely meet the quantity that will be distributed.

The total amount of energy to be generated daily is 14.7MWh

To convert to kilowatt hour, we get 14700kWh

The price per kilowatt hour = ₦13.61kWh

The total sales expected = ₦13.61kWh*14700kWh = ₦200067

To determine how many households the project will be able to cover one would have to consider the consumption trend with the households.

Hence, based on assumptions an average household in Nigeria is expected to have the following electrical devices and their estimated consumption shown in table 12.

To determine how many household the project can serve, one will have to divide the total electricity generated by the total electricity consumed per household and that this is shown below.

The total electricity generated = 14700kWh

The total electricity consumed per household = 4.32kWh

= 14700kWh / 4.32kWh = 3403 households

Table 12. Electricity consumption calculation

Electrical gadgets	**Consump-tion**	**Cost (₦)**	**Estimated time used per day**
Air condition (1,5 hp)	0.7kWh	9.527	1hr
Fridge	1.37kWh	18.6457	24hrs
Lights (bulbs)	0.06kWh	0.8166	6hrs
Fans (ceiling fan	0.75kWh	10.2075	12hrs
Televisions	0.22kWh	2.9942	8hrs
Iron	1.1kWh	14.971	1hr
Mobile phones and lap-tops	0.12kWh	1.6332	3hr
Total	**4.32kWh**	**58.7952**	

5 PROJECT CYCLE

Every project must be planned carefully for it to be successful, a waste incineration project is not excluded. The waste to energy project has three main stages which are the feasibility phase, preparation phase and then implementation phase. Each phase involves other sub-phases which deal with decision making, cost consideration, environmental considerations to mention a few. The diagram below shows what procedure to follow in order to have a successful project.

Table 13. Waste incineration plant project phases./5/

Phase and Step		Purpose and Issues to Consider	Duration
Feasibility Phase	Prefeasibility Study	Waste quantities, calorific values, capacity, siting, energy sale, organization, costs, and financing	6 months
	Political Decision	Decide whether to investigate further or to abort the project	3 months
	Feasibility Study	Waste quantities, calorific values, capacity, siting, energy sale, organization, costs, and financing in detail	6 months
	Political Decision	Decide on willingness, priority, and financing of incineration plant and necessary organizations	6 months
Project Preparation Phase	Establishment of an Organization	Establishment of an official organization and an institutional support and framework	6 months
	Tender and Financial Engineering	Detailed financial engineering, negotiation of loans or other means of financing, and selection of consultants	3 months
	Preparation of Tender Documents	Reassessment of project, specifications, prequalification of contractors and tendering of documents	6 months
	Political Decision	Decision on financial package, tendering of documents and procedures in detail and final go-ahead	3 months
Project Implementation Phase	Award of Contract and Negotiations	Prequalification of contractors. Tendering of documents. Selection of most competitive bid. Contract negotiations.	6 months
	Construction and Supervision	Construction by selected contractor and supervision by independent consultant	2 1/2 years
	Commissioning and Startup	Testing of all performance specifications, settlements, commissioning, training of staff, and startup by constructor	6 months
	Operation and Maintenance	Continuous operation and maintenance of plant. Continuous procurement of spare parts and supplies.	10–20 years

5.1 Feasibility Phase

In this phase, there are three main sub-phases to consider namely prefeasibility study, government decision and feasibility study.

After the project is presented to the interested parties, it is at this stage that further investigation will be done to see if the variables, such as the amount of waste, location for the plant, and the need for the plant are worth the effort. When this is done, the investor decides whether to carry on or not based on the outcome of the prefeasibility study. After this a more detailed study is done again to ascertain that the variables are good enough for the project to be profit-able. The ideas outlined in the final feasibility study will then be transformed into the project agreement which helps to move to the next phase. The environ-mental impact assessment is also done in accordance with the guidelines in the EIA handbook. The EIA must be done by a qualified agency that is not linked to the government to allow them to perform their obligations without being biased or influenced by the government.

Based on the standard set by the World Bank on similar projects this process may be as long as 21 months, also considering that the project belongs to the state government, there will be little or no delay so it is estimated that this may take 23 months in Nigeria due to the level of bureaucracy.

5.2 Preparation Phase

This is the administrative phase of the project. At this phase, all ideas gathered from the feasibility studies are implemented; a qualified project manager is employed to pilot the project, financial documents are signed and the source of funds for the project is confirmed and then the investors are ready to go on to the final phase. It is at this phase that all the stakeholders are identified and issues that may affect the implementation is settled.

5.3 Project Implementation

It is at this phase that a Project Implementation Unit (PUI) is formed to help to oversee the progress of the project. This unit is made of people with good managerial, technical and financial skills. The PUI works hand in hand with the project manager to make sure that the specifications of the project are followed. At this phase, all parts needed for the construction of the plant are on site and a work plan is made about the estimated time it will take for the project construction to be completed. As estimated by the World Bank it takes about two years and six months to complete the construction of a waste incineration plant, so this project is expected to follow the same time frame as parts are expected to be on ground before the commencement. When the construction is done, then the project will be tested and commissioned for full operation. The waste incineration plant has a life span of 10 to 20 years with a proper yearly shut down maintenance.

5.4 Stakeholders Analysis

The main stakeholders to consider in a waste incineration project are listed be-low.

1. Cross River State Ministry of Environment
2. Nigerian Electricity Regulatory Commission
3. Energy Commission of Nigeria
4. Calabar Water board
5. The Calabar Municipality Leaders
6. Waste Management commission
7. Scavengers

5.4.1 Cross River State Ministry of Environment

This ministry is responsible for setting policies that keeps industries from causing harm to the environment and are responsible to set a standard for the amount of pollutants any industry can release into the atmosphere. This ministry has no direct mandate in the en-ergy sector.

5.4.2 Nigeria Electricity Regulatory Commission

This commission is responsible for the power regulation across power generation, transmission and distribution companies in the country./11/ They also create a competitive power sector and the set codes of conducts, grant license, amendments of electricity market rules and set tariffs for energy generated.

5.4.3 Energy Commission of Nigeria

This commission was established in 1988, they are charged with the responsibility of developing strategic plans and the coordination of national policies in the field of energy in all ramification./11/ They also advice the government on energy strategies and dissemination of information, promoting research, development as well joining up with international energy related organization.

5.4.4 Cross River State Water Board

This body is responsible for water treatment and distribution in the City of Calabar and the suburban areas that surround the capital of the state (Cross River State). The water treatment plant is about 1000 meters from the chosen site for the waste incineration project, which makes it easy for the waste water from the plant to be transported there for treatment. Since this body falls under the government, it will work hand in hand to help further the project and supply water when needed.

5.4.5 Waste Management Commission

The Waste Management Commission works with waste management companies to collect waste around the state, they give out contracts and share areas in which different waste collection firms are to cover. This commission also works hand in hand with the Ministry of Environment and the Ministry of Lands and Housing to choose a landfill site which will not have health effect on humans and taking into consideration the effect on the environment at large. They will help in channeling the waste collected around the state to the waste incineration plant and they will also play a key role in showing residents how to sort waste before disposing in designated waste bins.

Calabar Municipality Leaders are the land owners and are very important since they control the locals living around the site that has been chosen for the project. These people must be handled with care as they can mobilize the youths against the progress of the project. Adequate compensation must be given to them for the lands that will be used for the project.

Other stakeholders to consider are small recycling firms and scavengers but they will not have any direct impact on the project.

5.5 Socio Economic Impacts of the Project

The waste incineration project comes with benefits economically and improve the health of the residents in the city. Economically waste collection will create jobs for the local waste collecting companies, thereby giving income to individuals. Furthermore, studies carried out by the Cross River State Health Commission shows that there has been an increase in cases of malaria in the city due to the waste that have been disposed by the road and gutters, which serve as a breeding ground for mosquitos. The waste incineration project will help to channel the waste from streets to become fuel for the plant, thereby removing breeding grounds for mosquitos.

Keeping the environment clean has been a goal for the state and this project plays a big role in achieving this goal by removing unnecessary landfills within the city and eradicating the stench that comes from it. This will in turn create an opportunity for investors to invest in the state and help in improving the state’s revenue. Students from tertiary institutions can also be interns in the project and learn about the plant. This will improve their technical skills and prepare them for employment in the field of waste incineration.

6 CONCLUSION

The research about the benefits of waste incineration in Calabar yields positive outcome in ways, such as keeping the city clean, providing electricity, improving the health of the people and generating income to the state.

It also shows the amount of waste generated by the by Calabar South and Calabar Municipality which amounts to 76905 tons of waste per year without considering the peak period. This calculation was made based on values received from the World Bank data which shows that on the average Nigeria has 0.49kg of waste per capita a day. This was used, together with the population of the city, to determine the amount of waste to serve as fuel for the incineration plant.

The total energy to be obtained from this plant is 12 megawatts and is expected to serve 86000 households. This project will help the dwellers in these house-holds to invest in businesses that require the use of electricity.

REFERENCES

/1/. Waste management resources. 2009. Accessed 2.10.2016. http://www.wrfound.org.uk/articles/incineration.html.

/2/. Nigeria Energy Situation. Energypedia. Accessed 07.7 2016. https://energypedia.info/wiki/Nigeria_Energy_Situation. (Accessed 07.07.2016).

/3/.https://www.google.fi/search?q=waste+bins+in+calabar&client=firefox-b&source=lnms&tbm=isch&sa=X&ved=0ahUKEwiHs72O-ZXPAhWFF-CwKHc2bCQsQ_AUICCgB&biw=1280&bih=915#imgrc=-znAhBaBE5k_pM%3A. (Accessed 24.09.2016).

/4/. Independent statistics and analysis U.S Energy Information Administration. Accessed 28.05.2017. https://www.eia.gov/energyexplained/index.cfm/data/index.cfm?page=biomass_waste_to_energy

/5/. file:///C:/Users/My%20Own/Desktop/Waste%20IncinerationWorldBank.pdf. (Accessed 2.10.2016).

/6/. http://coalspot.com/technical/file/Calorific%20value.pdf. (Accessed 2.10.2016).

/7/. http://cdn.intechopen.com/pdfs/18646/InTech-Air_pollution_control_in_municipal_solid_waste_incinerators.pdf. (Accessed 2.09.2016).

/8/. https://www.google.fi/search?q=moving+grate+incinerator+technology&client. (Accessed 14.10.2016).

/9/. http://www.bioenergyconsult.com/moving-grate-incineration/. (Accessed 05.11.2016).

/10/.http://www.kablitz.com/reciprocating-grates.html. (Accessed 22.10.2016).

/11/. file:///C:/Users/My%20Own/Downloads/giz2015-en-nigerian-energy-sector(2).pdf (Accessed 2.10.2016).

/12/. http://www.sciencedirect.com/science/article/pii/S0956053X15301185 (Accessed 24.11.2016).

/13/. https://www.mastersthesiswriting.com/blog/sample-dissertations/waste-management-dissertation.html#more-170. (Accessed 24.09.2016).

/14/. http://www.academia.edu/4403452/Municipal_Solid_Waste_Impact_and_influence_on_GHG_Case_Study_for_Ghana_Nigeria_and_South_Africa (Accessed 2.10.2016).