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TECHNOLOGY, COMMUNICATION AND TRANSPORT

WASTE-TO-ENERGY PROJECT:

AN INTEGRATED SUSTAINABLE WASTE MANAGEMENT IN YENAGOA METROPOLIS.

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Abstract

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Most developing African countries challenges with waste disposal, which has become a menace to the environment and the residents. However, due to the development of technology and advancement, numerous approaches of combating waste disposal have been researched from waste recycling to waste-to-energy through incineration or bio processes.

The aim of this project was to design and construct a sustainable waste incineration plant that can solve waste disposal problems in emerging economies, particularly in Yenagoa Metropolis, the Bayelsa State Capital of Nigeria, in order to have access to sustainable electricity generation, and distribution, and the reduction of pollution causd by a poor waste management framework in the state capital.

This thesis was made to ascertain how waste could be used for power generation, and how power generation could be sustainable and how it could be possible to accelerate Waste-to-Energy power plant market growth for socioeconomic sustenance, as a profitable investment for Bayelsa State government and other investors from the private sector. The outcome of this thesis would indicate investment's sustainability and profitability, while also saving the eco-system from the danger of an improper waste management and disposal strategy.

This thesis has potential to trigger an awakening to many states in Nigeria, especially to Lagos State that has the capacity to generate 0.5 kg of waste per day per person, and produce more than 10,000 tons of waste in a day to join the cause of eliminating and/or reducing wastes, thereby making the environment free from pollution caused by various uncontrolled waste dumps in the state.

Keywords
Waste, energy, power generation.

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1.0 INTRODUCTION

In many places in the world, the growing demand for a reliable power source is frightening. Urbanisation and the rapid growth of megacities is the root cause of this dilemma. Sustainable electricity generation is essential for economic and social development. While some wealthy countries have long constructed capital infrastructures to meet the growing problem of ensuring reliable energy supply, African countries continues to face poor and unreliable electricity generation, transmission, and distribution. Developed countries, aided by R&D, have long sought to annex sustainable and renewable energy resources such as bio, solar, wind, wave, thermal, and nuclear power to fulfill contemporary society's growing demand. African countries, Nigeria particularly, is moving in the opposite direction. Nigeria has a consistently failing electricity grid, with an average per capita usage of 150 kWh, which remains amongst the lowest according to World Bank (The World Bank, 2014).

The focus of this thesis is on the use of waste to produce electricity in Yenagoa, Bayelsa State, Nigeria, where about 90% of the population requires power to run their homes, businesses, and industries. This is caused by unreliable power supply, as well as the relatively hot weather during the dry season, which tends to consume more electricity. If power is available, it will come at a hefty cost. The Waste-to-Energy project will create 10 megawatts of electricity, which will be added to the grid and power more homes in Yenagoa and its environs. According to The Guardian, (2016), Port Harcourt Electricity Distribution Company (PHEDC) blames the power outage in Yenagoa on insecurity and customers' refusal to pay their power bills on time. The company's management also stated that while on official duties, some of their employees were attacked and assaulted by residents. Insecurity is a contributing factor in the problem of poor electricity generation and distribution in some states, including Bayelsa State. According to TVC News, (2020), a further development showed that a daily supply of at least 12 hours of power in Yenagoa is possible. When officials from PHEDC met with Governor Duoye Diri in government house in Yenagoa, Bayelsa State, this was one of the important decisions taken.

1.1 Problem Statement

According to Sambo et al., (2010), electricity production in Nigeria has been all-embracing throughout the last 40 years, notwithstanding the use of oil-fired, gas-fired, hydro power stations, and coal-fired power stations, even though hydroelectric power and gas-fired power generation takes precedence. This is predicated on the assumption that oil, gas, hydro and coal were the country's main fuel sources for generating power, and that they are constantly available. Nigeria has the world's greatest coal reserves, with 2 billion metric tons of verified reserves and 650 tons of unconfirmed reserves. In Nigeria, 95 percent of coal is consumed outside of the country, principally for the production of electricity, railway transportation, and industrial heating in the cement industry.

Nigeria has a 45 percent electrification rate. Aside this amount, and in conjunction with several significant issues that are deflating the country's power supply system, the demand for energy continues to rise. In 2015, the nation's power supply averaged at 3.1 GW, that is roughly a third the nation's lowest energy need, forcing customers to lean on personal generators. The table below shows data from 2014, with the residential sector accounting for more than half of all power consumption" (GetInvest, 2021).

TABLE 1. 2022 Consumption of Electricity (Doris Dokua Sasu , 2022)

Economic Sector	TJ
Industry	13,747
Transport	Nil
Residential	58,910
Commercial and Public Services	27,304

Nigeria has been producing power in commercial amounts for decades, despite the country's sluggish development of electricity infrastructure and comparatively insufficient energy supply. The need for power is expected to rise dramatically in the future years. According to CSEA Africa, (2018), household demand for power is the largest and will continue to grow as a result of urbanization (4.23%/year) and the growth of the populace (projected at 2.7%/year), whereas the total rate of growth is pegged at 1.1 percent, which represents a rate twice that of the global average. As the country emerges from its most recent recession, commercial and industrial demand is expected to improve. Currently, the anticipated GDP fluctuates between 4.50% to 7%. The research estimated that by the end of 2040, the demand for energy will increase from 45490 MW in 2020 to 213122 MW, but estimates regarding the demand for power vary greatly. However, the majority of studies showed that the existing imbalance between supply and demand has been quite considerable and may be part of the status quo.

According to CSEA, (2018), the Nigerian Electricity Supply Industry (NESI) faces the issues listed below:

- Sector governance: This issue is made worse by the inconsistent application of established policies, norms, and regulations.
- Inadequate customer tariffs and pricing: This issue is caused by rising supplier costs brought on by inflation, currency depreciation, unexpected infrastructural constraints, and the failure to modify tariffs in a way that is appropriate.
- There are infrastructure limitations throughout the entire value chain, from fuel to energy distribution, as well as a lack of diversification in the energy sources used to generate energy (thermal 80 percent and hydro 20 percent), gas pipelines insufficiency, outdated power plants and machinery, including insufficient and poor maintenance of the systems used to transmit and distribute electricity, which is made worse by vandalism.
- (ATC&C) Reduce Aggregate Technical, Commercial and Collection Losses Non-reduction: Power sector changes have made it possible for power distribution firms (Dis-Cos) to operate in a way that is not justified for the sector's long-term survival. In contrast, distribution businesses are unable to make up for financial shortfalls due to a lack of investment in system integration and metering, which is understandably because of low tariffs combined with the lack of the ability to get loans from bank because of debt.
- Theft of electricity, consumer debt, and non-payment practices: This is quite pitiful, especially considering the government agencies, departments, and institutions who knowingly owed the electricity sector $72 million at year's end 2016, considerably contributing to the cash shortfall in the sector.
- Cash Deficits in the Sector: In 2015 and 2016, there is thought to have been a combined cash deficit of $1.3 billion. The difference between the tariff and service delivery costs accounted for $1.2 billion of the

total amount, while the remaining $100 million was the result of distribution businesses' failure to reduce ATC&C's losses.

Additional Issues

According to Sambo et al. (2010), the following are other power generation and distribution issues that the sector must address:

- Poor and insufficient upkeep and utilization of current infrastructure
- Unnecessary postponements of the launch of new projects
- There is no viable connection between the government and stakeholders, particularly joint ventures between international oil companies and independent electricity providers (IPP)
- Insufficient power is exported from recently completed and operating power facilities.
- A fluctuating supply of domestic gas resources for power generation
- The National Grid is still not connected to many rural areas in the country.
- The transmission system is overworked and in danger of failing.
- Poor and insufficient power supply for end users
- Only 4,000MW of the built 12,522MW capacity is available, which is little for a nation with such high power demands.
- Old National Grid, outdated equipment, and inadequate maintenance
- Insufficient government funding commitments for routine sector repair, updating, and expansion
- Constant damage to gas lines and cables, as well as inadequate security and oversight of the nation's electrical infrastructure
- Frequently lacking the necessary equipment, components, and vehicles for the upkeep and operation of the power system
- The lack of communication and infrastructure monitoring tools for electricity generating, transmission, and distribution systems.
- Poor customer satisfaction due to load shedding, low voltage, inconsistent billing, irregular bill payment, and sudden power outages
- Insufficient or nonexistent competency training programs; ineffective technical worker recruitment practices; and, last but not least, an unsuitable tariff structure that would not provide adequate funding for the development and upkeep of the power infrastructure.

1.2 Study Purpose and Objectives

The purpose of this research is to increase power supply in Yenagoa by employing an incinerator facility that burns wastes as fuel. The nation's energy supply is significantly behind what is anticipated based on the current energy demand and consumption, despite the fact that there are a vast number of energy sources accessible, making the current power generation mechanism unsustainable for a variety of reasons. However, there is still opportunity for expansion and the construction of new power plants, particularly the ones that uses renewable energy reources, away from the existing power plants, which have limited power producing capacity. The nation has yet to fully utilize its abundant renewable energy resources (bio, wind, wave, sun, hydro, nuclear) and other clean and renewable energy sources.

If this project is successful, other states will look at it and try to reproduce same in their jurisdictions, particularly Lagos State, which has a high capacity to produce 0.5 kilogram in a day per person and genetate wastes of above 10,000 tns daily (Wale Bakare, 2021). The project's design goals and purpose are listed below in order to make it feasible:

1. To create a state-wide sustainable waste management and disposal plan
2. To completely remove solid municipal waste as fuel combustion in an incinerator facility.
3. Use the waste-to-energy facility to produce electricity for the city of Yenagoa.

The design goals are essential since this thesis would be established as a working life project based on these project criteria and because they are all focused on resolving the three major problems mentioned above.

1.3 Importance of the Study

This thesis primarily focuses on the building of a 10 MW waste-to-energy plant in the Nigerian Bayelsa State capital city of Yenagoa. This will produce extra power to meet the city and nearby communities daily power needs. Based on reports, 80 to 90 percent of the population needs electricity to run their homes, businesses, and industries. This is due to Nigeria's unreliable power supply as well as the country's generally hot weather, during the dry season, which tends to increase electricity consumption. This project is important for a variety of reasons. The state government will be able to create a sustainable waste management and disposal policy thanks to this project, first and foremost. By using it as fuel for the incinerator facility, it will also get rid of wastes. Finally, it will offer a sustainable solution to the issue of waste management in the state capital and create 10 MW of electricity through the waste-to-energy plant to address the lack of a consistent power supply in the state capital.

1.3.1 Sustainable waste management and disposal

Nigeria lacks an efficient waste management and disposal system. Every state in the federation is experiencing the same issue. Household waste is typically deposited on the streets, gutters, roads, and other disposal locations both inside and outside the state capital. This project would bring sustainable solution to the waste management problems in the state. According to Stanley H., et al., (2018), the issue of waste management is a global one that tends to pose additional issues in African countries, especially in Nigeria with a high percentage of open dumping of waste on the streets, highways, drainages, and numerous disposal sites".

1.3.2. Generation of 10 MW of Electricity

The main goal of this project is to build a waste-to-energy plant that will use municipal waste as fuel to create 10 MW of power in the Yenagoa metropolis. As seen in FIGURE 1 below, this project would help Nigeria fulfill its rising need for electricity.

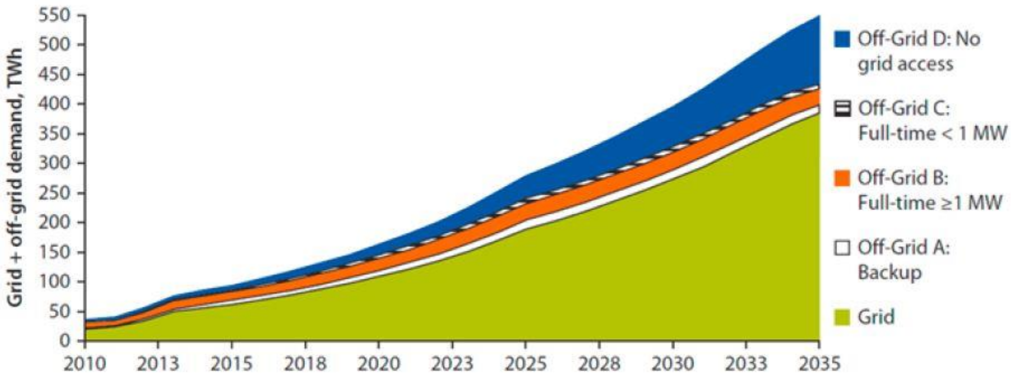


FIGURE 1. Projected electricity demand in Nigeria (Chanchangi, Yusuf, et. al., 2018).

Therefore, it is crucial to look into the feasibility and applicability of this project and determine whether the state government and other interested private sector business owners can participate in it. The proposed thesis project will lay out a clear path for other states to follow.

1.4 Access to Electricity in Yenagor, Bayelsa State and Nigeria

According to Oluseyi, Peter et al., (2009), Nigeria consumes 0.2% of the world's energy. The World Bank (2014) estimates that Nigeria's per-capita energy consumption is 145 kWh, which is lower than that of Finland (15,250 kWh) and the US, (12,994 kWh) respectively. Meanwhile, the country's energy-related carbon dioxide emissions total 91.94 million metric tons, or about 0.4 percent of all carbon dioxide emissions worldwide. Nigeria consistently emits less energy than is expected given the Kyoto commitment. Despite the aforementioned statistics, more than 75% of Nigerians lack access to power, proving that demand outweighs supply.

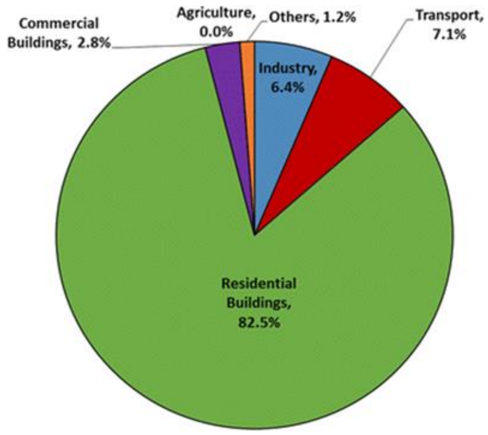


FIGURE 2. By Sector Nigeria's Primary Energy Consumption (Kwag, Byung Chang, et., al., 2019).

It makes sense that 75% of Nigerians do not have access to basic electricity. Most companies find it difficult to compete for the given reasons. This trend has had a significant impact on Nigeria's socioeconomic development. According to Fabiyi et al. (2016), the issue of intermittent power supply is of critical concern to citizens, the Nigerian government, and the businesses engaged in various economic sectors. Government in her desire to solving the problem of power in the country and refining the dependability on the power system in Nigeria, had in one point or the order, fused the Niger Delta Authority (NDA) and form the National Electric Power Authority (NEPA) from Electricity Corporation of Nigeria (ECN) in 1972; and in 2005 changed the abbreviation of NEPA to Power Holding Company of Nigeria (PHCN), concentrating primarily on restructuring the power system;

Power Holding Company of Nigeria (PHCN) was denationalized and divided into 18 separate entities in 2012. Conversely, information so far gathered indicated that these changes, restructuring and transformations have had little or no direct effect on the accessibility of electricity in the country, as power is the greatest worry to consumers". Customers barely have six continuous hours of electricity. Since there is a limited source of power and it is frequently rationed, and major part of the country only receives 6 to 8 hours of electricity every day.

TABLE 2. Power Stations Installed Generation Capacity in MW (GetInvest, 2021)

S/N	Power Station	Installed Capacity (MW)	Average Available Capacity (MW)	Average Operational Capacity (MW)
1	EGBIN	1,320	941	539
2	AFAM VI	685	587	455
3	OKPAI	900	536	375
4	TRANSCORP UGHELLI	480	463	374
5	JEBBA	570	431	262
6	OLORUNSOGO GAS	335	277	189
7	IHOVBOR NIPP	434	374	182
8	GEREGU NIPP	450	328	179
9	KAINJI	720	444	173
10	OLORUNSOGO NIPP	760	260	171
11	OMOTOSHO NIPP	500	306	169
12	OMOTOSHO GAS	335	280	163
13	SHIRORO	600	508	153
14	GEREGU GAS	414	159	131
15	SAPELE NIPP	450	184	111
16	IBOM	190	91	76
17	SAPELE	504	219	69
18	ALAOJI NIPP	720	158	67
19	ODUKPANI NIPP	561	234	64
20	AFAM IV-V	724	3	2
21	ASCO	294	270	0
22	OMOKU	110	0	0
23	TRANS AMADI	150	0	0
24	AES GAS	180	175	0
25	RIVERS IPP (Independent Power Producer)	136	0	0
	TOTAL	12,522	7,141	3,879

1.4.1 Generation of Power

According to USAID, (2021), Nigeria has abundant hydro, gas, oil, and solar energy, with possibility to produce 12,522 MW of electricity out of the total installed capacity of 16, 384 MW. However, most of the time, it could only produce 4,000 MW per day, which is barely enough for more than 195 million people. With its technical assistance and support, Power Africa has helped the country's distribution companies improve their revenue by $250 million. Technically, this money might have been invested back into the distribution power network to enhance service delivery and increase accessibility (USAID, 2019).

TABLE 3. Power Connections and Generating Capacity (USAID, 2019)

Generating Capacity	Connections
• Installed Capacity: 16,384 MW	• Current Access Rate (3): 60%
• Hydro: 2,062 MW	• Urban: 86%
• Gas: 11,972 MW	• Rural: 34%
• Wind: 10 MW	Power Africa new connections: 291,058
• Solar: 7 MW	
• Other/Diesel/HFO: 2,333 MW	
Power Africa new MW to date at financial close: 3,043 MW	

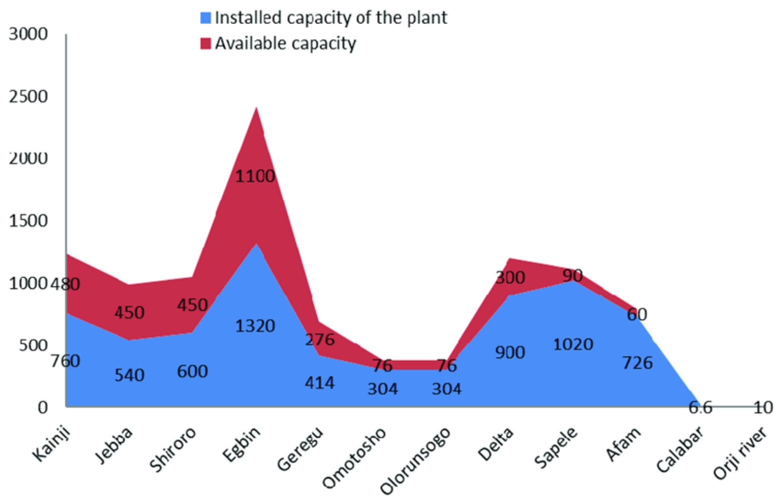


FIGURE 3. Nigeria power generation plant and their utilization capacity (Olatunji, Obafemi, et. Al., 2018)

1.4.2 Transmission of Power

The transmission system is made up of high voltage sub-stations that has a theoretical overall transmission volume of 7,500 MW with transmission lines more than 20,000 km, according to NERC, (2021). In spite of the fact that power transmission has not yet reached all Nigerian cities and villages, the transmission now has a rolling capacity of 5,300 MW, which is more than the average generation's operational capacity of 3,879 MW and lower than the installed capacity (12,522 MW). Without closures, the entire structure is essentially centrifugal, which causes inherent reliability problems. According to criteria for developing countries, which range from 2 to 6 percent, there are, on average, 7.4 percent transmission failures throughout the system, which is a significant amount. The system's failure rates have decreased compared to prior years, from a high of 42 in 2010 to a low in the most recent year. All of these specifics highlight how significant the problems are for the sector's operational and structural aspects of transmission.

FIGURE 4. Nigeria Transmission Network (NERC, 2021)

1.4.3 Power Distribution & Marketing

NERC oversees Nigeria's power production, transmission, and distribution as a regulator. In Nigeria, there are eleven electricity distribution companies, or "DisCos," each of which has a service region. But as Sambo et al., (2010) noted, the distribution system is appallingly subpar, the voltage level is low, and the tarrif system is generally imprecise. There have never been better interfaces between the general public and the DisCos, who are charged with the duty of providing adequate transmission coverage and a reliable supply of power, including a successful retail plan plus top-notch client service.

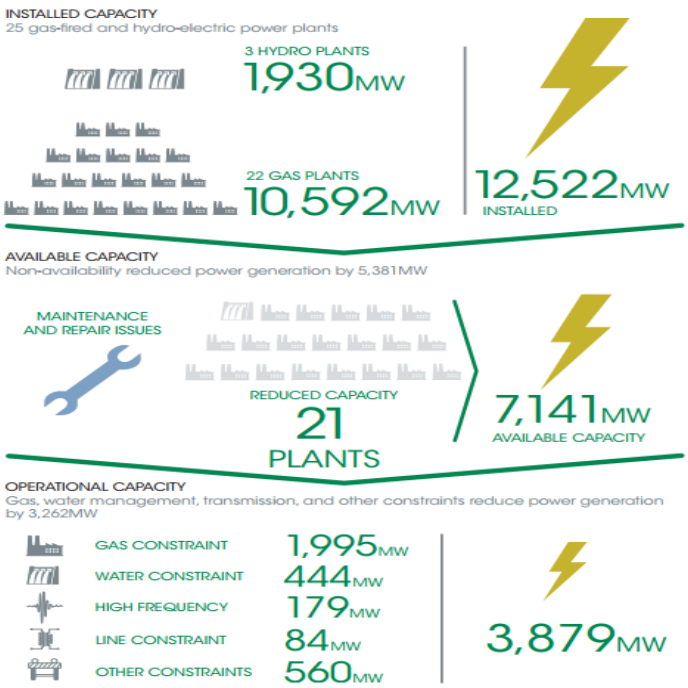


FIGURE 5. Generation Efficiency of Power in Transmission and Distribution in Nigeria (GetInvest, 2021)

1.5 About Bayelsa State

In the core Niger Delta region, Bayelsa State is inbetween Delta State and Rivers State. It is the most southern state in Nigeria. Yenagoa serves as the capital of Bayelsa State, one of the 36 states that made up the Nigerian federation. Eight local government areas currently make up the state: Brass, Ekeremo, Kolokuma/Opokuma, Nembe, Ogbia, Sagbama, Southern Ijaw, and Yenagoa. One of the newest states in the in the country, it was formed in 1996 from a portion of the former Rivers State. Ijaw or Ijo is the primary spoken language, with other languages such as Kolukuma, Bomu, Mein, Nembe, Epie-Atisa and Ogbia. However, English is the country's official language. Yenagoa, the state's capital. It is a small city with a population of 1,704,515 as of the 2006 census, which was expected to grow to 2,278,000 in 2016. (Citypopulation.de, 2020). Location coordinates are 4.926 latitude and 6.2593 longitude. Yenagoa is situated at N 4 55'34" and E 6 15'34" in the North and East Hemispheres, respectively.

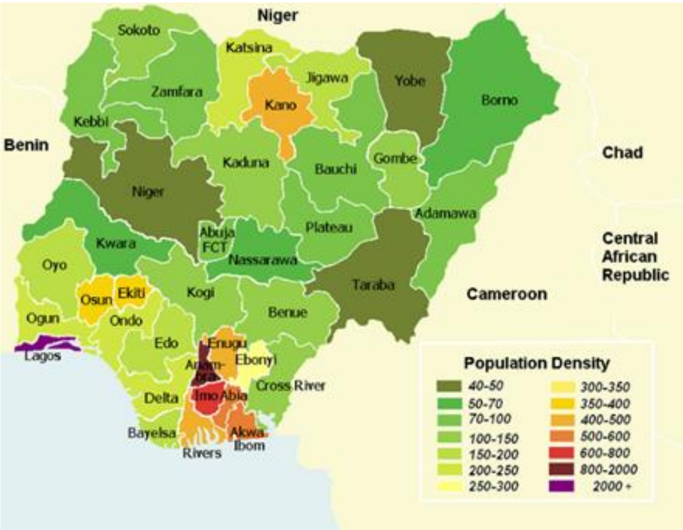


FIGURE 6. List of 36 states and capital in Nigeria (Wikipedia, 2022)

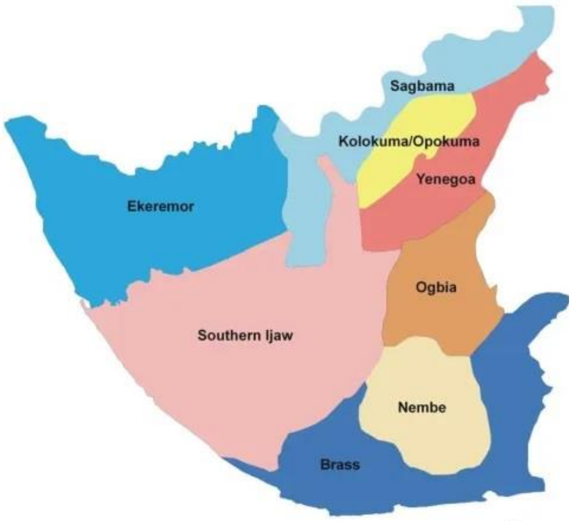


FIGURE 7. Bayelsa State and 8 LGA's (Nigeria Galleria, 2017)

1.6 Waste Management in Yenagoa, Bayelsa State.

The most persistent and difficult environmental issue facing Nigerian rural and urban communities is waste management and disposal. As population densities rise, so does the volume of solid garbage produced. Nigeria is a significant generator of municipal garbage in Africa because of population expansion. With an increasing amount of waste being produced in the nation each day, sustainable and effective waste management is becoming a threat, despite the implementation of numerous environmental legislation, programs, and plans. According to Chinedu, Ike (2018), wastes of 42 million tns on average are produced yearly in Nigeria, with a daily waste generation rate of 0.65-0.95 kg/capita/day. In an updated assessment conducted by BioEnergy Consult, (2021), "barely 20 to 30 percent of wastes are collected" out of the 42 million tons that are yearly generated, which 50 percent as much as the 62 million tons of waste that are produced annually in sub-Saharan Africa, and the issue of managing these wastes has become a serious issue for the nation.

Yenagoa, the capital of Bayelsa State, is a small city with most of its regions being unplanned and filled with so many squalid structures. Typically, wastes are collected rather than sorted, segregated, or repurposed. At various locations throughout towns and throughout the state, these wastes are deposited or dispersed on the streets, highways, gutters, and in the most common regions (Stanley H., et al., 2018). Despite the absence of an effective waste management system, government contractors are assigned to various regions and localities around the state, and part of their obligations under their contracts is to collect and dispose of waste from those locations in designated dumpsites. Scavengers or private garbage vendors are at these dumpsites collecting up metals, plastics, tires, and other reusable and recyclable waste items for sale or delivery to waste management or recycling firms. Originally, these wastes are not sorted or isolated from sources. The only waste segregation technique now in use is ineffective and unsustainable. The state government would need to educate the people about waste separation, reduction, reuse, and recycling if possible in order to effectively sort waste at the source. In addition to using it as fuel for the waste-to-energy plant, this would enhance the state's waste management system.

2.0 LITERATURE REVIEW

The economy of Nigeria is dependent on fossil fuel (gas) 87.5% thermal and hydroelectric energy sources 12.5%. Despite having an installed capacity between 12,522 and 16,384 MW, according to various official reports, the nation can rarely produce the required amount of power. It is interesting to note that the existing transmission capacity to the final consumer is only between 3,500 MW and 5,000 MW. Given the aforementioned, it would not be incorrect to say that Nigeria's energy sector should be considered to be in a state of disarray, with significant losses directly related to the non-availability of the already installed capacity, along with the extremely high significance of the existence of both technical and non-technical challenges based on a deficient energy supply value chain. Despite numerous power outages that affect consumers, electricity is still transmitted to those who are linked to the national grid. This is despite the fact that Africa has one of the lowest rates of annual energy use per person at less than 150 kWh. These accounts suggest that many active firms and corporations have standby generators. Despite the lack of data on the utilization of generators and their generating capacity, it is estimated that backup generators generate between 14 GW and 20 GW of power (Get-Invest, 2021).

In response to this development, the government finished a comprehensive, nine perennial procedure of reforming the electricity industry that was branched on privatizing Nigeria's primary power producing and distribution system in 2013. To address the supply and distribution issues, the government sold 15 of its owned electricity producing and distribution companies to private owners in 2015. (GetInvest, 2021). Having the potential to produce 12,522 MW of electricity from existing facilities (USAID), unfortunately, only 4,000 MW are produced, that is very inappropriate for almost 200 million people. For nearly 60 years of its existence, the nation has struggled to provide an unbroken supply of electricity. Governments in the past have tried and spent billions of money, yet they have produced nothing (GetInvest, 2021). See TABLE 1 for reference.

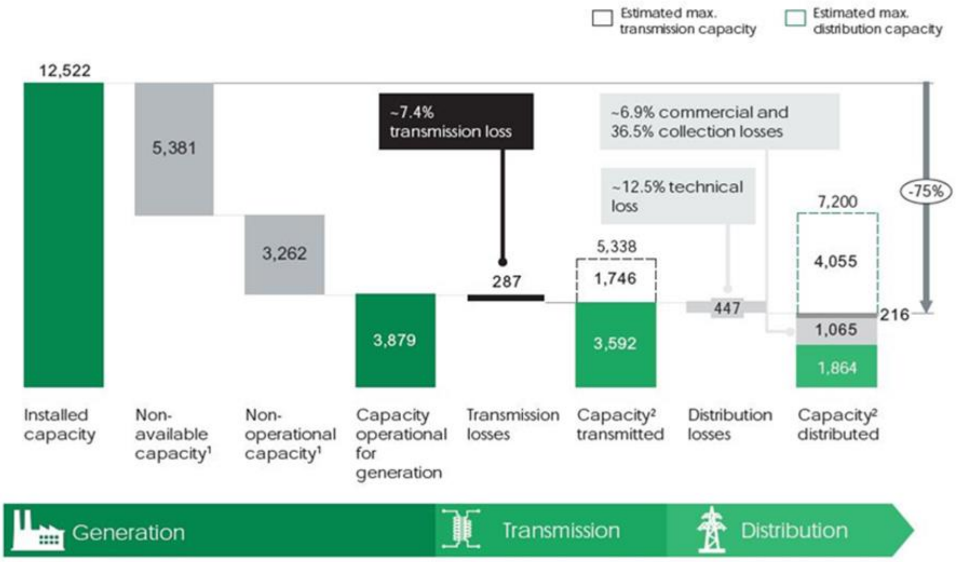


FIGURE 8. Nigeria Power Sector Energy Flow (GetInvest, 2021)

TABLE 4. Power consumption and transmission in Nigeria (The Worldbank Data)

Country	Electric power	
	Consumption per capita kWh	Transmission and distribution losses % of output
	2014	2014
Nigeria	144.5	16.1

Despite there has been consistent and increasing demand for energy in most part of the globe due to development and globalization. It has turned into a problem for emerging nations, particularly in Africa. However, the main goal of this project is to produce power for the city of Yenagoa in the Nigerian Bayelsa State. Based on findings, 85 and 90 percent of the state populace requires electricity to run their homes, places of work, factories, and air conditioning units. The main focus of this thesis is the development of a 10 MW waste-to-energy facility that will contibribute or increase power production and supply in the sate and also distribute to towns and villages around the vicinity for their power supply. As a small planned city with some shanties areas, wastes in Yenagoa metropolis are collected by contractors in agreement with Bayelsa State Environmental Sanitation Authority. Usually, municipal waste are collected together without segregating, recycling and disposed of in a public dumpsite (Stanley, H. et al., 2018). Most times, wastes are used for landfill some couple of kilometers away from the city. Municipal waste is seriously impacting the states environmental sustainability, and is directly and negatively affecting human health.

Grandwater, the primary supply of drinking water in the state, can get contaminated with materials dangerous to human health from improperly and recklessly disposed waste. While solid waste burning pollutes the environment (air, land and water), posing major health challenges such respiratory infections, cancer, and other linked ailments, pollutants enter the human body through ingestion of water, vegetables, and animal products. The Waste-to-Energy facility will run on waste from the dumpsites. Residents will benefit from the energy collection from the waste plant since it will create electricity and eliminate the hazardous stench that comes from the waste sites. Municipal garbage would be eliminated in Yenogoa Metropolis as a result of the construction of a waste-to-energy plant, which would be in line with government initiatives and goals for the production and distribution of energy.

2.1 Fuel from Waste

Municipal solid waste includes energy-rich resources such as complex trash, plastics, papers, by-products of wood, and many more, according to the U.S. Energy Information Administration, (2020). 85 pounds of every 100 pounds of municipal solid trash are reportedly burned and utilized as fuel to create power in the US. By turning 2,000 pounds of waste into ashes that weigh between 300 and 600 pounds, incinerators may cut the volume of waste by 87 percent. Municipal waste, sometimes known as trash or garbage, is burned in a waste-to-energy facility to create steam, which is then utilized to generate power.

There are various sources of fuel used in running different plants. However, based on the intended design and construction of this project, municipal waste is the fuel option for the incineration plant. This is practically so because of the availability of waste resource. As stated by Chinedu, Ike (2018) about 42 MT of waste is yearly generated in Nigeria, in that, just about 20 to 30 percent of these waste is collected and this was opined by Wale Bakare, (2021). It is also crucial to keep in mind that wastes with lower calorific values typically have poor combustion, which would result in problems with environmental pollution. The ineffective waste separation, high moisture content, mixing of building and demolition debris, dust from road sweepings, and drain silt present in municipal solid waste are all contributing factors to the wastes' poor calorific value. Another crucial issue is the formation of very heterogeneous waste both in size and composition, aside having a high moiture content.

2.2 Configuration of Waste in Yenagoa

An efficient tool to lessen the danger brought on by an inadequate waste management system is strategic waste management and control. Steps have been taken by both the governmental and business sectors to ensure better public health. However, in contemporary society, where environmental deterioration has emerged as a major problem in the majority of nations, particularly in light of the expanding population and the ongoing demand for power supply. Globally, nations are creating policies to support environmental sustainability for the protection of public health based on this concept (Ebikapade, et al., 2017).

2.2.1 Household Waste

Domestic trash is essentially waste produced by household activities including cleaning, cooking, storing clothes and furniture, using outdated kitchenware and utensils, gardening, and other activities. Domestic garbage in the city of Yenagoa consists primarily of food waste and tiny amounts of paper, plastic, glass, and metal. The majority of households and companies have taken advantage of the lack of a sufficient government enforcement and monitoring program for trash disposal, which has hampered the use of appropriate environmental policies to resolve the problems of waste management and disposal. The retail industry is one important sector that produces a significant amount of garbage, and it has a very large scale because it employs more people than any other type of business. Both the amount of trash produced in this industry and the best methods retailers may employ have not been sufficiently studied. In Yenagoa metropolitan, the retail industry is the primary generator of municipal waste. Plastics, papers, cans, tins, cardboard, wood products, and furniture make up the majority of the waste produced by this industry (Ebikapade, et al., 2017).

2.2.2 Waste from Commerce

Commercial wastes are typically produced by enterprises and consist of cardboard, paper, retail packaging, cans, and food wrapping, which should be disposed of legally. Commercial wastes are not allowed to be disposed of in residential trash cans. These wastes are produced at workplaces like offices, retail stores, hotels, restaurants, and other commercial facilities. Due to the fact that they share almost all of the same natural components as household garbage, they are not entirely distinct from it. In Yenagoa, wastes generated from the food market make up a larger portion of the commercial wastes produced, along with smaller amounts from other sources. Commercial wastes can contain certain health risks, thus they are not completely free from danger.

2.2.3 Waste from Institutes

Due to their creation and origin, industrial and institutional wastes are regarded as garbage. Wastes generated by hospitals, government buildings, clinics, jails, and schools are referred to as institutional wastes. These waste types often consist of domestic and commercial garbage that is not found in houses but is nonetheless deemed dangerous in some circumstances. While industrial wastes are trash produced by factories, foundries, and mills.

The wastes might be liquid, solid, gaseous, sludge-like, and toxic, but they most definitely are not household trash. They come more from packaging than from food, can be dangerous and contagious, especially if they come from hospitals, and in that case, proper waste segregation methods is required. Given that both classes of garbage involve hazardous waste, it is essential that businesses and institutions take the necessary actions to guarantee that wastes falling under these categories are handled correctly and safely.

2.2.4 Wastes from Industries

These wastes come from manufacturing or industrial activities. Concrete and masonry waste, metal scraps, cafeteria waste, gravel and soil, trash, solvents, oils, weeds, grass, and trees, chemicals, wood waste, and many other things are among them. This category of trash is wholly reliant on the nature of the industry and its manufacturing processes. If there are more metals, plastics, and papers in the garbage, then packaging materials are used more frequently in industrial or manufacturing processes. Climates, seasons, and the socioeconomic activities of the region allocated for waste collection all affect how this material is composed differently.

2.2.5 Construction and Demolition Waste

Depending on the building materials used, waste produced during construction and demolition mostly consists of bricks, concrete, ceramic, stone, soil, packaging materials, wood, etc. Construction trash should not be used in a waste-to-energy facility (World Bank Technical Paper No. 462, 2000).

2.3 Heating Value

A lower calorific value (H_{inf}) is of the utmost importance, which could depend on the design of the incinerator, and is based on the various physical and chemical factors of the waste. The heating value is the capacity of waste to burn sustainably in the process of combustion without additional fuel. Low-quality fuels needs a design that reduces loss of heat and provides to dry waste prior to combustion. However, water vapor from the incineration process and the fuel's moisture content are diffused with flue gas in the process of burning. Energy-containing water vapour gives the contrast between the lower fuel and calorific higher values (World Bank Technical Paper No. 462, 2000). According to IEA Bioenergy, (2003) A ton of MSW can produce about 600 kWh of energy and typically has a calorific value of coal that is roughly one-third that of MSW (8–12 MJ/kg as gotten against 25–30 MJ/kg for coal).

2.4 Calorific Value

Waste that needs to be burned in an incinerator must adhere to a set of specifications and minimal standards, particularly in terms of calorific value. It is the mass of waste expressed in KJ/kg, J/mol, or Btu/m^3, and its demand varies depending on the technology being used and how efficiently it operates. Typically, though, it will not be less than 6,500 kJ/kg. Burning garbage with lower calorific value could be likely in relatively explicit conditions if managed skillfully. Wastes with a lower calorific value, however, can only be burned with additional fuel. Another need, in cases of fluidized bed combustion, is the size of the waste to readily enter the grate or into the burner. It is practical to slice large tires into smaller pieces before burning them as one example of a burnable item (World Health Oorganization, 1996).

TABLE 5. Calorific value of waste materials examples (Igniss Energy, 2022)

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
Braun carbon	7 - 12	1673 - 2867
Petrol (benzine)	45 - 47	10573 - 11231
Coal	15 - 27	3584 - 6452
Diesel	46	10992
Ethanol	30	7168

2.5 The Issue of Waste Disposal in Yenagoa

Not just in Yenagoa but across the entire nation, the problem of garbage disposal is a serious one. According to Abowei et al., (2017), wastes are essentially non-useful resources that cannot be consumed, manufactured, or converted into anything else. Municipal solid wastes are superfluous materials that are ready to be thrown away. They can be solid or semi-solid and are not beneficial for further use. They are also not economically significant or have any other creative uses or benefits for the owner. Wastes come in a variety of forms with various components and properties, including domestic, industrial commercial, construction, agricultural, mining, electronic, and medical waste.

Cities in Nigeria have struggled with the issue of rural-urban migration. This is a result of the local population's desire to keep up with modern advancements and technology. But unhappily, due to unproductive, insufficient, and terrible sanitary facilities, the growth in population and the activities associated with it have demanded a large volume of garbage that is managed improperly. They consequently pollute the environment as a result of careless handling and management. According to Abowei et al., (2017), illegal garbage disposal has a detrimental effect on the ecosystem, as well as contributing to socioeconomic, environmental, and health problems, which are technically dependent on their strategic management. The following methods are used to address the issue of trash disposal in the metropolis of Yenagoa:

2.5.1 Peoples Attitude

People in Yengoa are aware of waste management practices, according to Stanley et al., (2018), who also noted that they have an informed and positive attitude toward managing and disposing of garbage. This is so in that, their consciousness can vary according to their genda, income, and educational attainment. Residents who are accustomed to disposing of rubbish are adamant about storing wastes in bins before disposing of them at temporary or appropriate dump sites. On the other hand, trash is left in the backyard, burned in the open, dumped in rivers, and left by the sides of the roadways. However, the current collection and disposal methods are inefficient. Residents observed these inefficiencies and blamed them on the inaccessibility and high cost of waste collection and disposal materials (waste bins, polythene bags, and brooms), as well as the small number of government-selected waste sites. The State Environmental Sanitation Authority has been ineffective in their role as a result of insufficient funding, lack of employees, and a lack of operating supplies and equipment. In order to lessen the problem of municipal trash disposal in Yenagoa metropolis, it is imperative that the State government provide new locations for waste collection, support the cost of supplies for waste disposal, and sufficiently pay the state sanitation authority.

2.5.2 Waste Disposal Mechanism and Non-availability of Facility

According to Stanley et al., (2018), the Bayelsa State Environmental Sanitation Authority is primarily in charge for the evacuation of waste. However, not all of the factors that contribute to their effectiveness are related to personnel, funding, and equipment. The Bayelsa State Environmental Sanitation Authority (BSESA) acknowledged that a major obstacle to their capacity to successfully carry out their duties is the lack of operating garbage collecting vehicles and insufficient work materials. However, Elenwo et al., (2019), noted that there is a gap between the amount of garbage produced and suitable waste disposal and collection mechanisms, and that the state lacks the relevant data regarding the enormous amount of domestic waste that is generated in the city. And so, contractors are not able to satisfy the demand for waste generation and evacuation, which has led to a snowball effect of inefficiency. Other than the aforementioned, the State does not have a clearly defined waste management strategy. The answer is that in order to enable efficacy and accountability, it is crucial to establish sufficient waste management systems and oversight for government-registered organizations and contractors.

FIGURE 9. A Road in Yenagoa with smelly heaps of wastes (Igoniko Oduma, 2018)

FIGURE 10. Heaps of waste being burned around Tombia in Yenagoa (Stanley, Herbert, et. al., 2018)

TABLE 6. Physical Classification based on the mass of solid waste stream (Angaye, Tariwar, et. al, 2019)

Waste stream Coordinates	A (Akenfa)	B (Etegwe)	C (Opolo)	D (Kpansia)	Total mass(kg)
	Mass (kg) N04° 59^{I} 57.8^{II}E006° 23^{I} 23.6^{II}	Mass (kg) N04° 57^{I} 57.8^{II}E006° 21^{I} 11.6^{II}	Mass (kg) N04° 56^{I} 57.8^{II}E006° 20^{I} 08.2^{II}	Mass (kg) N04° 55^{I} 30.4^{II}E006° 19^{I} 04.2^{II}	
Garbage or food	12.46	5.96	9.11	5.79	33.32
Paper	3.33	2.43	5.00	4.14	14.90
Plastic	2.00	0.90	1.38	0.84	5.12
Nylon	2.26	1.12	1.02	6.61	11.01
Metal	0.97	0.75	1.81	0.78	4.31
Wood	0.26	0.44	1.18	0.41	2.29
Electronic	1.28	1.06	1.64	1.71	5.69
Glass/Ceramics	1.03	0.74	0.94	0.77	3.48
Unclassified	1.46	1.01	1.15	1.00	4.62
Total	25.11	14.43	23.24	17.04	79.82

2.5.3 Waste Segregation or Sorting

There is practically little or no waste segregation or sorting practiced in Yenagoa metropolis, and this is the same in all states of the federation, particularly where the technology of recycling and re-use of waste has not been embibed. Despite some level of recycling, the percentage is minimal. The reason for this assumption is because of the amount of recycleable waste generated daily that are littering the roads, streets and gutters, with no intervention protocol to evacuate them. Stanley, Herbert, et. al., (2018) supported this assumption by stating that waste are collected without segregation or recycling. To improve the states sanitary conditions, government should make provision for waste disposal materials or better still fund the cost of these materials through the sanitary agency or its subsidiary.

2.6 Solid Waste Generation in Nigeria

According to Beatrice Abila & Jussi Kantola, (2013), a stargering 25 million tones of wastes are annually produced in Nigeria. It stated that in urban settlements, the rates ranges between 0.66 kg/per person/day to 0.44 kg/per person/day for local settlements in contracts to 0.7-1.8 kg/per person/day obtainable from advanced nations. There has been a steady rise in the generation of municipal wastes by houses, educational, commercial, among other institutions. The generators of municipal wastes in Nigeria are homes, industrial, commercial, agricultural and institutional commerce . From urban to rural areas, as well as from one state to another, there are differences in the type and quantity of garbage produced. The amount of waste created directly relates to the population, socioeconomic standing, and level of development. Additionally, the quality of the garbage that is produced varies from state to state and gets worse every year. Additionally, a state's arrangement of wastes is dependent on its socioeconomic position, level of development, and amount of commercialization, all of which are related to soci-oeconomic and developmental growth.

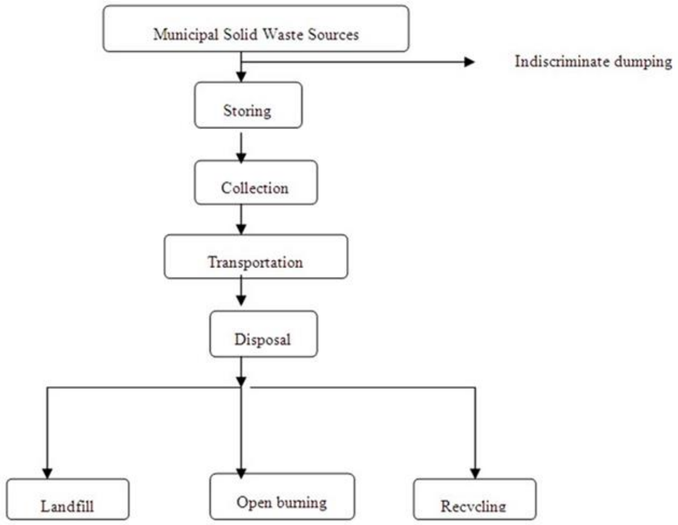


FIGURE 11. Nigeria’s solid waste management flowchart (Abila, Beatrice & Kantola, Jussi, 2020)

2.7 Effects of Solid Waste on Climate Change

Climate change, according to Enete, (2010), is any modification of the climate over time, whether brought on by a natural event or sparked by human activity. In 1988, the International Panel on Climate Change (IPCC) was promogated to address this problem by laying the groundwork for the United Nations Framework Convention on Climate Change (UNFCCC), which was established in 1992. According to Nabegu, Aliyu., (2012), the Nigerian government endorsed this development in 1997 as a positive move in the correct path. Accordig to UNFCCC, climate change is an intentionally or unintentionally alteration of the climate brought about by human actions that redefined the climatic conditions, combined with the climate's original changeability perceived in an equivalent period of time (Enete, 2010). According to EPA, (2016), scientists have found a rise of 1°F in the average temperature of the earth's surface, with a majority of these changes attributed to human activity. The average earth's temperature rising by only a little bit would lead to:

1. Wider temperature ranges
2. More frequent and powerful storms
3. Flooding along the coast, marshlands, and other low-lying beach regions
4. Some locations have received additional rainfall, while others have not received enough.
5. Wider spread of some types of illnesses

Such significant climatic ups and downs harm societies and national economies in addition to changing the usual world and causing many anxieties. It is also not possible for humans or the environment to adapt to such changes, but it is evident that any climatic changes cannot be quickly reversed because greenhouse gases persist in the atmosphere for a very long time. It may take decades or possibly entire epochs to reverse climate change.

Currently, the majority of Nigeria's waste is managed in poorly controlled landfills, where anaerobic deprivation of organic matter occurs and CH_4 emissions are produced. Once organic garbage is transported to an open dumpsite, as it is customary in most Nigerian cities. Wastes immersed beneath layers of earth that eventually deplete oxygen and allow organic material to decompose in anaerobic conditions. Methane is created through anaerobic degradation, which is brought on by the practice of disposing of trash at open dump sites (Nabegu, Aliyu., 2012).

2.8 Collected Amount of Waste in Yenagoa

The quartile method of estimation was used in a study by Tariwari, et al., (2019), which examined the physical classification of municipal solid waste dumped in four industrial waste dumps in Yenagoa. The data indicated that an overall waste mass of 79.82 kg, 33.32 kg was made up of food waste, 14.90 kg was made up of paper, plastic 5.12 kg (6%), 11.01 kg was made up of nylon (13%) wood 2.29 kg (3%), metal 4.31 kg (5%), electronic 5.69 kg (7%), ceramic/glass 3.48 kg (4%) and uncategorized waste 4.62kg (5%). The effects of inappropriate municipal waste management and disposal are directly related to the ecology since the disposal of unprocessed and unclassified waste has adverse consequences. If households avoids improper garbage disposal, it would be environmentally good. Policies that promote trash reduction, reuse, and recycling should be developed by the state government and other stakeholders.

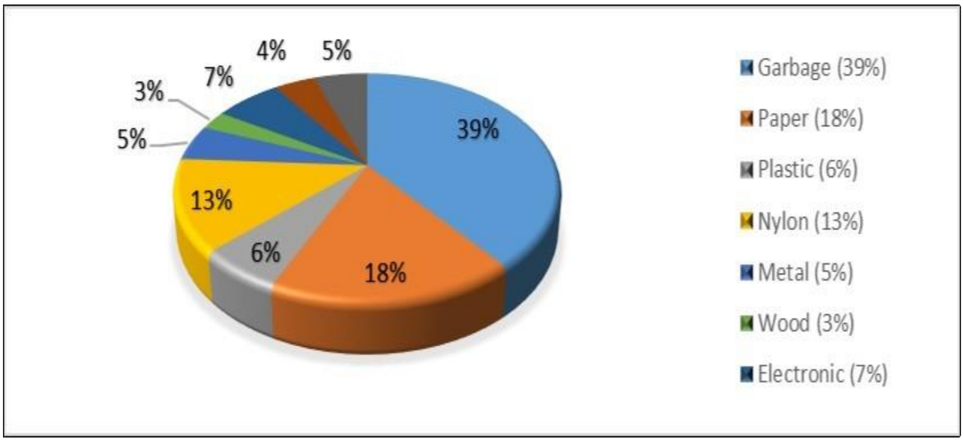


FIGURE 12. Municipal Solid Waste Characterization ((Angaye, Tariwar, et. al, 2019)

The table below is an illustration of the population growth in Bayelsa State. Though, most of the local government areas are in close proximity except Nembe and Brass LGA's that are located offshore. The primary jurisdiction is Yenagoa Local Area where the waste-to-energy plant will be located due to accessability.

TABLE 7. The population development in Bayelsa State (National Population Commission of Nigeria - National Bureau of Statistics 2006-2016, www.Citypopulation.de)

Name	Status	Population Census 1991-11-26	Population Census 2006-03-21	Population Projection 2016-03-21
Bayelsa	State	1,121,693	1,704,515	2,278,000
Brass	Local Government Area	...	184,127	246,100
Ekeremor	Local Government Area	124,279	269,588	360,300
Kolokuma/Opokuma	Local Government Area	...	79,266	105,900
Nembe	Local Government Area	...	130,966	175,000
Ogbia	Local Government Area	...	179,606	240,000
Sagbama	Local Government Area	119,759	186,869	249,700
Southern Ijaw	Local Government Area	267,371	321,808	430,100
Yenagoa	Local Government Area	...	352,285	470,800
Nigeria	Federal Republic	88,992,220	140,431,790	193,392,500

To get the overall waste composition per day, we multiply the generated waste per capita and the area of the population, and to arrive at the overall waste volume per year, we multiply total waste amount per day with 365 days.

TABLE 8. Calculation of waste generation in Yenagoa LGA

Waste Parameters	Waste Values
Population of the area	470,800 people projected as at 2016
Waste per capita	0.65kg/capita/day
Waste per day	0.65kg/capita/day*470,800 = 306,020kg/day
Waste per year	306,020kg/day*365days = 111,697,300kg/year = 111,697.3 tones

To get the total value of waste composition per day, we multiply the % of waste by the population of the area.

TABLE 9. Calculation of waste composition in Yenagoa LGA

Total Waste (Types) Comp.	% of Waste	Projected Pop.	Total amount of waste derived/day
Food waste	39	470,800	39*470,800 = 18,361,200/day
Plastic	6	470,800	6*470,800 = 2,824,800/day
Paper	18	470,800	18*470,800 = 8,474,400/day
Glass/ceramics	4	470,800	4*470,800 = 1,883,200/day
Wood	3	470,800	3*470,800 = 1,412,400/day
Metals	5	470,800	5*470,800 = 2,354,000/day
Electronic	7	470,800	7*470,800 = 3,295,600/day
Nylon	13	470,800	13*470,800 = 6,120,400/day
Uncategorized	5	470,800	5*470,800 = 2,354,000/day
		Total	100*470800 = 47,080,000/day

2.9 Energy Content of wastes

In a research from Abubakar, et al. (2018) gives the illustrations below:

TABLE 10. Energy content of waste and calculated moisture content, where Mc = Moisture content (Abubakar, A. et. al., 2018)

Waste types	% Share of the waste by mass	Wet weight (kg)	Dry weight (kg)	Moisture mass (kg)	Moisture content (%)	Typical energy kJ/kg (as discarded)	Total energy kJ (based on 100 kg sample)
Organic	24.1	2.22	1.40	0.82	36.936	18,000	433,800
Plastics	10.2	0.94	0.80	0.14	14.893	32,600	332,520
Paper	9.8	0.90	0.77	0.13	14.444	16,750	164,150
Glass	9.3	0.86	0.84	0.02	2.326	150	1395
Metals	6.4	0.59	0.57	0.02	3.390	700	4480
Textiles	13.2	1.22	1.01	0.21	17.213	17,450	230,340
Polythene	27.0	2.49	2.31	0.18	7.229	32,600	880,200
Total	100.0	9.22	7.70	1.52	M_C = 16.486		2,046,885

The content (Ec) of energy is calculated thus:

E_c = (As discarded) Typical energy / 100 Equation (1)

On dry basis, the energy content is calculated using

$E_{dry} = E_{discard}$ (100 / 100 - % moisture) Kj / kg Equation (2)

On ash-free basis, the energy content is

$E_{dry} = E_{discard}$ (100 / 100 – % moisture - %Ash) kJ / kg Equation (3)

By applying equation (1) in the above table, for as discarded, the energy content for municipal solid waste is at 20468.85 kJ/kg. The overall moisture of 16.486% on dry basis, the energy content is computed by applying Equation (2) above which is 24510.66 kJ/kg. For the ash free basis, supposing the value of the ash is 5%, the energy content is calculated by applying Equation (3) to be 26071.65 J/kg.

Below are the energy contents of some fuels based on some energy related conversion factors.

TABLE 11. Energy content of some fuels (DeepResource, 2012)

Energy Source	Energy in KWh	Energy in Joules
1 kilogram of dry wood	5,3 kWh	19,0 MJ
1 kilogram of coal	8,1 kWh	29,3 MJ
1 cubic metre of natural gas	8,8 kWh	31,7 MJ
1 litre of petrol	9,1 kWh	32,6 MJ
1 litre of diesel-oil	10,0 kWh	35,9 MJ
1 kilogram of hydrogen	33,6 kWh	120,8 MJ
1 kilogram of Uranium 235	22,2 million kWh	80,0 million MJ

2.10 Processes of Energy Conversion

At high temperatures, it is possible to convert biomass wastes to alternative energy sources, which will dissolve into minute and sparser composite particles of liquid and gas, along with certain solid components. A thorough oxidation process called incineration produces carbon dioxide (CO_2) and water (H_2O) as byproducts. Fractional breakdown can create a variety of usable fuels by controlling the combustion process with the use of temperature, pressure, and other inhibitors by controlling the oxygen flow. The three main thermo-chemical conversions are pyrolysis/charcoal production, combustion, and gasification. The advantages of these processes include quick reaction times, a reduction in large-volume biomass, a liquid operating range, and the generation of solid and gaseous products, in contrast to other processes that require additional heat to complete. A thorough grasp of energy systems is required for engineering and technology, which depend on the ability to use energy sustainably in a variety of ways.

3.0 WASTE TO ENERGY PLANT

3.1 Technology

There are numerous waste-to-energy systems and processes available today. However, the mass-burn method, which is most commonly used in Europe and the US, ignites untreated municipal solid waste in a sizable burner that also has a boiler and a generator to provide energy (U.S. Energy Information Administration, 2020). A method that processes municipal solid trash to remove the majority of the incombustible materials and produce refuse-derived fuel (RDF) is another, and becoming more and more popular in Europe.

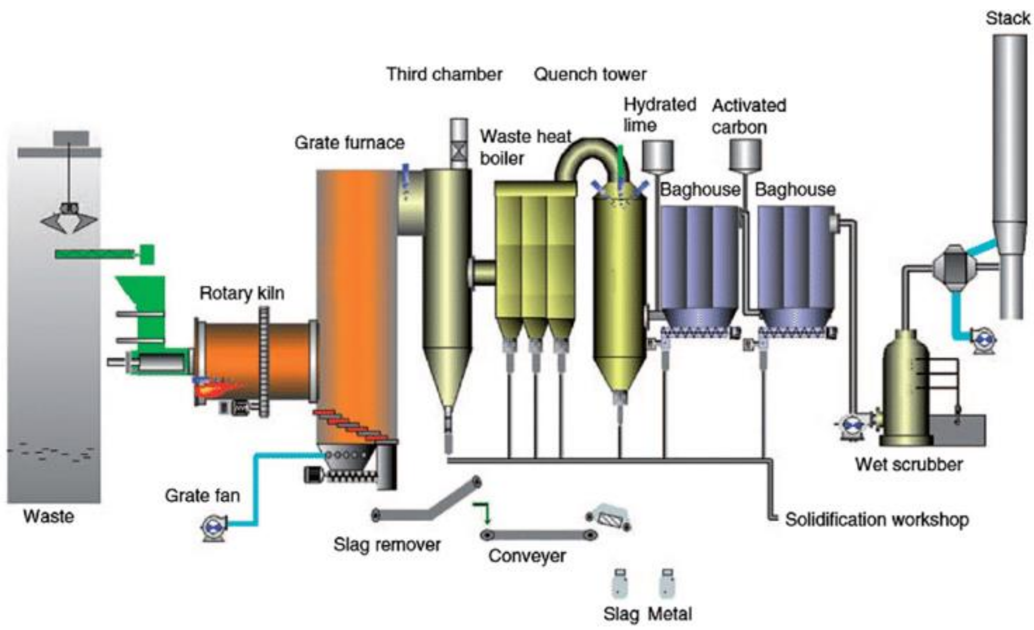


FIGURE 13. A Waste-to-Energy Plant (Zjup, Wdse & Jiang, Xuguang & Li, Yanhui & Yan, Jianhua, 2019)

The mass-burn system uses a boiler and a generator to generate power while burning massive amounts of untreated municipal solid waste in an incinerator. This system, which complies with technical performance requirements and can burn huge configurations of waste with high calorific values. It is generally in use and is adequate. Without human separation, size reduction, and chopping, the system's capacity to function will be hampered while burning untreated garbage. When picking a waste-to-energy plant, it is vital to take into account the technology that is feasible, as well as the technological capability in connection to the amount, type, and location of the waste that is accessible. As a result, the mass-burn system with a moving grate is the technology type that satisfies this requirement. Conpanies with variety of references from facilities that have successfully functioned for many years in low- and middle-income economies are important factors to keep an eye on. The combustion technology should be created in such a way as to prevent the formation of pollutants, especially organic substances like dioxins. Putting safeguards in place to guarantee the combustion process is technically efficient is also vital. The essential components of an incineration plant are listed below, and their functions will be covered later.

1. Pit for storing waste
2. Hopper
3. Super heater
4. Electrostatic precipitator (ESP)
5. Grate
6. Economizer

7. A fan that drafts
8. Furnace
9. Boiler
10. Ash collector at the bottom
11. Chimney
12. Scrubber
13. Cyclone

3.2 Moving Grate

Moving grate combustion means that in order for there to be a complete and efficient combustion, the grate should be able to move the waste to the incineration chamber. 35 metric tons of garbage can be burned at an incineration plant by itself in an hour of processing. For an incinerator plant, there are primarily 4 types of moving grate, as listed underneat:

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

A grate system that moves allows for the burning of a wide variety of wastes without the requirement for waste treatment. The remnants are then carried to the ash pit where they are water-treated by washing away the ash. On the grate, the waste is initially dried, and burned in a heat between 850 ºC to 950 ºC, followed by air supply.

3.2.1 Rotating Drum Grate

This grate slowly spins the waste at a changeable pace of roughly 3 to 6 revolutions in an hour, and allowing for an effective waste combustion while the spinning drum grate provides an inclined fuel bed for the waste burning. Due to their low efficiency, the revolving drum grate and the counter direction grate are frequently not used in the burning of garbage, therefore little is known about how they work.

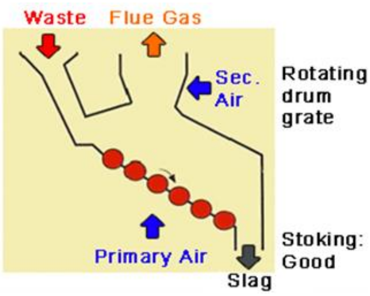


FIGURE 14. Rotating Drum Grate (Mecislav Kuras Institute of Chemical Technology in Prague)

3.2.2 Reciprocating Grate

Reciprocating grate's closed feed action of the grate series makes it suitable for most fuel kinds, if not all of them. Every cylinder's speed can be adjusted individually, and the bottom grate air can be adjusted for different parts. The reciprocating grate is a set of secured movement grate bars that is shaped like a staircase. Through the wind zone below the grate as a cooling effect on the grate layer.

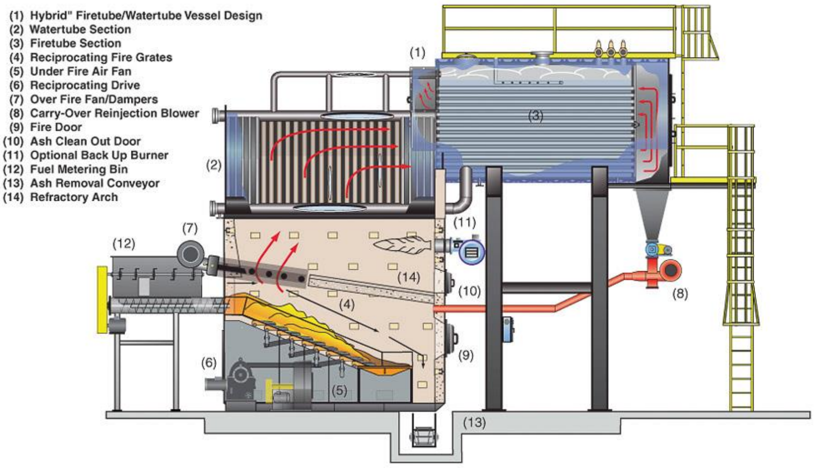


FIGURE 15. Reciprocating Grate (HurstBoiler, 2022)

3.2.3 Travelling or Horizontal Grate

The horizontal or travelling grate often uses a high calorific fuel content via the cycling grate layer to maintain a consistent load and cool the grate bar. As the fuel burns, the traveling grate serves as a conveyor and is connected to single bars to allow horizontal movement. At the conclusion, the burned-out fuel is transferred into the ash hopper beneath the grate.

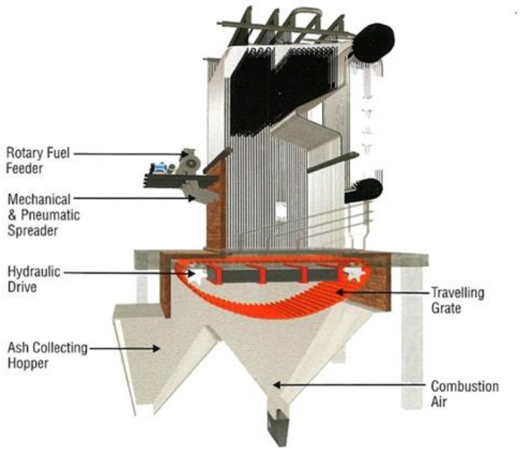


FIGURE 16. Travelling or Horizontal Grate (Full System Engineering Co, Ltd., 2019)

3.2.4 Counter Direction Push Over Grate

A counter direction push over grate operates similarly to the traveling grate. It does, however, have an extra layer that enters from the other way, improving the fuel mixture and allowing for its working capacity.

3.3 Recirculation of Flue Gas

Recirculation of flue gas occurs when flue gas portion is circulated through the boiler or burner during the burning process. Exhaust gas recirculation (EGR) is the common name for how combustion engines employ the burning process. One of the two primary purposes for flue gas recirculation is exclusive to gasifiers (B. Wilson, 2019). Flue gas recirculation is typically incorporated into the furnace's design. About 20 to 30 percent of the flue gas is suppressed and preserved through a safe conduit and sent to the furnace after passing past the dirt filter. The secondary ignition chamber, or initial pass of the burner, is the area flue gas will be introduced via several vents inside the turbulence region of the furnace. Some advantages of flue gas recirculation are:

1. As flue gas is circulated, oxygen and extra air can be greatly reduced, leading to a very high thermal efficiency (perhaps a 1 - 3% increase in efficiency).
2. When 20 to 40 percent of flue gas is circulated, NOx is reduced by 20 to 40 percent, and the production of dioxin is decreased when it is combined with a tiny quantity of extra air and little oxygen.
3. Stabilizes or exacerbates flow instability, especially at fractional load
4. Lessens the chance of a burst inside the minor ignition chamber of the burner during the first run.
5. Lowers the flue gas amount that enters the cleaning system for the flue gas

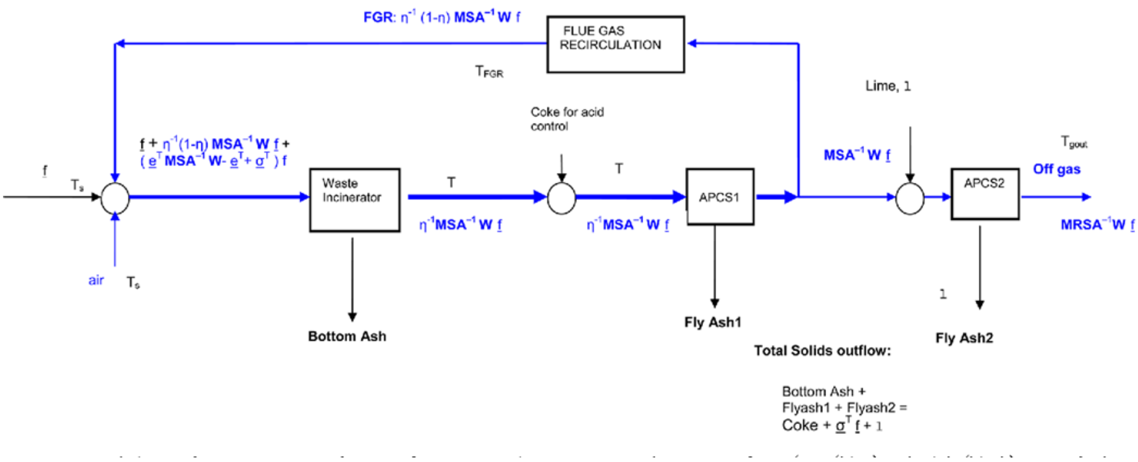


FIGURE 17. Flue Gas Recirculation (Tsiliyannis, C.A., 2013)

3.4 Fans and Combustion Systems

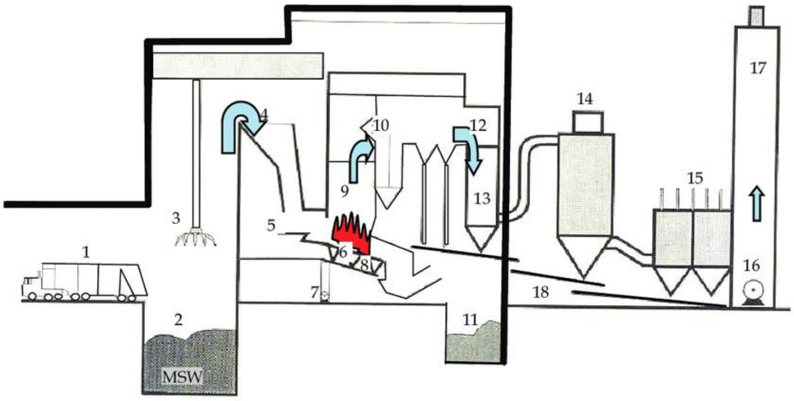
To ensure combustion efficiency, avoid a deteriorating (destructive) environment, incomplete flue gas exhaustion, and other potential issues. The design and regulation of the combustion air system must be given some amount of importance as the system delivers in the flue gas. Secondary air inlets are found above the boiler or furnace in the waste pit. Depending on the design, 3 to 5 rows of nozzles must be used to supply air into the furnace with the conclusion of the initial boiler run (after-combustiom chamber). By using motor-powered dampers, the secondary air sum delivered to individual row of vents is adjusted automatically. A manufactured air pre-heater with a bare tube structure should pre-heat the main air with damp waste and little energy. According to the waste's composition and moisture content, it should be possible to heat the main air to a temperature of between 10 and 145 degrees Celsius.

3.5 Control of Air Pollution

Every nation has its own standards, laws, and regulations on environmental pollution in order to limit the quantity of emissions that organizations can release into the atmosphere. These rules include everything from air pollution to land, water, and even the products that businesses manufacture. The purpose of ELRI, (2021) Special Criminal Provisions Act, (Cap H1 LFN 2004) of the Nigerian Harmful Waste which forbids transport, dumping, and hazardous waste disposal in territorial waters and on land is to enable businesses to fulfill the requirement of maintaining and operating a healthy environment. The ability of waste-to-energy plants to regulate the pollutants and flue gases they emit into the environment is constantly improving. With the help of this technology, flue gases are practically eliminated and reduced before being released into the environment.

With reference to 2000/76/EC EU Directive, (2000) an incinerator is any static or moveable technical component used in processing waste thermally, with or without recapturing ignition heat. This includes burning by waste oxidation in addition to other thermal methods for the treatment of waste such as pyrolysis or gasification provided the materials treated are burned afterwords. The description process involves the incineration plant and the site layout plan:

- Reception and handling of wastes (on site pretreatment facilities, storage)
- Combustion chamber (air-supply system and waste fuel)
- Recovery of Energy (economizer, boiler etc.)
- Gaseous clean-up emission facilities
- Site facilities for waste treatment or storing stack, filtrates and waste water
- Devices and systems for incineration operations control, monitoring and verifying ignition conditions.



1-waste collection vehicle	7-forced-draft fan	13-economizer
2-waste storage pit	8-Undergrate air zone	14-dry scrubber
3-waste handle crane	9-furnace	15-fabric filter baghouse
4-feed hopper	10-boiler	16-induced-draft fan
5-feeder	11-bottom ash bunker	17-stack
6-grate	12-superheater	18-APC residues conveyor

FIGURE 18. Simplified scheme of a MSW incinerator(Quina, Margarida et. al., 2011).

The above figure shows a flow of mass in an incineration plant. (1) A waste carrying truck discharges the waste in a storage. (2) there must be reasonable wastes in the storage to enable the plant receive constant fuel supply. (3) wastes are randomly taken from the hopper and sends to the feeder. (4) and moving grate is supplied with wastes. (5) in the ignition chamber combustion takes place. (6) at this point, the plant is controlled, which enhances the process for the combustion to take effect, and to make sure there is a total burn-out of carbon. (7) at this level, it takes 60 mins or so to enable the draft fan to force the main air to pass under the below air grate inside the furnace region. (8) air is extracted from the storage for feeding furnace. (9) the reason is to guarantee the instability of flue gas, and to be sure there is total combustion, which has around 10 - 20% flue gas circulated again as secondary air. This is called an exothermic chemical reaction, which discharges excessive quantity of energy, which is carried in in heat form. The extracted air from storage is used in minimizing the pressure of the air and remove stink discharge from depository, which is un-indicated in the figure above. (10) the burner of boiler is the place energy is recovered. (11) the underneath where metals and ashes are filtered out, probably, for reuse and enhancement. (12). The economizer (13) underneath burned-out clinkers ready for dropping at (11) dry scrubber (14) Pollutants cleaning (15) fabric filter used for cleaning pollutants in the flue gas, afterwards discarded of as mono fills and finally, the processed gas (flue) is allowed through stack with help from a generated fan (Khallaf, 2011).

3.5.1 Waste Plant Gas Cleansing System

Waste incineration facilities, according to ABB Review, (1996), are outfitted with modern technology for purifying flue-gas, which ultimately results in no dioxins being released into the air. In contrast, they operate as dioxin sinks by removing the dioxins that were once entrenched in garbage, but in actuality they are lessening the pollutant's negative effects on the environment.

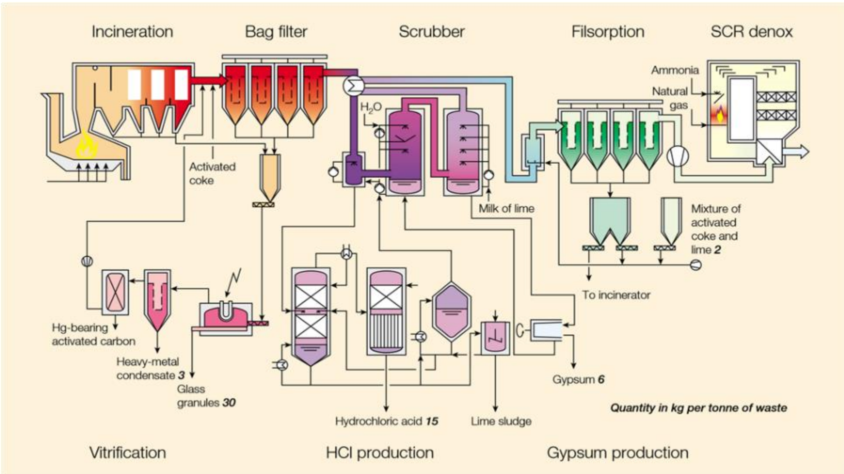


FIGURE 19. Flue-gas cleansing using the TCR method in waste incinerator facilities (ABB Review, 1996)

Before the flue gas leaves the stack, the following 3 essential components must be removed:

1. Fly ash, which consists of air-filled particles that are expelled by the gas movement;
2. Precursors of acids such as hydrochloric acid, sulfur oxide, and nitrogen dioxides;
3. Dioxins and their equivalents, which are mixtures created through fervent recombination with configurations like polychloro dibenzodioxins and the various furan equivalents.

The heat exchangers situated at the perpendicular tube surface, where the high / medium steam pressure is created before entering the cleansing system, exchange heat as the heated mixture of gas exits the furnace. Through a booster, some gas are redirected and introduced in the area under the grate that is moving. In subsequent cleansing procedure, many units purify the leftover effluent gas. The waste gases are cooled when heat exchange occurs at the surface of the boiler tube, and more new solids are created as a result, increasing the proportion of the particles. Additionally, these particles will be cleaned in order to comply with Nigerian environmental laws and regulations. The table below offers the estimated efficiency needed to remove each type of pollutant together with generally recognized legal emission limitations.

TABLE 12. Required efficiency for flue gas cleaning systems ((Quina, Margarida et. al., 2011).

Pollutant	Concentration in raw gas from boiler (mg/Nm^3)	Max admissible at exhaust (mg/Nm^3)	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 – 0.8	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

According to Khallaf, (2011), a sizable number of operations unit focusing on the main separation processes can clean the gas (flue) produced in the waste plant systems. Table 13 lists a blend of unit activities together with their unique ranges of reduction for each specific type of polluting flue gas. As Khallaf, (2011) stated, a well-designed system of gas cleaning procedures enables a drastic reduction in pollution.

TABLE 13. Cleaning processes for gases (Quina, Margarida et. al., 2011).

Pollutant	Process Steps	Reduction (%)
SO_x	Wet scrubber or dry multicyclone	50 - 90
HCl	Wet scrubber or semi-dry	75 - 95
NO_x	Selective catalytic reduction	10 - 60
Heavy metals	Dry scrubber + electrostatic precipitator	70 - 95
Fly ash *	Electrostatic precipitator + fabric hose filter	95 - 99.9
Dioxins & Furans	Activated carbon + fabric hose filter	50 - 99.9

3.5.3 Activated Carbon and Fly Ash Separation

Waste plants fly ash is a fuel composition, which essentially is stable, and typically stored and used as new cement-making materials. Most often contaminated with heavyweight irons and other hazardous materials. Waste incinerator fly ash products should be regarded as harmful leftovers that need to be inerted before being disposed of in a regulated landfill. The carbon that is created, which often takes the form of powder, is frequently used to absorb organic contaminants like furans and dioxins. In a specific cleaning stage, this powdered carbon production is added to the fly ash. The main tools used to remove fly ash and activated carbon solid particles include cyclones, cloth hose filters, and electrostatic precipitators (Khallaf, 2011). Here, we primarily take into account the degree of fly ash separation and applicability.

3.5.4 Cyclone

Cyclones are thought to be effective at removing solid particles when they have a regular diameter of between 0.1 – 2 m for gaseous flow. As Khallaf, (2011) mentioned, their design was reviewed at one point, and because of how extensively stainless, construction steel can be used depending on their level of permissibility and operating temperature. Cyclones are typically utilized as the primary separators in incinerator flue gas cleaning, followed by various units of separation designed to contain fly ash particles of smaller sizes (Khallaf, 2011).

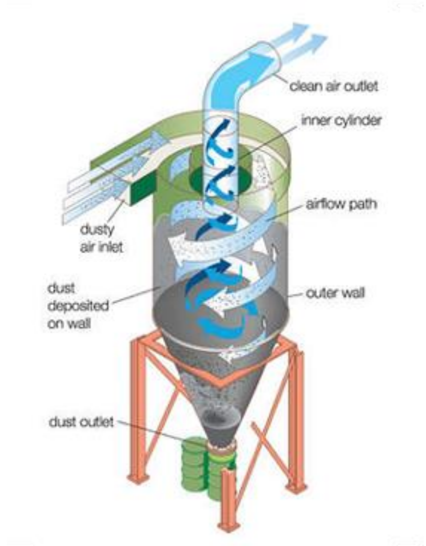


FIGURE 20. Cyclone (Shohanpal Mechanical Works, 2020)

3.5.5 Electrostatic or Electrified Precipitators (ESP)

According to Khallaf, (2011), Dr. Frederick Cottrell, developed the notion of particle separation using an electric field approximately a century ago. In order to prevent the reintroduction of aggregates made with the collected particles into the gas stream, the collecting area must be properly configured to maintain an acceptable wideness of the laminar boundary layer, which is fully dependent on the rapper and plate configuration. Gas speeds in the area of precipitation are typically never greater than 1 m/s and are typically lower than 0.5 m/s. In an incinerator plant, just as numerous, other process equipment have to be calibrated to steady state, so that the electrostatic precipitation be adjusted to that condition, however, with a system controlled, and equipped to regulate under destabilized to the highest conditions. Dynamic regulation is mostly needed and the fine regulation of efficiency is of maximum importance (Khallaf, 2011),

TABLE 14. Fly ash and activated carbon (AC) separation (Khallaf, 2011)

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 ºC	≥ 20 µm
ESP	up to 99%	up to 80%	50 to 300 Pa	450 ºC	0.08 to 20 µm
Fabric hose filters	up to 99%	up to 99%	500 to 2000 Pa usually with a booster fan	240 ºC	0.04 to 50 µm

TABLE 15. The most effective methods in the reduction of the key pollutants in an incineration plant (Archibong, 2017).

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, …)	Wet-scrubbers Semi-dry scrubbers (e.g. suspension 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 nitogen (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 non-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 revovery efficiency
APC residues	Treated (e.g. solidification/stabilization and disposed off) 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 Residues from Incineration Process

The by-products of the oxidation reaction between the carbon, hydrogen, and non-combustible elements present in the fuel in an incineration facility are primarily CO_2, H_2O, and fly ash. Though other potentially dangerous compounds can develop when the incineration processes do not occur in their fullest form. The types and concentration of contaminants in the waste stream or flue gases that are released during a burning process depend on the type of procedure, the type of waste being burned, and the burning environment. These pollutants can come from three different sources: they can be found in waste feed, can be created during combustion as a result of incomplete oxidation, or can be created during a reformation reaction in a gas cooling system or an air pollution control device (APCD) (National Research Council et al., 2000).

3.6.1 Slag

The byproduct of waste incineration or the ignition process in power plants is known as slag or ash. Slags produced by waste incineration facilities are crucial for ensuring environmental safety. In actuality, the last products of the municipal waste management system are slag and ash.

- Preparation of Slag

For every ton of waste processed at a waste-to-energy facility, roughly 250–350 kilos of slag are produced. Slag is the original waste, however it has entirely different characteristics according to its mineral makeup, iron content, scrap content, water content, and heavy metal material content. Prior to the re-use of wastes (bottom ash) from incineration plants, the grate ash should be properly treated and stored in a way that it complies with the standards of quality, based on its subsequent intended use.

- The Process

Slag is typically transported via conveyor from the waste incineration to the waste treatment facility, where it is kept for at least one day to allow for air and CO_2 integration. After that, the slag is sorted and compressed. In metallurgical factories, scrap iron and non-ferrous metals like aluminum, brass, and copper are separated from the slag and used as raw materials. A classifier is cleansed and cleaned of any partially burned residues. Concurrent chemical and physical processes will occur in the slag. In order to preserve the slag over time, it is crucial that partially burned wastes be taken into account based on technical recommendations and rules following processing. Slag cannot be used as a raw material or as a component of derivative products for the construction of roads unless the requirements specifications are met. Time and technology can combine nicely to improve the bottom ash's quality (Kowalski, et al., 2014).

TABLE 16. Incinerator Residues Chemical Composition (World Bank Technical Paper NO. 462, 2000).

Element	Unit	Slag	Fly Ash	Dry/semidry plus fly ash	Wetplus fly ash
O	g/kg	450	-	-	-
Si	g/kg	250	150	75	80
Ca	g/kg	75	100	250	150
Fe	g/kg	75	25	15	50
Al	g/kg	50	70	25	30
C	g/kg	50	-	-	-
Na	g/kg	25	30	15	2
K	g/kg	15	35	25	5
Mg	g/kg	10	15	10	75
S	g/kg	5	25	15	5
Cu	g/kg	3	1.2	0.7	1.2
Zn	g/kg	2.5	30	15	30
Cl	g/kg	2	75	200	35
Pb	g/kg	1.5	10	10	10
F	mg/kg	500	-	-	-
Cr	mg/kg	350	650	200	250
Ni	mg/kg	250	150	100	60
As	mg/kg	15	150	175	90
Cd	mg/kg	1.5	400	300	650
Hg	mg/kg	0.05	8	15	650

3.6.1.1 Slag Removal Process and Disposal

After burning the waste in the grate, some leftovers fall through gravity through the grate hole and into a bath with water or de-slagger which lowers the temperature. There, they are dissolved and some sodium chloride (salt) is extracted from the leftovers that have not been burned. Due to evaporation occurring during the operation, the water level in the de-slagger must remain constant. Slags are employed in landfills based on their amount of toxicity. Before dumping it, it must be treated if the amount of toxicity is too high (Archibong, 2017). Slag can be removed and disposed of in an incineration plant using a variety of techniques. One of them is based on PN-EN 12457, a European standard. It is a thermal treatment for metal waste that calls for metals elution tests and calls for absorbance with purified water at a waste proportion of 10 dm^3 per kg. An analytical sample weighing approximately dry matter of 0.090 kilogram is put inside a bottle container (from PP), and adequate amount of clean water is add on to make sure liquid is to solid phase ratio is equivalent as 10 dm^3/kg. The mix is then put together for an entire day, after which the contents are sifted, and the eluate result is processed for the component concentration (Wielgosiski, et al., 2014).

This approach is inadequate since it only takes into account the degree of pollution to determine the whole metal content and does not account for its bioavailability or its effects on the environment (Wielgosiski et al., 2014). A technique based on sequential extraction and analysis, however, allows for a more thorough heavy metals assessment and their effect on the ecosystem. Fractionation is centred on the categorization of an analyte or class of analytes from a derived specimen according to their chemical and physical properties, and it aids in the separation of metal forms of solid evaluations (samples). The sequential extraction method makes use of this concept to permit the separation of metal traces in chemical formations that can be released into a liquid under specific conditions for growth activities. The specific sample is treated with various hostile solutions as part of the overall analysis of sequential extraction. The distillates are then broken up using centrifugation, while the hard components are put through a second removal phase utilizing extractants that are developing and becoming more potent. Processes like physical and chemical solubility in water, oxidation and reduction, ion exchange, including complexation, are included in the following fractions phase. Water-soluble fractions, hydroxide fractions, residual fractions, exchange fractions, and fractions linked to the organic substance are a few examples of fractions that can be separated (Wielgosiski et al., 2014).

3.6.2 Fly Ash and Boiler Ash

As flue gas goes from the furnace and into the boiler at an incinerating waste facility, along with the best, nonburnable materials. Some combustion products will remain when the boiler ash are transferred from the boiler to below hoppers due to furnace's decreased flue gas speed. However, the flue gas treatment procedure will be applied to these finest materials. By the time the flue gas temperature in the boiler decreases, a large number of gaseous mixes evaporate heavy metals and their compounds, such as lead chloride ($PbCl_2$), zinc chloride ($ZnCl_2$), and cadmium chloride ($CdCl_2$), which then precipitate on the materials to make the fly ash. The Fly ash can be consumed separately or possibly in ESP or in addition to the byproduct of reaction of a partially dry or dry treatment of flue gas process. In most cases, it is typical to combine fly ash with boiler ash or the stream of the reaction product. About 2 to 3 percent of the entire waste is produced by this mixed combination, which is composed of mineral particles, inert, unpredictable-soluble salts (NaCl), and weighty metal compound ($CdCl_2$ that is able to disinitegrate). Usually, the ash will always be powdery and the grain size is very small (World Bank Technical Paper NO. 462, (2000).

3.6.2.1 Removal Boiler Ash and Fly Ash Disposal

The bottom hoppers of the boiler and ESP are where the ash is collected, and it is then transported in a conveyor that is closed into the silo. After being extracted in large quantities, the ash is ladened into a truck tank which is then sent to a landfill. To prevent the ash from generating dust at the landfill, it must first off be dampened with water or new sludge gotten from used scrubber liquid treatment. The dampening technique involves using gas or air to increase a material's moisture content. If a safety tarp is to be utilized, a truck with slush could be employed. The mass is improved by humidity by roughly 30%. (World Bank Technical Paper NO. 462, 2000). The ash is not suitable for use in construction operations because to its extremely high salt and heavy metal content, and there has not yet been any industrially known use for it. On the other hand, stringent and closely regulated landfilling is the only known technique of disposal.

3.6.3 Dioxins Filters Spent Absorbent

Most time adsorbents used from dioxin filters are recycled into the waste incinerator where they are burned, destroying the adsorbed dioxins. Alternatively, the used adsorbents could be utilized to treat the acid scrubber water, converting it to thin sludge. In order to avoid this, they typically do not implement a different stream of waste product that may be gotten rid of off the plant (World Bank TP 462, 2000).

3.6.4 Water Treatment Sludge

When HCl and SO_2 are extracted out of the flue gas using damp procedures, some waste-water streams are created, which has to be treated. When acid water is treated, hydroxide/TMT sludge is created, which is essentially 1 kg of dry stuff every metric ton of garbage burned (Table 15). The dry material content of the raw, thin sludge that is removed from the setting tank typically ranges from 8 to 10 percent. It is a liquid, thus pumping it is appropriate and not difficult. Gypsum ($CaSO_4.2H_20$) sludge is typically produced when SO_2 is collected wet. The amount of sludge depends on how quickly SO_2 is removed, but a standard ratio is 3 kg of dry material per metric ton of garbage burned (World Bank Technical Paper NO. 462, (2000).

3.6.4.1 Removal of Sludge and Disposal

Since sludge is mostly used to humidify the boiler ash and then mix landfill and fly ash with these ashes, it might be utilized for a variety of tasks. However, more chloride is added to the ash because the water contained in the thin sludge has $CaCl_2$ in mixture. As an alternative, it is asserted that the mixture's filtrate characteristics are tougher compared to the two components alone. Two of the sludges can be instead mixed or dewatered separately in a filter press, centrifuge, or vacuum filter. The leaching characteristics of the sludge are often more harsher than those of the dry and semi-dry treatment wastes since they are essentially landfilled. The gypsum is occasionally collected and used in industrial operations (World Bank TP 462, 2000).

3.7 Incineration Plant Waste and its Application

Wastes gotten from incineration plants can be used for various purposes as mentioned below:

- Road and Drainage Construction
- Production of cement
- Used as Manure for Agricultural Production

3.7.1 Road and Drainage Construction

Currently, residues of waste incineration do not simply find their way in landfills; rather, energy recovery and the management of solid municipal trash incineration ashes are gaining more and more attention around the world. Through the development and use of management methods and policies, numerous nations have reaffirmed the advantages of using these ashes. With the help of environmentally friendly policies established by their planned rules, many European nations have successfully used incineration trash as a sustainable resource for transportation (Tasneem, Kazi, 2014).

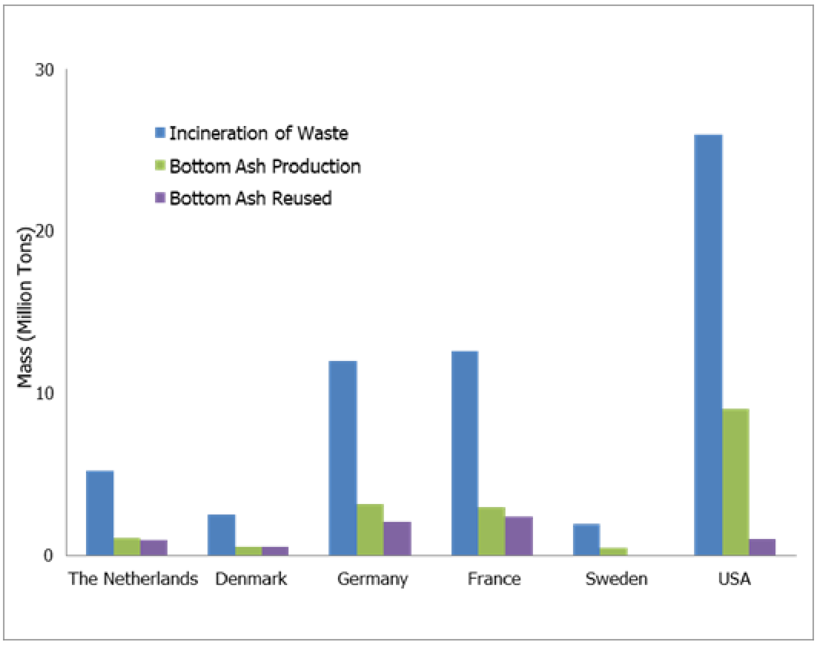


FIGURE 21. Incineration Waste Usage in European countries in 2003 (Tasneem Kazi, 2014)

Many countries, including the US, Sweden, Denmark, Japan, and others, have built motorable roads using bottom ash and fly ash. Boiler ash, which is formed of grate ash and occasionally, grate shifting, is one of the main components or by-products of waste incineration. In essence, it is made up of minerals, ferrous and non-ferrous metals, organic carbons, ceramics, and glasses. It is environmentally encouraged to process this byproduct before utilizing it to build roads in order to limit its leaching characteristics, as this could have a dangerous effect on the chemical composition of subsurface water. The boiler ash can then be utilized as a replacement for the typical road construction material after being treated (Archibong, 2017).

3.7.2 Production of Cement

The cement industry is one of the main contributors to climate change. Cement manufacture is one of the energy-intensive industrial processes and ranks second to water in terms of global product consumption. However, cement is also made from sludge from incineration facilities that contains silicon oxide, aluminum oxide, calcium oxide, phosphorus pentoxide, and ferrous oxide. Although the main ingredients needed to make cement are gypsum, clinker, and limestone. Due to the presence of calcium oxides and silicon, dried sludge can also be utilized in the manufacturing of mortar, making it an excellent raw material for the cement industry with additional advantages such as:

- Environmental conservation
- Cost-effective waste disposal;
- Less waste going to landfills that can be dangerous for the soil's composition

However, the European Commission claimed that using trash and biomass in place of fossil fuels is a false way to combat climate change as part of the EU Emissions Trading Scheme (EU ETS), (2012) reform.

3.7.3 Used as Manure for Agricultural Production

- Soil texture

According to Basu et al., (2009), the physical characteristics of a collection of soil mixed with fly ash of about 50% can be calculated. These experiments showed that the fly ash combination of soil is inclined to contain less density measurement, excessive water-retention capability, and reduced hydraulic conductance than ordinary soil because its surface-texture maneuvering via fly ash combination. High rates fly ash can drastically switch the physical soils looks by frequently increasing the content of silt. It has been tested to convert sandy and clayey soil to loamy soil by adding 70 t/ha of fly ash. Fly ash was added at a rate of 200 t/acre, which refined chemical and physical properties of the soil changed the textural USDA classification of refuse to silt loamy from sandy loamy. Many agricultural crops production will be increased by a high concentrations of Ca, Na, Zn, Mg, K, and Fe that fly ash contains (Basu et al., 2009).

- pH Value of Soil

Based on its origin, fly ash could either be alkaline or acidic, and it can be functional in preserving the soil pH level. One most valuable fly ash chemical properties is its ability to distribute soil acidity, which is provided by the carbonate and hydroxide salts. Fly ash is used as a material for liming to distribute the acidity of the and provide plants with readily accessible nutrients (Basu et. al., 2009). It further stated that the mass of readily dissolvable dry weight Ca of 24.5 g/kg of the fly ash gotten at an industrial power plant fluidized bed boiler operated in Oulu by Laanilan Voima Oy, which is located North side of Finland was more than 15 times the usual value of dry weight (1.6 g/kg) in plowable land in the centre of Finland (Basu et. al., 2009).

3.8 Different Waste Incineration Technologies

There have been many incineration technologies investigated, with mass burning being the most common method for handling unprocessed garbage in a boiler with moving grates. Similar developments have been made in other ignition methods, such as fluidized bed technology and the generation of fuel obtained from trash in a rough or pelletized form. There are several instances, mostly in the US, where unprocessed garbage is burned in rotary boilers. However, there aren't many small-scale swinging furnace factories in France. As a result, it should be highlighted that each technique has intrinsic advantages and disadvantages, just like the technology of mass burning does (Haukohl, 1996). Different forms of garbage are treated using incineration technology. However, with advancements in combustion technology and pollution management systems, separate sites often use incineration to burn both municipal and hazardous garbage. It is technically possible to employ joint therapy. Hospital waste and other hazardous wastes can be safely treated in municipal garbage incinerator facilities, however this is not permitted in Germany and a number of other nations (Haukohl, 1996).

3.8.1 Mass burning on a moving grate

This waste-burning technique has been developed and tested in conjunction with an efficient modern air pollution and control mechanism, and it can meet the challenging technical performance and environmental requirements that are currently mandated by the EU and also enshrined in WHO air quality recommendations. Any proven technology that can accept enormous amounts of waste composition is the moving grate. In an ideal plant, waste is gathered in a receptor zone before being dumped in the bunker. The waste from the bunker is combined and fed into a hopper, which also feeds the incineration, by an overhead crane. First, the waste is heated on grate, dried, after which burned. The fan provides enough oxygen during the whole passage of garbage through the incinerator to ensure complete burning. Prior to being cleaned and released through the stack, the post-burning chamber ensured that the flue gas underwent additional thermal treatment (Haukohl, 1996).

3.8.2 Fluidized bed combustion

The burning process in fluidized bed incineration depends on replacing the typical grate with a bed of hard particles and fuel that is fluidized through air flow from below. Burning occurs inside and above the bed. An inert substance, typically sand, but occasionally lime or ashes, makes up the fluidized bed's composition. In this case, the fuel is waste, and only a small portion of the bed material is made up of fuel. This technique, which includes a variety of designs including circulating fluidized beds, revolving fluidized beds, and bubbling fluidized beds, has been around for a while. Fluidized bed incineration very recently, more specifically in the last 10 to 15 years, started to gain popularity. Although fluidized bed technology has not been established for long-term use of waste incineration in Europe, there are incineration plants operating in Sweden, the United States, and Japan, and new plants are being considered for use or are currently being built in the United Kingdom, Spain, and France (Haukohl, 1996).

3.8.3 Refuse-derived fuel (RDF)

The concept of producing fuel from refuse is based on replacing dense fuels like coal in a conventional energy or district heating plant with fluff up produce (rough or fluff up fuel from refuse) or densified bits obtained from the burnable components of mixed garbage. The production of refuse-derived fuel necessitates a thorough pre-treatment of waste comprising several sorting and shredding procedures, whether the waste is made up of densified or undensified bits. Many large-scale factories in the USA and Europe have adopted the technology in use for the two types of fuel products (densified or un-densified). Based on the waste's composition, the fuel produced may contain significant amounts of chlorides or heavy metals, and its incineration in smaller plants without adequate air pollution control equipment could have adverse impacts on the ecosystem and human health.

3.8.4 Gasification Technology

The utilization of gasification technology to create a syngas intermediate from sorted MSW was one of many R&D possibilities identified by the US Department of Energy, (2019) survey for cost-competitive waste-to-energy projects. This entails developing techniques for biological conversion, such as genetically modifying stronger organisms to reduce the cost of separation, as well as improved design of a reactor that could allow continuous operation. Research on thermochemical conversion may lead to formation of new inhibitors with increased durability, pollutant tolerability in addition to high-temperature, high-pressure gas cleanup techniques (US Department of Energy, 2019). There are several thermal energy conversion techniques for treating solid wastes, including combustion, gasification, and pyrolysis. Due to its potential benefits over conventional MSW burning, municipal solid waste (MSW) gasification is a promising alternative fuel production technique for solid waste management. There are many uses for the so-called "syngas" that is created during gasification. It is possible to use it as a gas fuel that is burned in a conventional burner or a gas engine, then coupled to a boiler and a steam turbine or gas turbine to utilise the heat or generate electricity. (Seo, Yong-Chil et al., 2018).

3.9 Best Available Technology (BAT) for Waste-to-Energy Plant

According to a study by the European Commission, (2006) technology has advanced quickly in the last 10 to 15 years for the incineration sector. Laws specific to the sector drove many of these adjustments, which, in turn, specifically decreased the level of emissions from individual facilities. The segment is currently developing ways that lower costs while maintaining or improving environmental performance as part of the process' continuing evolution. The aim of waste incineration is to handle waste in order to reduce the amount and risk, while also catching or eliminating harmful potentially substances. The process of combustion can create avenues to help regain energy, mineral and/or chemical matter from waste.

According to a study by Neuwahl, F., et al., (2019), the European Union reached the following conclusions about Best Available Technology (BAT) in relation to the listed activities in Annex I of EU 2010/75/Directive:

5.1 Slags or bottom ashes treatment from waste combustion is inherent in disposal or recovery wastes that are hazardous with more 10 tons in volume in a day.

5.2 Waste recovery or disposal in incineration fercilities:

- For waste that is non-harmful containing a volume in excess of 3 tons for an hour;
- For waste that are hazardous that is produced in excess of 10 tons per day.

5.2 Waste co-incineration plants' waste disposal or waste recovery:

- For harmless waste that is produced at a rate of more than 3 tons per hour;
- For hazardous waste that is produced in excess of 10 tons in a day.

Of which, actual cause is not to produce materials, and in situations at minimum where one or more of the below conditions are met:

- Only just waste, aside the described waste in the EU Directive 2010/75 of Article 3(31)(b) is incinerated;
- 40 % or more of the released resulting heat is gotten through wastes that is harmful;
- Heterogeneous urban waste is incinerated

5.3 Clause (a) Bottom ashes and/or slags treatment from waste combustion that have a volume greater than 50 tons per day of non-harmful waste.

5.3 Bottom ashes and/or slags treatment from waste combustion, and/or a combination treatment or disposal, for waste not harmful with a volume more than 75 tns in a day.

3.10 Waste Incineration Plant Advantages and Disadvantages

TABLE 17. Waste Incineration Plant Advantages and Disadvantages (World Health Organization Regional Office for Europe, WHO/EURO Ser.14/6).

	Advantages	Disadvantages
Incineration in general	Volume of waste reduced by up to 90%	High investment cost
	Weight of waste reduced by up to 80%	High cost of operating
	Leaves largely inert residues (except fly ash)	Provokes public opposition
With energy recovery	Energy production from finite sources is displaced	Higher cost of investment
	Extra income from sale of heat or power	Reasonably high cost of operating
Technology	Waste-to-Energy incineration reduces the amount of wastes, control of disease, filling of land, and recovery of energy (electricity and heat).	Complicated technologies used in the facility (construction and operation).
Different technologies		
Mass burning	Most of the waste stream is processessed untreated	Large-size plants provoke more opposition
	Large-size plants have economies of scale	
Fluidised bed	Smaller-size plants provoke less public opposition	Some preprocessing of waste is required
	Better-quality emissions control	Smaller-size plants have less economies of scale
Refuse-derived fuel	Less capital intensive than incineration (maybe 10% of cost)	The emissions clean up costs are transferred to the point of combustion, if not burned onsite,
	Combustible with other fuels	Only part of the waste stream is processes, balance needs disposal
Fluff	Limited energy use in manufacture	Very difficult to store and transport
		More sophisticated combustor required
Pelletised	To store and transport is easier	More energy needed to manufacture
	Burns on conventional grates	

3.11 Waste Incineration Plant Operations

A comprehensive combustion of dense and flue gas must be considered while designing an incinerator, according to Liu, (2020). Total combustion requires the appropriate air ratio, the right temperature, and enough withholding time. The ratio of the air is the original proportion of air given, be taken to assumed volume of air needed to aid burning. The main recommended delivery air percentage for a hard combustion chamber is between 1.2 and 1.4.

A heating range of 850ºC and above, a holding period of 2 seconds or even prolonged, and sufficient disturbance is needed in the lower-level combustion area to prevent incomplete burning of flue gas, which would also prevent the formation of dioxins. The combustion area's supplementary air addition raises the proportion to 1.7 to 1.9. Recently, a design with a reduced air fraction was created to improve energy recovery effectiveness (Liu, 2020). Carbon dioxide (CO_2), oxygen (O_2), and carbon monoxide (CO) amounts should be continuously computed in order to better monitor burning conditions. Some Japanese regulations stated that to prevent dioxins, carbon monoxide, concentrations of CO must be at 30ppm which is (37.5 mg/m^3N) alternatively lower (O_2 at 12 percent ; with 4-hour average value).

Waste incineration plants should ideally generate a large number of employment chances for energy specialists and qualified individuals who have previously received the appropriate training in the many sectors of endeavor. The operating structure allows for flexibility in the waste plant's continuous operation. In order to ensure the welfare and safety of employees as well as the host communities, the Bayelsa State Government will exercise oversight over the appointment of the board of directors that will handle administrative tasks, logistics, and supply chain procedures.

3.12 Greenhouse Gas (GHG) Emissions

By the middle of this century, the world's energy sector will move from fossil fuels to zero carbon, thanks to the energy transition. The primary message is that reducing energy-related CO_2 emissions is necessary to slow down climate change. Although the world is currently undergoing an energy transition, there is an urgent need to decarbonize the energy industry in order to reduce carbon emissions and the effects of climate change. Energy-saving techniques and renewable energy sources may be able to achieve the required 90 percent reduction in carbon emissions (IRENA, 2021). There are primarily two ways that a waste-to-energy facility reduces greenhouse gas (GHG) emissions. (1) reducing methane (CH_4) gas emissions from landfills once a replacement option is available (2) Energy from trash acts as a fossil fuel substitute. However, waste-to-energy incineration plants emit more greenhouse gases (GHGs) than source reduction and reuse combined. Although they may not be necessary, life cycle analyses and emission control methods are strongly advised. (Liu, 2020)

4.0 THE ECONOMICS AND FINANCE OF WASTE INCINERATION PLANT

According to Rand et al., (2000), waste incineration demands a high and considerable financing option with a bigger share of foreign currency in addition to a high cost of operation and maintenance. Due to these factors, burning garbage results in a cost per metric ton in a net treatment that seems extremely inflated when compared to the option of landfilling, which is another option. The net treatment cost based on one metric ton of waste burnt will typically range from $25 to $100 in 1998, with an average of about $50. The real cost of an incineration plant is purely depending on the plant size and sales earned from electricity proceeds. The final price of landfilling varies from $10 to $40 USD according to the standard (i.e., the amount of layers in a membrane used for treatment of leachate) of the landfill itself. Therefore, when considering starting a waste incineration facility project, the higher net treatment price is an important consideration. General charge, tipping fees, public subsidies, and certain combined forms of these arrangements may all be used to fund projects. Once more, the aptitude and disposition to pay ought to carefully be examined to lessen the chance of careless burning or disposing (Rand, et. al., 2000).

4.1 Economics

The economics of incineration plants vary significantly between states and countries, according to the European Commission, (2006), and this is due to factors other than technology, such as waste management policy. However, the following considerations typically have an impact on the cost of garbage incineration:

- Land acquisition costs.
- Scale (small scale operation are often disadvantageous).
- Utilization rate of plant.
- The actual requirements for treating flue-gases and effluents (restricted emission value limits can lead to the decision of specific modern methods that in some cases, may incur significantly more operational and financial expenses)
- Recovery and ash deposits treatment (bottom ash is frequently employed in building, in which case the cost of landfilling is disregarded. The various methods and laws pertaining to the necessity prior to recovery or disposal, for treatment, and also the features of the disposal site, result in a wide range of fly ash treatment prices.
- The effectiveness recovery of energy and the revenue from delivery. Energy unit cost of delivered, earnings receipt for simply heat or electricity or for both, and these factors are all significant contributors to net costs.
- Recovered metals and the money earned from them,
- Gate fees can be greatly influenced (by a factor of 10 to 75 percent) by subsidies or taxes collected for emissions or incineration.
- Architecture requirements,
- The expansion of the nearby area for trash delivery access and the need for other infrastructure's availability,
- Capital market costs, tax and subsidy costs, building costs and depreciation periods.
- The price of insurance.
- Costs related to administration, employees, and salaries.

Along with private businesses, the owners and operators of the incinerator plant could be governmental entities. The finance cost of a capital project may differ based on ownership. Regular investors also include public-private partnerships (PPPs) (European Commission, 2006). The idea of using a moving grate for mass burning is relevant subsequent financial planning and analysis cost assessment as for the technology. Here is a topmost, well-known and well-tested technology for municipal solid waste incineration. Besides, there are no other better technologies that would be recommended for the burning of normal municipal solid waste (Rand et al., 2000).

4.1.1 Investment Costs

The capacity or size of the incinerator is one of several variables that affect the incinerator's actual cost of investment (the amount of metric tons in a day or year and the matching the waste's decreased calorific value). In terms of the cost of investment per metric ton of size, smaller facilities are often more expensive than larger ones. The technology depending on the energy source producer, beginning with straightforward reduction of all excessive heat (without sale of energy) to combined power and heat generation. Additionally, demand or anticipated emission quality level greatly influences the equipment needed for flue gas cleaning, which in turn greatly influences the investment costs (Rand, et al., 2000).

As Rand, et al. (2000), indicated, the yearly (and daily) size for an ordinary new waste incinerator projected in the figure following below which determines the cost of investment:

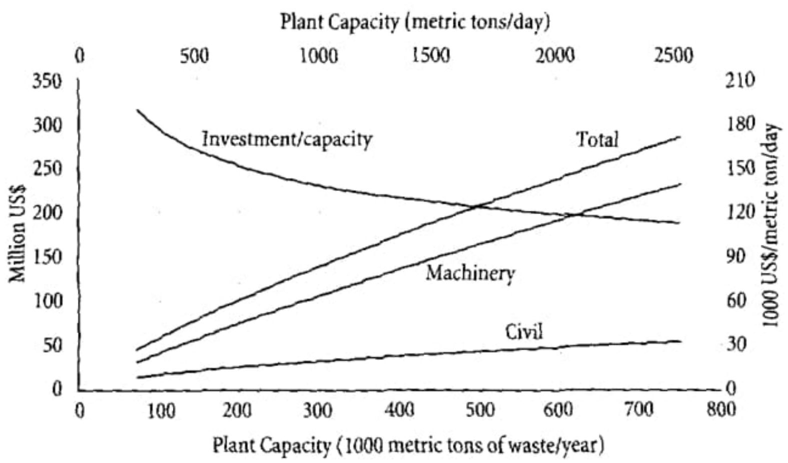


FIGURE 22. Estimated Investment Costs (World Health Organization, 2000)

The rationale for design is a decreased calorific waste value of 9 MJ/kg (2150 kcal/kg). The real cost of an investment will increase with a higher calorific value, and so forth. Additionally, the following specifications are in accordance with a typical plant design in (Rand, et al., 2000).

1. Number of incineration lines.

According to Rand et al., (2000), the smallest ability to every line of incineration is at 240 t/d (10 t/h) while highest is at 720 t/d (30 t/h). At minimum, there has to be two lines of incineration (so that at minimum, plants should be at 500 t/d). When figuring the essential daily limit centered on yearly measuring the volume of waste and the rate availability (number of every year hours of operation) 7500 is assumed. In addition, 5 percent additional capability is assumed in order conceal the requirements of seasonal variations.

2. Production of Energy

The plant primarily produces steam for the production of electricity, and yet if it also produces heat and power combined, or sells steam and electricity, extra heat is removed. Thus, steam boilers, turbines, and other machinery are installed at the plant including cooling / condensing units.

- Should the fercility be configured just to produce hot water, the overall investment cost can be reduced by about 30%.
- Flue gas cleaning

To achieve standard level emission control, the facility is configured using dry or semi-dry cleaners and a bag house filter or electrostatic precipitator as a result. If the plant is set up in accordance with straightforward level emission control, the overall cost of the project can be reduced by about 10%. Nevertheless, the overall cost of investment must increase by roughly 15% if the facility is to comply with modern-level emission control. As described in Figure 22, the typical investment cost for a daily capacity in metric tons is calculated using the previously specified specifications. Foreign exchange typically has to cover at least 50% of the cost of investment for the plant's technological component.

4.1.2 Expenses for Operation and Maintenance

The expenses for operating and maintenance for incineration plant consist of:

- Fixed operating costs
  - Administrative and salary cost
- Varying operational expenses
  - The price of chemicals for the system for cleaning flue gases
  - Electricity price (if the power plant is set up with a generator/turbine set and steam turbine, means net electricity production would take place)
  - Water and waste water handling cost
  - Residue disposal cost
- Cost of maintenance
  - Technology maintenance cost (machinery spare parts)
  - Building maintenance cost

The number of employees, the mix of engineers with and without experience, and the level of wages in the area all have a significant impact on the operating fixed cost. The yearly operational fixed cost for facilities in South and Southeast Asia is anticipated to be 2% of the total investment as opined by Rand et al., (2000). The specialized flue gas cleaning system is mostly responsible for the variable operating cost. But more importantly, the actual cost of removing the cleansing of the flue gas residue possesses a powerful hold on the fluctuating operating expenses. The total variable operational expenses are anticipated to be 12 dollars per metric ton of incinerated solid waste based on the exact cost of disposal of US$100 for Air Pollution Control (APC) in metric tonnage deposit and 5 dollars for a bottom ash in tons of metric that is disposed of or reused.

According to standard procedure, the annual cost of maintenance is estimated to be 1% of the investment in civil works and a further 2.5% of the investment in technology. The results of the annual costs of operation and maintenance are displayed in Figure 23 below. The figures arise from the amount of garbage that has been treated and the investment cost that was previously mentioned. The annual capital expense as well as the total cost of incineration are also provided. The calculation took into account a 15-year planning horizon and an actual interest rate of 6%. (Rand, et. al., 2000).

4.1.3 Sale of Electricity

Energy sales as per Rand et al., (2000), play a significant role in the trash incineration industry. In exceptional cases, the proceeds from the sale of energy can cover 80% to 90% of the whole expense. The average in North America and Europe is around 40%, with trash having a composition with a lesser calorific value between 9 and 13 MJ/kg.

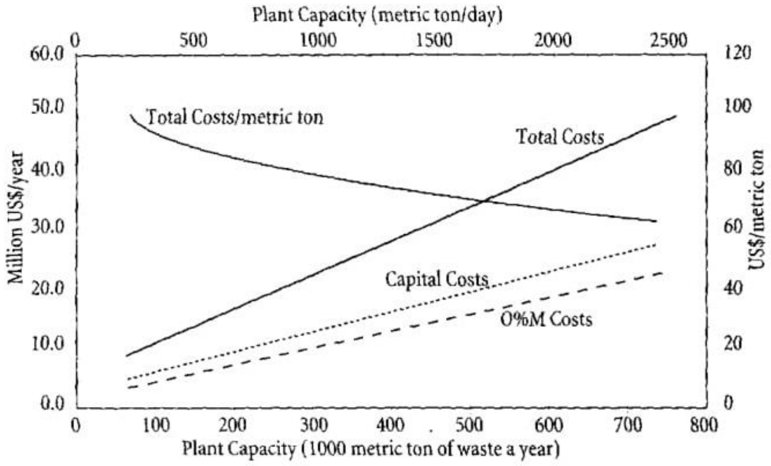


FIGURE 23. Yearly Incineration cost (World Health Organization, 2000)

On the other hand, it is crucial to remember that an incinerator plant's major goal is waste treatment, which ensures a certain degree of reduction and helps to make the waste non-hazardous. The energy content (net calorific value) of the trash has a significant impact on the revenue from prospective energy production and sales. In order to generate heat, electricity, and combining electricity and heat, Table 17 above indicates energy production per metric ton of garbage incinerated. Additionally, the estimated revenue from energy sales is based on the US$15/MWh price of heat and the US$35/MWh price of electricity.

TABLE 18. Energy yield and income from Energy (World Health Organization, 2000)

Heat value	*CHP*			*Heat Only*		*Power Only*	
H_{inf} MJ/kg	*Power MWh/t*	*Heat MWh/t*	*Income US$/t*	*Heat MWh/t*	*Income US$/t*	*Power MWh/t*	*Income US$/t*
6	0.33	1.08	28	1.33	20	0.58	20
7	0.39	1.26	33	1.56	23.	0.68	24
8	0.44	1.44	37	1.78	27	0.78	27
9	0.50	1.63	42	2.00	30	0.88	31
10	0.56	1.81	47	2.22	33	0.97	34

Note: CHP 76 percent of yield as heat.

The precise energy requirement should be taken into account, especially for the production of simply heat. Despite the heating system's size, it is typically required to cool some heat produced during the dry season (summer), which lowers the annual earnings from selling the heat. If the proposal includes sales of production and process steam, then this revenue should be compared to a specific sales contract. The revenue in US dollars for each metric ton of supplied stream depends primarily on the steam's temperature and pressure.

4.2 Financing

The primary funding options for an incineration plant project in Nigeria includes government and public subsidies, Private Public Partnerships (PPP), earnings from the sale of heat and energy, and unrestricted user fees. Funding methods as these are not exclusive of one another but may be combined with.

4.2.1 Public Private Partnerships in Nigeria

The Nigerian government is receptive to public-private partnerships in a variety of industries, including concessions, franchising, leasing, equity, and joint venture involvement, according to a World Bank study from 2020. In fact, many of the federation's states—including Bayelsa State, where the Waste-to-Energy Project is expected to be built—are focusing on fostering public-private partnerships (PPP) initiatives. Lagos State estimates that the PPP framework will be necessary for 70% of its upcoming and ongoing projects. Government has outlined steps it will take in a published document to ensure that private investment is used where it should be, to address infrastructure deficiencies, and to enhance public services sustainably (The World Bank, 2020).

The government would ensure that the transfer of accountability to the private sector is in line with international best practice in order to uphold its pledge of transparency and accountability, and this would be accomplished through open competition. The creation of the PPP's laws, regulations, and procurement processes is the government's clear and simple duty for the Infrastructure Concession Regulatory Commission (ICRC). The ICRC will collaborate with States to provide a coordinated and well-organized framework for Nigerian infrastructure improvement and to hasten the development of a market for PPP projects. Government has guaranteed investors that, subject to compliance with the terms and circumstances of the PPP contract, all completed contracts in accordance with the ICRC Act will be valid and enforceable, and venture capitalists will be able to recover their predicted profits (The World Bank, 2020).

4.2.2 Government / Public subsidies

Government and public subsidies come in all shapes and sizes, from the federal to the state level, and they can lower the tariff load for customers. Grant finance, favorable credit terms for plant services, and general tax reductions or levies are all examples of subsidies. Subsidies may be provided derived from or connected to environmental taxes. Whereas fee waivers derived from taxation relieve end user population's financial burden and place it on the federal or state government. This can lead to ineffective operations of the plant. Subsidies of fees can potentially diminish incentives of management which would reduce price and eradicate optimal practice of management (Rand, et. al., 2000). The finance structure should let the project provide service that customers could afford, are eager to accept. This will ensure that the investment is sustainable and the service is appropriately priced. The standard threshold for the trash fee by international development banks is 3 to 4 percent of the household returns. Any increase in garbage fees should be supported by an improvement in service or a reduction in environmental effect (Rand, et. al., 2000).

4.2.3 Income from sale of energy or heat

Contracts for energy sales to suppliers may be a funding need, and a consistent demand for energy produced by the plant may in some circumstances be a severe obstacle to acquiring funding for the plant. It is important that new energy sources with lower costs in the area will reduce cost for sales of energy by offsetting yearly expenses.

Furthermore, a volatile energy marketing mix will make it difficult to estimate operating expenses and raises the risk of financing the plant.

4.2.4 Fees proceed from users populace

In a perfect world, user fees from homes and businesses would cover the majority of the annual net capital and operating costs of the plants. Public support is necessary for the incineration plant to be independent in establishing charge schedules, which will again allow the plant to finance itself. This implies revenues must be equal to all expenditures of maintenance and operation including devaluation plus funding costs. Fees for home services are frequently collected in addition to taxes from other public service fees, accentuate the typical amount of waste that many types of households produce (single-family, apartments, homes, etc.). These service fees represented a source of income that was well-secured and dependent on the success of the state government in collecting local taxes. Big company clients typically pay gate or tipping fees in exchange for being allowed to deliver waste directly to the incinerator. There is a greater chance that the garbage will not be accepted, which would result in fluctuating plant income. Unstable clients may resort to illegally burning or dumping waste as a cheaper alternative waste treatment technique. To balance capital and operational costs, measures must be taken to ensure that the facility receives an adequate supply of waste. Before approving bank loans, local authorities who can pledge themselves to the provision of a sufficient minimum volume of waste to the incineration facility typically demand it (Rand, et. al., 2000).

Consumers must be motivated to use the incinerator facility by public control or incentives. In addition to gate fees, the solutions may include clearly billing commercial customers for predictable waste generation, controlling competing landfills, leveling costs through enhanced disposal prices or financed incineration taxes, and enforcing fines for illegal burning, dumping, and use of landfills. When assessing project risk, the local government must take considerable measures to institute and enforce control (Rand, et. al., 2000).

4.3 Cost-Benefit Analysis

The calculations and estimates used in this research are based on the premise that the treatment net cost for waste of one metric ton burned is usually twice least as expensive as the net price for the complementing and organized landfill. While operating garbage incineration, there is a considerable financial risk of failure due to:

- Extensive investment costs and foreign currency requirement
- The technical installations' complexity calls for expert laborers and the availability of spare parts, among other things.
- Exceptional specifications for size and configuration (i.e. the required minimum net calorific value)
- The necessity of a complete, developed waste management system and overall operational setup
- Stable prices and demand for energy.

The greater the cost for a specific incineration project, the greater risk for net treatment must be evaluated initially before going forward by undertaking a cost benefit analysis (CBA). The feasibility phase should include the cost-benefit analysis. The local interplay between the social and economic environment heavily influences the content and result of the cost benefit analysis. Some essential elements that must be well-thought-out are:

- Waste transportation distance
- Land utilization and reclamation
- Tourism and city growth

- Waste disposal effects on the environment (both immediate and future)
- Transfer of technologys and workers education improvements and skill levels
- Local jobs
- Sustainable energy production.

Political considerations occasionally have a significant impact in the choice to use waste incineration because many industrialized nations would like to participate in the technical improvement. Waste disposal at properly designed and efficiently run landfills is an economically, ecologically, and sustainably sound choice if the cost-benefit analysis turns out to be unfavorable. It is undeniably healthier to increase the capabilities and quality of current landfills (Rand, et. al., 2000).

4.4 An Estimated Investment Cost of Waste-to-Energy Plant

Waste to Energy International, (2015), estimates that a plant with an annual capacity of 250,000 tons per annum (TPA) would cost $US 169 million, or $US 680 per ton. This number provides a preliminary estimate of the cost of a waste-to-energy facility. The price of the incineration plant has been the subject of much discussion in the market. Numerous businesses are offering alluring discounts, but they all typically share the same problem: nothing actually works. A potential client should request samples of reasonably priced bidders' operational products from them. When a reaction is anticipated, switch back to widely used technology. No matter what the process, whether it be plasma treatment, gasification, pyrolysis, or incineration, the price difference should not exceed +/- 50% (Waste to Energy International, 2015). However, if it is feasible, this project would be entirely sponsored by the Bayelsa State Government through a public private partnership (PPP).

Investment, operational, and maintenance expenditures make up the costs of municipal solid waste incineration, according to Tehrani et al. (2015). The real cost of investment for waste plant based on vast variable arrays: (1) Plant size; (2) Waste's lower thermal value; (3) Land acquisition costs, etc. The amount of metric tons the plant burns per day or per year could be used to determine the cost of investment for an incinerator for municipal solid waste.

$$I = 2.3507 \times C^{0.7753} \qquad (1)$$

In that I denotes cost of investments in millions of USD, while C denotes the capacity of the plant (which stipulates a 1000 metric tons of yearly wastes).

This computation is supported by specific criteria that are typical of a plant's make-up according to research conducted in Tehran, Iran (Tehrani, 2015). This relationship's difference of 3%, which is sufficient for an anticipated cost, is equal to the cost of investment for an incinerator facility in Mazandaran, north of Iran. Fixed operating expenses, variable operating costs, and maintenance costs make up operating and maintenance costs. Salaries and administrative expenses are included in fixed operational costs and amount to 2% of the total investment. The entire cost of the chemicals used in the flue gas cleaning system, the handling cost for waste water, water and waste disposing cost, make up variable operating costs. Per metric ton of garbage burned, the total variable operating costs are computed at US$17. According to standard procedure, the yearly maintenance expenditures are projected to be 1% of the money invested in construction works and an additional 2.5% of the capital investment in technology. As previously noted, the following formula can be used to determine operating and maintenance costs:

$$A = 0.0744 \times C^{0.8594} \qquad (2)$$

In that C is the capacity of the plant (annually 1000 metric tons of waste) and A is the annual operating and maintenance cost in millions of dollars (Tehrani, 2015).

4.5 Price of Electricity in Nigeria

Nigeria Electricity Regulation Commission (NERC) has distinguished consumers between those who have meters and those who do not. Customers with meters, however, pay more for their energy subscription because of these following four factors:

1. The client's location: There are 11 power distribution companies (DisCos) operating in Nigeria: Benin, Eko, Enugu, Ibadan, IKeja, Jos, Kaduna, Kano, Port-Harcourt, and Yola are the local electricity distribution companies, and customers must consequently be aware of the company that delivers their electricity.
2. The Customers Tariff Class: Each and every power user must fall under a particular tariff class.
3. Rate of Duty: This is determined by the class of the customer's tariff. There is a unique applicable tariff rate for each tariff class. This demonstrates that each DisCo's tariff rate is different for customers in another class of tariff.
4. The energy amount used, is expressed in kWh.

TABLE 19. Five main Classes of Tariff (NERC, 2021)

	Tariff Class	Description
A	Residential	Customer who exclusively uses his/her premise as his/her residence – flat, house, or multi-storied building
B	Commercial	Customer who exclusively uses his/her premise for other purposes aside using it as residence or for goods manufacturing or as a factory
C	Industrial	Customer who uses his/her premise for goods manufacturing plus ironmongery and welding
D	Special	Customers like agriculture and agro-allied industries, religious houses, water boards, government research institutes, government and teaching hospitals, and educational establishments.
E	Street Lights	Street Lightening or lights

TABLE 20. Electricity Prices in Nigeria (Global Petrol Prices, 2021)

Nigeria Electricity Prices	Household, kWh	Business, kWh
Nigerian Naira	24.290	39.838
U.S. Dollar	0.059	0.097
Euros	0.05	0.08

In the last quarter of 2020, the cost of electricity, which accounts for all components of the energy bill, was 0.059 US dollars per kWh for consumers and 0.097 US dollars for companies (cost of power, distribution and taxes). In a global context, families paid an average of 0.138 US dollars per kWh, and enterprises paid 0.123 US dollars. Although, the above table only provides two data points, it is feasible to estimate several data points at various stages of electricity use in homes and businesses. The information presented above is calculated for businesses using a yearly consumption of one million kWh, and it is approximated for families at the average level of annual residential power use (Global Petrol Prices, 2020).

Yenagoa produces 111,697 tons of waste overall on average per year. This will generate 13.6 MW of electricity with a caloric value of 10 MJ/kg and a combustion power of 38.8 MW, for a total yearly electricity energy of 108.6 GWh. The cost for producing this will be $0.196620315 per kWh. This implies that the amount of energy produced will correspond to the tonages of waste burned.

According to Nairametrics, (2015), NERC, offers consumer varieties They are billed monthly by the Discos under tariff classes and occurring at irregular intervals for customers on prepaid meter system. Residential clients, businesses, industrial, government entities, denominations, and streetlightenings are on different tariff. The classifications were then split up into non-Maximum Demand Customers and Maximum Demand Customers. Consumers who are MD have their own unique transformers, which is the main distinction between MD and Non-MD customers. An estate or bank, for instance, might have a special transformer. Contrary to Non-MD clients who share transformers with neighborhoods. Customers who are not MDs generally pay higher Fixed fees.

TABLE 21 A. Classes of electricity customers (Nairametrics, 2015).

Maximum Demand (MD)	Customer Class
R3	Small estate, government houses,
C2	Hotels, banks
C3	large supermarkets, hypermarkets
D2	Large scale industrials, Metal companies
D3	Oil companies, large construction companies
A1	Schools, Churches, and Mosques
A2	Medium size barracks
A3	Large barracks, large Agric processing companies
S1	Streetlights

TABLE 21 B. Classes of electricity customers (Nairametrics, 2015)

Non-Maximum Demand Customers (Non-MD)	Customer Class
R1	Customers with consumption below 50 kilowatts
R2	Customers with consumption above50 kilowatt
C1	Small businesses e.g., small barbing and hair dressing saloons
C2	Hotels
D1	Small industries e.g., welders, pure water companies
D2	Large scale Industries, Metal companies
A1	Schools, Churches, and Mosques

4.6 Calculating the Price of Electricity in Nigeria

By applying mathematical calculations,

Current Charge = (Consumption x Energy multiplier charge) + fixed charge.

For example, for a R2SP premise with a fixed charge of ₦750 and a monthly consumption of 140 units. The current charge is calculated thus: (140 X₦13.20/kwh) + ₦750, which is equal to ₦2598 ($12.998.72 at $1 = #415.37) = (€12.350.67 at €1 = #437.32) (Ikeja Electricity, 2016).

5.0 PROJECT LIFE CYCLE

The feasibility phase, project preparation phase, and project implementation phase are the three main stages of the project life cycle for setting up and operating a waste incineration plant. After completing one phase, important political choices would need to be taken over whether to move on to the next step or not. Decision-makers must be involved in a number of minimal stages that are part of each specific phase. The stages are depicted in the Figure 24 below. After the duration of each stage's completion, the overall amount of time since the project's beginning is shown. If everything remained the same, the project would typically take about six years to complete before the facility could be fully operational. For such a project to be successful, it would be crucial to hire a qualified consultant who is independent and has extensive experience working on such projects from the very beginning of the planning stage. Recognizing public opinion on waste incineration and ensuring that the public is knowledgeable about all stages, especially the attainability key phases of project planning (Rand, et. al., 2000).

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	6 months
	Political Decision	Decide on willingness, priority, and financing of incineration plant and necessary organizations	6 months
Feasibility Phase	Establishment of an Organization	Establishment of an official organization and an institutional support and framework	6 months
	Tender & 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 ½ 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

FIGURE 24. General Implementation Plan for Waste Incineration Plant Construction (World Health Organization, 2020)

5.1 Feasibility Phase

Pre-feasibility and feasibility analyses are part of the feasibility phase. A political and economic decision would be taken in the interim to determine if moving forward with a more thorough investigation is implied. The table below outlines the major issues in this phase:

TABLE 22. Main activities that would be part of the pre-feasibility and feasibility Studies (World Health Organization, 2020)

Prefeasibility Study	***Feasibility Study***	
Waste collection area	Land use and demographic information	Land use and demographic information
Waste sector	Stakeholder identification Existing waste management system and facilities (collection through disposal) Preliminary SWOT assessment	Stakeholder analysis Detailed system description and analysis SWOT analysis
Energy sector	Stakeholder identification and assessment Institutional setup Market evaluation	Stakeholder analysis Institutional setup Market analysis Detailed information about energy generation and consumption pattern
Waste generation	Waste generation forecast based on current data and literature values Calorific value of waste Incineration plant design load	Waste survey Revised waste generation forecast Annual variation of surveyed waste calorific value Plant design load and calorific value
Plant siting	Identification of siting alternatives	Selection of plant location
Plant design	Tentative plant design • Furnace • Energy recovery • Flue gas cleaning • Building facilities • Mass balance • Staffing	Conceptual plant design • Furnace • Energy recovery • Flue gas cleaning • Building facilities • Mass balance • Staffing
Cost estimates	Investments Operating costs Energy sale Cost recovery	Investments Operating costs Energy sale Cost recovery
Environmental assessment	Preliminary EA	Full EA according to OD4.01
Institutional framework	Project organization Waste supply Energy sale Plant organization and management Training needs assessment	Project organization Draft waste supply and energy sale agreements Plant organization and management Tender model HRD plan

The content of the two elements (phases) is nearly identical. In contrast, the pre-feasibility study frequently focuses on data and information sources. The pre-feasibility study might therefore be considered to be simply a preliminary assessment of the viability of the incineration of waste from the area (Yenagoa Metropolis) under examination, as well as of any existing institutional structure. This phase entails a careful analysis of all indigenous requirements, a conceptual design that is sufficiently inclusive of the transmission networks throughout the entire plant, and the required framework for an economically fair evaluation throughtout the project. A municipal solid waste incineration project requires the collaboration of a large number of professionals, the majority of whom are not readily accessible locally.

The intended client (Bayelsa State Government) should think about hiring unrestricted expert to closely collaborate with local employees and businesses. If there are competing local interests, it would be the role of the consultant to act as a mediator and share experience gathered through time from similar initiatives. Decision-makers should use feasibility reports as a resource when deciding on either to move the project forward or not. And then, when evaluating the entirety of an existing structure. In the subsequent phase, the concepts and plans described at the feasibility stage would be developed into a tangible project contracts, including recommendations (Rand, et. al., 2000).

5.2 Project Preparation Phase

The preparation phase is a political phase and the process requires several significant decisions that would be made. The goals are to make sure that plans established from the feasibility study become visible.

5.2.1 Project Implementation Unit

There is a development of a specific unit or role for the project due to the large level of engagement the organization designing and executing the project experiences. The project's overall management, including commissioning and monitoring, will be handled by the project execution or implementation unit (PIU) and its related private advisers. When the plant has been given to the customer (Bayelsa State Government) for management, the PIU may be suspended, or it may join the plant's operational team, or it may continue to operate in a limited capacity to oversee the performance of the state-owned or indigenous plant operator.

The Project Implementation Unit and its advisors will be in charge of creating:

- Agreement(s) on supply of waste
- Energy sales agreement
- Environmental and Social Impact Assessment
- A preparation for final disposal of the remains of incineration
- Agreements on loans and financing
- Project bid specifications
- Contract Agreements
- An arrangements to control construction-related activities
- An arrangement to oversee plant commissioning and acceptance testing

The degree of detail for these specific documents is based on the type of tender. Were the plant to be developed based on several contractual agreements, the whole process has to be elaborate in complete details, and all agreements must be duly signed.

5.2.2 Draft Agreements / Letters of Intent

Before the project moves on to the implementation phase, the preparation stage takes away any erroneous predictions that could lead to the project's failure. The project need be redesigned technically and financially to remove divisive rumors. Borderline issues must be resolved by finalized agreements or irrevocable letters of intent. Unresolved concerns about the plant's economy must be addressed at the planning stage. The project's funding must also be agreed upon; loans must be negotiated, and it must be made clear under what issues Bayelsa State Government is willing to lend as a cosigner or guarantee obtained under a supplier. There may be another way to recoup the costs of incineration. Based on an evaluation of the ability and desire of waste generators to pay, a potential allocation of gate fees and state or local government budget payment should be implemented.

5.2.3 Political Decision

Before moving into the implementation phase, the PIU organizes a statement for political decision-making once every project concern has been addressed to the greatest extent possible. Several multimillion dollar initiatives have been discovered to have failed, stopped, or been abandoned either from the beginning or at some point during the project life cycle. Megaprojects in this region of the world (Nigeria) are influenced directly or indirectly by political affiliation or support. Due to geographic, geopolitical, or regional factors, a project's economic impact is frequently a factor in whether it will be approved or whether it will be transferred to a location where it will be ineffective.

Another thing to consider is if the government is changed based on a new party structure or a change within the same party structure. There are many political parties in Nigeria, but only two of them have held sway at the federal and the state levels. Nigeria has been ruled by the People's Democratic Party (PDP) since 1999 until 2015. Afterwhich, the APC Party won the 2015 presidential general election by a combination other parties, whose party compositions alone could not have competed with the PDP. After sevarl years of dominance, the PDP suffered its first-ever presidential defeat as a result of these parties coming together to establish the APC.

5.3 Project Implementation Phase

5.3.1 Tendering

In addition to the standard competition used in the tender selection process, there should be two additional steps in the administration of the tender process: pre-qualification of qualified contractors and tendering among selected contractors. Before contracts are closed, the PIU shall conduct tender examination, negotiations, modifications, and submission of tender documents with recommendations from political decision-makers. Although most countries have thorough bidding procedures that guarantee impartiality and fairness in contract awarding rules, which take into account cost and quality in the purchase of equipment and services for the general public. The World Bank and other long-term lending institutions uses sets of comparable rules to follow.

To thoroughly reevaluate the acquisition standards, plus the best procedure for tendering, is important. It is beneficial to reevaluate the accessibility, competitiveness, efficiency, and capabilities of indigenous suppliers of services and equipment in order to choose the most practical and lucrative implementation formula (Rand, et. al., 2000).

5.3.2 Construction, Erection, and Commissioning

The tendering procedure forms the basis for the PIU's responsibilities during building, erection, and commissioning. The duties could range from simple financial oversight to complex supervisory responsibilities. But commissioning for process plants will also include management to ensure that the functional criteria are met, in addition to the supply range and work quality. Differences in waste configuration by season could call for functional management during times when the waste's calorific value is high and low. Testing for final approval is essential. Other pertinent considerations include providing operational assistance and timely, appropriate personnel training. However, having a qualified and internationally skilled consultant to help the customer (Bayelsa State Government) with supervising and establishing plant performance requirements and layout is the most important component in executing a successful and economically operating plant (Rand, et. al., 2000).

5.3.3 Staffing and Training

Six to twelve months prior to the plant's commissioning, hiring should start. Management and strategic operational staff should spend a minimum of three to six months receiving training at facilities that are similar. It would be advantageous if operators of plants and staff who does maintenance participates during the final stages for installation and phase of commissioning to enable them learn about the structure and operation of the plant firsthand. Before beginning, programs for employee training should be introduced. This is generally included in the services that the equipment provider would provide, and it would be managed by international trash incineration experts or business partners with extensive knowledge of operating incinerators.

5.4 Stakeholders Analysis

Carpenter, (2021) asserts that a significant issue organizations confront is the issue of stakeholders. It is crucial to understand what a stakeholder is before delving further into who our stakeholders are. A stakeholder is a person, group of people, employees, clients, organizations, the government, etc. whose interests may have an impact on business operations, either directly or indirectly, or who may be affected by the actions of corporate enterprises. A technique called stakeholder analysis enables organizations to identify and assess the significance of important individuals, teams, communities, institutions, or levels of government that may significantly affect the success or failure of a venture or project. The following list includes the key parties involved in this trash incineration project:

- Host Communities
- Bayelsa State Water Board
- Bayelsa State Electricity Board

- Bayelsa State Environmental Sanitation Authority
- Bayelsa State Ministry of Environment
- Nigerian Energy Commission
- Electricity Regulatory Commission of Nigeria
- Nigeria Content Development & Monitoring Board

5.4.1 Host Communities

Given that the project will be located in Yenagoa LGA in Bayelsa State, it is crucial to consider the important role that host communities play in the growth and success of any publicly or privately funded project, particularly one of this scale. Typically, host communities are involved in the project's feasibility phase through the state and their local government officials, which would entail signing a memorandum of understanding (MOU). The MOU's text would provide a thorough account of how women, children, the elderly, and youth would be involved and how the project would affect their day-to-day lives and the environment around them (land, air and water). The MOU should also specify the kinds of employment opportunities and training that the contractor will offer to the host communities, as well as its commitment to corporate social responsibility (CSR). For the state to promote peace and development, the Bayelsa State Government must also play a significant role. The state government may stop all contracts between the conyractor and the host communities where there are bridges of contracts.

5.4.2 Bayelsa State Water Board

Although the majority of home owners have drilled boreholes for water production, the Bayelsa State Water Board is directly in charge of the production, treatment, and distribution of water in the city of Yenagoa. There is insufficient water infrastructure to provide homes with treated water. Boreholes are often sunk by 80 to 90 percent of homeowners to provide their own water supply, and the water board has little or no control over this. Only residences connected to the state water board must pay water rates. Despite the state's own water generation and treatment facilities, there is no effective infrastructure network connecting the entire state for a sustainable water distribution.

5.4.3 Bayelsa State Electricity Board

This is the state arm of the Federal Ministry of Power which is the Bayelsa State Electricity Board is saddled with the regulation of energy activities in state. They are completely responsible for the inspection, supervision, monitoring and maintenance of all electrical infrastructure and state owned power generating plants, and the enforcement of the payment of electricity bills for consumers not on meter.

5.4.4 Bayelsa State Environmental Sanitation Authority

Waste management and disposal in the state are handled by the Bayelsa State Environmental Sanitation Authority. In addition to scavengers and private waste recyclers, who are also in the waste management business, there are a number of private and indigenous companies that are hired to collect and dispose of rubbish across the state capital. Despite all of these growth efforts, the state is still unable to handle the everyday trash generated (306,020 kg). Every month, there are often designated Saturdays for general sanitation, during which vehicles and people (apart from those performing required tasks) are not allowed to travel. Criminals are frequently detained and fined. On sanitation days, wastes on all drainage, roads and temporary dumpsites are cleaned and transported to landfills without proper waste segregation. The Bayelsa State Environmental Sanitation Authority work together with other departments in Bayelsa State Ministry of Environment to effectively collect or dispose wastes in designated dumpsites.

5.4.5 Bayelsa State Government Environment Ministry

The government's environment ministry is in charge with environmental regulations regarding air, water, and land pollution and forbids businesses from posing environmental risks. Standards for the amount of pollution that businesses are permitted to leak into the environment are also determined by them. However, they do not currently oversee or provide coverage for the energy sector (renewable energy).

5.4.6 Nigeria Energy Commission

1979 Act Number 62 established the Nigerian Energy Commission, which was subsequently revised by Acts 32 of 1988 and 19 of 1989 respectively. Commission for Energy for each Member State was established following the Heads of ECOWAS meeting on May 29th, 1982 in Cotonou, where its members states decided to each enact laws, with an arm of the government machinery to be responsible for overseeing and coordinating all energy affairs in each member state (Energy Commission of Nigeria, 1989). Therefore, the Nigerian Energy Commission is tasked with planning strategically, and overseeing an implementation of governmental policies regarding all aspects of power. The commission also provides advise to the states and the federal government on energy policy, new technology pertaining to energy resources, and the encouragement of study, knowledge, and the growth of organizations dealing with energy.

5.4.7 NERC - Electricity Regulatory Commission of Nigeria

A 2005 law called the Electric Power Sector Reform Act established a self-governing NERC to oversee all technical plus financial direction of Nigeria’s electricity producing and distribution sector. The Commission is tasked with enforcing operating standards and norms, determining consumers' rights and obligations, and fixing costs that reflect industry tariffs among other licensed operators. The Commission's central office is in Abuja, and it has six regional offices spread across Nigeria's six geographic zones (NERC, 2021).

5.4.8 NCDMB - The Content Development & Monitoring Board

The NOGICD Act, often known as the Nigerian Oil and Gas Industry Content Development Act, was passed in April 2010, established the Board for the Development and Monitoring of Nigerian Content (NCDMB). This organization is saddled with power with the development of policies that will oversee, coordinate, and carry out the provisions of the recently passed NOGICD (Nigerian Content Development & Monitoring Board, 2010). Some goals include, but are not limited to, the following key functions:

- To check that service providers and operators are following Nigeria Content regulations. This relates to the creation of jobs, the use of locally produced goods, total spending, and the use of materials for services in operations and projects.
- To issue certificates of authorization for projects and operations that adhere to the requirements for Nigerian content.
- To participate in targeted capacity-building initiatives that would enhance local capabilities, including those related to manufactured goods, local supplier development, infrastructure and facilities, and human capital development.

5.5 Socio Economic Impacts of the Project and Stakeholders Engagement

Any modifications made in the process of and management of waste would have a huge socioeconomic effect on the people, organizations, businesses, non-governmental organizations (NGOs), and governmental agencies who rely on waste management for their livelihood. The table below lists potential stakeholders and interest groups:

TABLE 23. Typical Stakeholders for Construction of an Incineration Plant (World Health Organization, 2000)

Stakeholders	Stakeholder Interests	Possible Stakeholder Influence
Scavengers	Changed waste management may affect or eliminate their source of income.	Scavengers' activities may affect the properties and amounts of waste.
Community groups and nearby citizens	Project may lead to adverse community impact - for example, traffic, noise, visual impact, etc. Positive impacts could include work opportunities.	Termination, delay, or change of projects due to community protests
Nature NGOs	Reduced impact of waste management on nature	Termination, delay, or change of projects due to NGO protests.
Environmental NGOs	Reduced impact of waste management on the environment.	Termination, delay, or change of projects due to NGO protests.
Neighbors	Reduction of noise, dust, traffic loading, and visual impact. Impact on real estate prices.	Termination, delay, or change of projects due to neighbor protests.
Collection and transportation companies	Wish to maintain or expand the business.	New requirements for sorting, containers, and vehicles.
Energy producers	Opposition to purchase of energy from smaller external producers.	Barriers to sale of energy at local market prices.
Waste generators	Wish to maintain low waste management service charges.	Opposition to large investments and increased service charges.

5.5.1 Scavenging and Informal Economic Activities

Scavengers and unofficial recycling businesses play a crucial role in the real process of waste collection, disposal, and recycling in developing nations like Nigeria. This includes low-income individuals, employees of government agencies responsible for waste collection, and certain small-scale recyclers who are located or reside near the authorized dump site, at waste collecting facilities, or along the streets and highways that lead to waste management facilities.

FIGURE 25A. Scavenger sorting plastics for resell in Yenagoa Metropolis, Bayelsa State (Bassey Willie, 2020)

FIGURE 25B. Scavengers sorting plastics for resell (Investment Monitor, 2022)

Profits from the selling recyclable products, including bottles, cardboard, paper, plastic, steel cans, and metals and aluminum serves as primary sources of revenues in Nigeria for waste recyclers and scavengers. Any change to the system of waste management will unintentionally impact their means of subsistence. This informal scavenging actions could actually reduce the amount of wastes collected or the calorific value at the waste-burning facility. Based on this important component, special attention should confered to activities for unofficial waste management and scavenging. Such actions would lessen the socioeconomic difficulties that a waste-to-energy plant may bring, deal with potential barriers to planned service enhancements, and eventually control the waste flow (Rand, et. al., 2000).

5.5.2 Advanced Waste Treatment Facilities and Socio-Economic Impact

A cutting-edge waste treatment facility typically needs finance, which includes government or private capital as well as significant incomes to cover the increased expenses of operation and maintenance. Similar to this, a state-of-the-art waste treatment facility produces a profitable end product, such as heat or steam, energy, and recycled materials, with the exception of engineered sanitary landfills (metals). Adopting a cost recovery method that stabilizes incomes from profitable output and from waste treatment costs to be paid to waste producers is crucial when profitable outputs are produced. Depending on state or federal legislation, the energy market, and the waste-to-energy plant, the profit from the sale of heat, steam, and power ranges in-between 0% and 40 percent of the total yearly costs. This is due to:

- With suppliers own plants and other fuel in use, energy can generate high investment returns
- Suppliers own plant capacity could be useless, and so ROI already made would be fewer
- The unwillingness of supplier to depend on outside energy suppliers
- Energy supply is not adequately guaranteed or stable
- Waste incineration plant is not properly positioned inside the present energy infrastructure system.

To ensure significant returns from energy sales from waste incineration facilities, state or federal laws encouraging energy generated from renewable energy source (solid waste) is essential. Almost all industrialized countries with waste incineration technology have implemented such regulatory measures, forcing district heating and electrical firms to pay a lower price for energy from incinerators plants set price. In growing economies, it is especially important to be reasonable or affordable. Low-income individuals might find it challenging to cover the full cost of a state-of-the-art system for managing waste. Reviews can play the role of assessing amount of genuinely affordable. An example, fees for distinctive services may be levied against households earning above-average salaries, private manufacturing and service firms, and public institutions (Rand, et. al., 2000).

A political decision should be taken regarding how to handle trash producers who are unable to pay the full service rates. The government budget, the wealthier waste producers, or each poor waste producer individually could cross-subsidize the service prices for the poor trash producers. Any situation should have a policy that is consistent with the general pricing schedule additional public utilities services which includes water, heating, sewerage, and electricity (Rand, et. al., 2000).

5.5.3 Combatting the “Not in my backyard” (NIMBY) Syndrome

Modern incineration plants are not well understood by the general public, and as a result, there are typically negative feelings and a lack of confidence in the technical and environmental performance of these facilities. In general, waste is tied to odor issues, whereas smokestacks and incineration are connected to the release of black fume and particles. People are generally aware of the infrequent open burning of collected solid trash, for instance. Similar to dumping, trash incineration facilities are typically constructed near or in residential areas. Therefore, NIMBY can be a form of open protest. Through public education and consultation processes, it is crucial to ensure that people are given or have the right knowledge to argue for or against garbage incineration in order to overcome this (Rand, et. al., 2000).

Due to its environmental features, it is essential to communicate information about incineration technology in a thorough and reliable manner, including the local and worldwide effects on the environment. At the outset, during events like community general meetings and hearings, the community should be encouraged to voice its concerns. In these circumstances, the customer (Bayelsa State Government) can present environmental protection measures and discuss potential risks and implications. Following community general meetings and hearings, extra environmental safeguards or a public nuisance mitigation actions scheduled or publicized (Rand, et. al., 2000).

Environmental Impact Assessment (EIA) guidelines have been introduced by numerous governments, including Nigeria. The majority of multinational corporations and national and international development institutions also have their own EIA criteria. These criteria typically call for public participation in the hearing procedures for NGOs and community organizations. The UN Environment Programme (UNEP) indicated in a 2011 report that oil and gas development and exploration had resulted in extensive, ongoing soil and water degradation in Ogoni villages. Hundreds of thousands of Ogoni people now face serious health hazards, lack access to clean drinking water, and are unable to support themselves as a result of the government and oil companies' systematic and ongoing inability to clean up (Ojo, 2020). Just recently, the people of Ogoni Land in Nigeria's Rivers State received a $111 million judgment against SPDC for spill of crude oil that occurred throughout Niger Delta area in 1970. (Mimi Mefo, et al., 2021).

FIGURE 26A. Oil spill in Ogoni land (Friends of the Earth International, 2011)

FIGURE 26B. Oil spill in Ogoni land (Africa Prime News, 2018)

FIGURE 26C. Oil spill in Ogoni land Sustainable Economy Nigeria, (2020)

FIGURE 26D. Oil spill in Ogoni land Friends of the Earth International, (2019)

A hearing and Environmental Social Impact Assessment (ESIA) could offer a channel for communicating actual environmental and social impacts. Essentially, even though the dumping is done in modern hygienic landfills reinforced using engineering liner gas treatment and leachate controlling technique for landfill, and energy plant operating using energy conversion, and global industrial pollution regulatory actions would environmentally be preferable to disposing of. Therefore, it's important to identify the ideal location and minimize any potential disruptions to the local area.

6.0 RECOMMENDATIONS AND CONCLUSION

6.1 Conclusions

This research outlines advantages associated with waste incineration in Yenagoa Metropolis as well as the advantages of a comprehensive waste disposal and management system that will produce electricity, maintain a clean environment for residents, enhance their health, and generate revenues for the state government. Additionally, it shows the annual waste production in Yenagoa and its surroundings, which totals 111,697.3 tons without accounting for peak periods. This estimate was created using recorded data from reliable sources and according to a data from World Bank, Nigeria generates 0.65 kg of solid waste a person on average. The amount of waste that could be used as fuel for the waste incineration plant was calculated using this number and the populations of the eight Local Government Areas in Bayelsa State.

An ordinary waste incineration facility that uses mass-burn incineration can typically convert 1 ton of waste into between 500 and 700 kWh of power. The amount of electrical energy produced by the incineration of 2,200 tons of waste each day will be around 1210 MWh (2,200 kg x 550 kWh), albeit this varies depending on the content of the waste and the type of treatment. In light of Table 8, it is therefore predicted that:

1. Daily Power Generation: 306,020kg/day x 550kWh = 168,311,00 kWh/day = 16831.1 MWh/day
2. Annual Power Generation: 111,697,300kg/year x 550kWh = 61,433,515,000 kWh/year = 61433514.9513 MWh/year = 61433.5149513 GWh/year

A typical generator, such as a coal plant with a 1 megawatt capacity, will produce an amount of electricity comparable to that which can power 400–900 households for a year. Consequently, the anticipated total energy output would vary between 10 and 50 megawatts, enough to power more than 9,000 households for a whole year (10MW x 900 homes). According to these analyses, this project will promote economic growth by producing a significant number of employment and enabling household members to make investments in small and medium-sized firms (SMEs), which depend on a steady supply of electricity.

Municipal solid waste is burned for two reasons. It is a waste treatment procedure that offers many advantages over standard trash disposal methods like landfilling. Once more, the creation of 10 megawatts of power is an advantage of garbage incineration that has been heavily stressed in this project. The findings show that garbage incineration plants have a high levelized cost of energy (LCOE). Although a high LCOE could make trash incineration plants unfeasible, certain parameters might aid in defining certain advantages of municipal solid waste incineration. Solar drying is one straightforward method that can be utilized to increase waste heating value and drastically lower levelized energy costs (LCOE).

1. Alternative energy production processes, such as steam production and district heating, should be investigated based on the low heating value of waste.
2. It is significant to acknowledge the role that incinerators plays in the process of waste treatment. In a similar vein, the costs connected with energy generation are also attributed to waste disposal.

Therefore, it can be concluded that additional research should be done despite the high levelized cost of energy (LCOE) for waste incineration plants due to the fact that these facilities have the ability to both dispose of waste and produce electricity (Tehrani, et. al., 2015).

6.2 Some Recommendations

The statistics used to assess the potential viability or failure of a waste incineration plant in Yenagoa city, in Bayelsa State of Nigeria, may be inconsistent or imprecise for a variety of reasons. In addition to the substantial investments made in the project and its viability, waste incineration has health dangers. The types of waste burned, operating procedures, emission control technologies, permissible emission levels, chemical types emitted, proximity to other sources of pollutant exposure, environmental characteristics, frequency of off-normal emissions, and the biological and behavioral characteristics of the public who may be endangered by environmental pollutants vary greatly from one plant to the next. Combustion presents some improbabilities that are unusual, while other improbabilities are inherent to any action that releases toxins into the environment (National Research Council, et. al., 2000).

Some ambiguities and contradictions can be reduced or better understood in a particular way, while others remain unchanged due to their nature. However, it would be necessary to make the right choices regarding the placement, layout, operation, and regulations of incineration plants. Decisions that fully account for uncertainty and inconsistency are the most operational. Quantifiable estimates of risk may not be able to replace previously held beliefs of concerned or prejudiced people as major uncertainties increase. People who support incineration technology are more likely to put it in the spotlight, while those who oppose it are more likely to focus on circumstances with significant exposures. In light of the scenarios outlined above, it is advised that:

1. Individual and communal preferences should be brought out, decision analysis should be used, theories of science policy, socioeconomic welfare, and ethical concept should be used to inform decision-makers about individual and communal values regarding undefined negative worries.
2. In-depth socio-economic data should be routinely acquired prior to and during the operation of the plant in order to conduct a thorough and realistic assessment on the socio-economic influences of trash incineration plants on their host communities.
3. A projected waste incineration plant's psychological, social, economic, and environmental effects should be assessed, and where necessary, they should be mitigated or compensated for.
4. The political borders or territory of a single community should not be used to define the boundaries of a locality that may be touched by a waste facility from the outset. Instead, the assessment's scope should be determined by the region where impacts are most likely to materialize.
5. It is crucial that those who make decisions work together with risk advisors to recognize the ambiguities and discrepancies related to evaluating the health risks of trash incineration that may have the greatest influence on the precise decision to be made.
6. Sensitivity studies should be used to examine the significance of off-conventional activity emissions in addition to regular stack emissions or fugitive emissions when evaluating the risks to public health posed by waste incineration.

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