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# WASTE TO ENERGY MANAGEMENT IN GHANA

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Tämän opinnäytetyön tavoitteena oli tutkia Ghanan jätehuollon ongelmia ja mallintaa puitteet jäteratkaisujen käytännölliseksi toteuttamiseksi Ghanassa ja valita sopiva jäte-energiateknologia maahan.

Tämä tutkimus toteutettiin tapaustutkimuksena, jossa hyödynnettiin erityisesti laadullista analyysiä. Tärkeät tekijät Ghanan jätehuollon analysoinnissa tehtiin kirjallisuuskatsauksen kautta. Kirjallisuuskatsauksen tavoitteena oli kartoittaa Ghanan jätehuollon keskeiset kysymykset ja valintakriteerit.

Tutkimustulosten mukaan asianmukaisen jätehuoltojärjestelmän täytäntöönpanon keskeisiä ongelmia Ghanassa ovat varojen, jätelainsäädännön ja täytäntöönpanon puute sekä jätteen kosteuspitoisuus. Lisäksi tutkimus osoitti WOIMA-teknologian soveltuvuuden Ghanaan.

Selvitys voi auttaa ohjenuorana Ghanan ja todennäköisesti myös muiden Afrikan kehittyvien maiden jätehuoltoratkaisujen kehittämisessä ja toteuttamisessa.

Avainsanat jätehuoltojärjestelmä, jäte-energiateknologia

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## ABSTRACT

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The purpose of this thesis was to study the waste problems in Ghana and make a practical framework for implementation waste solutions and select a proper waste to energy technology in the country.

This research employed a case study research method, especially qualitative analysis. The important factors in analysing waste management in Ghana were done through a literature review. The literature review was carried out to identify the key issues and selection criteria for waste management in Ghana.

Findings of the study presented that the key problems of implementation of a proper waste management system in Ghana are lack of funds, lack of waste legislation and enforcement, and the moisture content of the waste. Moreover, the study showed the suitability of WOIMA technology for Ghana.

The study can assist as a guideline for implementation of a waste to energy plant in Ghana and probably other developing countries in Africa as a practical point.

Keywords Waste management, waste to energy technology

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# 1 INTRODUCTION

With a rapid global population growth lifestyle has changed with a continuous increasing waste with civilization development. The increase in civilization waste creates health and social risks. Environmental waste management is a global issue which prevents the economic growth, sustainable development, and public inclusion. Especially in developing and low-income countries waste mismanagement threatens population health and pollutes environment. The solution of waste disposal is limited in developing countries due to negative economic legislation, political barriers, poor technology, and operational limitation. /10/

The major solution of waste management in developing countries implements traditional pattern: open burning, open disposal, and open waste collection. The disposal of waste causes heavy metals pollution within ground water, and surrounding environment which pollutes plants and spreads diseases. Unattended open burning causes atmosphere harmful emission ($CO_x$, $NO_x$, SO). Open waste picking causes serious health risks to pickers. /10/

In developing and low-income countries waste disposal is the main problem due to governance barriers and limitations. High investment capital and high operation cost are the key factor barriers. Waste management faces management challenge due to government limitations in Africa. In Africa, generated waste increases in an irregular rate which is predicated to rise about 57% in 2050. /15,28/

In Ghana, rapid urbanization causes municipal solid waste (MSW) mismanagement due to lack of proper infrastructure, technical inefficiencies and funding. The solid waste picking technique varies between developing countries and developed countries. In Ghana, the solid waste collection happens house-to-house and usually illegally on the street and open spaces. Absence of waste management poses serious health problems for Ghanaians, as well as economic and environmental problems. In Ghana, population growth increased the daily urban waste generation to 2200 tonnes in 2010. The cost of waste collection is about six Ghana cedis

for one ton of waste in Accra and the local government has spent only US$ 307340 out of 472250 US$ for monthly waste collection in the city. /2,15,21/

## 1.1 Research Problem

In Africa waste management is an enormous challenge to governments. Over the years, the Ghanaian Governments have mostly been concerned with urban waste management rather than rural due to production of waste in big cities. Therefore, the irregular waste collection and indiscrimination dumping had resolved in temporary ways as open controlled burning and unloaded at a few dumpsites. Currently, the country daily solid waste is produced about 13000 tonnes and cities authorities have attempted to handle this challenge. In cities, less than 40% of the residents are served with solid waste collection services. In major cities, the collection of solid waste and disposal of solid waste has risen the cost of waste management. Unsuccessful traditional waste management has created a major natural environment impact on people life and health. /2,15,18/

These problems compel to need of study to bethink the waste management systems in Ghana and specify a pragmatic solution, to be converted to selection proper waste to energy technology.

## 1.2 Research Questions

According to discussed problems above the research study has focused on the following questions:

1.What are the key problems in waste management in Ghana?

2.What are the main criteria in selecting a waste to energy technology for Ghana?

## 1.3 Research Methodology

The research methodology informs the case study design, analysis, and data collection among others due to elaborate study methods selection for the thesis. The

aim of research is to find answers to questions through the usage of scientific methods. Research is a process to achieve a reliable solution to the problem by planning, analysing and interpretation of collected data, which are for advancing knowledge to progress promotion. /14,24/

A study is a qualitative research which is focused on the outcome of the relevant process in the waste to energy and its performance. Qualitative research provides a comprehensive pattern for deriving non-numerical collected information to resolve the problem /5/. This case study is qualitative.

A case study can be a qualitative or quantitative probe, further, there is a significant difference between those in procedure than quality where qualitative can be quantified. A case study can bear of one or more cases, where its purpose comprises analysing, definition and solution discovering for a case. In a case study scholar should define questions where the object of the probe is an existing phenomenon which requires the selection of an adequate pattern by material collection. Using written materials and interviews are usual sources. /12/

For characterizing, a case study can do research mapping which is to analyse data, search the aspects of the problem, clarify poorly known principles and improve hypotheses. This thesis focuses on a single case study which means to concentrate only to clarify unknown phenomena by getting new information for the theoretical framework whereas a multiple case study can bear of several cases. /12/

The data of a study case can be collected in two major ways, namely, primary and secondary. Primary data collection is directly made by a researcher, whereas secondary data collection is made by an intermediary (someone else). Research data will be analysed through materials. Analysing data can be defined as form the object and value with fragmentarily compacting information throughout the research process while adding the validity and reliability. Reliability means that the results of measurement are repeatable where the research can give non-random

results whereas validity means the ability of the probe procedure those types of measurement which are supposed to measure. /12/

Literature review was selected as a research method in the current study. A literature review was carried on PESTLE factors and selection criteria for waste to energy technology and how they influence the waste management issues in the case country, Ghana.

The key assumption from the previous analysis assumes that waste generation grows primarily based on two factors: gross domestic product (GDP) growth and population growth. The gross domestic product (GDP) growth describes as a country advances economically, its per capita waste generation rates increase and economic growth is reflected using GDP per capita. The population growth is defined as the population of the country grows, amounts of waste generated rise accordingly. In this study, we have a third factor, the Human development index (HDI). As HDI improves, people change their attitude to waste and environmental issues.

### 1.4. Outline of the Study

This thesis is divided into five related chapters.

Chapter 2 presents discussions on literature which are linked to the subject under study and how the empirical study is run.

Chapter 3 presents the waste management sector to doing business in Ghana.

Chapter 4 brings the results from data collated which are analysed and discussion of the study are documented.

Chapter 5 presents the conclusion and recommendations to the study. These are shown as a result of information obtained from research finding and analysis.

# 2 LITERATURE REVIEW

## 2.1 The Concept of Waste Management

The interaction between the human and the environment produces waste. Uncontrolled wastes have a direct effect on human environment and life. Waste simply is defined as all redundant or left-over of a product to discard which is not no-marginal value for the holder. The Environmental Protection Authority (EPA) of Australian Environmental Protection Act in 1997 defines waste as “waste means any solid, liquid or gas, or any combination of them, that is a surplus product or unwanted by-product of an activity, whether the product or by-product is of value or not.” /3,7,10/

Waste management is an activity that comprises a public service of waste (collection, transportation, recycling, and treatment) which gets human health, environment protection and enhances country economic by job creation. There are three common waste management concepts as waste hierarchy, extended producer responsibility (EPR) and polluters pay principle (PPP). /7,27/

Waste hierarchy is an effective system for the collection and disposal of solid waste management with the reduction of the amount of waste for reusing resources. The priorities of waste hierarchy are avoidance and reduction of waste by recycling resources. The second most important priority of waste hierarchy considers the improvement of resources which comprise three parts: recycling, reusing and recovering /8/. Figure 1, below presents the waste hierarchy from the most preferred to the least preferred (above to bottom).

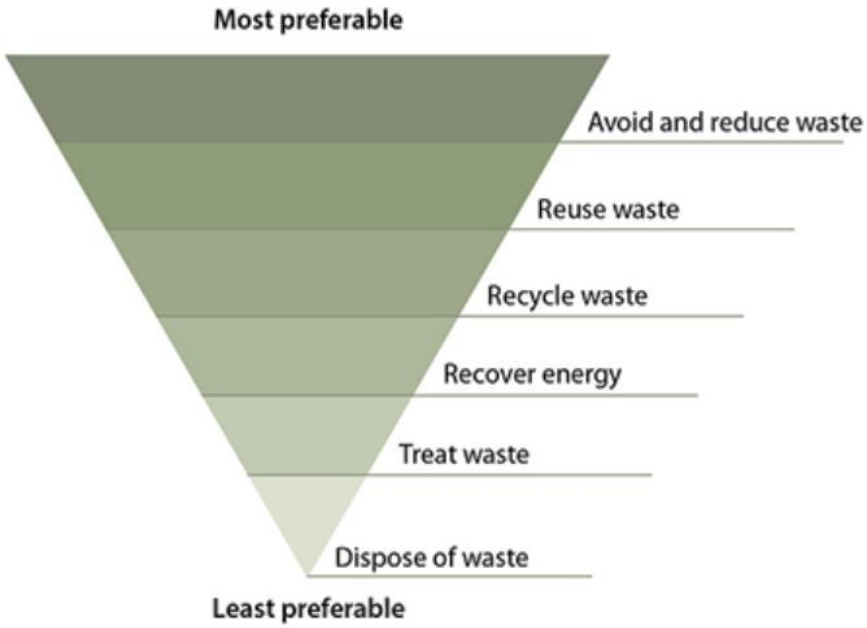


**Figure 1.** Waste hierarchy /8/

The goal of energy recovery is to absorb energy form waste into different forms of electricity or heat sources. The priority of the waste hierarchy is treatment and disposal of the waste. /8/

Another waste management concept is Extended producer responsibility (EPR) which is designed as a producer to obligate the lifecycle of a product. The goal of extended producer reliability in waste management is to avouch that producers manufacture products that are recyclable and reusable. /20,27/

Another waste management concept is Polluters Pay Principle (PPP) which focuses on ensuring manufacturers whose by-products pollute environment will bear to cost of waste management. The main function of this concept in waste management is pollution prevention and control on the environment. /9,27/

## 2.2 Classification of Waste

Waste is in different forms which is classified in a wide range of diversities. Before waste classification its properties and sources must be known. For a proper waste

management system, waste can be classified into sorts according to their sources, physical state, material composition and the level of risk related with waste substances /4/. Table 1 presents the classification of waste risk associated.

**Table 1.** Classification of waste /4/

| **Criteria for waste classification** | **Examples of waste types** |
|---|---|
| Sources of premises of generation | Residential, commercial, industrial, municipal services, building and construction, agricultural |
| Physical state of waste materials | Liquid, solid, gaseous, radioactive |
| Material composition of waste | Organic food waste, paper and card, plastic, inert, metal, glass, textile |
| Level of risk | Hazardous, non-hazardous |

Furthermore, waste can be classified according to source-classification, which is based on the fact that waste issues from different sectors of society as residential, commercial and industrial sources. In a study in Asia, the World Bank (1999) has identified the source classification as residential, commercial, industrial, municipal services, construction and demolition, processing and agricultural sources /4/. Table 2 shows the sources, type of waste in generates, and the type of solid waste involved.

**Table 2.** Sources and types of municipal waste /4/

| **Sources** | **Types of solid waste** |
|---|---|
| Residential | Food waste, cardboard, plastics, textiles, leather, yard wastes, wood, glass, metals, ashes, special wastes (e.g. bulky items, consumer electronics, white goods, batteries, oil, tires), and household hazardous wastes |
| Commercial | Paper, cardboard, plastics, wood, food wastes, glass, metals, special wastes, hazardous wastes |
| Construction and demolition | Wood waste, steel waste, concrete waste, dirt waste |
| Industrial | Packaging, food wastes, construction and demolition materials, hazardous wastes, ashes, special wastes, scrap metals |
| Institutional | Paper, cardboard, plastics, wood, food wastes, glass, metals, special wastes, hazardous wastes |
| Agriculture | Spoilt food wastes, agricultural wastes, hazardous wastes (e.g. pesticides) |
| Process (manufacturing, etc) | Industrial process wastes, scrap materials, off specification products, slay, tailings |

Waste classification based on their sources is an effective way of specifying the relative contributions of the different sectors of society to the waste stream, for planning the collection and disposal. The outcome of an example of waste classification according to material composition was conducted by Surrey County, the

UK (2002, 2003), where the analysis of household waste streams identified in nine main types of materials: paper or card, plastic film, dense plastic, textiles, miscellaneous, combustibles, glass, ferrous metal, garden waste and food waste /4/. Below is an example of material classification of waste in Table 3.

**Table 3.** Examples of Material classification of waste types /4/

| **Waste type** | **Example** |
|---|---|
| Paper | Newspaper, cardboard, office wastepaper, Magazine, Glossy |
| Plastic | Bottles, expanded polystyrene, film plastic, other rigid plastics |
| Glass | Clear glass, green glass, amber glass, non-recyclable glass |
| Metals | Steel cans, aluminium can, other ferrous, other aluminium |
| Organics | Yard waste grass, food, paper, wood, textiles, diapers, other organics |
| Inorganic | Electronics, carpets, drywall, other construction and demolition, and others |

The definition of municipal waste according to the Official Journal of Europe Union in 2015 comprises collected waste items from household resources which bear the variety of types of waste in different country. The definition of MSW differs in different country, whereas in general, MSW does not bear of produced wastes from commercial, agriculture, forestry, fishing, septic tanks, sewage sludge, construction and demolition waste, hospital waste, vehicle waste. /26/

Hazardous wastes are those types of waste which comports potential threats and high risks to the environment and public health where need strict disposing control. /6/

Electronic waste or e-waste is discarded electronic or electronical items by their owner without the intent of re-use which are almost from households or commercial sources. /6/

### 2.3 Waste Treatment and Collection

The treatment of solid waste refers to any activities which are implemented to reduce the costs of transportation or disposing of wastes, and any processes where to reduce risks to health and environment. Typically, waste management has considered only about recycling (treatment) with a proper technology, but certainly recycling (treatment) is only one the most crucial in SWM chain. Recycling (treatment) is not the most significant chain that requires major attention or expenditure, and not also the chain which comprises the greatest impact on the urban environment. The collection is the most important chain to be considered since recycling with an adequate technology in the place. There are different types of waste treatment required by law in many countries. /6/

Waste collection is the collection of solid waste from the production point (local, shop, business premises, industrial, commercial, institutional, markets) to the disposal or treatment point. This includes sweeping, gathering and storage of the waste, the loading, unloading and transformation of these waste, and all steps of transporting the waste while it reaches the destinations. Waste is collected in several methods through house-to-house pick-up, curb side pick-up system, community bins, self-delivered and contracted service. /6/

House-to-house or door-to-door pick-up method is where waste collectors go to individual houses to collect garbage. This is common in developing countries in some middle and low-income areas. /6/

The curb side pick-up method is where users leave their garbage outside their homes according to a pick-up schedule set with local authorities. This is done in different ways according to the country or the city. Most commonly the waste bin is pushed to the roadside to empty it by collectors via their truck or by the workers. In the developing countries, this method is done in high-class and some middle-class citizens. /6/

Community bins or communal central containers are designated in a fixed point or centre in the neighbourhood, where users bring their waste. This method is practised more in the developing countries in low and poor-income areas. /6/

Self-delivery is for people who do the collection themselves. The waste generators deliver the garbage or the waste directly to a dumping site which is either an authorized or unauthorized site. This method is very usual in developing countries. /6/

Contracted or delegated service is the responsibility of every municipality to ensure that the waste collection is done in a more effective way so that municipal facilities arrange the collection schedule and charges with customers. This method brings the private firms onboard by giving them licence as private operators for waste collection behalf of municipality or business firms. /6/

### 2.4 Waste to Energy (WtE) Technologies

Waste to energy (WtE) is a systematic way whereby energy is recovered from waste and used as electricity or heat for consumption. Some forms of waste are municipal waste, agricultural waste and some industrial waste. Studies have shown that energy recovered from waste is obtained via several means. Waste to energy conversion technologies according to their energy conversion processes are incineration, thermo-chemical, bio-chemical, thermal, and mechanical and chemical WtE technologies. /22/

### 2.4.1. Incineration

Incineration or combustion is a thermal energy recovery technology where energy generation process from waste involves the burning and combustion of waste under high temperature. In the incineration process energy which is recovered from waste can be used as electricity and heat by steam production through turning on steam turbines. Incineration is an effective way for reduction, the volume of waste and requirement for the land space. Furthermore, incineration plants can be located close to the centre of gravity of waste generation to reduce the cost of waste transportation. Waste incineration is only applicable for certain requirements which are involved heavy investment and high operation costs. /22/

### 2.4.2. Thermo-chemical WtE Technologies

Gasification takes place when waste or biomass is converted into gas with the help of gaseous compounds under high temperature. This process produces synthetic gas for electricity or heat generation. /11/

Pyrolysis is a thermal process of the waste or biomass decomposition under high temperature in the absence of oxygen whereby produces liquid fuel for generation of heat energy or feedstock. /11/

Torrefaction is a thermal process of low heating waste (biomass) at the temperature between 200°C and 300°C under an inert atmosphere to generate waste as a more energy-dense product, namely, torrefied pellets (TPOs) or briquettes which bear of similar properties to coal and charcoal. These substituted products can be used for household heating, biomass co-firing and gasification. /11/

Plasma technology is a process of thermal decomposition of waste or low-energy biomass under high temperature to supply plasma as a high-energy synthetic gas which the produced energy can be thermal or electric current or electromagnetic radiation. /11/

Hydrothermal liquefaction is a thermochemical liquefication process for bio-oil or biocrude production at low temperature under high pressure with or without catalysis in the presence of hydrogen. In this process, waste is converted into bio-oil which is used as fuel for heat or electricity generation. Further, hydrothermal liquefaction is an effective method for high moisture content waste to reduce the cost of waste (feedstock) drying. /16/

### 2.4.3. Bio-chemical WtE Technologies

Anaerobic digestion is a process where the microorganisms in the organic waste break down as biogas. This process takes place in the absence of oxygen at the temperature between 55°C and 66°C. Methane and non-methane components are formed during biogas production. Methane production in anaerobic digestion process happens within 3-5 weeks which is 2-5 times more than what is recovered from landfills. The amount of energy generated depends on the methane content of the waste which can come from the organic fraction of municipal solid waste (MSW), some agricultural waste such as maize stalks and rice husks, and industrial waste. /22/

Landfill gas can be recovered for electricity generation when waste is broken down on a landfill without the present of oxygen. Landfill gas is estimated to contain approximately 40- 60% of methane which can be used for energy generation. It takes two weeks for biogases to be released in large quantities for using in drilled wells to combustion turbines for electricity production /22/. Figure 2 presents a typical framework of waste to energy which shows the idea of waste recovery.

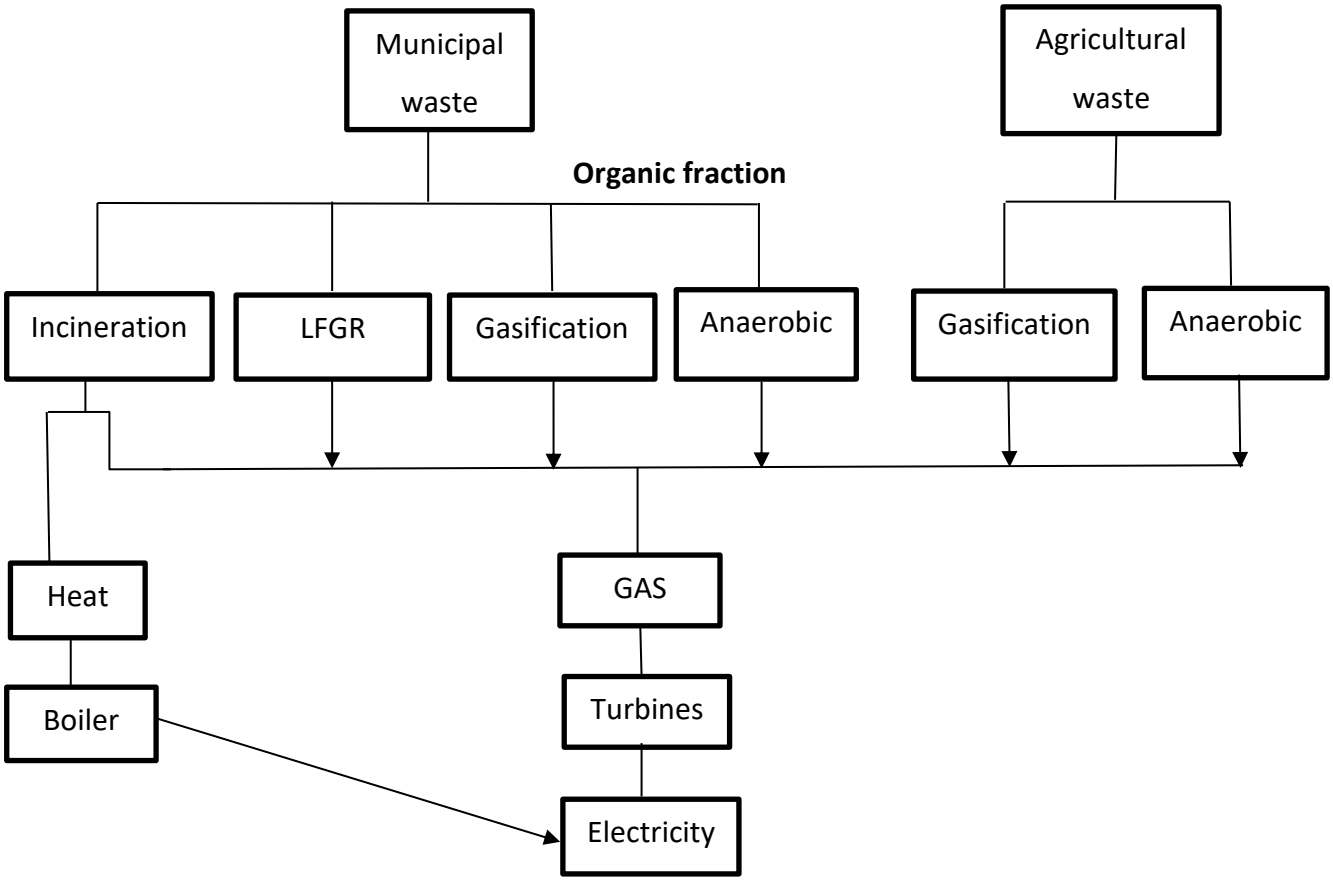


**Figure 2.** Waste to energy framework /22/

Composting is a process where biodegradable waste decomposes as compost (solid product) in the present of oxygen. This compost can be used for recovery of the agricultural soil condition, erosion prevention, soil carbon storage which is used in the process of reclaiming land and a final cover for landfills. /11/

Bioethanol fermentation is a process where waste is converted into bioethanol as biofuel by alcohol-fermenting microorganisms, whereby, using as engine fuel to electricity generation. /11/

### 2.4.4 Mechanical and Thermal WtE Technology

This kind of WtE technology merge mechanical and thermal processes to supply energy due to the production of refuse derived fuels (RDF) while MSW pulverizes

and dries to create solid fuel. The combustion of this solid fuel releases thermal energy as heat. /26/

### 2.4.5. Chemical WtE Technology

Esterification or transesterification is a process where the fats and the oils in waste or biomass are converted into ester and glycerol in the presence of catalysts due to reaction them with alcohol. The produced ester can be used as biofuel and the by-product glycerol has commercial value. /16/

## 2.5. Selection Criteria for WtE Technology

Choosing the waste to energy technologies depends on the waste characteristics, the goal of energy generation, resource availability and local conditions of plant location. The aim of WtE plant can be to produce fuel for heating, cooling, electricity, biogas for vehicles and biofertilizers. Local conditions comprise economic conditions, substrate availability, and biomass or substrate source availability to plants. /22/

The other factors that affect the choice of WtE technology are the humidity and composition of the waste. The high moisture content of waste affects its calorific value while using an incinerator but in an anaerobic digester, the moisture of waste will not be a problem because water will be added in the digestion process. All types of waste can be treated together by an incinerator without the need for separation, whereas an anaerobic digester requires waste separation before using and it can only use of organic waste. /22/

Resource availability and the purpose of production and supply are required for continuous increasing biogas using. There are certain factors which affect the composition of waste as the season, income and location of the sources of the waste. Low-income countries have the high composition of organic wastes whereas high income countries have a higher composition of paper, plastics and other organic materials. /22/

Gasification of MSW generates more electricity than incineration whereas incineration is a better option if both the production of electricity and heat are targeted for energy generation. Gasification of MSW has a lower gate and produces less greenhouse emissions per kWh produced electricity if a thermal product is not used. /22/

Space restrictions: WtE technologies can reduce the volume and mass of waste between 75 to 90 percent while there is not enough and adequate land for waste disposal whereas WtE technologies resolve the problems of the landfill need. /26/

Energy generation: The energy requirement especially in the renewable energy sector is increasing with time while there is a high energy value within waste to use, and it faces the requirement of renewable energy. /26/

Climate change: WtE technologies can reduce green-house gas emissions and harmful gases while many efforts have been done to decrease the harms of climate change. WtE technologies can also help countries to meet their climate purposes by remove the waste from landfills, reduction open burning and replacement fossil fuels. /26/

Health and Environment: In developing countries, waste is discarded in open dumpsites, streets and ground water which pollute environment and create serious health problems. WtE technologies can effectively eliminate these issues. /26/

### 2.6. Challenges of Implementation of a WtE Plant

In developing countries, the implementing of a waste to energy plant bears various technical challenges such as waste characteristics, governance challenges including social, financial and legislative perspectives. These challenges are described below.

Waste Characteristics: The type of waste is significant to build a WtE plant for leading a project successfully or not. The waste characteristics directly affect the energy efficiency of a WtE plant. Each region has the specific waste composition and quantity. Furthermore, the waste quantity varies with different seasons and natural disasters. /26/

In developing countries, MSW comprises a high moisture level organic wastes which has a low calorific value to generate energy in a WtE plant, moreover, the MSW contains inert materials, such as construction and demolition waste without energy value for the WtE plant. The poor quantity and quality of the waste can be named as a hindrance to implementation a WtE plant. /26/

Costs: Investment and operation costs are two major factors which specify a thermal WtE plant development, thus the cost of an incineration plant is averagely higher than other waste technologies. Any problems with the investment and operation costs could collapse the WtE implementation project. /26/

Investment costs are all costs of the project development and planning which include the cost of siting, feasibility studies, permitting, consultation, design, land, equipment, and construction. /26/

Operation costs are all costs of the project which require to keep the project on working including the cost of labour, fuel, energy, maintenance and repair, emission control and monitoring, revenue collection, public communication, management and administration, the safe disposal of residues, accident response and decommissioning. /26/

The total cost of a thermal WtE plant is usually higher in developed countries, whereas developing countries carry out basic low-cost plants due to the high investment costs that may rise risks and more pollution at the end. These costs are higher in developed countries due to higher labour costs, architecture and stricter emission standards. Furthermore, the equipment costs of a thermal WtE plant are

usually the same worldwide as engineering, construction, land and labouring in different countries. /26/

Legal: Thermal WtE legal challenges are varying in every developing country based on the country and local conditions for each WtE project. Legal aspects are most depending on the economic, environmental and social associates of a country. /26/

Environmental: Waste incinerators are one of the leading sources of air pollutant worldwide while, currently the technology has improved with a better operation of combustion and plants are equipped with flue gas cleaning systems. Developing countries have to develop their incineration technologies due to the poor maintenance technology and operation systems of incinerators which bear more emissions to air whereas, the European Union has changed its incinerators into other WtE technologies, due to stringent emission laws. /26/

Social: Public opposition against thermal WtE projects can be a great issue. Public approval or social licence is necessary for building a WtE plant. There are three reasons, including plant site allocation, the lock-in effect, and potential trade-offs of the 3Rs which are disapproval from the public due to the negative aspect of the health and environmental impacts of the incinerators. /26/

### 2.7. Integrating a WtE Technology in a Location

In developing countries, establishing an integrated WtE technology in a location follows some key factors, such as preliminary conditions, technical proportion, implementing conditions and stakeholder analysis that are described below. /26/

Waste Characteristics Identification: The data of waste collection and waste analysis should be done for the integration WtE technology in the country. The implementation of incineration WtE requires waste data which should be identified. Waste characteristic identification includes the following objects. /26/

1. Waste assessment survey of the city or municipality:

- Waste data collection such as waste quantity, density, value, calorific, collection coverage, rate of recycling and the rate of landfill disposal
- Future waste quantity data such as city population, intercity and transboundary waste stream, waste created from tourism industry and natural disasters
- Imported waste which means if there is a need to import waste, thus the waste survey of those areas should be done carefully.

2. Waste management efficiency analysis:

- This analysis is made using waste evaluation survey such a benchmark indicators
- Waste management tool which combines a qualitative indicator for generating waste and composting, further composite indicators
- Analysis of waste collection, treatment, disposal, the 3Rs (recovery, recycling and reuse) and governance aspects

Technical Proportion: City or municipal infrastructure and technical requirement conditions should be considered.

1. The requirements of infrastructure:

- Availability of a controlled landfill close to the incineration plant where flue gas residue can be disposed off
- Availability of market and disposal for the WtE plant residue
- A proper and efficient waste collection and transportation in the city to carry the waste off to the plant
- The identification of types of energy generation and its demand and approachability for the end user
- The local capacity of the city for controlling emissions

2. Assessment of potential WtE technologies in a place:

Experts should be consulted to determine what kind of technology would be adapted for the city based on the waste management efficiency and local environment.

3. Minimizing incineration using and final disposal:

Strategies should be improved to maximize reuse, recycling and composting of waste for operating in the incineration plant, furthermore, for example waste sorting facilities to evoke recyclable materials before incineration and end residues using as road construction or reclamation materials.

To meet the implementation conditions, the following assessment should be carried out:

1. Life Cycle Assessment: Impacts and co-benefits of the plant overall its life cycle should be assessed.

2. Emission Assessment: All direct emissions including biogenic carbon emissions, indirect emission from burned materials and GHG emissions should be considered, moreover the amount and toxicity of flu gas and waste residues have carefully examined.

3. Financial Model: In developing countries, long-term financial resources are compulsive for sustainable a WtE project. Initial investment costs to be included are:

- Direct revenues such as gate fee, the waste fee of the citizens, sale of generated energy
- Indirect revenues such as raising tipping fee at landfills, the regularization of the open waste dumping
- Government subsidies
- International funds
- The investment of private sector

- The investment of Public Private Partnership (PPP)
- The access of foreign currency

Stakeholder Analysis: The acceptance of a WtE project by the stakeholders is crucial to implement the project. A stakeholder mapping and analysis should be done that strategies can be initiated based on them. Opposition implementation a project should be expected due to negative environmental and health impacts from citizens, whereas a good public communication is beneficial to progress the project. Communication with the public and stakeholders via open consultation and dialogues for the planning progress and encouraging supporting policy decision should be done to implement a WtE plant. /26/

The decision-making of implementation of a WtE plant is affected by factors such as waste data and characteristics, infrastructure, environmental aspect, economic aspect, legal aspect, social aspect, risk assessment and alternatives that should be considered building a WtE plant or not. /26/

# 3 WASTE MANAGEMENT IN GHANA

## 3.1. Background of Ghana

Ghana is a country located in the Sub-Saharan region in the West Africa close to the equator with a total land area of 238535 $km^2$ which has 55.9% of this land area being cultivated. It is bordered on the West by Ivory Coast (Cote d'Ivoire), Burkina Faso in the North, Togo in the East and the ocean Gulf of Guinea in the South. Ghana was originally called Gold Coast before its independence from the British. The British established the full control of Ghana from 1874 until March 1957 when the country gained independence. Ghana has been quite a stable country over past decades by democratically elected successors. /22,25/

Ghana is one of a few Sub-Saharan countries with continued positive economic growth over past decades. The rapid economy growth had changed the country from a lower income status to a lower middle-income status from July 2011. /22/

## 3.2. Energy Sector

The energy generation in Ghana is mainly from 55.8% of hydro and 44.1% of thermal and additionally only 0.1% of solar. In 2014, the use of final users for biomass/charcoal 40% and petroleum (gas and crude plus petroleum products) 47% were accounted for the final energy consumption. The per capita energy consumption in 2014 was 0.26 TOE/capita. Electricity depends on primary energy carriers such as hydro, biomass, coal, natural gas and petroleum as a secondary energy carrier whereas, the combustion in the thermal plant is done using light crude oil, natural gas and petroleum diesel as fuels or primary energy carriers by discharging greenhouse gases to the environment. /22/

A huge portion of the electricity generation is made up by hydro in Ghana but in a period time (2006-2007) hydro electricity generation has reduced due to drought in the country. For a long time in Ghana, the primary energy supply has been mainly biomass from wood, about 47% of the total energy supplied, which is still

a remarkable portion of the energy supply. However, it is a renewable energy source which is not used sustainably due to the wood coming from the cutting trees and burning whole forests. In 2012 approximately 64% of the urban population has access to electricity and only 40.1% of rural population. The low access to electricity by the population can be a reason for the predominant use of wood for people depending on wood for lighting, heating and cooking. /22/

There are about 100 biogas plants currently installed in Ghana whereas most of those are for bio-sanitation interventions, such as waste treatment plants and bio-latrines to health and educational institutions in urban areas. The users (firms and individuals) make use of these energy sources due to uninterrupted supply power that is not assured with the grid connection. There are at least four biomass co-generation plants which are used palm oil mills with an average annual power generation of 7 GWh. /22/

The total energy demand of Ghana in 2015 has been between 14000 GWh to 16400 GWh with its supply availability about 15000 GWh. The potential of renewable energy has increased so that the Energy Commission has as part of its strategic national energy plan to promote 2% penetration in the use of biogas to heat and cook in institutional kitchens, laboratories, hotels and restaurants by 2020. /22,23/

### 3.3. Key Stakeholders in Waste Sector in Ghana

MSW management and energy production are part of the main challenges which need to develop in big cities and countries. In most developing countries, resource recovery is for low-income people to improve its life. Huge problems are faced in major capital cities on the waste management system due to high population with the high daily waste generation rate, high rural-urban migration and high unemployment rate which refers serious concerns about. In Ghana, the formal waste

management system only focuses on the provision of waste collection and transportation services from the sources to disposal sites, which are un engineered landfills polluting environment and ground water. /4,23/

Currently, a more systematic approach namely, sustainable and integrated solid waste management has developed to merge stakeholders. Over past years, the private sector in waste management (including waste pickers) has become more especially, in waste operations /25/. The key stakeholders in waste management in Ghana are identified including waste disposal service providers in Table 4 below.

**Table 4.** Key stakeholders in waste management in Ghana /4/

| **Category of stakeholders** | **Actors** |
|---|---|
| Waste disposal service providers | • Municipal Waste Management Departments<br>• Private sector waste companies<br>• Informal waste collectors/waste pickers |
| Public institutions with functions affecting solid waste management | • Environmental Protection Agency<br>• Town and Country Planning Department<br>• Lands Commission<br>• Department for Urban Roads |
| Waste disposal service clients | • Households<br>• Businesses<br>• Institutions |

Figure 3 presents the conceptual diagram of waste sector stakeholders and their responsibilities in Ghana.

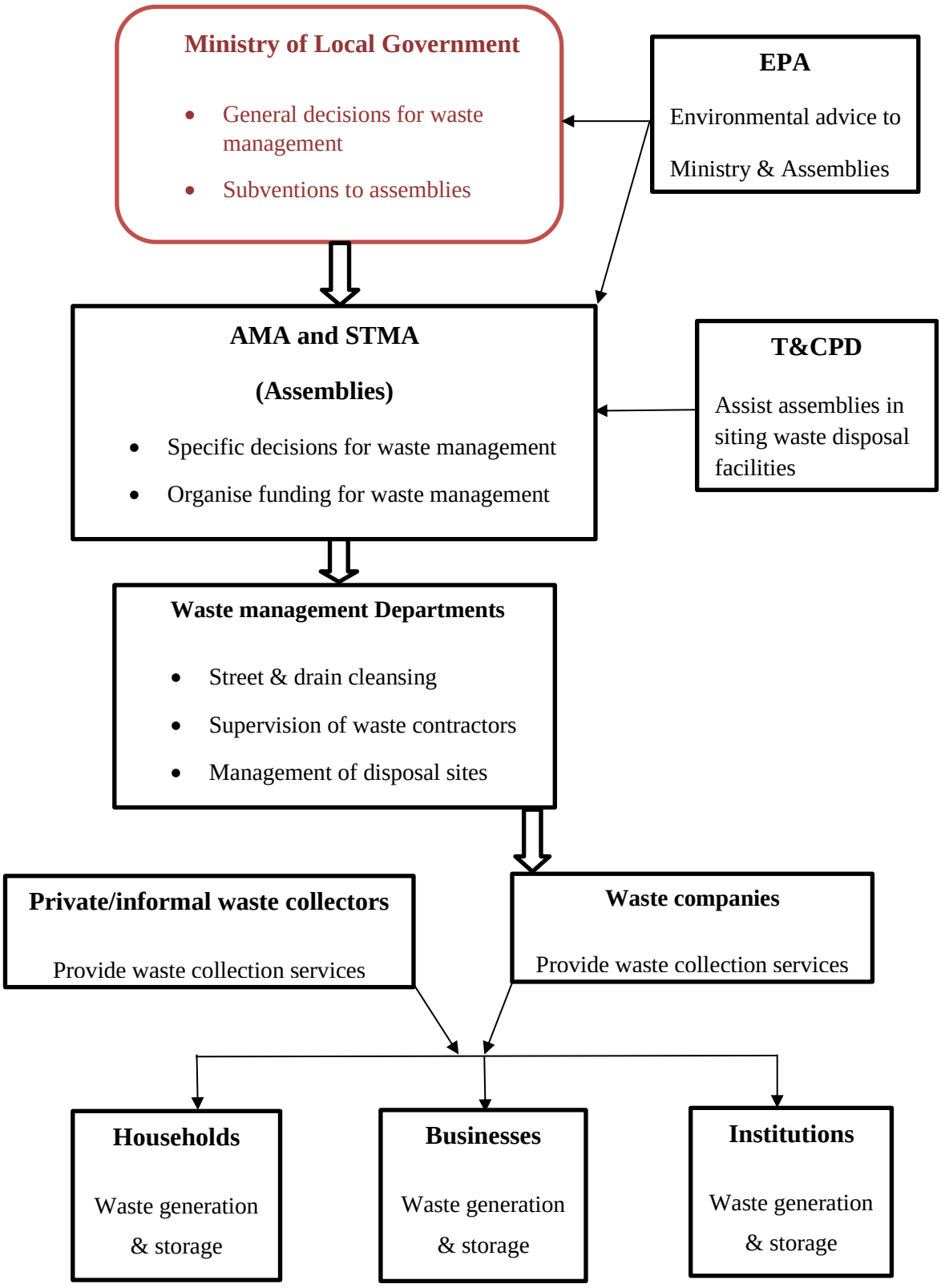


**Figure 3.** Conceptual diagram of waste sector stakeholders and their responsibilities in Ghana /4/

There are waste companies contracted under the public-private-partnership arrangement to work within the country as shown in Table 5.

**Table 5.** Some private sector companies active in waste /circular economy in Ghana /25/

| **Company** | **Line of business** |
|---|---|
| Alliance Waste Ltd (part of the Jospong Group) | Collection of household, commercial and institutional waste and disposal at approved waste disposal sites |
| Ashanti Waste and Environmental Services Ltd (Jospong Group) | Integrated waste management company. Ashanti waste is a subsidiary of Zoomlion for the Ashanti region. |
| Environment 360 (NGO) and Evolve recycling (for profit) | Awareness raising, community and corporate recycling programs, sale of recyclables. Has a program with GIZ of Germany on PET bottles recycling |
| J. Stanley Owusu @ Company Ltd (JSO) | Recycling services for e.g. glass, paper and metals, management of household waste recycling sites, management of hazardous waste and landfill disposal |
| Jekora Ventures | Household waste collection, management and recycling in and around Accra. Recycling of organics and plastics, compost production |
| rePATRN | Recycling and recycling of PET bottles |

| | |
|---|---|
| SkyFox Services | Agri-business, water, renewable energy, sanitation and solid waste. Active in Ghana, Burkina Fasso, Sierra Leone and Guinea |
| Toahouse Company Limited | Construction of affordable housing using plastic waste (bottles). Also export of recyclable plastics (PET flakes) |
| UnIversal Plastics Products and Recycling (UPPR) (Jospong Group) | Plastic recycling company (part of Jospong Group) with plants across the ten regions of Ghana |
| Venital | Waste management and sanitation in Western Ghana |
| Waste Landfills Co Ltd (part of the Jospong Group) | Waste disposal, treatment and related services, including plastics recycling |
| Winsbeaver Company Ltd | Environmental services, a.o. in plastic waste collection |
| Zoomlion Ghana Ltd (part of Jospong Group) | Ghana's largest waste management company, also active in five other African countries. Waste collection, public cleansing, e-waste, compositing, recycling, liquid waste, etc. |

### 3.4. PESTLE Classification and Waste Management in Ghana

A PESTLE (also named PESTEL, Political, Environmental, Social, Technological, Economic and Legal) is an ideal tool for analysing the macro-environmental to business expansion in a country. This chapter defines an overview of description of

PESTEL analysis in Ghanaian market, WtE management and implementation in the country. Significant factors for WtE management development can be identified as an analytical framework which is considered in decision-making and implementation processes. Effective political factors of waste management in Ghana are shown below in Table 6.

**Table 6.** Political factors in waste management /19/

| **Factors** | **Description** |
|---|---|
| Government Stability | Ghana is one of a stable and multi-party democratic country in West Africa which can help to create small enterprises in the country. /25/ |
| Corruption | Ghana ranks number 75/ 180 in the corruption perception index 2020, same as India and Turkey (data 2018). It means corruption exists which can affect the WtE project cost. /25/ |
| Local government plan | Ghanaian Government can cooperate to invest in the waste management by laying the EU- countries foundation, especially in E-waste (electronic) management. /25/ |
| Government priorities | The country has established a decentralized local government system based on the constitution of the Republic of Ghana in 1992, which has provided a legal ground for the decentralization process. Currently, the country government has mostly, considered on a public-private-partnership (PPP) companies for waste management in Ghana. Non-Government Organizations (NGO) are in practicing collection waste |

| | |
|---|---|
| | around the country. Policies and systems are replaced to communicate for foreign support and board consultations. /25/ |
| Influence of politicians | The Environmental Sanitation Policy WMD is to provide solid waste management indirectly through public-private-partnership with private contractors in the country. Furthermore, the political influence comprises a high effective role to decision-making of a WtE project in Ghana. /25/ |
| Bureaucracy | Procedures take time in the country and permits may prolong for implementing a project. /25/ |

Environmental factors to effect in waste management in Ghana are presented below in Table 7.

**Table 7.** Environmental factors in waste management /19/

| **Factors** | **Description** |
|---|---|
| Environmental guidelines | Decision-making in solid waste management is done by the constitution and the Local Government Act, AMA in the country. |
| Environmental targets | The Energy Commission of Ghana comprises its strategic national energy plan to promote in the using 2% of biogas as energy source for heating and cooking by 2020. /22/ |
| Climate change | The government of Ghana with the support of World Bank has implemented the different phase between |

| | |
|---|---|
| | an Urban Development Projects and the Urban Environmental Sanitation Project (UESP). Accra Waste Management Project has only designed for wastewater and soil treatment. This project is not still implemented in the country. /22/ |
| Geographical landform | Ghana has huge potential for ethanol production based in the large volume of country in starchy crops such as cassava, yam, cowpea, maize, groundnut and sugar crops like as sugar cane, sugar beet and sweet sorghum and forest residue which are available to generate energy through anaerobic digestion around the country. /22/ |
| Environmental awareness | According to a study in 2019 most Ghanaian high-income residents and university students are concerned about waste mismanagement and environmental impacts and 87% of all surveyed households in the study case did not mind about waste management and collection. /13/ |

Effective social factors in waste management in Ghana are shown in Table 8 below.

**Table 8.** Social factors in waste management /19/

| **Factors** | **Description** |
|---|---|
| Demography | Ghana has approximately 31 million population with a total land area of 227540 $km^2$. Over 52,7% of urban population is estimated in over ten administrative regions. The rate of waste generation in Ghana is about |

| | |
|---|---|
| | 0.47kg/person/day (2015) which means about 22500 tons of waste around the country per day. /4, 25/ |
| Culture | Ghana is a mostly Christian country (72%) with a mainly Muslim minority in the north of the country. Religion has a significant and visible role in Ghana. The official language is English, furthermore, Akan is the most important language in the south. /25/ |
| Local/national events | National and traditional festivals and activities produce amounts of waste in the country. |
| Socio-economic indicators | The major waste categories in Ghana are 61% biodegradable waste (organic and paper), 14% plastics, 6% inert, 5% miscellaneous, 5% paper, 3% metals, 3% glass, 1% leather and rubber, and 1% textiles. /25/ |
| Resource consumption patterns | MSWs are generated from households 55-80%, 10-30% followed by commercial and market districts with huge quantities from streets, industries and institutions. /25/ |
| Rural-urban daily migration | The increasing rate of urban population in major cities has changed life standards in the country and most of solid wastes are generated in cities. /15/ |
| Philosophical change | SWM has got important due to serious public health issues and risk for the government. /13/ |
| Resistance to change | In Ghana, government authorities and private sector actors bear to key roles in SWM as social protection programs, education and health. /15/ |

Technological factors in waste management in Ghana are presented in Table 9 below.

**Table 9.** Technological factors in waste management /19/

| **Factors** | **Description** |
|---|---|
| Skill workers, experts | A lot of research has been done on waste management over several years in Ghana. An effective scheme is still absent in the country. Waste collection and treatment is inadequate in the country. Furthermore, the country has no data of waste sources and their management which are caused lack of the reliable information of MSW in decision-making. /4,13,15/ |
| Application of suitable technology | In Ghana, inadequate equipment, low technology system and operational funds play key roles to supporting waste management. Most of about 100 installed biogas plants in the country are just located for bio-sanitation intermediates as waste treatment plants and bio-latrines for health and educational institutes in urban areas. /22/ |
| Facilities availabilities | According to a study, Ghana comprises relatively with a high access electricity for grid extension (PV technology) about 85% in the cities and approximately 67% in the rural areas in 2018. There are inadequate sites and facilities for WtE management operations in Ghana. |

| | |
|---|---|
| Rate of technology change | An unsuccessful experiment of production biogas from human waste and cow dung for supply electricity and cooking does not encourage to promote biogas use. /22/<br><br>The trade of second-hand electronical equipment from development countries has issued concerns in the country. |
| R&D activities | There are inadequate skills, knowledge and capacity of planning waste management programmes in the country. |

Effective legal factors in waste management in Ghana are presented in Table 10 below.

**Table 10.** Legal factors in waste management /19/

| **Factors** | **Description** |
|---|---|
| Local policy | Environmental legislation and regulations are available in Ghana. /25/ |
| Relevant SWM law | Government has formulated various legislation, adequate policies and regulations for the controlling of waste and strategic action plans to develop and implement waste management. There are available prepared guidelines and standards for waste management in the country. There are three main problems for MSW in Ghana, such as lack of SWM political commitment, resources scarcity (funds, logistical and land |

| | |
|---|---|
| | space for disposal waste) and lack of the enforcement of the waste disposal by-laws. /4,25/ |

Effective economic factors in waste management in Ghana are shown in Table 11 below.

**Table 11.** Economic factors in waste management /19/

| **Factors** | **Description** |
|---|---|
| Potential income from waste | Tariff the rate of waste to energy is around US$ cents between 17,5 to 18,5 cents/kWh. /25/ |
| Trade restriction on waste | Mostly unfree category trade country. /25/ |
| Availability of funds | The weak national economic policies of the country and poverty in rural areas have made to consider foreign support in waste management and implementation in Ghana. An encouraging framework for private investment needs to be adopted on SWM. In Ghana, 80% of the waste services are done by the private sector. /25/ |
| Interest and tax | Corporate tax rate in Ghana is between 25% and 32,5%.<br><br>Interest rate is between 6% and 10%. |
| Economic growth patterns | Average GDP growth rate in Ghana is about 8,14% (2018). /25/ |

| | |
|---|---|
| Incentives | Environmental Sanitation Policy in Ghana has based on the SWM strategy according to private, non-governmental organizations and foreign investment to develop waste management in the country. |

### 3.5. Current Waste Management Situation in Ghana

One of the greatest challenges which humanity faces in modern times is waste management. In Ghana, cities and towns have faced serious waste management problems such as heaps of uncontrolled waste, polythene bags and disposal sites overflowing with contamination which cause serious health hazards such as cholera, dysentery, malaria and typhoid to residents. Urban produced wastes have created more concern about waste management in Ghana. The variety of produced wastes are sent to a few dumpsites, but majority enter in drains, stream and other places. /2/

The current state of waste management in Ghana is prioritized on waste collection services, transportation and open disposal. In Ghana waste management services are mostly inefficient and ineffective. There are no appropriate waste disposal facilities and sites for waste management in Ghana. The waste companies are responsible for waste collection but the collection fees can contribute to the waste collection situation in the country. There are two main types of waste collection method in Ghana, namely, door-to-door and communal containers (disposal at refuse dumps) and other traditional methods, such as burning and burying. In wealthy areas, inhabitants tend to concentrate on their waste through the door-to-door collection method where citizens pay the waste fees for the getting service. In poorer areas, households, market vendors and other residents receive little or no service for waste removal, therefore, inhabitants should take their waste

to the communal containers. This method is happened via different transport vehicles such as donkey carts, three-wheeled tractors and tricycles /2,25,26/. Figure 4 shows the current waste situation in Ghana.

**Figure 4.** Current waste situation in Ghana /2,25/

According to the Director of Sanitation of the Ministry of Sanitation and Water Resources, currently 80% of waste services in the 254 Metropolitan, Municipal and District Assemblies (MMDAs) of Ghana are enabled by the private sector which impressively gone forward waste collection services in the major cities in Ghana. /25/

A predominant actor of the private waste sector in Ghana is the Zoomlion Ghana Limited company, which is part of 45 other companies that are organized the Jospong Group. The company has 3000 staff and 85000 project staff in the other African countries such as Togo, Liberia, Angola and Equatorial Guinea and with plans moving into Nigeria, Benin, Guinea and Uganda. Zoomlion waste-related activities are comprised waste collection and processing service, waste separation,

recycling, composting plants, such as the Accra Compost and Recycling Plant (ACARP) and Accra IRECOP (a Public Private Partnership between the Ghanaian Government and Zoomlion where the Government has contributed lands for Zoomlion investment to build the waste separation and composting facility) plant, plastic recycling, transfer station for waste, construction of waste sanitary landfills and oil waste management. Based on design, IRECOP can provide 400 tons of waste as daily fraction, such as paper, cardboard, refuse-derived fuel (RDF), different types of plastics, organics and other kinds of waste which can supply 60 tons of compost daily. /25/

In Ghana, the circular economy concept is relatively unknown since on 7 and 8 May 2019 in an EU seminar on Circular Economy Opportunities in Ghana, the concept has expressed to attendees. Nevertheless, the circular economy approach divided into ten, namely, R-strategies which can categorize a range of existing initiatives or business driving from the sustainability point of view in Ghana in Table 12 below. /25/

**Table 12.** R-strategies in the circular economy /25/

| **Type** | **R#** | **Name** | **Strategy** |
|---|---|---|---|
| **Smarter product use and manufacture** | R0 | Refuse | Make product redundant by abandoning its function or by offering the same function with a radically different product |
| | R1 | Rethink | Make product use more intensive (e.g. through sharing, or by putting multifunctional products on the market) |

| | | | |
|---|---|---|---|
| | R2 | Reduce | Increase efficiency in product manufacture or use by consuming fewer natural resources or materials |
| **Extend the lifespan of the product or its parts** | R3 | Re-use | Re-use by another consumer or discarded product which is still in good condition and fulfils its original function |
| | R4 | Repair | Repair and maintenance of a defective product so it can be used with its original function |
| | R5 | Refurbish | Restore an old product and bring it up to date |
| | R6 | Remanufacture | Use parts of a defective products in a new product with the same function |
| | R7 | Repurpose | Use discarded products or its parts in a new product with a different function |
| **Useful application of materials** | R8 | Recycle | Processes materials to obtain the same (high grade) or lower (low grade) quality |
| | R9 | Recover | incineration of materials with energy recovery |

### 3.6. Waste Characteristic in General

Waste characterization can be defined as discovering how much different kinds of waste such as paper, glass, organics and other types of waste are discarded in the waste stream which can help to plan for waste reduction and waste recycling to

protect resources. Knowing the waste characteristics is the most important stage to choose a proper technology in the city or municipal. Imported waste means that there is a need to import waste, thus the waste survey of those areas should be done carefully. /6/

One of the significant factors of design and selection the waste collection equipment is waste characteristics (both quantities and composition). Some factors which affect varying waste characteristics are described below. /6/

Cooking and eating habits: Different types of food and vegetables produce different amount of waste. Cooking and heating with solid fuel has a big effect on the waste due to burning other discarded waste such as paper or foil which come difficult to recycle. /6/

Social and economic factors: Lifestyle diversity can affect the amount and type of the produced waste in the cities. The waste type of high-income areas is mostly different from poorer areas whereas in high-income areas discarded more durable items, such as clothing and electrical equipment. /6/

Recycling and reuse: In some cities of the developing countries, much of the organic (food and vegetables) waste is fed to livestock and poultry, further, some recyclable materials, such as drink and food containers are reused for household purpose. Waste pickers may also segregate and sort through wastes for taking out what they can use or sell which can be impressed the waste collection. /6/

Municipal architecture: In the developing countries, the cities where the houses are constructed of mud brick and unpaved floors and courtyard comprise huge quantities of soil and dust in the waste. /6/

Climate and geography: Seasonal climate affects the quantity and composition of the waste. Heavy rainfall increases the moisture content of the solid waste and wind can increase huge piles of leaves in the certain times of the year. /6/

### 3.6.1. Waste Characterization in Ghana

The MSW of Ghana comprises organic, biodegradable, plastic, paper, metals, glass, leather, rubber, textile, hazardous waste, E-waste, non-combustible and combustible. /2/

Municipal or household waste are generated from human activity sources. According to a study in 2015, waste generation from commercial is difficult to quantify on per capita, however, household waste is the main source of waste in Ghana. Municipal or household comprises food waste, inert materials, batteries, yard waste, wood, plastics, papers, paint containers, textiles with sometimes the addition of the commercial wastes, construction and demolishing materials. Ghana with a population of 30 million produces tons of waste per day which non-biodegradable wastes include plastics, textiles, metals, glass, rubber and leather about 22%. /2, 25/

Hospital or medical waste types in Ghana include syringes, needles, plastic waste, glass, cotton, sharps, cardboards/wrappers/papers, masks/gloves/sheets and pampers. /6/

Table 13 presents forms and sources of waste generated in Ghana with generator sources.

**Table 13.** Forms and sources of waste generated in Ghana /2/

| **Sources** | **Waste generators** |
|---|---|
| Residential | Single and multifamily Dwellings |
| Commercial | Stores, hotels, restaurants, markets, office buildings |

| | |
|---|---|
| Construction and demolition | New construction sites, road repair, renovation sites, demolition of buildings |
| Industrial | Light and heavy manufacturing, fabrication, construction sites, power and chemical plants |
| Institutional | Schools, government centre, hospitals, prisons |
| Agriculture | Crops, orchards, vineyards, dairies, feedlots, farms |
| Process | Heavy and light manufacturing, refineries, chemical plants, power plants, mineral extraction and processing |

The waste collection and composition in Ghana depend on the community and lifestyle of people where the average of waste generation rate and type of waste are different /23/. Table 14 presents daily waste generation per capita in Ghana by finding the average of the regional data.

**Table 14.** Average national daily waste generation per capita by waste type /6/

| | |
|---|---|
| Biodegradable waste (organics and papers) | 0.318 kg |
| Non-biodegradable waste (metals, glass, textile, leather, rubbers) | 0.096 kg |
| Miscellaneous waste | 0.55 kg |

The waste classification according to the economic lifestyle has a major role in waste generation and composition whereas waste generation quantities are different around the country /6/. Table 15 shows the average waste generation per capita according to Areas in Ghana.

**Table 15.** Average solid waste generation per capita by Areas in a day in Ghana /6/

| | |
|---|---|
| Metropolitan | 0.72 kg |
| Municipal | 0.40 kg |
| Districts | 0.28 kg |
| National | 0.47 kg |

The daily rate of produced waste is approximated about 2700 tons and since collection is estimated at 80% which means to bring up availability of 2500 tons daily. /13/

### 3.6.2. Energy Potential in WtE

Energy recovery from solid waste bears the potential to be converted into new materials, energy and other valuable products, such as heat and electricity. Energy recovery from solid waste can be provided as a local energy resource for people who can reduce the impact of MSW on the environment and health. /22/

According to a study in the United States (2006) in each MSW incineration system, about 15% of the waste to electricity can be produced. Furthermore, MSW from one million people can power 12400 cars, generated electricity to 30900 houses and 15100 houses heated in the United States and Europe. Using energy from waste can be employed as a substitute for wood and fossil fuels energy for heating, cooking, lighting and electricity can be generated. /22/

The produced ethanol from the by-product fermentation of sugary and starchy crops can be used as fuel for electricity generation in boilers and gasifiers. When ethanol is mixed with petrol, it can reduce greenhouse emission from vehicle uses while it grows its oxygen content and provides effective combustion in gasoline. /22/

Table 16 presents the value of energy released from a combusting a unit mass of a solid waste sample which is done via a chemical property measured with the bomb calorimeter based on published data on the energy value of the municipal waste in Ghana in 2013.

**Table 16.** Energy content and energy recovery potential of municipal waste in Ghana /23/

| **Caloric value (MJ/kg)** | **Heat (MWh/t)** | **Power (MWh/t)** | **Heat and Power (MWh/t)** | **Energy Content (MWh (t))** |
|---|---|---|---|---|
| 6 | 1.25 | 0.5 | 1.35 | 1.7 |
| 8 | 0.6 | 1.6 | 1.95 | 2.25 |
| 14 | 0.56 | 3.1 | 3.25 | 3.9 |

Due to the presence of modest to high energy value materials the energy recovery from waste is possible. For example, in Ghana the calorific value of solid waste range is from 14 MJ/kg, 11MJ/kg and 20 MJ/kg (low-income, middle income and high-income communities), whereas, the needed calorific value for energy recovery should not be less than 6 MJ/kg while the waste can combust its own without the need for auxiliary fuel. /23/

The calorific energy of MSW depends mostly on the moisture content of the waste. If the high moisture of the waste is above 50% on average undertaking waste separation should be done before utilizing WtE /6/. Table 17 and Table 18 show the waste component with calorific value in Accra city and the entire caloric value of Ghana.

**Table 17.** Waste component with calorific value in Accra /18/

| **Components** | **Energy content (MJ/kg)** |
|---|---|
| Plastic | 30 |
| Paper and cardboard | 16 |
| Textile, rubber and leather | 17 |
| Glass and metals | 0 |
| Biodegradable (organic) | 9 |
| Other, Combustible | 16 |
| Other, non-combustible | 0 |
| Moisture content | 50.0% |

**Table 18.** Chemical composition of household waste from Ghana /18/

| | |
|---|---|
| Calorific value (MJ/kg) | 13.9 -29.9 |
| Moisture (%) | 25-76 |
| Ash content (%) | 2.2-19 |

| | |
|---|---|
| Volatile solid (%) | 31-88 |

Accra Metropolitan Assembly (AMA) in 2018, reports the results analysis of the daily collection of MSW in tons for the private service provider and the informal sector, shown in Table 19 below.

**Table 19.** Daily collection (tons) rate of MSW in AMA (from AMA/WMD) /18/

| **Year** | **Companies under PPP (tons)** | **Informal Sector (tons)** | **Waste management department (WMD) (tons)** | **Total (tons)** |
|---|---|---|---|---|
| **2018** | 673 | 439 | 10 | 1.122 out of 1.463 |
| **Percentage contribution in 2018** | 46% | 30% | 0.7% | Within 76.7 |

The growth rate of population of Ghana (in 2017) is estimated around 3% annually and 4.4% in capital city Accra. Due to urbanization in Ghana, waste generation has increased while the waste collection from communal bins is estimated to be 57.3%. The rate of generated organic waste is estimated as 79% in Ghana with 0.23kg/person/day. An average waste generation rate in Accra is estimated as 1463 tons/day by producing 0.6kg/person/day and the collection rate is 76.7% in a day. The recent population of Ghana has produced about 12710 tons of household MSW daily. /18,21,22,23/

# 4 RESULTS ANALYSIS

The data presented below uses population growth, human development index and gross domestic capital to estimate waste generation in Ghana. For example, the results show that as HDI increases, the level of waste per capital increases (see Figure 6 below). Similarly, as GDP per capital increases, the waste per capital increases (see Figure 7). This shows that as governments invest in developing energy potential in waste to energy, the human development index would increase. The increase in HDI may more awareness and that can improve social acceptance (see discussions in Section 4.1).

**Table 20.** The collected data of estimated of waste generation in Ghana via population growth

| Year | Population Growth Rate | Waste per capita (generated) (kg/day) | Waste Collected (kg/day) | Energy Potenial (MW) | Year | HDI | GDP per capita |
|---|---|---|---|---|---|---|---|
| 2010 | 24658823 | 11589647 | 6953788 | 20245 | 2010 | 0.565 | 1.299 |
| 2011 | 25398588 | 11937336 | 7162402 | 20852 | 2011 | 0.574 | 1.549 |
| 2012 | 26160545 | 12295456 | 7377274 | 21478 | 2012 | 0.577 | 1.588 |
| 2013 | 26945362 | 12664320 | 7598592 | 22122 | 2013 | 0.586 | 2.345 |
| 2014 | 27753723 | 13044250 | 7826550 | 22786 | 2014 | 0.59 | 1.971 |
| 2015 | 27849205 | 13089126 | 7853476 | 22864 | 2015 | 0.59 | 1.744 |
| 2016 | 28684681 | 13481800 | 8089080 | 23550 | 2016 | 0.598 | 1.744 |
| 2017 | 29545222 | 13886254 | 8331752 | 24257 | 2017 | 0.602 | 2.026 |
| 2018 | 30431578 | 14302842 | 8581705 | 24984 | 2018 | 0.606 | 2.202 |
| 2019 | 31344526 | 14731927 | 8839156 | 25734 | 2019 | 0.611 | 2.202 |
| 2020 | 32284861 | 15173885 | 9104331 | 26506 | | | |
| 2021 | 33253407 | 15629101 | 9377461 | 27301 | | | |
| 2022 | 34251009 | 16097974 | 9658785 | 28120 | | | |
| 2023 | 35278540 | 16580914 | 9948548 | 28964 | | | |
| 2024 | 36336896 | 17078341 | 10247005 | 29833 | | | |
| 2025 | 37427003 | 17590691 | 10554415 | 30728 | | | |
| 2026 | 38549813 | 18118412 | 10871047 | 31649 | | | |
| 2027 | 39706307 | 18661964 | 11197179 | 32599 | | | |
| 2028 | 40897496 | 19221823 | 11533094 | 33577 | | | |
| 2029 | 42124421 | 19798478 | 11879087 | 34584 | | | |
| 2030 | 43388154 | 20392432 | 12235459 | 35622 | | | |
| | | | | | | | |

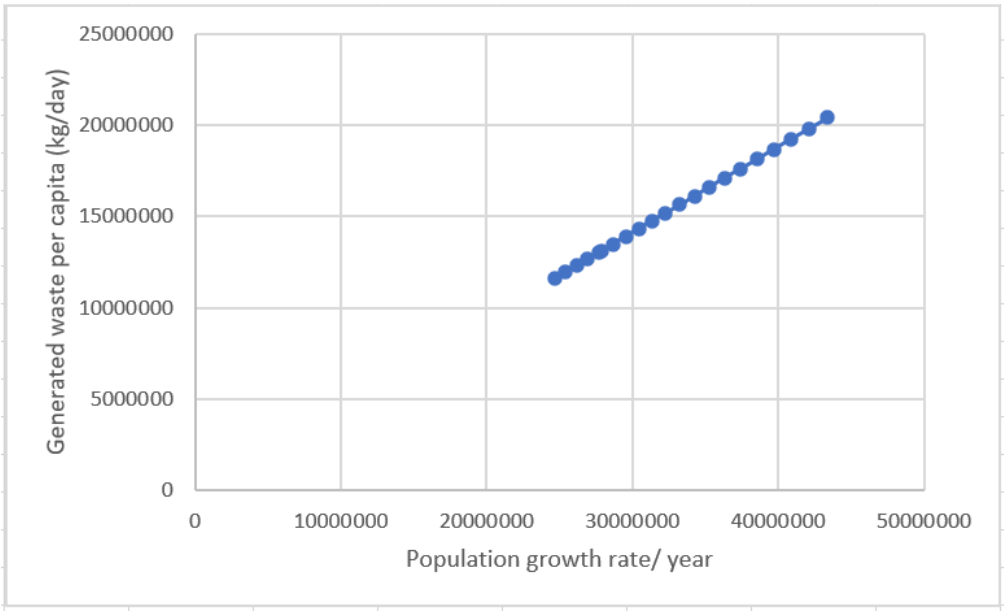


**Figure 5.** Generated waste per capita (kg/day) by population growth rate

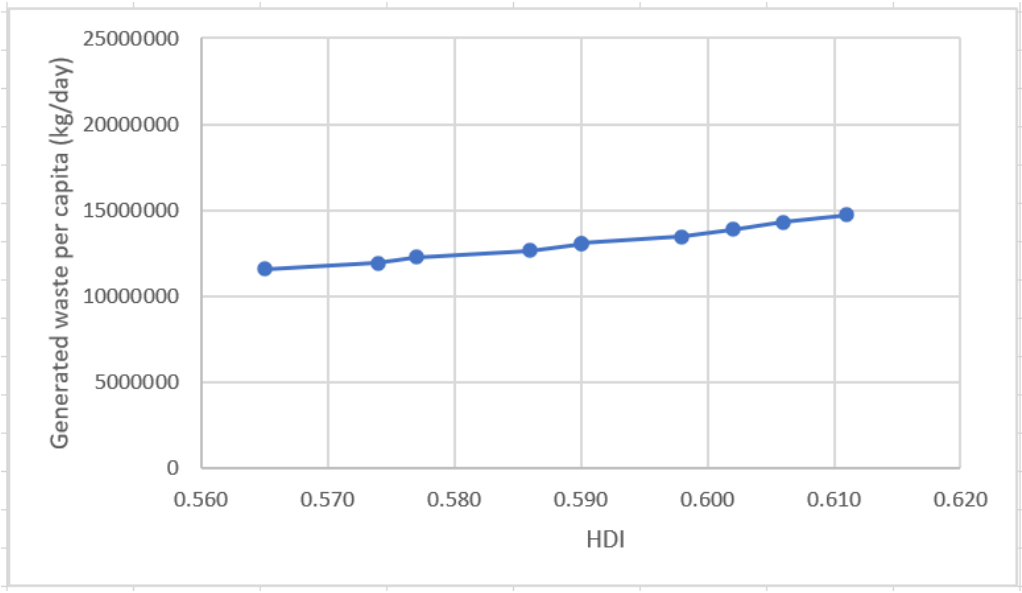


**Figure 6.** Generated waste per capita (kg/day) by HDI value

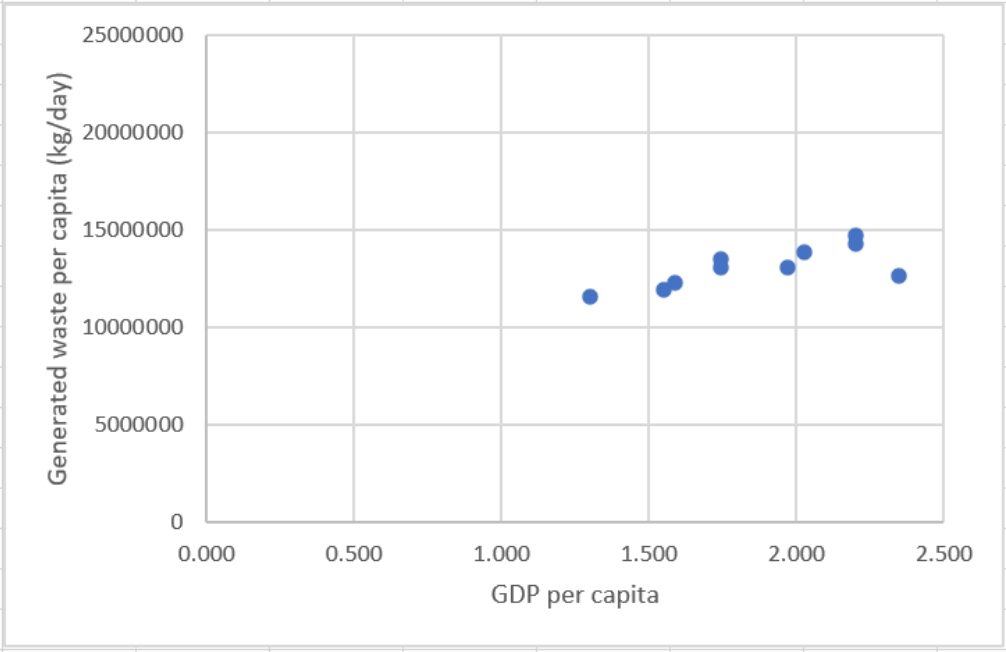


**Figure 7.** Generated waste per capita (kg/day) by GDP per capita

### 4.1. RQ1: What Are Key Problems in Waste Management in Ghana?

There are some problems and challenges with MSW management which affect directly a suitable waste management in Ghana. Based on the literature review, a summary of the key problems is presented below.

**Lack of proper authorities and institutional performance:** According to the Ministry of Environment in Waste Management Department, their department faces serious understaffing and lack of key personnel in engineering, administration, economic and environmental health for a suitable waste management in Ghana. Due to lack of professional staff in the solid waste department, it becomes a major problem for gaining suitable advance on the waste management in Ghana. /1/

**Lack of political will and commitment:** In Ghana, solid waste collection is not prioritized highly by local governments, due to other social problems, such as poverty, unemployment, infrastructure, social interventions, economic issues, trade problems, the knowledge limitation of health and education. The country requires new laws and regulation in the sanitation sector. /1/

**Poor infrastructure and institutional planning:** According to Accra Municipal Assembly (AMA), the Ghana Statistical Services are made between 5 to 10 percent high-income inhabitants, 19 to 25 percent middle-income habitants and the rest are low-income inhabitants, which makes it difficult for waste companies to get access to with their equipment due to the bad conditions of the roads and layout. /1/

**Financial problems:** Due to inadequate funds to purchase equipment in waste department for the waste management the cities are also linked to the shortage of staff in the country. Waste collection requires resources to services and proper technologies. /1/

**Poor attitude and cultural lifestyle:** Due to lack of education and enforcement people litter around cities, furthermore, the unwillingness of the households and shop owners to pay for waste services create more challenges on the MSW in the country. /17/

**Unsuitable logistics:** Poor waste collection and transport vehicle in the country form a major problem in big cities due to rapid urbanization where the facilities of solid waste are not enough for all residents. /1/

### 4.2. RQ2: What Are the Main Criteria in Selecting a Waste to Energy Technology in Ghana?

The WOIMA technology (Figure 9) is a thermo-chemical WtE technology which utilised the pyrolysis process with moving grate incineration method to combusting the waste. The dried waste is burned at high temperature via an anaerobic (pyrolysis) process on a layered moving grate with air supplier coming from beneath the grate. The char burns and moves to the bottom ash compartment (cooling pool) which is carried to the ash proceeding unit through conveyor belts. /29/


**Figure 8.** WOIMA modular WtE power plant system /29/

The incinerated waste is combusted in a chamber under adiabatic conditions. The collected heat of the waste is flowed from the radiation channel into the recovery boiler. Generated steam is transformed into superheated saturated steam for the steam genset between membrane walls on the radiation channel. The saturated and superheated steam is transferred to a steam generator set, the heat and the pressure are moved through the rotating turbine into electricity. There is an emission control system for air cleaning from the pollutants. /29/

The WOIMA power plant technology is a modular plant which means the units of the plant can be easily moved. The plant has secure enclosures, the platforms of installation with technical solution and protective housing on site. /29/

Below are the technical properities of WOIMA WtE power plant: /29/

- The plant is designed based on 20’ and 40’ container-size module
- It uses between 150 and 200 tons of solid waste daily /30000-200000 tons annually

- The incineration capacity of plant is 5-7 tons hourly
- 30 years lifespan
- Between 1 and 4 incineration lines can be built
- 2.7 MW (net) electricity/ line
- Production of 200 $m^3$ drinking water daily (if provided with suitable raw sources)
- Fuel calorific value is 7-16 MJ/kg
- Can bring out waste moisture content of up to 55%
- Possibility to add different auxiliary system on the plant
- Land needed is less than one hectares

Sorts of waste that WOIMA plant can process are as follow: /29/

- Municipal solid waste (MSW)
- Refind waste fules (REF, RDF or SRF)
- Industrial, commerical and inustitutional waste
- Construction and demolition waste
- Agricultural waste
- Different biomasses (rice husk, empty fruit brunch (EFB))

The WOIMA technology offers a waste to energy solution, further pre-sorting solutions, waste collection and reception expertise, and waste-to-value solutions. WOIMA can provide an ecosystem of various solutions and technologies to obtain maximum values based on the needs of a country. /29/

The WOIMA waste pre-sorting process starts with tipping storage which acts as a buffer where 24/7 waste garbage deliveries can be offered and a continuous waste flow to the plant for operation. Shredding is the next step of waste crushing and passing through a conveyor belt with a magnet that removes metal parts. Waste screening takes place after shredding where waste is screened and evenly distributed on a conveyor belt. All inert and harmful materials, such as glass, metals, E-waste, PVC are removed and recycled as a raw material in the manual sorting

stage. In the storage step, combustible waste will be sent to the buffer storage to supply continuous fuel. The buffer is measured to cover the pre-sorting plant when is not operating in weekend and holidays. Combustible waste will be sent to the WOIMA incineration plant for proceed. /29/

Based on the literature review on selection criteria for WTE, WOIMA Technology is suggested for Ghana (see Table 21).

**Table 21.** Selection Criteria for Waste to Energy: Case WOIMA

| | **Type of Technology** | **Situation in Ghana** | **WOIMA Technology** |
|---|---|---|---|
| | Incineration | - | - |
| **Waste quantity** | - | Available | Yes |
| **Waste calorific value** | Minimum 7MJ/kg | 10.47 MJ/kg | Yes |
| **Technology Status** | Widely used in developed countries | Suitable | Yes |
| **Types of solid waste** | Unsorted waste | Inappropriate sorting waste in Ghana | Suitable |
| **Appropriate scale** | Decentralized and community based | Suitable for Ghana due infrastructure issues | Suitable for small cities |
| **Final products** | Heat and Electricity | Electricity | Heat and Electricity |

| | | | |
|---|---|---|---|
| **Capital investment** | High | Lack of capital | Modular technology of WOIMA can reduce investment cost |
| **Operational cost** | High | Lack of Capital | Modular technology of WOIMA can reduce operating costs |
| **Land requirement** | Low | Space available peri-urban area | 3500-5500 square metres |
| **Needed skills** | Technical skills required | Training required | Possibility of Turnkey plus provided by WOIMA |
| **Pollution issues** | Pollution from syngas and toxic emission | EIA | WOIMA Technologies pollution control standards |

**Waste data and characteristics:** According to the literature that showed the waste quality and quantity, the waste meets the WOIMA WtE technology requirement. Ghana has a challenge to implement a WtE plant due to the non-sorting of MSW resources for either households or business and lack of the separation system of the solid waste. Based on a disposal site the characterization of MSW presented organic and recyclable composition (paper, plastic, metals, textile) of 60- 80% with

a relatively high moisture content of 40-60% and no specific seasonal waste stream /23/. The rapid urbanization of Ghana increases the amount of produced waste and undoubtedly the waste management problems in the country that means there will be needed WtE solutions.

**Infrastructure:** The number of waste collection systems, transportation system and controlled landfill exist to operate by Zoomlion (The Jospong Group) for a WtE which means the infrastructure of Ghana can support WOIMA plant implementation.

**Environmental aspects:** The Ghanaian Government has over the years interfered with adequate national policies and strategies frameworks especially in environmental sanitation. Although, the WtE emission standards follow the international standards which are not administered smoothly in the country due to lack of staff, expertise, administrators and legal and security personnel to the enforcement of existing by-laws on waste management. The country has the capacity of regular emission monitoring to the right technical plan but there is the lack of availability of compensatory strategies that reduce the environmental impacts. The pollution of the waste and the waste piles at the landfill sites are a serious risk to the environment and the health of waste pickers and residents. Ghana Environmental Assessment Regulations in 1999 put in place engaging to submit environmental management plots. /1,18,23/

**Economic aspects:** The produced energy from the WOIMA plant could be accessed by local users and become to the market to sale. There can be the availability of the market potential by foreign funds and supporting.

**Legal aspects:** There is not available a comprehensive framework and decommission regulation for WtE technologies in Ghana but WOIMA Corporation can provide collaboration to implement a WtE plant in Ghana.

**Social aspects:** The work conditions of formal and informal waste collectors can be improved by the implementation of a WtE technology due to collaborating with WOIMA Corporation in Ghana.

**Risk assessment:** Ghana has suffered some natural disasters such as earthquakes, landslide, land and sea erosion, tidal floods, droughts, pest and insect infestation (army worm, African swine fever), wildfires, disease epidemics in the past decades /4/. These types of natural risks can affect choosing the location of a WtE plant. Furthermore, these kinds of disasters may affect the relevant activities such as waste collection, waste composition, waste transportation, the infrastructure (road and electricity grid connection) damaging, or the plant could be broken down or flooded and other related damages.

**Alternatives:** Currently, the country has high potential of bioenergy which could be an alternative for WtE technology to produce bioenergy in Ghana. The WOIMA plant is a suitable option with the local conditions and waste parameters in Ghana due to high level organic waste.

# 5 CONCLUSION AND DISCUSSION

Increasing waste problems in Ghana requires an adequate waste solution while municipal solid waste collection and management is a challenge for the country. Rapid urbanization increases pressure on the lead to have a practical waste to energy implementation to control waste situation in the country. The study launched into highlighting solid waste problems in order to create an adequate waste management system by giving practical steps to implement a WtE technology in Ghana. The study revealed that thousands of tons of waste are produced daily in Ghana a problem yet to be resolved. The study was made on the current waste situation management and implementation factors for a waste to energy technology in Ghana. In this thesis, the variant types of wastes and waste to energy technologies were showed by discovering different aspects and processes to implement a WtE technology in Ghana. The PESTLE analysis of Ghana was addressed to figure out the waste situation in the country.

The study presents that the key barriers of implementation of an adequate waste management system in Ghana are lack of funds, lack of waste legislation and enforcement and the moisture content of the waste. The moisture content of waste in Ghana was around 40-60% which can affect the energy generation levels from the WtE plant. Due to lacking proper fund in the waste management sector in the country is critical for implementation a WtE projects, furthermore, the difference average of the income of residents for the payment of waste services is a major issue for any WtE projects. Due to poverty and other serious social problems, there is not suitable legislation linked to waste management which could affect the solution of waste problems and implementation a WtE project. Moreover, the study showed the WOIMA technology suitability for Ghana.

The study can be assisted by gathering information as a guideline for determining the implementation of waste management systems and selection of waste to energy technology in a practical point in the country.

The limitation of the research is linked to time and data collection, when the waste data collection was derived as secondary data from open sources, in Google form that can affect the quality of the study. Because the visit to Ghana was not possible, it was difficult to obtain accurate data.

In the end, the research found the human poor activities and rapid urbanization towards the environment in Ghana and that the country has great opportunities for supply energy from crop residues and other waste sources.

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