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CONVERTING MUNICIPAL SOLID WASTE TO ELECTRICITY FOR SUSTAINABLE WASTE MANAGEMENT: DETERMINANT FACTORS FOR SUCCESSFUL SET UP OF A WASTE TO ELECTRICITY FACILITY

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A dissertation Submitted to Strathmore Business School, Strathmore University, in Partial Fulfillment of the Requirements for the degree of Masters in Business Administration

Strathmore Business School

Strathmore University

Nairobi, Kenya

June, 2015

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DECLARATION

I declare that this work has not been previously submitted and approved for the award of a degree by this or any other University. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person except where due reference is made in the thesis itself.

CAROL CHEPKEMOI KOECH

JUNE 2015

Approval

The Thesis CAROL CHEPKEMOI KOECH was reviewed and approved by the Supervisor

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To my dear husband Denis, my daughters Laura and Elsie, My sons Nathan and Leon, your words of encouragement, commitment and support during this journey shall forever be remembered.

I also extend my sincere appreciation to the entire SBS staff, faculty, and my class of 2011 and syndicate 2 members for their support throughout my studies. I would like to mention David Mathuva from the research office who provided invaluable feedback. To the faculty, the knowledge I acquired will go a long way to building our nation Kenya.

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ABBREVIATIONS

BAT	Best Available Technology
CER	Certified Emission reduction
CDM	Clean development mechanisms
CREB	Clean Renewable Energy Bonds
EPA	Environmental protection Agency
GoK	Government of Kenya
GHG	Green House Gas
LFG	Landfill gas
LFGTE	Landfill gas to Electricity
MSW	Municipal Solid waste
NEMA	National Environmental Management Authority
RDF	Refuse Derived Fuel
RECs	Renewable Energy Certificates
SWM	Solid waste Management
WTE	Waste to Energy

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ABSTRACT

Municipal Solid waste is a major challenge in most cities and especially in developing countries where budgetary constraints exist. This is exacerbated by the ever increasing urbanization which puts even more pressure in the existing infrastructure. With Africa having the highest rate of urbanization at 3.5% annually and the least developed waste management infrastructure, an urgent solution is required in order to save the environment and the health of people living near the open dumps which is the most common final waste disposal system.

The study sought to find the entrepreneurial opportunity in the final waste disposal in the city of Nairobi. The study sought to estimate the potential of electricity in the current waste generated in Nairobi city by using the different waste to energy technologies i.e. Landfill gas to electricity and incineration. Literature was reviewed on landfill gas to electricity, incineration, factors affecting successful set up of a waste to electricity facility and the benefits of converting waste to electricity.

The study also sought to understand the factors that have the most impact for setting up a successful waste to energy facility and a survey was administered to players in the municipal waste segment. Factor analysis was done to identify the factors that have the most impact in successful set up of a waste to electricity facility. Data collected from the survey was analyzed and the factors with the greatest impact successful set up of a waste to electricity facility were identified. The factors identified were: Stakeholder involvement for political support, regulatory framework and municipal waste chain management. The other factor was location in order to understand the available waste quantities and the environmental impact. The last factor was economical with incentives to attract investors being a key component to this.

The benefits of setting up a waste to electricity facility were articulated as employment creation, carbon credits and carbon tax, financing and tax incentives, revenue from sale of electricity and heat and environmental benefits.

Key Words: *MSW, Waste to Energy, Landfill gas, Solid Waste management, Factors*

CHAPTER 1: INTRODUCTION

1.0 Background

Urbanization is on the rise in Africa and this trend is expected to continue in the future. Of concern is that the infrastructure and land use planning including for waste management is not coping with the growth of urban areas (around 3.5% annually, highest in the world). This is particularly urgent in the slum areas which constitute a big part of many of the cities and towns in Africa (UNESC, 2009)

Solid Waste Management (SWM) is a major public health and environmental concern in the urban areas and many developing countries. The situation in Africa, particularly in the large urban towns is severe. The public sectors in many countries are unable to deliver services effectively, regulation of the private sectors is limited and illegal dumping of domestic and industrial waste is a common practice. Local authorities charged with the responsibility of providing municipal services have found it increasingly challenging to play this role. Nairobi's solid waste situation, which could be taken to generally represent Kenya's status, is largely characterized by low coverage of solid waste collection, pollution from uncontrolled dumping of waste, inefficient public services, unregulated and uncoordinated private sector and lack of key solid waste management infrastructure (Njoroge, Kimani, & Ndunge, 2014).Municipal solid waste is defined to include refuse from households, non-hazardous solid waste from industrial, commercial and institutional establishments (including hospitals), market waste, yard waste and street sweepings (UNDP/UNCHS/WORLDBANK, 1996).

Proper management of solid waste provides benefits to the environment, quality of life of people living in the urban areas and generates employment and income. The principles of sustainable waste management strategies are thus to: minimize waste generation, maximize waste recycling and reuse, and ensure the safe and environmentally sound disposal of waste.

1.1 Municipal solid waste chain

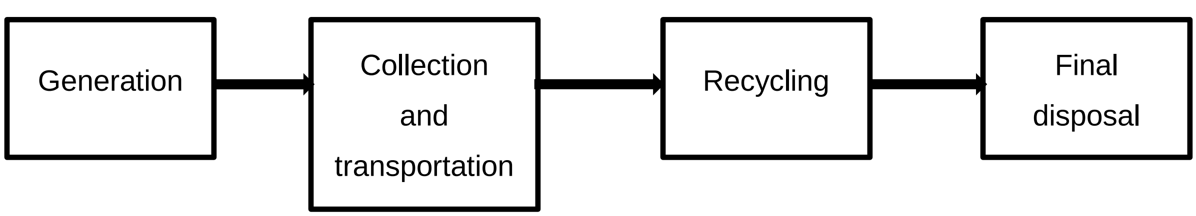

Figure 1 1 Municipal solid waste value chain

Source: Author

1.1.1 Generation of waste

The waste generated by a population is primarily a function of the people's consumption patterns and, thus, of their socio-economic characteristics. At the same time, waste generation is conditioned to an important degree by people's attitudes towards waste: their patterns of material use and waste handling, their interest in waste reduction and minimization, the degree to which they separate wastes and the extent to which they refrain from indiscriminate dumping and littering (UNDP/UNCHS/WORLDBANK, 1996).

Waste prevention—often called source reduction—means reducing waste by not producing it. Examples of waste prevention would include purchasing durable, long-lasting goods and seeking products and packaging that are as free of toxic substances as possible. It can be as simple as switching from disposable to reusable products, or as complex as redesigning a product to use fewer raw materials or to last longer. Because waste prevention actually avoids waste generation, it is the preferred waste management activity. Overall, waste prevention conserves resources, protects the environment, and prevents the formation of greenhouse gases (EPA, 2002).

The types of Municipal Solid Waste (MSW) produced change according to the standard of living in the city. Wastes generated in low- and middle- income cities have a large proportion of organic waste, whereas the wastes in high-income cities are more diversified with relatively larger shares of plastics and paper. The changing composition of waste in turn influences the choice of technology and waste management infrastructure, and underscores the importance of waste separation (United nations, 2011)

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1.1.2 Collection and transportation

Many cities in developing countries have low collection and the quality of collection services are poor. Waste collection services are generally non-existent in poorer neighborhoods such as slums. While there are some successful examples where the private sector and communities are involved in waste management services, in many cities of developing countries, involvement of these segments of society is still very limited. The wastes collected typically end up in open dumps, where they may be burnt and in some cases are deposited in illegal dumping sites (United nations, 2011)

The collection efficiency is the quantity of MSW collected and transported from streets to disposal sites divided by the total quantity of MSW generated during the same period. The collection efficiency is a factor of manpower availability and transport capacity. (Sharholy, Ahmad, Mahmood, & Trivedi, 2008)

The collection rate of MSW in Nairobi City is as low as 33% which leaves about 2,690 tonnes uncollected .The total solid waste reuse and recycling in the city is about 100-150tons/day (Allison, 2010) which is approximately equivalent to 3.7% of total waste generated. With the assumption that collection of recyclables/reusables happens before final collection, uncollected waste reduces to 2,540 tonnes per day. This could be assumed to be largely disposed-off in inappropriate ways such as burning and illegal/indiscriminate dumping either by collectors or due to non-collection (Khamala & Aganda , 2013).

1.1.3 Recycling

Separation of waste at the point of generation is largely not practiced in Kenya. Scavengers of recyclable materials e.g. glass, paper and plastics today exist in open dumpsites. Studies have been done on the many opportunities to recycle (Allison, 2010).

1.1.4 Final disposal

The common methods employed for MSW disposal in urban cities are composting, landfilling, recycling, and incineration. The feasibility and implementation of any disposal method or a combination requires knowledge concerning waste composition and characteristics. The advantage of incineration is that there is a considerable reduction of between 60 to 80% of the original weight in addition to power. Also, whereas other fuels have to be purchased for power production, MSW is considered free. However, Waste to Energy (WTE) feasibility assessment requires data on waste composition, density, moisture content and calorific value. The bulk density is critical for estimation of collection, storage and tipping costs.

The uncontrolled manner in which solid waste is disposed of at most open dumpsites creates serious health problems to humans, animals, and environmental degradation. The Dandora Municipal waste dumping Site, located to the East of Nairobi, is the main dumping site for most of the solid waste from Nairobi city. The site is about 8 kilometers away from the city center and occupies about 30 acres of land. Surrounding the dump are informal settlements and the residential estates. Over 2,000 tonnes of waste generated and collected from various locations in Nairobi and its environs are deposited on a daily basis into the dumpsite and what initially was to be refilling of an old quarry has given rise to a big mountain of garbage. Dumping at the site is unrestricted and industrial, agricultural, domestic and medical wastes (including used syringes) are seen strewn all over the dumping site (Njoroge, Kimani, & Ndunge, 2014)

Attempt on the relocation of dumping location have been made. A master plan for the improvement of solid waste management (SWM) in Nairobi City was formulated in 1998, by JICA, on request by the Government of Kenya (GoK). The plan identified Construction of a new sanitary landfill site at Ruai and closure work of the existing Dandora dumpsite as priority projects. With the expiry of time and non-implementation of the priority projects a survey on integrated solid waste management was carried out between August 2009 and September 2010 which recommended urgent improvement and closure of Dandora dumpsite by Nairobi city council. The dumpsite is still open today (Njoroge, Kimani, & Ndunge, 2014).

1.2 Waste to electricity technologies

Energy recovered from waste can be used for generation of electricity, generation of heat and generation of heat and power (commonly referred to as combined heat and power).The energy generation option selected will depend on potential end users to utilize the heat and/or power available (Department for Environment food and rural affairs(DEFRA), 2013).Two major waste to electricity technologies exist: Waste to Energy and landfill gas to electricity (LFGTE).

1.2.1 Waste to Energy

Waste-to-Energy (WTE) or energy-from-waste is the process of generating energy in the form of electricity and/or heat from the incineration of waste. There are several technologies used such as thermal, direct combustion, pyrolysis and gasification. (Stringfellow & Witherell, 2014)

1.2.2 Landfill gas to electricity

Landfill gas is generated through the anaerobic decomposition of organic waste present in municipal solid waste. Landfill design and operation contributes to the decomposition process. Generation starts shortly after a landfill begins receiving waste and can last for up to 30 years after the landfill closes (MATTHEWS, 2005). The gas is collected and used as a fuel to generate electricity.

1.3 Statement of the research problem

Waste generation is expected to increase significantly as a result of industrialization, urbanization and modernization of agriculture in Africa. This will further aggravate the currently-existing capacity constraints in waste management. The changing lifestyles and consumption patterns of in particular the growing urban middle class is increasing the complexity and composition of waste streams in Africa. Adoption of technology is generating high amounts of e waste. Municipalities are struggling with budgetary constraints. Waste has a huge energy potential that can be tapped and converted into economic use.

Using waste to generate electricity not only creates an additional revenue stream for the city but also reduces the burden of waste management. For a long time, solid waste collection and disposal in Nairobi has been characterized by general inefficient, unfavorable and inadequate organizational set-up. The current dumpsite in Dandora is overflowing with waste and an urgent solution needs to be found. The new landfill project at Ruai has not proceeded with the required urgency because of conflicting interests.

The studies done on waste management has focused on situational analysis and the current status of waste in Nairobi City. Some studies have focused on entrepreneurial opportunities for small and medium enterprises mainly on recycling and composting.

Little is known about the electricity potential that the municipal solid waste in Nairobi has and the factors that should be considered when setting up a waste to electricity facility. Converting the waste to energy could be a long term solution to the municipal solid waste management challenge in Nairobi City. It is critical to estimate the electricity potential from the municipal solid waste before studying the factors needed to set up a waste to electricity facility. This study therefore seeks to explore the estimated potential of electricity, and the determinant factors for successful set up of a waste to electricity facility .The study will also seek to explore the economic model that is likely to be successful in setting up a waste to electricity facility and seek to articulate the benefits of converting waste to energy.

1.4 Research objectives

1. To estimate the electricity potential of the municipal solid waste in Nairobi city based on different conversion technologies.
2. To determine the factors that has the greatest impact in successful set up of a waste to electricity project
3. To articulate the benefits of converting waste to electricity.

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1.5 Research questions

1. What is the estimated electricity potential of municipal solid waste in Nairobi city based on different conversion technologies
2. What factors have the greatest impact for successful set up of a waste to electricity project
3. What are the benefits of converting waste to Electricity

1.6 Justification of the study

Findings will inform the city county and private investors of the options available to convert municipal solid waste to electricity and the policy and stakeholder management that is needed for a successful waste to electricity project.

1.6.1 Academic significance

Most studies have been conducted relating to waste management in Nairobi city. This study aims to contribute to that knowledge. It will specifically aim to show the potential of the waste as a resource rather than a burden in the context of Nairobi city.

1.6.2 Policy significance

The aim of this study is to inform the city county on the value of waste. The electricity potential will help the city to direct resources to the waste management process as there will be a clear business case for the same. Additional revenue from electricity sales to the grid will be generated, which can then be reinvested back into the city waste management system. It is expected that the results of the study will inform investors willing to partner with Nairobi city in the municipal solid waste management process. The city could also consider options of outsourcing the entire waste management process including final disposal to private companies as there will be a business case to do the same.

1.7 Scope of the study

This study concentrates on establishing the electricity potential from municipal solid waste, the factors to be considered for successful set up of a waste to electricity facility and articulate the benefits of setting up such a facility. Focus on recycling and source separation will not be made.

1.8 Limitations of the research

The data used for calculation of the electricity potential is based on previous studies. Waste collection data is not readily available and there could be some level of inaccuracy in the data.

1.9 Study format

Chapter 1 provides a background to the study and builds a case for the research study on terms of looking at waste as a resource. This is followed by Chapter 2 which provides an in-depth literature review on the different technologies of converting waste to electricity and the electricity potential based on that. Literature on the factors to consider on setting up a waste to electricity project is considered. The chapter concludes by highlighting the benefits of converting municipal waste to electricity. Chapter 3 begins by laying the study setting .It also outlines the research methodology, describing the analytical framework adopted and corresponding data needs. Chapter 4 presents the results and discussions on the electricity potential and the factors to consider when setting up a waste to energy project. The study concludes with chapter 5 where an overview of the study, the conclusions and recommendations are presented.

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CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

In this chapter, a background has been set by exploring literature on different waste to electricity generation technologies. Literature on Landfill gas to electricity, gasification, anaerobic digestion, incineration and pyrolysis has been reviewed. The technologies have been defined and the pros and cons of each have been studied. The calculation and assumptions of electricity potential from municipal solid waste for each of these technologies has been stated.

The chapter then highlights the factors that determine successful set up of a waste to electricity project. The chapter further studies the stake holders that should be involved in the set -up of such a project. The chapter concludes by looking at the benefits of setting up a waste to electricity project.

2.2 Waste to Energy technology options

Energy recovered from waste can be used for generation of electricity, generation of heat and generation of heat and power (commonly referred to as combined heat and power).The energy generation option selected will depend on potential end users to utilize the heat and/or power available (Department for Environment food and rural affairs(DEFRA), 2013).

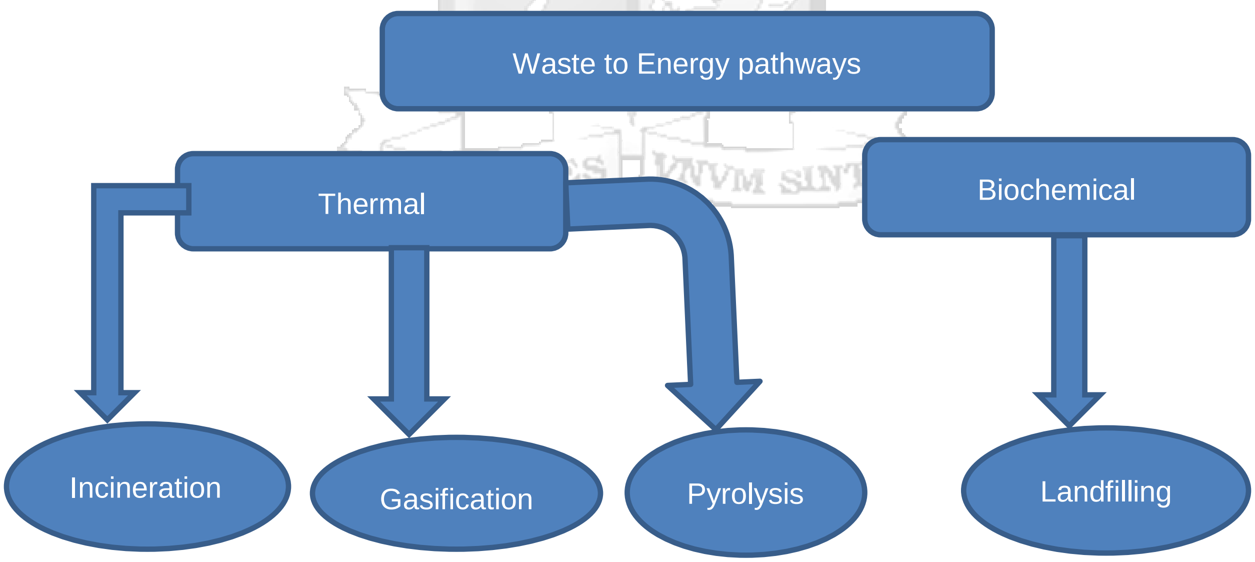

Figure 2 1: Waste to Energy technology options

Source: Incineration of municipal solid waste (DEFRA,2013)

2.3 Landfill gas to energy

Landfilling is defined as placing solid and semi solid wastes on the ground, compacting and covering it with suitable material to isolate it from the environment. A sanitary landfill is defined as a method of disposing of MSW to minimize effects on human health and the environment. Generally consists of a pit lined with clay and plastic to prevent leachate from seeping into groundwater, drainage pipes to draw off leachate for treatment, deposits of MSW in thin layers that are frequently covered with soil or other materials to keep out water and prevent waste from blowing away or attracting pests, and a system to collect methane to prevent explosions (the methane is either flared or used as fuel) (Beede & Bloom, 1995).The concept of sanitary landfilling was first introduced in the UK in 1912 and in the United states sanitary landfilling became a common method of MSW disposal during the 1930s (Ghosh & Hassan, 2015)

Many local authorities in developing countries spend over 30% of their budgets on refuse collection and disposal and can only collect 50-70% of MSW. Most do not meet environmentally safe MSW disposal levels because of lack of sanitary landfills (Rotich, Zhao, & Dong, 2006) .In India, it is estimated that 80-90% of the budget is spent on collection and transportation (Sharholy, Ahmad, Mahmood, & Trivedi, 2008).

Open dumps are the preferred method of disposing of solid waste as an alternative of landfills in most African countries. In open dumps refuse is simply dumped in low lying areas on open land. Open dumps are characterized by an absence of engineered measures, no leachate management or consideration of landfill gas management, and few if any operational measures, such as registration of users, control of the number of tipping fronts, or compaction of waste (Remigios, 2010)

Landfill gas (LFG) is generated through anaerobic decomposition of organic waste present in municipal solid waste. Landfill design and operation contributes to the decomposition process. Generation of landfill gas starts shortly after a landfill begins receiving waste and can last up to 30 years (Jaramillo & Matthews, 2005).The typical composition of landfill gas is 58% methane, 41 % carbon dioxide and certain traces of H_2S, HCI, HF and other chemical compounds, exact composition varies with age and type of waste. Methane, the major component is flammable and therefore gives the landfill gas its potential for energy use (LeBel, 2008).

The greater the amount of biodegradable organic material in a landfill site, the greater it's potential to generate landfill gas. There are many factors which influence landfill gas production including: Types of waste, size and depth of the waste body, moisture content, landfill pH, temperature and waste density.

2.3.1 Energy options for landfill gas

(EPA, 2012) has identified four options of utilizing landfill gas as an energy source: Electricity generation using internal combustion engines, gas turbines and micro turbines; Combined heat and power i.e. systems that generate both electricity and thermal energy; Direct use of LFG by end users on fuel boilers, kilns, dryers, greenhouses and other thermal applications; Alternate fuel for pipeline and vehicle use.

2.3.2 Electricity potential from landfill gas

The potential of landfill gas is defined as the electricity that would be produced from it if all the MSW were disposed in landfills. The power generated from landfill gas is a factor of the Internal combustion Engine efficiency, the energy content of the landfill gas and the landfill gas collection efficiency. The production of the landfill gas is estimated using a decay model and is impacted by the amount of waste deposited in the landfill, the year in which the waste was deposited and the climate of the area in which the landfill is located (Jaramillo & Matthews, 2005).

(Cherubini, Bargigli, & Ulgiati, 2008) Estimated a methane production rate of 140Nm3 per tonne of landfilled waste. A fraction of 50% of the landfill gas is assumed to be recoverable via pipes and can be used for energy recovery. The estimated energy content of collected biogas is 3.12 E+09MJ, given the biogas lower heating value of 17.73MJ/m3. The biogas is thus burnt in turbines with 28% efficiency to produce 2.43 E+08 kWh of electricity per year.

(Siddiqui, Zaidi, Panday, & Khan, 2013) Estimated that 100 tonnes of MSW with 50% organics can generate 1-1.5MW of power.

In order to set up a landfill gas to electricity project, several cost considerations must be made. This includes the basic gas collection and treatment costs, electricity projects incur additional costs for purchasing generators, and interconnecting the LFGTE to the nearby grid. For direct-use projects the major costs are associated with purchasing rights-of-way and installing a pipeline from the treatment skid to the point of energy use (Godlove & Singleton, 2010).

2.3.4 Benefits of landfill gas to energy

Several benefits of using landfill gas as an energy source exist. Firstly, LFG to energy reduces greenhouse gas emissions. Secondly, it generates additional revenue to local governments by sale of LFG directly to end users or into the pipeline, and/or from selling electricity generated from LFG to the grid. Thirdly, there is increased economic benefit through job creation and market development since the ecosystem of a landfill gas to energy project includes engineers, construction firms, equipment vendors, utilities and end users. Fourthly, LFG to energy demonstrates environmental leadership by enhancing community awareness on the benefits of clean development mechanism. Finally, LFG to energy reduces environmental costs, improves air quality and conserve land (EPA, 2012).

2.3.5 Disadvantages of landfilling

The European Union landfill directive (1999/31/EC) obliges member states to reduce the amount of biodegradable waste that they landfill to 35% of 1995 levels by 2016 (for some countries by 2020).The overall aim of this directive is to provide stringent operational and technical requirements on the waste and landfills, to provide for measures, procedures and guidance to prevent or reduce as far as possible negative effects on the environment, in particular the pollution of surface water, ground water, soil and air and on the global environment including the greenhouse gas effect, as well as any resulting risk to human health from landfilling of waste, during the whole lifecycle of the landfill (European Union, 1999)

A powerful argument against landfilling is that it is wasteful of natural resources. Landfilling, for example, not only buries materials that have some value and causes environmental problems but it also means that fresh materials and energy are required, with all the environmental consequences and costs associated with resource exploitation, energy generation and manufacturing processes. There is increasing pressure in finding suitable sites for landfills. There are also rising costs of managing landfills in order to meet the stringent environmental controls and licensing requirements. There is a local impact and public resistance of landfills mainly caused by perceived impacts of traffic, noise, smell, vermin, birds, litter, visual impact, disease and perhaps most importantly reduced property prices (Murray, 1997).

2.3.6 Barriers in LFGTE project development

While LFG recovery technologies are mature world-wide and there are many options for its utilization, however there are several barriers in using LFG as an energy source. These barriers include technological intricacies, financial and economic limitations, regulatory issues, lack of awareness, and interconnection challenges. The non- technical barriers include the distance between landfill sites and the power grid and the grid connection condition (Siddiqui, Zaidi, Panday, & Khan, 2013)

For the city of Nairobi, JICA had recommended setting up a new engineered landfill in Ruai. This has however not been implemented because the selected location has received opposition from the Kenya Airports Authority because the location is close to a flight path, increasing the likelihood that scavenging birds could inadvertently fly into planes. The availability of land is a challenge in Nairobi with the ever expanding population.

2.4 Incineration

Incineration is the process of control and complete combustion, for burning solid wastes. It leads to energy recovery and destruction of toxic wastes, for example, waste from hospitals. The temperature in the incinerators varies between 980 and 2000C. The heat generated from combustion is used to produce steam to drive a steam turbine to generate electricity. One of the most attractive features of the incineration process is that it can be used to reduce the original volume of combustible solid waste by 80–90% (Sharholy, Ahmad, Mahmood, & Trivedi, 2008).

Waste incinerators have existed since the 19th century with renewed interest across the United States, Europe and Asia since the 1970s. In the 1990s, major regulatory reform occurred across the world to reduce the environmental and health impacts of mass burn incinerators and waste to energy plants. As opposed to older plants, modern plants have been designed to produce energy as the primary objective, and dispose of waste as a secondary objective. For example, in Europe there are set energy recovery levels that must be reached if a plant is to be classed as a legitimate waste to energy resource recovery operation rather than a disposal operation. The energy recovery level varies depending on the age of a plant.

In simple terms, waste to energy process generally has the following five components: Waste arrival and storage; Core reactor (i.e. where the waste is converted to energy); Energy recovery; Air pollution control and residual product processing (EPA, 2013).

There are two major technologies of incineration: Moving grate technology and fluidized bed technology. Moving grate technology moves the burning waste from the inlet to the outlet. In order to get an efficient combustion with low emissions of carbon monoxide and hydrocarbons, it is important to maintain the waste level on the grate and monitor the feeding speed so that the fuel is fully combusted when it is discarded. Waste incineration in a fluidized bed is done in a bed of sand where the waste is only a small fraction of the waste in the furnace (Karlsson & Jönsson, 2012).

2.4.1 Comparing incineration with landfill gas to Energy

(De Souza, et al., 2014) In a study on the energy potential from MSW in Brazil, concluded that thermal treatment yields the highest relevant energy potential. With an assumption of 455kwh/ tonne of MSW and a plant operating for 8000 hours per annum, the study estimated that the annual MSW of 18,933 Kilo tonnes could generate 1077 MW of power. The calorific value of MSW is impacted by the moisture content and the composition of the waste in terms of organics, paper, plastics and cardboard. This argument was further confirmed by (Funk, Milford, & Simpkins, 2013) where they concluded that MSW combustion can produce about nine times more electricity per tonne of waste than energy recovery from landfill gas. (Kaplan, Decarolis, & Thorneloe, 2009) also concluded that the electricity generated per tonne of MSW using Landfill gas to electricity ranged from 41-84kwh while using combustion ranged from 470-930 kwh, they estimated that for the 166 million tonnes of MSW generated in the United States of America, the electricity potential ranged from 0.85- 1.8GW while if combustion was used, this potential reached 9.7-19GW.

2.4.2 Gasification

Incineration of solid waste under oxygen deficient conditions is call gasification. The objective of gasification has generally been to produce fuel gas, which would be stored and used when required (Sharholy, Ahmad, Mahmood, & Trivedi, 2008).

In a study on Malaysia, (Kathirvale, Yunus, Sopian, & Samsudin, 2003) carried out a simple evaluation to estimate the amount of energy that could be recovered if the MSW was to be incinerated. The evaluation was based on the net amount of energy that could be obtained per ton of the MSW treated. The basis of evaluation was that the incineration used the gasification technology with heat recovery of the hot gases at 25% efficiency. The calorific values range between 1540-2640 kcal/kg. They were able to estimate the potential energy to be 639kw/ tonne of waste at 2200 Kcal/kg.

There are significant environmental benefits of MSW gasification, including reducing the need for landfill space, decreasing methane emissions from the decomposition of organic materials in the landfill, and reducing the risk of groundwater contamination from landfills.

2.4.3 Pyrolysis

Pyrolysis is a high-temperature process that is optimized to produce pyrolysis oils, bio-char, and synthesis gas from dry biomass. Pyrolysis consists of heating the feed material in a vessel without the addition of oxygen. Pyrolysis technology is still under development (Funk, Milford, & Simpkins, 2013)

2.4.4 Refuse Derived Fuel

Refuse Derived Fuel (RDF) is produced from combustible components of municipal solid waste. The waste is shredded, dried and baled and then burned to produce electricity, thereby making good use of waste that otherwise might have ended up in landfill. In India, many RDF plants are in operation. Combustion of the RDF from MSW is technically sound and is capable of generating power. RDF may be fired along with conventional fuels like coal without any ill effects for generating heat.

In a study using 4 different strategies of combusting the MSW residue as is, removing the organic wet fraction, producing RDF with aerobic bio- stabilization and producing RDF by first removing the organic fraction of the MSW (Consonni, Giugliano, & Grosso, 2005) estimated that 1 tonne of MSW can generate 527-588 kw for a small waste to energy plant with capacity of 100,000 tonnes per year. The energy potential for a large plant of up to 600,000 tonnes has a potential of generating between 587 and 807 kw/tonne, this is largely because of increase in efficiency for larger plants. This is consistent with the findings of (Funk, Milford, & Simpkins, 2013) in a study of waste in Boulder in the US, where they estimated that 215 Tonnes per day of MSW could generate 5.6MW of power assuming 91% capacity factor. This yields an estimate of 570kwh/ tonne.

Some Turkish cement companies have explored the use of RDF as a fuel to supplement the firing of cement kilns and the results concluded that it was viable though no economic advantage existed. Some of the benefits of using RDF as a fuel for cement kilns reduces fuel costs and reduce landfill disposals, environmental benefits on air emissions and allows recovery of saleable materials. There were concerns around the untested nature of this fuel that included ability to supply and feed RDF continuously to the cement kilns, effect of RDF on the chemical composition of the cement quality and chemistry, long term effects on the kiln operation and effect on air emissions (Kara, Gunay, Tabak, Yildiz, & ENC, 2008). The cement industry can also play an additional role of using ash from waste incinerators in the cement manufacturing process (Bogdan, 2011).

The main concern for waste to energy technologies is how to manage emissions from the process and the process residues. Air emissions can be controlled through technology and process similar to that in other industries, while process residues can be managed through controlling the waste input and proper disposal as per regulatory guidelines. Odour is generally the most complained about environmental pollution issue. Waste to energy plants can be designed to minimize odours as the entire process is contained in a building (EPA, 2013).

2.5 Factors that affect the successful set up of a waste to Energy plant

In highly industrialized European countries, waste incineration plants have been used increasingly over the last 50 years mainly because it has been more difficult to find landfill sites in densely populated areas (Rand, Haukohl, & Marxen, 2000).

Given the pressure on land in Nairobi, the factors discussed below specifically focus on incineration technology and not landfill gas to energy.

2.5.1 Geographic Location of the waste to Energy Facility

Geographical location is very important in order to minimize community concerns and health and environmental risks (EPA, 2013). Appropriate siting can ensure that ancillary impacts such as noise, odour and greenhouse gas emissions from the transport of waste are minimized.

(Bogdan, 2011) has identified several factors that need to be taken into account when selecting the location of a waste to energy facility including geographical position, applied method of waste management, economic conditions of the location, infrastructure, possibility of transport by train, possibility of using heat for district heating and industrial purposes, vicinity of cooling water, meteorological conditions and environmental impact.

(Rotich, Zhao, & Dong, 2006) Found out that little or no consideration of environmental impacts was paid in the selection of dumpsites in five local authorities studied in Kenya. Convenience took priority in the siting of dumpsites, for example in Eldoret; an abandoned quarry was used for MSW disposal despite the site being in a water catchment area.

2.5.2 Economic Factors

Decisions regarding the adoption of a waste to energy project as a waste management strategy must continually be based on sound economic analysis that considers the resources of the community and the anticipated environmental impacts and benefits (EPA, 1995). Economic drivers to developing the waste to energy sector includes waste disposal and land fill gate fees/landfill tax, penalties and avoidance schemes, energy prices, investment subsidies (Garcia, 2008).

Table 2 1: Thermal conversion technologies

Technology	Description
Combustion	This is the dominant waste to energy approach taken globally. Combustion uses excess air or oxygen to drive the reaction in combusting waste into heat, ash and a flue gas. The heat is often then used to produce steam to drive a steam turbine to generate electricity. The specific reaction conditions and the systems for extracting useful energy from the process are critical factors that determine the efficiency of a facility.
Gasification	Involves the conversion of waste into synthetic gas (syngas) using a limited amount of oxygen. The process is more efficient than direct combustion and converts about 80 per cent of the energy in the waste into syngas. Most gasification plants use air in the process rather than pure oxygen as it is cheaper, however it produces a lower quality syngas. Most gasification is undertaken at high temperature (at least 900°C), although certain technologies run at lower temperatures where the waste is treated for a longer period of time. Gasification can be undertaken in combination with combustion in modular plants.
Pyrolysis	Pyrolysis does not involve any oxygen or air. In this case waste is placed into an air-free reactor and heated using an external source of energy. The waste is then converted into solid char, pyrolysis oil and syngas through physical and chemical processes. True pyrolysis is undertaken at a low temperature (around 400°C), however, pyrolysis undertaken at a higher temperature (around 800°C) changes the amount of each product produced – at higher temperatures more syngas is produced. For waste to energy purposes, syngas is the currently preferred energy product as it is easier to convert into electricity.

Source: Author

A waste to energy facility can be privatized and can include both ownership and operation or operation only. Staff recruitment and maintenance may be crucial when deciding the plants ownership. The privately owned and operated facilities can better retain staff, since they can pay competitive salaries and incentives (Rand, Haukohl, & Marxen, 2000).

Several tender and contracting models exist as shown in the table 2.2 below. In each of these models, there exists an entrepreneurial opportunity.

2.5.2.1 Revenue sources

A WTE facility earns revenues by two primary means. First, by collecting a tipping fee for the MSW that the municipality sends to the WTE facility for treatment; and second, by selling the energy produced (Duong, 2014).

In order to secure revenues from sale of electricity, an offtake agreement is critical and feed in tariff must be attractive. The off taker of the electricity could be the grid or any other private company. This is especially important in securing financing for the waste to energy project and also attracting investors in this space (Hashizume, 2014). A Feed-in-Tariff allows power producers to sell renewable energy generated electricity to an Off-taker at a pre-determined tariff for a given period of time.

When electricity prices are higher, waste-to-energy power producers receive a higher price for the energy they produce. In September 2011, the price of electricity in Sweden was approximately €0.20 ($0.36) per kilowatt-hour, In the United states, the price is $0.10 per kilowatt-hour ***(Williams, 2011)*** and in Kenya, the tariff from biomass sources is $0.10 per kilowatt hour. It is most feasible when the energy can be sold to a single consumer for its own use or resale. The consumer may be a utility company with it’s an existing distribution network for power distribution or a large steam consuming industrial complex. (Rand, Haukohl, & Marxen, 2000)

Table 2 2: Applicable Tender and contracting models for waste incineration plants

Tender Model	Clients obligations	Contractors obligations
Multiple contracts	Financing, function specifications, tendering, project coordination, construction supervision, ownership and operation	Supply and detailed design of individual parts for the plant
Single turnkey contract	Financing, function specifications, tendering, Client supervision, ownership and operation	Responsible for all project design, coordination and procurement activities
Operational contract	Multiple or single turnkey contract, ownership, supply of waste	Operation of the completed and functional plant in a certain period
Build Operate	Financing, function specifications, tendering, Client supervision, ownership and supply of waste	Project management, contractors supervision, operation and maintenance
Design Build Operate	Financing, overall function specifications and tendering, ownership after transfer, supply of waste	Detailed design, project management, supervision, operation and maintenance
Build Own Operate Transfer	overall function specifications and tendering, ownership after transfer, supply of waste	Financing, design, project management, supervision, operation and maintenance, ownership until transfer
Build Own Operate	overall function specifications and tendering, supply of waste	Financing, ownership, design, project management, supervision ,performance guarantees, operation and maintenance

Source: Municipal Solid Waste Incineration: Requirements for a Successful Project, Volumes 23-462, page 23

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2.5.2.2 Set up and running costs

The actual investment cost for a waste incineration plant depends on a wide range of factors especially the size of the plant, the number of metric tonnes per year or per day and the corresponding lower calorific value of the waste. This is also affected by the overall environmental restrictions in the country and whether there is a requirement for flue gas cleaning. (Rand, Haukohl, & Marxen, 2000)

Operating costs are made up of fixed costs and variable costs. The fixed operating costs are those of administration and salaries, while variable costs include cost of chemicals for cleaning the system, cost of electricity, cost of water and handling of waste water and cost of residual disposal. The maintenance costs include costs to maintain machinery (spare parts) and buildings. (Rand, Haukohl, & Marxen, 2000)

Wastes to Energy facilities involve a high capital cost layout. According to the main research organization in WTE in the US (Waste-To-Energy Research and Technology Council 2012), the capital costs range from $150,000 to $200,000 per daily ton of capacity in the EU and the US. The main operating costs are usually considered to be maintenance and labor costs. According to interviews with private companies in the WTE business, maintenance costs range from $5 million to $6 million per year, and typical labor costs are calculated for a team of 7 workers per shift, working 8 hours shifts. Other expenses such as materials, services and supplies are estimated to range from $500,000 to $1 million per year (Duong, 2014).

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2.5.2.3 Direct subsidies and tax incentives

Subsidies can come in many forms such as production grants and tax credits, feed-in-tariffs, low interest / preferential loans to producers, or accelerated depreciation allowances (Williams, 2011).Public subsidies can be in form of grant financing, favorable term loans for plant facilities, or general tax levies. Subsidies can be financed from the budget or linked to environmental taxes (Rand, Haukohl, & Marxen, 2000).

2.5.3 Legislation

Waste management strategies cannot be implemented without the support and guidance of legislative framework. Legislation should contain a series of ordinances and regulations aimed at managing solid waste, including procedures and methodologies for monitoring and enforcing the regulations. Consistent national policies on MSW legislation are needed. The policies should encourage cross-jurisdictions and inter-agency coordination, and facilitate implementation of economic instruments for improving waste management (LI, 2007)

Scientific evidence, public awareness and increased levels of participation in environmental campaigning have led to government's worldwide implementing regulations and legislation. Examples include: EU Landfill Diversion Directive, recycling targets and climate change regulations (Garcia, 2008).

Sweden has issued special legislation for some waste categories, with an aim of resource wastage, to limit emissions of hazardous substances or to phase out the use of certain substances that have no part in an eco-cycle society. Special legislation for instance, applies to electrical waste and batteries. Some of the examples of legislation include: the landfill directive, the waste framework directive, waste incineration directive, control measures for biological treatment, landfill ban on organic waste. There are also clear guidelines on which technology to use under the Best Available technology (BAT) framework which stipulates that the technology must be efficient and the costs associated with it must be reasonable to performance (AVFALL SVERIGE).

In Kenya, Legal frameworks concerning solid waste at national level are very few and scattered through a number of Acts and by laws at city and municipality levels. The Environment Management and Coordination Act (1999) provide the framework for the coordinated management of the environment. The Act deals with waste management including standard setting, disposal site licensing, control of hazardous, industrial and hospital waste. Under the Act, responsibility for the storage, treatment and collection of hospital, industrial and hazardous wastes will be the generator. There is no categorization in these legislations which were enacted to cover municipal waste only. There is also no legislation on waste reduction and recycling (Njoroge, Kimani, & Ndunge, 2014). The waste management regulations (2006) under the National Environment Management Authority (NEMA) are meant to streamline the handling, transportation and disposal of various types of waste. Under these regulations, NEMA licenses transporters, incinerators, landfills, composers, recyclers and transfer stations. Facilities to be licensed include local authorities, transporters and handlers of various types of waste. It also provides an opportunity for investment in various aspects of waste management. (Government of Kenya, 2006)

For the city council of Nairobi, the solid waste management by laws requires people to separate waste at source, it governs waste collection and recycling, however there is no specific mention of the final disposal and treatment of waste in the by- laws (The City Council of Nairobi, 2015).

(Njoroge, Kimani, & Ndunge, 2014) Recommended that sanctions and penalties of waste mismanagement should be put in place and strictly followed and also specific policies and regulations to solid waste management addressing all types of waste and with clarity of the roles and responsibility of each citizen should be developed.

2.5.4 Management of the Municipal Solid waste chain

The waste chain includes the generation of waste, collection and transportation and also recycling. This value chain is a critical factor to consider when setting up a waste to energy facility as it determines the quantities and characteristics of waste that will end up in the waste to energy facility.

2.5.4.1 Waste quantities and composition

The potential of energy production depends on the amount and quality of the MSW. Without a good idea of the quantities that can be expected, decisions about equipment and space needs, facilities, markets, and personnel cannot be reliably made (EPA, 1995). For a waste-to-energy project, both sizing the facility and calculating the quantity of energy that the facility will generate are based on characterizing waste volume and type. In the long term, the quantity of waste available for the facility will be affected by other options, including source reduction, recycling and composting. Inaccuracies in waste characterization studies for these alternatives can severely and negatively impact the economic viability of the program. Future community trends, such as population growth, must also be considered in developing a waste characterization profile.

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Waste composition affects the calorific value of waste and hence the potential for power generation. The moisture content is a big factor in the success of waste to energy plant, if it is high, incineration will not work. The calorific value of the waste is how much (chemical) energy is stored in the waste per tonne that could potentially be converted into useful electrical or heat energy when burned. Waste such as plastic has a high calorific value whereas other wastes such as kitchen waste that is very wet have much lower values. Moisture content is affected by the presence of organics in the waste. In order to operate the incineration plant continuously, waste generation must be fairly stable throughout the year. China has overcome the issue of moisture content by designing bunkers that hold waste for 5-7 days instead of 2-3 days, using hot air from combustion to dry the waste, longer combustion times and adjustments to the combustion technology (De Souza, et al., 2014).

(Rand, Haukohl, & Marxen, 2000) Have suggested a minimum calorific value of 6MJ/kg throughout all seasons and that a forecast of waste generation and composition are established on the basis of surveys in the collection area for the planned incineration plant. The annual amount for incineration plants should not be less than 50,000 tonnes and the weekly variation in the waste supply to the plant should not exceed 20 per cent.

Waste generated is a factor of population and its economic status. In India, the relative percentage of organic waste is generally increasing with the decreasing socio- economic status, so rural households generate more organic waste than urban households (Sharholy, Ahmad, Mahmood, & Trivedi, 2008). In a study of waste recycling in developing countries, (Troschinetz & Milhelcic, 2008) established that the relationship between MSW generation and income varies with the developmental stage of a nation. As a country develops, its waste generation rate increases. In contrast, a weak correlation exists between income and waste generation for middle and upper income countries, and waste generation actually decreases in the wealthiest countries. It is estimated that the current waste generated in Nairobi city is 4016 tonnes per day and the growth rate is at 7% p.a. (Allison, 2010)

The number of people in a household has shown a correlation to per capita waste generation as a higher number of people in a given household results in less waste generation per person per day. Climate and seasonal changes also affect the amount of organic material generated as a waste product of preparing fresh foods. The MSW generation rate per capita per day in some sample countries is shown in the Table 2.3 (Troschinetz & Milhelcic, 2008)

Table 2 3: Waste generation (kg /person/day) in selected countries

Country	USA	EU	China	India	Brazil	Philippines	Botswana	Sri Lanka	Kenya
MSW kpd	2.08	1.51	1.08	0.46	0.85	0.38	0.33	0.34	0.53*

Source: Sustainable recycling of municipal solid waste in developing countries

(Allison, 2010) Concluded that the composition of waste from Nairobi city is largely organics, but this is shifting towards more paper, plastics and glass. JICA study (1998) determined the Nairobi Municipal Solid Waste stream to comprise of: 51% food waste, 17% paper (15% recyclable), 12% plastics (5% containers), 7% grass and wood, 3% metal, 3% textile, 2% glass, and others (5%) and ITDG (now called Practical Action) in 2004 gave a slightly different municipal solid waste composition with organics comprising 61%, 21% plastics and 12% paper. The waste composition for Nairobi city is summarized in Table 2.4.

Table 2 4: Waste composition in Nairobi City.

Waste Type	**Percentage composition**			
	MoLG & FARID 1985 (Cited in Kibwage,1996)	**JICA, 1998**	**ITDG, 2004 (Cited in Bahri,2005)**	**UNEP/CCN/NTT, 2009**
Organic	78	58	61.4	50.9
Paper	10.2	17	11.8	17.5
Plastic	4.1	12	20.6	16.1
Glass	3.8	2	0.7	2.0
Metals	1.9	3	0.6	2.0
Other	2	8	4.9	11.4

Source: Review of Municipal Solid Waste Management: A Case Study of Nairobi, Kenya: page 17

In Sweden, a global leader is when it comes to dealing and recycling waste, Stockholm city has classified trash bins with identified labels, where the household can presort the trash before being collected (LI, 2007).

(Njoroge, Kimani, & Ndunge, 2014) Recommended that public awareness should be created especially at the generators level so as to minimize waste generation and for the generators to embrace the importance of proper waste management.

2.5.4.2 Collection and transportation

In many areas of Nairobi, waste collection is done by private players which are licensed by the city council of Nairobi. Even though this service has been privatized, there is still no separation of waste at source. Private collection services are provided under an open and completely unregulated but competitive environment; that is, private companies/organizations are free to provide services anywhere in the city and collect varying tariffs directly from customers. The City Council does not have contractual involvement with private companies but simply regulates them through a licensing procedure that is hardly monitored. (Kenya National Cleaner Production Centre, 2006)

In Sweden which is most successful in waste management, waste is collected by private contractors whose services are hired by the municipality. They either do manual collection, container collection or vacuum collection. These contractors are shifted after 4-6 years in order to guarantee working efficiency. (LI, 2007) Waste transportation is usually charged by garbage trucks, equipped with standardized lifts to suit the cans used for collection.

The average collection rate in Nairobi is about 33%, recycling rate is 3.7% hence leaving about 63% of waste uncollected (Njoroge, Kimani, & Ndunge, 2014).

2.5.5 Political support

Sustaining political support during the long and costly implementation process is vital to the program's ultimate success. When local government budgets are tight, a program may not survive the budget cuts unless there is continuing, strong political support. Political support is often crucial to obtaining financing and ensuring that the program gets the resources needed to construct facilities and operate them efficiently. Political leaders should also be kept informed of the program's progress on a regular basis so that political support for the program grows as the decision-making body reaches the point of actually committing its public or private resources to implementing the long-term program (EPA, 1995).

2.5.6 Stakeholder involvement

There is potentially large number of actors in the waste management process. Political bodies, waste generators, waste haulers, funding agencies, regulatory agencies, construction contractors, plant operators, energy and material buyers, landfill site owners, and citizens must all be included for a program to be successful. Each group has the potential for delaying or derailing the project. (EPA, 1995)A plan for informing the public about the program's progress should be developed and implemented as the program proceeds. Special effort should be made to generate public support before public bodies vote on program expenditures. The program must be seen by the public as something to be proud of, as an example of the progressiveness of the community and its commitment to a clean environment.

(Troschinetz & Milhelcic, 2008) Identified collaboration as a catalyst to heightened household awareness about recycling and waste, improve waste handling and disposal operations including characterization and segregation, strengthen law enforcement, utilize scavengers as a legitimate agent of MSWM, recommend inclusive policy initiatives, create integrated, sustainable MSWM plans and reduce expenses though cost sharing of facilities and equipment between agencies.

(United nations, 2011) Identified community involvement as a critical factor to take into account when setting up a waste infrastructure project, their needs and concerns should be addressed. Capital investments, future financial stability and institutional mechanisms should be satisfied in order to ensure proper maintenance and functioning of these facilities.

2.5.6.1 Stakeholders in waste to energy

Waste generators, industry, national governments and regulators, waste technology providers, private sector companies, academia, Non-Governmental organization (NGO), community based organizations, international finance institutions and United Nations (United nations, 2011)

A summary of stakeholders is provided in figure 2.2. (Rand, Haukohl, & Marxen, 2000)

2.6 Why Waste to Energy plants fail

In some places, the waste to energy plants have been set up successfully but fail to remain in operation due to managerial, financial or operational problems including low calorific value of waste due to scavenging, precipitation, or the basic composition of generated waste. The failure of MSW incineration plants is usually caused by one of the following: Firstly, inability or unwillingness to pay the full treatment fee, which results in insufficient revenue to cover for loan installments and operation and maintenance costs. Secondly, lack of convertible currency to purchase spare parts. Thirdly, operational and maintenance failures (including lack of skilled workers). Fourthly, problems with waste characteristics and/or quantities. Fifthly, poor plant management, inadequate institutional arrangements and overly optimistic projections by vendors (Rand, Haukohl, & Marxen, 2000)

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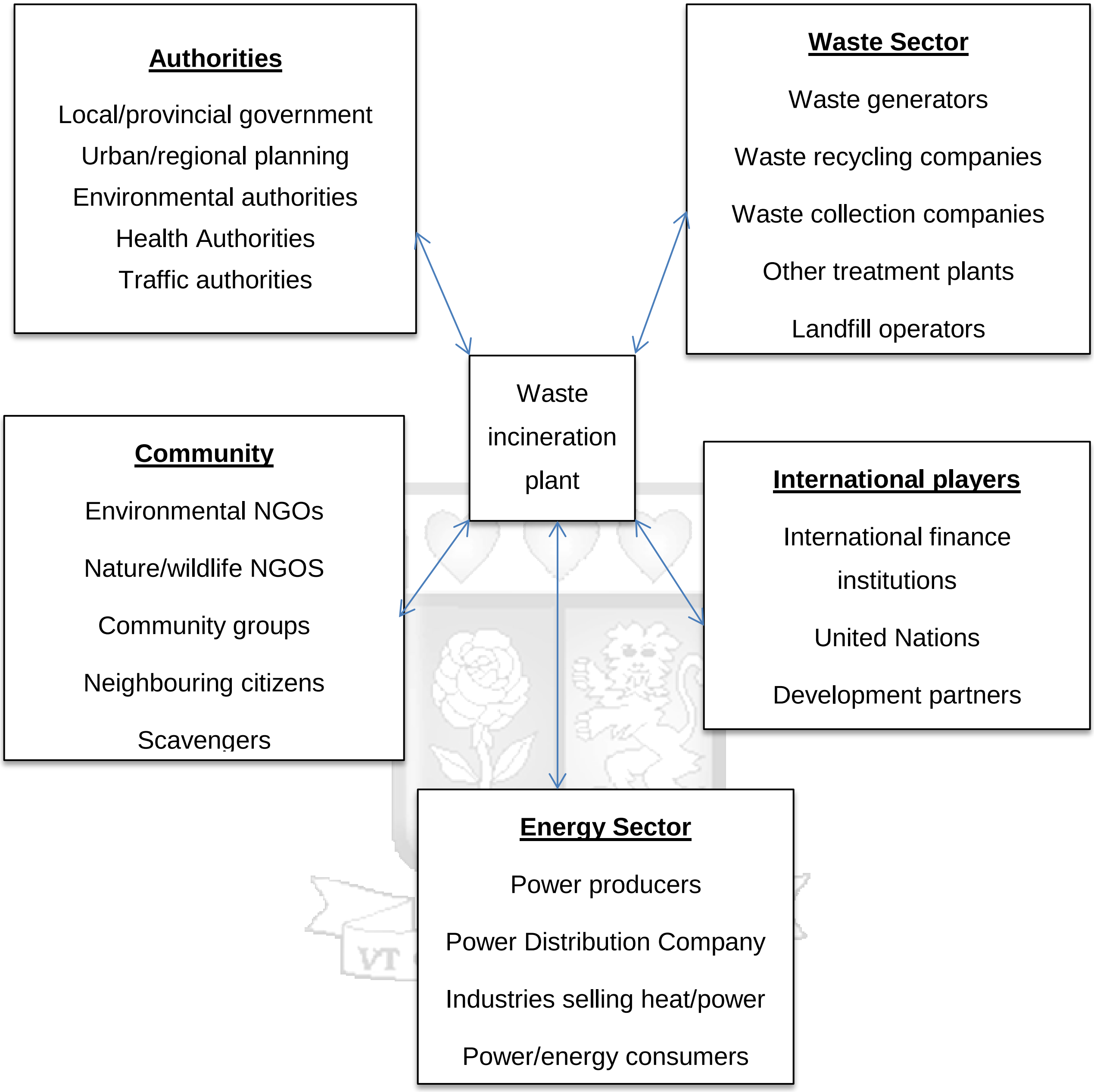

Figure 2 2: Stakeholders in a waste incineration plant

Source: Municipal Solid Waste Incineration: Requirements for a Successful Project, Volumes 23-462, page 6

2.7 Benefits of setting up a waste to energy project

A waste-to-energy plant is a complex operation in which solid waste is received, processed and converted to energy through thermal, chemical, or biological treatment.

2.7.1 Employment creation

In a study to identify the nationwide economic impact of waste to energy plants, (Berenyi, 2013) quantified that there is a multiplier effect of 1.6 for every job that is held at a waste to energy facility in the US. There are more than 5350 people working in 85 WTE facilities in the United States, which includes workers at specific sites, offsite employees of the several regional and national firms that own the WtE facilities and local government personnel dedicated to plant oversight and maintenance. Most employees at waste to energy plants are technically skilled, with many having to undergo periodic licensing and operations testing. There are also jobs created in the adjacent industries.

2.7.2 Revenues from sale of power and heat.

In the UK, the government offers incentives on electricity and heat generated from renewable sources. Waste to Energy is considered as source of renewable energy.

(Berenyi, 2013) Estimated that the waste to energy industry in the US generated more than USD 5.6 billion, of which US$ 3.2 billion is direct revenue from sale of electricity and heat and the balance is from tip fees and recycling sales revenue. There is a multiplier effect on the economy with every dollar generating 1.77 dollars in the overall economy.

2.7.3 Carbon credits and Carbon finance

Projects in developing countries that are voluntary and reduce emissions and can contribute to the sustainable development of the country and qualify under the clean development mechanism (CDM) can earn certified emission reductions (CERs). Carbon finance can help in establishing landfill project that recover LFG which otherwise would not have been possible (Siddiqui, Zaidi, Panday, & Khan, 2013).

Renewable Energy Certificates (RECs) is another additional source of revenue; it represents the property rights to the environmental, social, and other non-power qualities of renewable electricity generation. A REC, and its associated attributes and benefits, can be sold separately from the underlying physical electricity associated with a renewable-based generation source. In the United states, These RECs are being sold for between 3 and 4 cents per kilowatt-hour(kWh), on top of the price received for selling the electricity, and provide an excellent revenue stream for LFG electricity projects (EPA, 2014). These RECs are purchased by companies wishing to reduce their environmental footprint or used by utilities to comply with various renewable portfolio standards (Godlove & Singleton, 2010)

2.7.4 Financing and Tax Incentives

In the UK, several financing incentives exist to support setting up of waste to energy facilities which includes capital grants, prudential borrowing, waste infrastructure credits and private sector financing (DEFRA, 2013)

LFGE projects that generate electricity in the United States can benefit from two major federal tax incentives. The first incentive is called a production tax credit for renewable energy, which currently pays 1.1 cents per kWh generated and sold to a third party. This credit is available to entities for a 10-year period after the project begins operation. To receive this credit the LFGE project must begin generating electricity on or before December 31, 2013. In addition, there are tax exempt Clean Renewable Energy Bonds (CREB) programs that allow municipalities or not-for-profit electric cooperatives, which are typically exempt from federal taxes, to use bonds to fund renewable electricity generating projects. Unlike traditional bonds that pay interest, tax credit bonds pay the bondholders by providing a credit against their federal income tax. In effect, CREBs provide interest-free financing for clean energy projects. To qualify for CREB financing, the project must be deemed to be technically, financially, and legally feasible (Godlove & Singleton, 2010)

2.7.5 Environmental benefits

Reduction of carbon emissions is a key environmental benefit of waste to electricity conversion. The GHG mitigation potential from the existing project in Ratchathewa landfill in Bangkok was estimated from a life cycle perspective and the conclusion was that the overall contribution of the LFG recovery project for total Green- house gas (GHG) mitigation is 471,763 tonnes of CO_2-eq over the 10-year project time (Menikpura, Arun, & Bengtsso, 2013).

2.7 Conceptual framework

Independent Variables

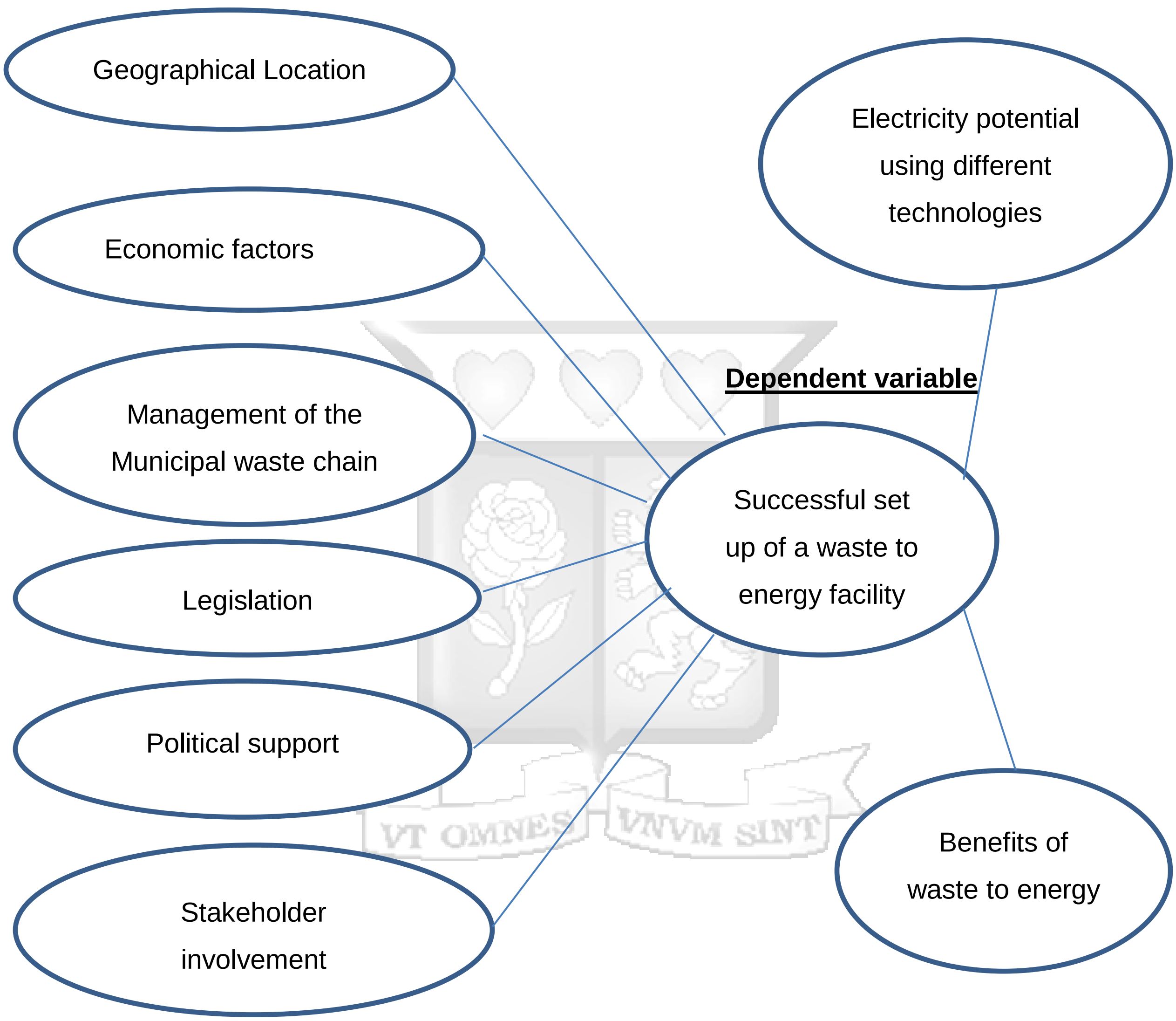

Figure 2 3: Conceptual framework

Source: Author

The conceptual framework has been derived from the literature review. The independent variables are factors for successful set up of a waste to electricity facility and the dependent variable is successful set up of a waste to electricity facility.

CHAPTER 3: RESEARCH METHODOLOGY

3.0 Introduction

This section begins with a description of the research design and strategy. An elaborate description of data collection and preparation process is clearly outlined, explaining how the data was measured and analyzed in accordance with the research questions described in chapter 1. The chapter then progresses to discuss the choice of the data analytical framework that was subsequently adopted in the study. The section concludes by comments on the ethical considerations regarding the approach adopted.

3.1 The Research Design

The selected research strategy is a survey. The survey approach is the most suited method for gathering descriptive information as it involves asking participants questions on how they feel, what their views are, and what they have experienced. In a survey, the investigator examines those phenomena which exist in the universe independent of his or her action. Its advantage is that, it allowed the collection of large amounts of data from a sizeable population in a highly effective, easily and in an economical way, often using questionnaires (Saunders, Lewis, & Thornhill, 2009).

This exploratory research sought to estimate the electricity potential from the municipal solid waste in Nairobi and analyzed the factors needed for a successful set up of a waste to energy facility.

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3.2 Population and sampling

Stratified random sampling was used to select the population. This was selected because the population to be interviewed was divided into different categories based on the stakeholder groups identified in the literature review in Figure 2-2.

The identified population was categorized as shown in table 3.1. The sample size selected was 40. The respondents targeted were senior management in the respective organizations and in the case of government, the senior officers in departments responsible for the waste sector.

Table 3 1: Population to be interviewed

Category	Identified Organizations
Regulatory bodies	National Environmental Management Authority(NEMA) Energy regulatory commission(ERC)
Residents and private sector alliances	Kenya Private Sector Alliance (KEPSA) Kenya Alliance of Residents Association(KARA) Nairobi Central Business District Association(NCBDA)
Community based organizations and NGOs	SOS, Practical action, International technology development group
Nairobi city county	Ministry of environment
Recycling companies	15 were selected
Private garbage collection & transport companies	10 were selected
Government of Kenya	Ministry of environment, water and natural resources
Higher educational institutions offering courses in urban planning	University of Nairobi- department of urban planning Jomo Kenyatta University of Agriculture and technology, Kenyatta University, Strathmore university
Donor agencies and development partners	JICA, World bank, ADB, IFC
United Nations	UNEP, UNDP

Source: Author

3.3 Data Collection Methods

Primary data was collected using interviewer- administered questionnaires(Appendix 1). A questionnaire is a data collection technique in which a person is asked to respond to the same set of questions in a predetermined order. The questionnaire is the most widely used data collection technique within the survey strategy. Because each respondent is asked to respond to the same set of questions, it provides an efficient way of collecting responses from a large sample prior to quantitative analysis. The interviewer administered questionnaire usually has a higher response rate (Saunders, Lewis, & Thornhill, 2009)

Research assistants were used to assist in data collection. They were trained on research skills; objectives of the study and the questionnaire to enable them collect data accurately.

Rating questions were used to collect opinions on how much the respondents agree with a set of statements using a five point rating scale. Ranking questions are used to triangulate the literature on understanding the benefits of setting up a waste to energy facility (Saunders, Lewis, & Thornhill, 2009).

3.4 Data analysis

Data collected was analyzed by descriptive statistics and inferential statistics using SPSS software.

Factor analysis was done on the independent variables in order to determine the factors that have the highest impact on successful set up of a waste to electricity facility. Multi collinearity test was done on the independent variables.

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3.5 Research Quality – validity, reliability and objectivity of the research.

(Saunders, Lewis, & Thornhill, 2009) Define reliability as the extent in which the data collection techniques and analysis procedures will yield consistent findings. There are four major threats to reliability: Participant error, participant bias, observer error and observant bias. Being conscious of these threats, the researcher followed scientific techniques and methods and it is hoped that the study generated reliable data and results. Further, the selection of respondents targeted persons in the organization were those who have enough experience and are familiar with the waste management challenges in the city of Nairobi.

(Saunders, Lewis, & Thornhill, 2009) Define validity as being concerned with whether the findings are really about what they appear to be about. Validity seeks to find if the relationship between two variables is causal. The researcher must take into consideration history, testing, instrumentation, mortality and maturation that affect research validity.

To achieve the validity of the research, the interview questions were framed based on theoretical framework. Further, all respondents were given a complete detail about the research under study and the role they could play in the successful completion of the research. The study was never affected by maturation, instrumentation, testing and mortality threats.

3.6 Ethical Issues in Research

In this study, special attention was paid to the ethical issue related to the interviewees comfort to participate in the survey and the management of confidential business information given to the researcher. The researcher gave a written declaration to assure the respondents of the confidentiality of their information and that such information would be used only for purposes of learning and stimulating discussion and furthering research in the area of waste to energy.

A letter authorizing data collection for purposes of this study from the university was obtained to affirm this position further (Appendix 3). The researcher used simple language allowing the respondent enough time to respond. Equally, the respondents were given complete liberty to refuse to answer any question they feel uncomfortable with or unfamiliar.

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CHAPTER FOUR: PRESENTATION OF RESEARCH FINDINGS AND DISCUSSIONS

4.1 Introduction

This chapter discusses the interpretation and presentation of the findings obtained from the questionnaires administered in the field.

This data is based on results from a survey done in Nairobi in the month of April 2015; targeting 40 companies sampled using stratified random sampling. The questionnaires were administered by interviewers, although in some cases, the respondents asked to complete the questionnaires on their own and return. Numerical data was analyzed using descriptive statistics and output presented using tables and pie charts.

In order to answer research question1, estimating the potential of electricity in Nairobi county, secondary data from literature review was used.

Factor analysis was used to deduce the most critical factors required for a successful setup of a waste to energy facility.

Table 4 1: Response rate

No of respondents targeted	No. of respondents met	Questionnaires returned
40	35	28

One of the main challenges faced during data collection was access, especially because research assistants were used to collect the data. Some organizations insisted on getting the researcher to personally administer the questionnaire. Some respondents requested to fill the questionnaire on their own and call the research assistants to collect when ready, but some of them did not respond. The researcher overcame this challenge partly by reaching out to some of her personal contacts in the organizations to assist in getting the responses.

4.2 Electricity potential from municipal solid waste in Nairobi city

It is estimated that the current waste generated in Nairobi city is 4016 tonnes per day (Allison, 2010).

4.2.1 Electricity potential from incineration technology

(De Souza, et al., 2014) In a study on the energy potential from MSW in Brazil, concluded that thermal treatment yields the highest relevant energy potential. With an assumption of 455kwh/ tonne of MSW and a plant operating for 8000 hours per annum, the study estimated that the annual MSW of 18,933 Kilo tonnes could generate 1077 MW of power.

(Kaplan, Decarolis, & Thorneloe, 2009) also concluded that the electricity generated per tonne of MSW using Landfill gas to electricity ranged from 41-84kwh while using combustion ranged from 470-930 kwh, they estimated that for the 166 million tonnes of MSW generated in the United States of America, the electricity potential ranged from 0.85- 1.8GW while if combustion was used, this potential reached 9.7-19GW.

(Funk, Milford, & Simpkins, 2013) In a study of waste in Boulder in the US, estimated that 215 Tonnes per day of MSW could generate 5.6MW of power assuming 91% capacity factor. This yields an estimate of 570kwh/ tonne.

Using these three assumptions, the annual estimated municipal solid waste generated assuming 100% collection rate is

Annual quantities of MSW = 4016 tonnesX365 days

=1,465,840 tonnes

The estimated potential of electricity in MW is summarized in the Table 4.1 based on the assumptions of the authors mentioned above.

The MW potential is calculated using the relationship below

$$\text{MW potential} = \frac{\text{Annual quantities (Tonnes)X Electricity generated per tonne}}{\text{No of operating hours}}$$

Table 4 2: Estimate electricity potential based on incineration technology

	De Souza et al, 2014	Kaplan, Decarolis, & Thorneloe, 2009-Lower limit	Kaplan, Decarolis, & Thorneloe, 2009-Upper limit	Funk, Milford, & Simpkins, 2013
Annual Quantities of MSW(Tonnes)	1,465,840	1,465,840	1,465,840	1,465,840
No of operating hours p.a	8000	8000	8000	8000
Electricity generated per tonne(kwh)	455	470	930	570
Electricity potential(MW)	83	86	170	104

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Taking the lower limit from the results above and the inefficiencies in the municipal waste chain, it can be estimated that the potential is in the range of **80-90MW.**

4.2.2 Electricity potential from land fill gas to energy

(Kaplan, Decarolis, & Thorneloe, 2009) also concluded that the electricity generated per tonne of MSW using Landfill gas to electricity ranged from 41-84kwh per tonne of waste generated. (Funk, Milford, & Simpkins, 2013) Concluded that MSW combustion generates nine times more electricity than landfill gas to energy.

The results are summarized in Table 4 3. From the results, it can be concluded that the electricity potential based on landfill gas to electricity is in the range of **8-15MW**

4.2.3 Electricity potential based on respondents

Respondents were asked to provide an estimate of the electricity potential and the results are summarized in the table 4.4. The mean quantity of power potential is 51-60MW. This is lower than the estimated potential based on calculations.

Table 4 3: Electricity potential based on landfill gas to electricity technology

	Kaplan, Decarolis, & Thorneloe, 2009- Lower limit	Kaplan, Decarolis, & Thorneloe, 2009- Upper limit	Funk, Milford, & Simpkins, 2013
Annual Quantities of MSW(Tonnes)	1,465,840	1,465,840	1,465,840
No of operating hours p.a	8000	8000	8000
Electricity generated per tonne(kwh)	41	84	63
Electricity potential(MW)	8	15	12

Table 4 4 Electricity potential from respondents

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0-10MW	2	7.1	7.1	7.1
	11-20MW	4	14.3	14.3	21.4
	21-30MW	4	14.3	14.3	35.7
	31-40MW	2	7.1	7.1	42.9
	41-50MW	2	7.1	7.1	50.0
	51-60MW	5	17.9	17.9	67.9
	71-80MW	3	10.7	10.7	78.6
	81-90MW	4	14.3	14.3	92.9
	Greater than 91	2	7.1	7.1	100.0
	Total	28	100.0	100.0	

4.3 Successful set up of a waste to energy facility

4.3.1 Importance of a successful set up of a waste to energy facility in Nairobi City

The researcher sought to establish the importance of a successful set up of a waste to energy facility in Nairobi City. Respondents were requested to rank the importance in terms of Likert scale of 1 to 5 where 1=Very important, 2=Important, 3=moderately important, 4=of little importance and 5=Unimportant. Of those who responded,57% of the respondents rated a successful set up of the waste to energy facility as very important; while 43% agreed that it was important, giving a mean and standard deviation of 1.43 and 0.504 respectively. As to whether waste to energy was a solution to the municipal solid waste challenges faced in Nairobi, 71% of the respondents strongly agreed and 29% agreed giving a mean of 1.29 and a standard deviation of 0.46. As to whether a solution to waste disposal lies in converting municipal solid waste to electricity, 57% of the respondents strongly agreed, 32% agreed, 7.1% were neutral and 3.6% disagreed, this gave a mean of 1.57 and a standard deviation of 0.79.The mean and standard deviation is summarized in table 4.4. The distribution of the respondents are summarized in figures 4.1, 4.2 and 4.3

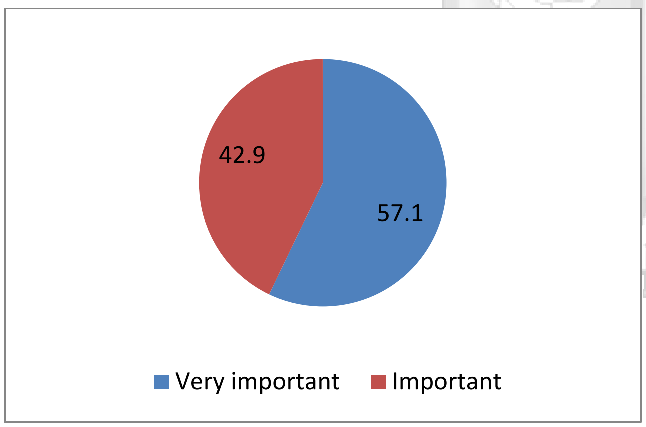

Figure 4 1: Successful set up of a waste to energy facility responses

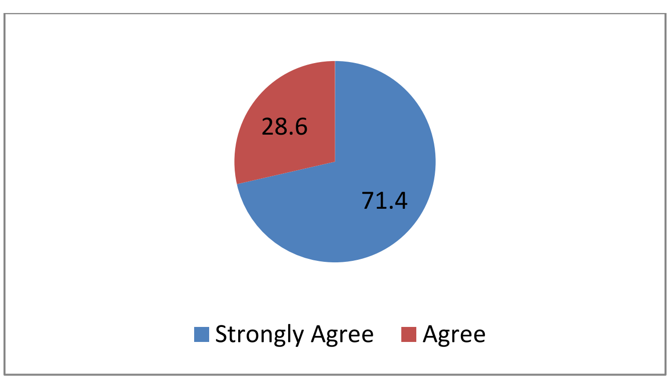

Figure 4 2: Waste to energy conversion is a solution to challenges in managing municipal solid waste in Nairobi responses

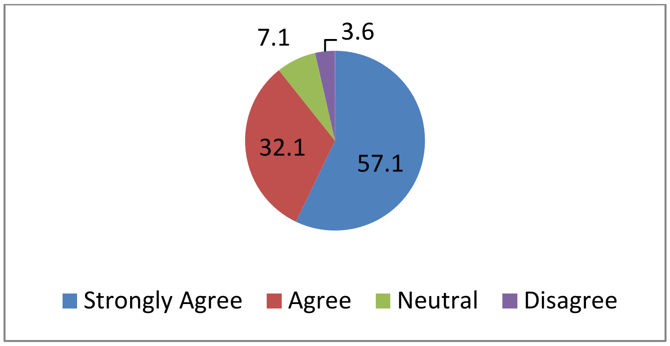

Figure 4 3: Responses to solution lies in waste to energy

Table 4 5: Descriptive statistics of Successful set up of a waste to energy facility

Descriptive Statistics

	N	Mean	Std. Deviation
Successful set up of a waste to energy facility	28	1.43	.504
Waste to energy conversion is a solution to challenges in managing municipal solid waste in Nairobi	28	1.29	.460
Solution to waste disposal lies in converting municipal solid waste to electricity	28	1.57	.790
Valid N (list wise)	28		

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4.4 Factors Determining Successful set up of a waste to Energy facility.

One of the main objectives of the study was to examine the factors that affect successful set up of a waste to energy facility in Nairobi City. The research in particular considered Geographical location, stakeholder's involvement, Economic factors, Legislative framework, Management of the municipal waste chain and political support were cited as major factors. Descriptive statistics and factor analysis was used to deduce the results.

4.4.1 Descriptive statistics on factors for successful set up

The respondents were asked to agree with a set of statements with ranking questions with 1 = strongly agree, 2= agree, 3= neutral, 4= disagree, 5= strongly disagree. Of those who responded, 82% strongly agreed that the geographical location of a waste to energy facility is critical to its successful set up while 18% agreed giving a mean and standard deviation of 1.18 and 0.39 respectively. This is summarized in figure 4.4

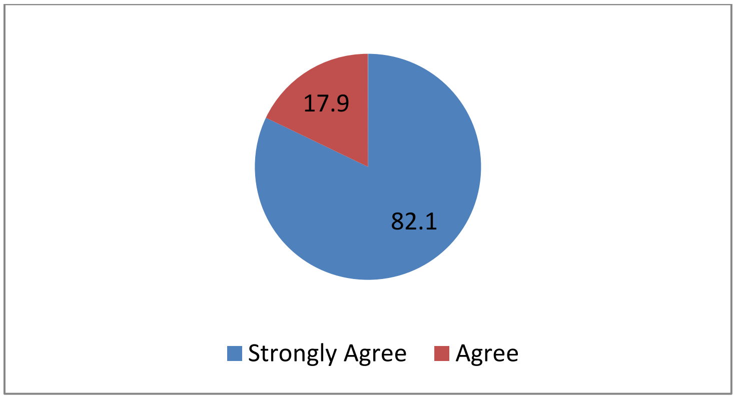

Figure 4 4: Importance of geographical location

On the stakeholder involvement, 78.6 % of the respondents strongly agreed that this was very important in successful set up of a waste to energy project, while 17.9% agreed and 3.6% disagreed. No respondents were neutral. The mean and standard deviation was 1.29 and 0.659 respectively for this factor. This is summarized in figure 4.5.

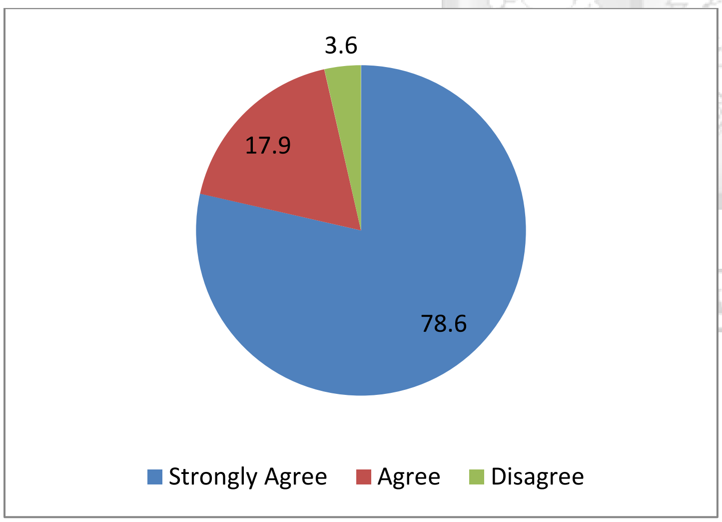

Figure 4 5: Importance of stakeholder involvement

As to whether a waste to energy facility needs to make economic sense;75% of the respondents strongly agreed it should be able to pay for its costs and generate some surplus amounts of money. 21.4 % agreed and 3.6% disagreed, giving a mean and standard deviation of 1.32 and 0.67 respectively.

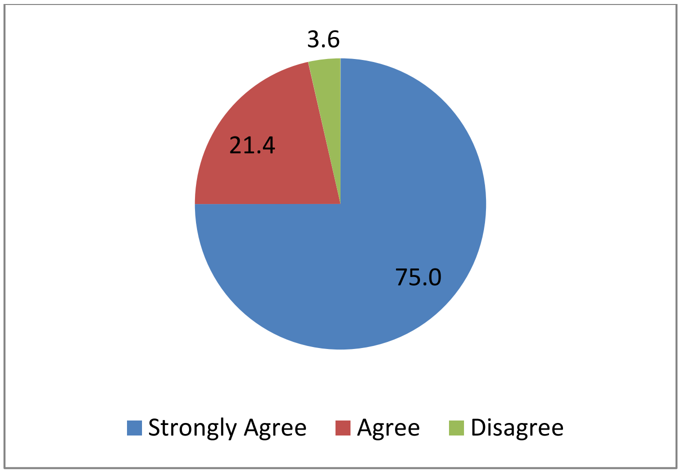

Figure 4 6: Importance of economic factors

On the legislative framework, 67.9% of the respondents strongly agreed that having policies that regulate the management of municipal solid waste is a critical factor in successful set up of a waste to energy facility while 32.1 % agreed giving a mean of 1.32 and standard deviation of 0.476.

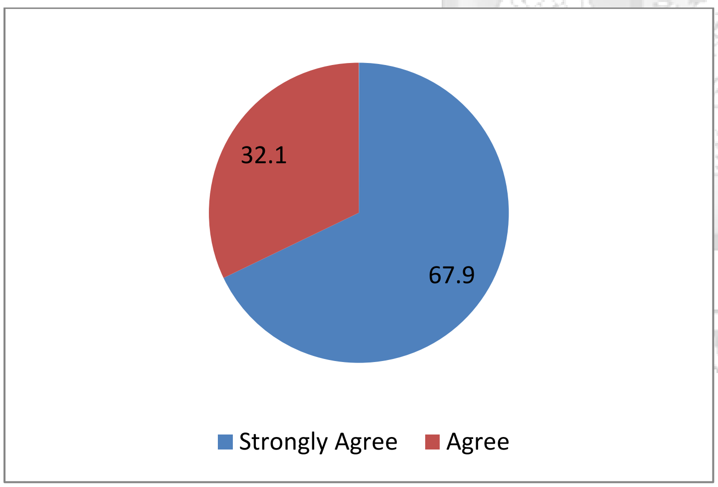

Figure 4 7: Importance of legislative framework

On the generation, collection and transportation of municipal solid waste ,82.1% of the respondents strongly agreed that it should be taken into account when setting up a waste to energy facility while 17.9 % agreed, no respondents disagreed. This gave a mean and standard deviation of 1.18 and 0.39 respectively.

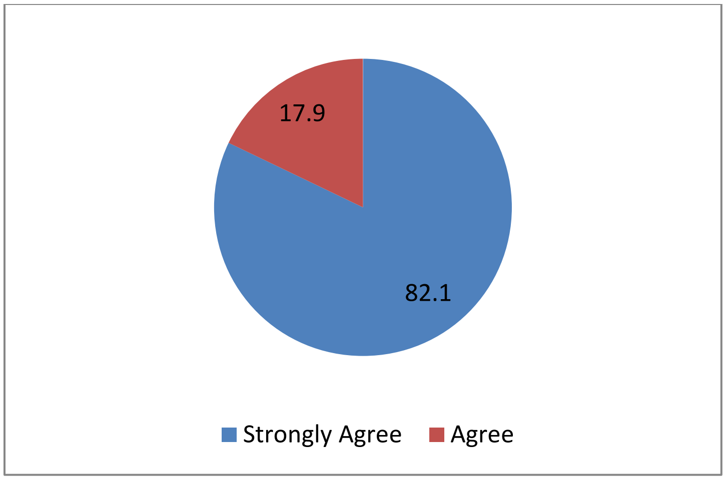

Figure 4 8: Importance of Management of the municipal waste chain

On the political support,50% of the respondents strongly agreed that political buy in is extremely important in successful set up of a waste to electricity facility, 42.9% agreed and 7.1% were neutral giving a mean and standard deviation of 1.57 and 0.634 respectively.

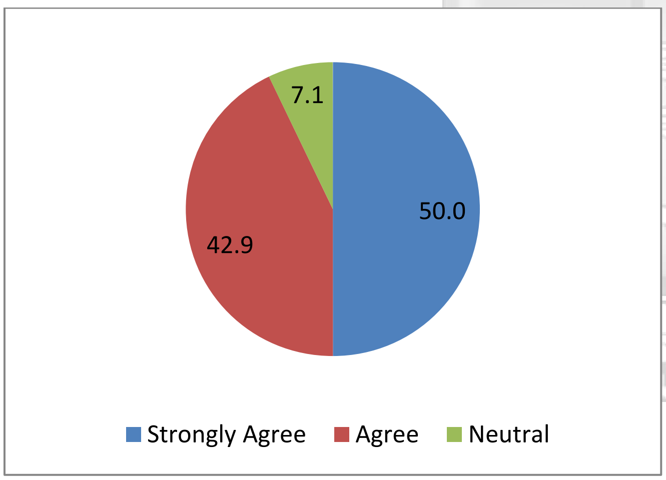

Figure 4-9: Importance of political support

Table 4 6:Mean and Standard deviation of factors affecting successful set up waste to energy

Descriptive statistics on factors

	N	Mean	Std. Deviation
Geographical location	28	1.18	.390
Stakeholder involvement	28	1.29	.659
Economic factors	28	1.32	.670
Legislative framework	28	1.32	.476
Management of the municipal waste chain	28	1.18	.390
Political support	28	1.57	.634
Valid N (list wise)	28		

4.4.2 Factor analysis

The second research objective sought to determine the factors that had the greatest impact on successful set up of a waste to electricity project. Factor analysis was used to identify these key factors and their factor loadings.

As a pre-test to factor analysis, the study used Kaiser-Meyer-Olkin measure of sampling adequacy (KMO) and Bartlett's test and the results presented in Appendix 2. The results show KMO statistics of 0.501, which was within the threshold of 0.5 set by Field (2005) as a minimum for patterns of correlation to be relatively compact. The resulting Bartlett's Test of Sphericity shows a significant value of 0.000, which implied that a strong relationship exists amongst the variables. The study therefore proceeded with factor analysis.

The initial solution presented in Table 4.6 shows six components had Eigenvalues greater than 1, and explained 80.45% of the variations. The first 6 components therefore explained 80.45% of the variations in successful set up of a waste to electricity facility, leaving 19.55% of the variations unexplained. The study therefore rotated the components in order to explain the remaining variations.

A scree plot was made to confirm the results in table 4.6. From the curve, the curve starts to flatten between component 6 and 7, and hence 6 components were retained

The study adopted a Varimax with Kaiser Normalization rotation method resulting in Table 4.7 below. Using the Principle Component Analysis (PCA) six components were extracted and after factor interpretation, they resulted in three factors namely: stakeholder involvement factor, location and Economic factor.

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Table 4 7: Total variance explained

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.418	25.991	25.991	4.418	25.991	25.991	3.197	18.807	18.807
2	2.682	15.778	41.769	2.682	15.778	41.769	2.844	16.729	35.536
3	1.931	11.360	53.128	1.931	11.360	53.128	2.233	13.134	48.671
4	1.852	10.894	64.022	1.852	10.894	64.022	2.072	12.190	60.860
5	1.517	8.922	72.944	1.517	8.922	72.944	1.762	10.365	71.226
6	1.276	7.506	80.450	1.276	7.506	80.450	1.568	9.224	80.450
7	.867	5.102	85.552						
8	.631	3.714	89.266						
9	.566	3.332	92.598						
10	.361	2.125	94.724						
11	.246	1.447	96.171						
12	.215	1.267	97.438						
13	.155	.913	98.351						
14	.135	.795	99.146						
15	.067	.393	99.539						
16	.048	.281	99.820						
17	.031	.180	100.000						

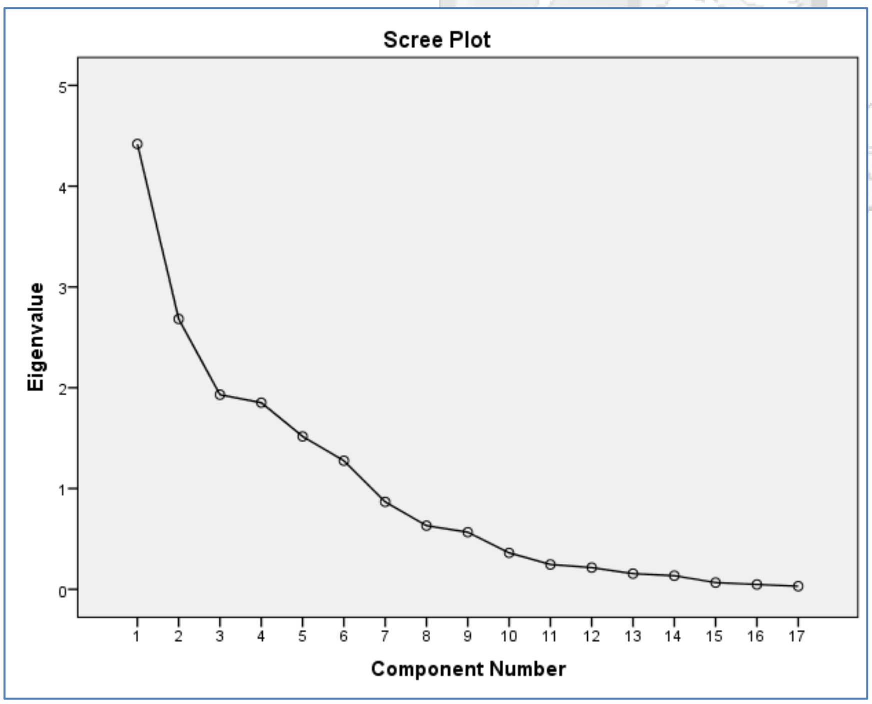

Figure 4-10: scree plot

Rotated Component Matrix[a]

	Component					
	1	2	3	4	5	6
Geographical location	.110		.841		-.109	.313
Environmental impact on location					.238	.903
Stakeholder involvement in overall project	.125	.829			.187	
Stakeholder involvement in early project stage	.162	.546	.370	-.159	.509	.314
Benefit articulation to stakeholders		.781				
Stakeholder involvement in planning stage	.892	.226		-.223		.111
Buy in from all actors	-.132	.187	.265	-.759		-.221
Community involvement	-.221	-.252		.156	.329	-.581
Economic benefit	.780	.217	-.189	.211	-.402	-.153
Incentives to attract investors	.122	.357	.696	-.206	-.172	-.190
Policy for waste management	-.258			.839	.153	-.169
Supporting regulatory framework	-.111	.380	.306	.716	-.144	-.110
generation of waste		.109	-.168		.891	
Collection and transportation	.189	.770	.331			
Source separation and recycling	.132	.265	.630	.245	.452	-.127
political buy in	.818	-.272	.331	-.140	.213	.107
political support	.924	.124	.185		.108	.129

Table 4 8: Rotated component matrix

The first component was defined by four variables, with political support reflecting a factor loading of 0.924 followed by stakeholder involvement in planning stage (0.892), political buy in (0.818) and Economic benefit (0.780). The four variables were interpreted as Political and stakeholder factors. The second component was defined by three variables, with stakeholder involvement in overall project reflecting a factor loading of 0.829, followed by benefit articulation to stakeholders (0.781) and collection and transportation (0.770). The three variables were interpreted as stakeholder involvement in waste chain management. The third component was also defined by three variables, with geographical location reflecting a factor loading of 0.841 followed by incentives to attract investors (0.696) and source separation and recycling (0.630). The three variables were interpreted as Location and investor factors. The fourth component was defined by two variables, with buy in from all actors reflecting a factor loading of 0.759 and supporting regulatory framework reflecting a factor loading of 0.756. The two variables were interpreted as stakeholder involvement in regulatory factors. The fifth component was generation of waste variable reflecting a factor loading of 0.891. This factor was interpreted as waste quantities factor. The sixth component was environmental impact on location reflecting a factor loading of 0.903. This was interpreted as environmental factor.

The analysis shows that of the six factors identified, stakeholder involvement will have the most impact in successful set up as it is included in three namely stakeholder and political factors, stakeholder involvement in the waste value chain and stakeholder involvement and regulatory factors. These three factors were further summarized to one factor called stakeholder involvement with sub factors namely regulatory, political and waste value chain. The other three factors identified are location and investor factors, environmental and waste quantities. These factors can be further summarized into location factors and economic benefits.

The table below shows a summary of the interpreted results

Table 4 9: Factors with the greatest impact for successful set up of a waste to electricity facility

Factor	Sub- factor
Stakeholder involvement	Political Regulatory Waste chain management
Location factors	Waste quantities Environmental impact
Economic factors	Investor

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4.5 Benefits of setting up a waste to Energy facility

The researcher sought to establish the benefits associated with employment creation, carbon credits and carbon finance, environment, revenue from sale of power and heat and financing and tax incentive that comes with setting up a waste to energy facility. Respondents were asked to rank the benefits on a Likert scale of 1-5 with 1= most important, 2=important, 3=moderately important 4= of little importance and 5= unimportant. The summary of the findings were presented in the table 4 .9.

Of those who responded, 64.3% rated employment creation as a benefit of converting waste to energy as most important, 25% rated important and 10.7% rated it as moderately important.

This gave a mean of 1.46 and a standard deviation of 0.693. The responses are summarized in Figure 4.11

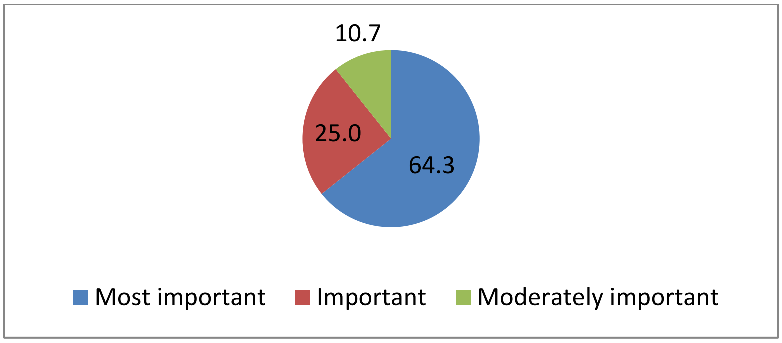

Figure 4-11: Employment creation as a benefit

On the importance of carbon credits and carbon finance as a benefit of setting up a waste to electricity facility, 57.1% of the respondents rated it as most important, 32.1% as important, 7.1% as moderately important and 3.6% as of little importance, giving a mean and standard deviation of 1.57 and 0.79 respectively. The responses are summarized in figure 4.12

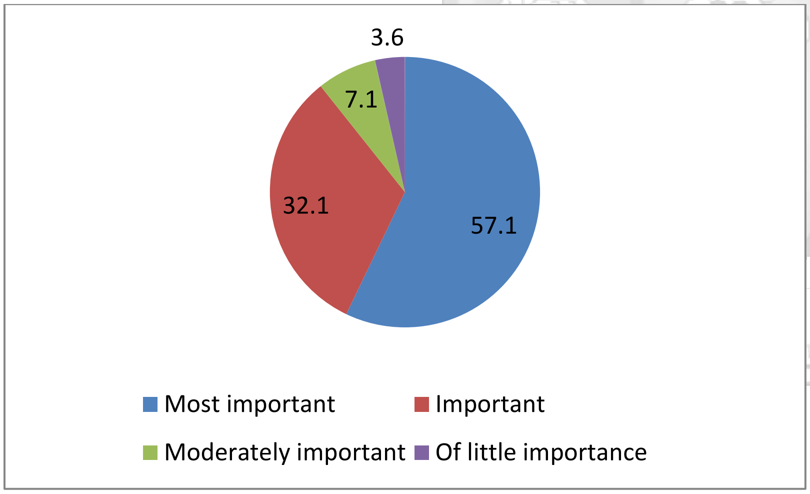

Figure 4-12: Carbon credits and Carbon finance as a benefit

On the environmental benefit, 50 % of the respondents rated it as the most important, 46.4 % as important and 3.6% as moderately important, giving a mean and standard deviation of 1.57 and 0.69 respectively. The results are summarized in figure 4-13.

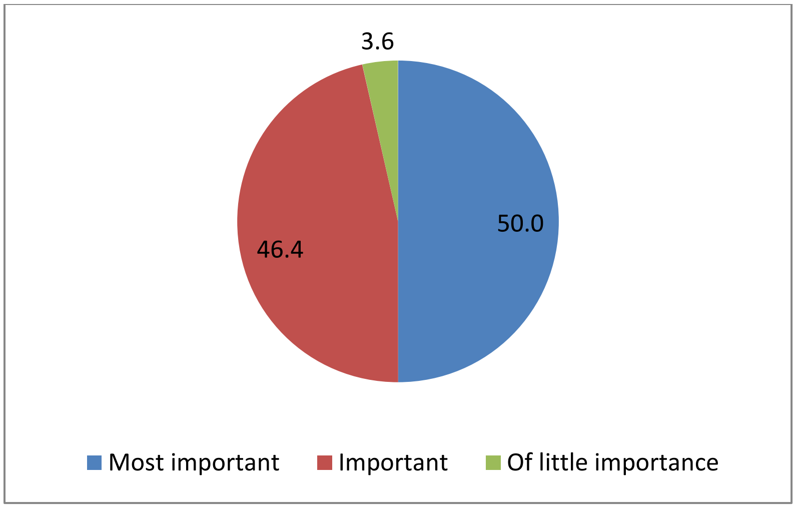

Figure 4 13: Importance of environmental benefits

On the revenue from sale of electricity and heat; 39.3% of the respondents rated it as the most important benefit, and a similar percentage rated it as important, 14.3% rated it as moderately important while 7.1% thought this was of little importance giving a mean and standard deviation of 1.89 and 0.916 respectively.

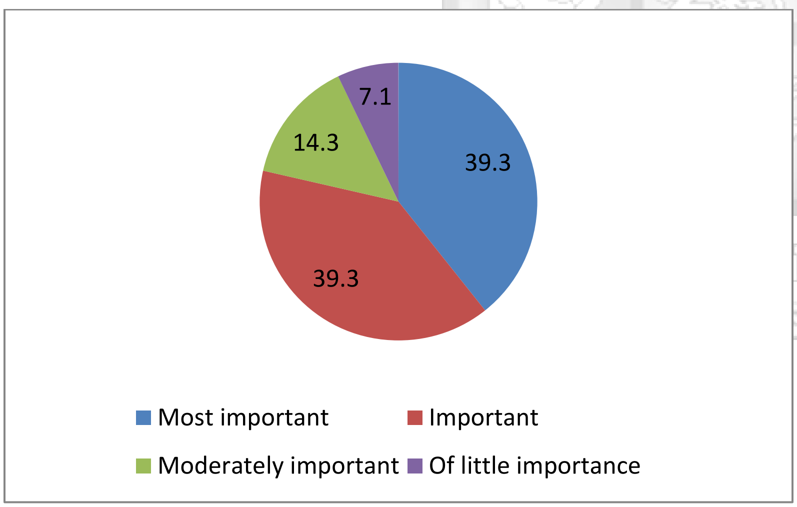

Figure 4 14: Importance of revenue from sale of electricity and heat

On financing and tax incentives, 53.6% of the respondents rated this as most important, 17.9% as important, 21.4% as moderately important and 7.1% as of little importance. This gave a mean and standard deviation of 1.82 and 1.02 respectively.

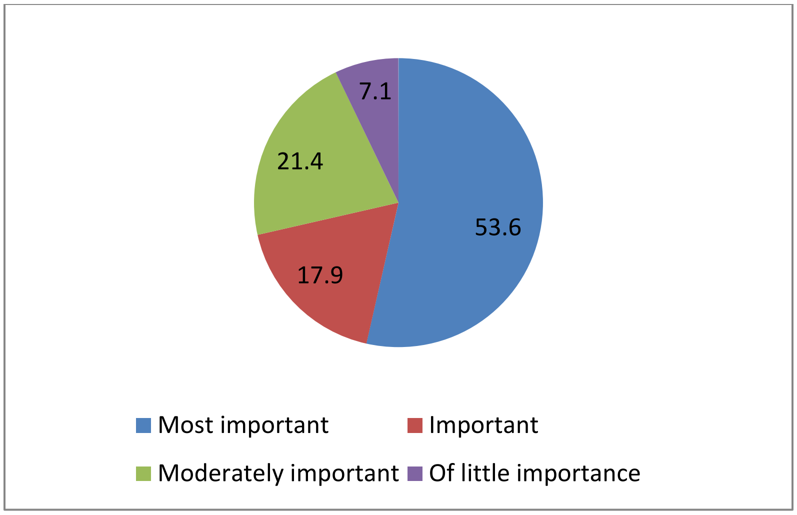

Figure 4 15: Importance of financing and tax incentives

Table 4 10: Benefit of waste to energy facility

Benefit of waste to energy facility

	N	Mean	Std. Deviation
Importance of Employment creation by setting up a waste to energy plant	28	1.46	.693
Importance of Carbon credits and carbon finance by setting up a waste to energy plant	28	1.57	.790
Importance of Environmental benefits by setting up a waste to energy plant	28	1.57	.690
Importance of Revenue from sale of power and heat by setting up a waste to energy plant	28	1.89	.916
Importance of Financing and Tax incentives by setting up a waste to energy plant	28	1.82	1.020
Valid N (list wise)	28		

From the Table 4 10, the respondents ranked employment creation as the most important benefit, followed by carbon credits and environmental benefit, then financing and tax incentives and lastly revenue from sale of electricity and heat.

4.6 Economic models of implementation.

The study tried to ascertain if privatization, public private partnership and public owned facility are more likely or less likely to contribute to the successful set up of a waste to energy facility.

Respondents were asked to rate the likelihood of success of different models of implementation on a scale of 1-5 with 1= Most likely, 2= More likely, 3=likely, 4= less likely and 5= least likely. The mean and standard deviations of the responses are summarized in table 4-10.

On privatization;64.3% of the respondents thought it was most likely to succeed, 14.3% as more likely, 17.9% as likely and 3.6% as likely. This gave a mean and standard deviation of 1.79 and 1.618 respectively.

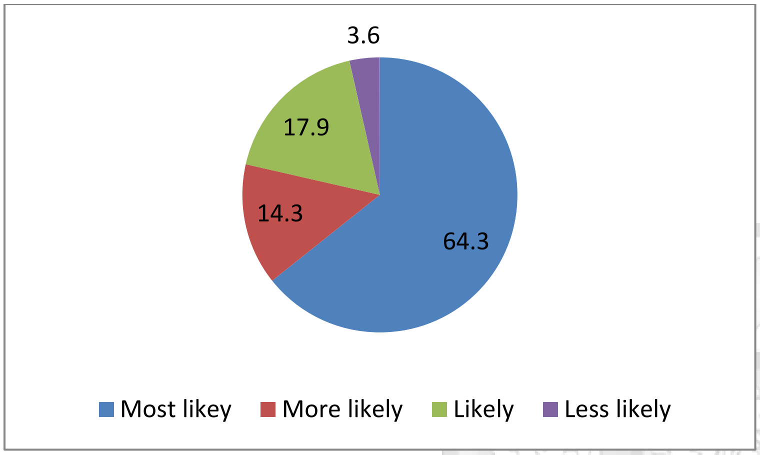

Figure 4 16: Likelihood of privatization success

On Public private partnerships as a model of implementation, 71.4% of the respondents rated is the more likely to be successful, 17.9% as most likely and 10.7% as likely. This gave a mean and standard deviation of 1.93 and 0.539 respectively.

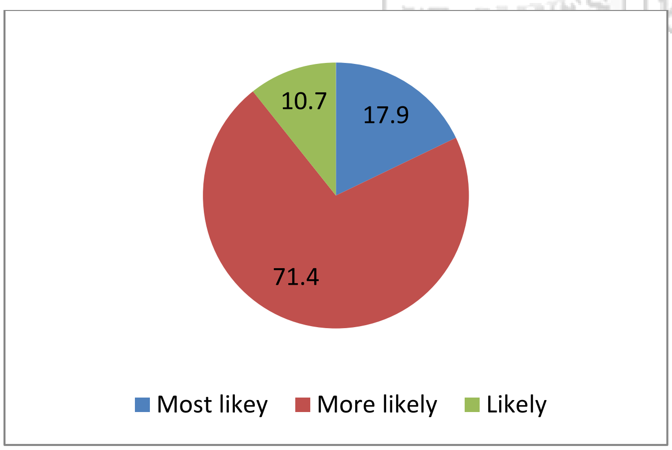

Figure 4 17: Likelihood of PPP success

On having a publicly owned waste to energy facility; 42.9% of the respondents thought that it was most likely to be successful, 21.4% as more likely, similarly 21.4% as likely, 3.6% as less likely and 10.7% as least likely. This gave a mean of 2.18 and standard deviation of1.335.

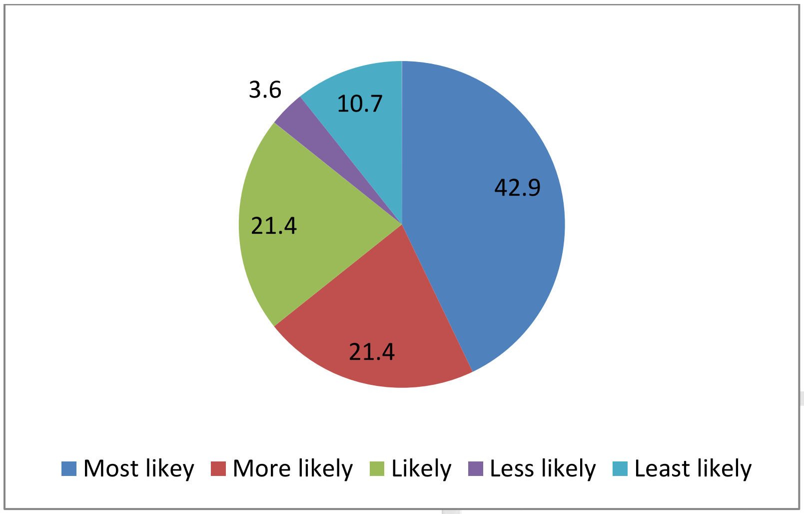

Figure 4 18: Likelihood of a publicly owned facility success

From the results in Table 4-11, it can be concluded that the most preferred model of execution is public private partnerships (mean=1.93, SD= 0.539), followed by privatization (mean=1.79, SD=1.618) and the least preferred model is a publicly owned facility (mean=2.18, SD=1.335).

Table 4 11: Economic models of setting up a waste to energy facility

Option of setting up a waste to energy facility

	N	Mean	Std. Deviation
Privatization as an option of setting up a waste to energy facility	28	1.79	1.618
Public private partnerships as an option of setting up a waste to energy facility	28	1.93	.539
Public owned facility as an option of setting up a waste to energy facility	28	2.18	1.335
Valid N (list wise)	28		

4.7 Discussion of results

Based on the responses and analysis, we can infer that the electricity potential of Nairobi City county municipal solid waste is in the range of 80-90MW. This was tested in the survey and the mean is 51-60MW. The potential from landfill gas to electricity is the lowest at 8-15MW.

The factors that will have the most impact in successful set up of a waste to electricity facility were reduced to 3 main factors namely; Stakeholder involvement, location and economic factors. The respondents felt that employment creation was the most important benefit, followed by carbon credits and environmental benefit. These should be used as benefits when justifying a waste to electricity project.

The economic model that is likely to be successful is privatization, followed by Public private partnerships (PPP) and the least likely model is a publicly owned facility. This should be taken into consideration when planning to set up such a facility. The Public Private Partnership Unit (PPPU) is established under Section 8 of the Public Private Partnership (PPP) Act, 2013 as a Special Purpose Unit within the National Treasury of the Government of Kenya (GOK). The Nairobi Solid waste management is one of the projects earmarked to be carried out under the PPP model and the status as of April 2015 is that the project is at proposal stage. (GOK), 2015)

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CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter highlights all other chapters and brings forth the conclusions that were drawn by the researcher in line with the said objectives. The chapter also describes the key findings derived from the analyses and discussions on the estimated electricity potential of the municipal solid waste, the factors that has the most impact on the successful set up of a waste to electricity facility, the economic model that is most likely to be successful and the benefits of setting up a waste to electricity facility.. This chapter is concluded by drawing of some policy recommendations on the subject matter and suggests potential areas for future studies.

5.2 An overview of the study

This study sought to identify the determinant factors for successful set up of a waste to energy facility. Various empirical studies were reviewed in order to understand the estimated electricity potential and identify the factors that are most critical for successful set up of a waste to electricity facility.

Literature was reviewed on different conversion technologies and the electricity potential, the land requirements, overall cost of set up and the environmental impact. The landfill gas to electricity option was not pursued further due to the large land requirement which is a scarce resource in Nairobi city. Six major determinant factors for successful set up of a waste to energy facility were identified namely: Geographical location of a waste to energy facility, Economic factors, legislative framework, and management of the municipal waste chain, political support and stakeholder involvement. The benefits of setting up a waste to electricity were identified as employment creation, environmental benefits, carbon credits and carbon tax, financing and tax incentives and revenue from sale of power and heat.

A survey was administered in order to identify the factors with the greatest impact on the successful set up of a waste to electricity facility and a factor analysis was done to identify these factors.

5.3 Conclusions

This study focused on identifying the entrepreneurial opportunities in and the factors that have the greatest impact in successful set up of a waste to electricity facility for successful waste management.

The first research objective was to estimate the potential of electricity from municipal solid waste in Nairobi city using the different waste conversion technologies. This was estimated to be in the range of 80-90MW using incineration technology based on literature review. The estimated electricity potential based on landfill gas to energy is in the range of 8-15MW. Based on responses from the interviewees on the question asked on what they thought was the electricity potential, a mean of 51-60MW was estimated. The incineration technology yields the highest electricity potential and also has the least land requirement.

The second objective was to determine the factors that have the greatest impact in successful set up of a waste to electricity facility project. Three main factors were identified that would have the greatest impact in successful set up of a waste to electricity facility. These factors are stakeholder involvement factors, location factors and economic factors. Stakeholder involvement is the strongest factor with sub factors on political, regulatory and waste chain management. It can be concluded that stakeholder involvement is required in order to get the right level of political support, to get the supportive regulatory framework and to ensure that the waste chain is managed effectively. The second factor that will have the greatest impact on successful set up of a waste to electricity facility is geographical location .This factor will impact the waste quantities that will be available to the facility as well as the environmental impact the facility will have. Of critical importance is the impact the waste facility will have on people living near such a facility. The third factor is the economic factor. The main issue here is for the government to have incentives that will attract investors who may want to invest in the waste to electricity sector.

The third research objective was to articulate the benefits of setting up a waste to energy facility. The benefits were identified in order of importance as employment creation, carbon credits and carbon finance, Environmental benefits, Financing and tax incentives and revenue from sale of power and heat.

An interesting observation was made on the economic model that would contribute to a successful set up of a waste to electricity facility. Privatization was the most preferred model of execution, Public Private Partnership model was also favored while a publicly owned waste to electricity facility is least likely to be successful in Nairobi city.

5.4 Recommendations

From the study, the municipal waste chain requires management. The authorities will need to ensure that the generation, collection, transportation and recycling activities are properly managed to ensure a successful waste to energy process and hence sustainable waste management. Sweden is one of the countries with best practice in waste to energy and a lot could be learnt from how they manage the municipal waste chain.

The legislative framework needs to be enhanced; the current legislative framework in Kenya for waste management is all included in the NEMA act and no specific legislation on waste management exists. The Waste regulations under NEMA only provide guidance to licensing of transporters, incinerators and other players in the waste sector. Specific legislation on waste generation, collection, transportation and final disposal does not exist. Legislation on penalties for hazardous wastes and e waste require to be in place. A dedicated institutional framework to manage waste would enhance the legislative framework.

In order to attract investors into Kenya, Incentives for investment in waste to energy will need to be in place at the government level. Some of the existing incentives in other sectors could be extended to waste to electricity sector. Incentives such as tax holidays and duty free importation of equipment could be considered.

5.4.1 Theoretical implications of the study

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Detailed studies should be done on stakeholders involved in the municipal waste chain and the impact each stakeholder has on setting up a waste to energy facility. A further study on different execution and ownership models of a waste to electricity facility in Nairobi is recommended. This could include models such as build, own, operate, and transfer and different variations of such models. A study on public private partnerships on waste management is recommended in order to understand critical success factors of such a model.

5.4.2 Managerial implications of the study

Managers involved in municipal waste management, renewable energy and associated industries will need to ensure that stakeholder mapping is clearly understood before a waste to electricity project is undertaken. It is important to understand the influence each stakeholder has in order to ensure that their interests and expectations are taken into consideration. In addition to understanding the gaps in regulation as well as the waste value chain, stakeholders involved in those areas will need to be involved in order to get all the required support. This is a critical component in project management that must be taken into account.

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APPENDICES

APPENDIX 1: QUESTIONNARE

Introduction

This study seeks to examine the factors that affect successful set up of a waste to energy facility for Nairobi City. Your organization has been chosen to participate in the study. The information provided will remain confidential and will be used exclusively for academic purposes. The questionnaire has three sections; section A seeks to understand if a waste to energy facility is a solution to the municipal solid waste challenges in Nairobi, B seeks to define factors for successful set up of the waste to energy facility, section C seeks to enumerate the benefits of setting up such a facility, section D seeks to understand the set up model that is most likely to be successful and section E seeks to find the estimated electricity potential. Kindly tick or fill in the spaces provided as appropriate. Thank you for participating.

Name of Organization………………………………………………………………………….

Interviewee designation……………………………………………………………………….

Interviewee name……………………………………………………………………….......

Contact number……………………………………………………………………………….

Email address: ……………………………………………………………………………….

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<u>Section A: Successful set up of a waste to energy facility</u>

1. How important is a successful set up of a waste to energy facility in the waste management problems experienced in Nairobi City (1- Very Important and 5 is Unimportant).

1.Very Important	2. Important	3. Moderately important	4 Of little Importance	5 Unimportant

2. Converting waste to energy can be a solution to the current challenges of managing municipal solid waste in Nairobi. How much do you agree?

1.Strongly agree	2.Agree	3.Neutral	4.Disagree	5.Strongly disagree

3. The current waste disposal situation in Nairobi cannot cope with the ever increasing population. The solution lies in converting municipal solid waste to electricity. How much do you agree?

1.Strongly agree	2.Agree	3.Neutral	4.Disagree	5.Strongly disagree

Section B: Information on factors determining successful set up of a waste to energy facility

Answer the following questions on a scale of 1 to 5.

Where 1 = strongly agree, 2=agree, 3=Not sure, 4=Disagree, 5 strongly Disagree

	Factors determining successful set up of a waste to energy facility	**1**	**2**	**3**	**4**	**5**
	Geographical location	**SA**	**A**	**NS**	**D**	**SD**
1	The geographical location of a waste to energy facility is critical to its successful set up.					
2	Siting a waste to energy facility is critical to its success because it reduces the impact on the environment					
	Stakeholder involvement					
3	stakeholder involvement is very important in successful set up of a waste to energy project					
4	Stakeholders can delay project implementation if they do not get involved at the earlier stages					
5	It is important to articulate the benefits of setting up a waste to energy facility to relevant stakeholders in order to gain their support					

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6	Waste to energy projects get delayed because of lack of stakeholder engagement in the planning process					
7	Getting buy in from all the actors in the waste value chain is important in setting up a waste to energy facility successfully					
8	Community involvement is a critical factor to a successful set up of a waste to energy project					
	Economic factors					
9	A waste to energy facility needs to make economic sense. It should be able to pay for its costs and generate some surplus amounts of money					
10	Governments can catalyze the success of waste to energy facilities by having incentives in order to attract investors					
	Legislative framework					
11	Having policies that regulate the management of municipal solid waste is a critical factor in successful set up of a waste to energy facility					
12	In order to be successful in setting up a waste to energy facility, a clear regulatory framework to support such set ups should be put in place					
	Management of the municipal waste chain					
13	The generation, collection and transportation of municipal solid waste should be taken into account when setting up a waste to energy					

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	facility					
14	Collection and transportation of municipal solid waste is very important to ensure adequate waste quantities are available for the waste to energy facility					
15	Source separation and recycling is important in determining the final waste composition that reaches the waste to energy facility					
	Political support					
16	In order to be successful in setting up a waste to energy plant, political buy in is extremely important					
17	A project that has political support is more likely to be successful than one that lacks political support					

Section C: Benefits of setting up a waste to Energy facility

1. How would you rank the following benefits of setting up a waste to energy plant in order of importance (on a scale of 1 to 5 where 1 is most important and 5 is least important)

    1. Most Important 2. Important 3. Moderately important 4. Of little importance 5. Unimportant

	1:	2.	3.	4	5
Employment creation					
Carbon credits and carbon finance					
Environmental benefits					
Revenue from sale of power and heat					
Financing and Tax incentives					

Section D: Economic models of implementation

1. There are several options of setting up a waste to energy facility. To what extent do you believe the set-ups below will be successful

	1.Most likely	2.More likely	3.Likely	4.Less likely	5. Least likely
Privatization					
Public private partnerships					
Publicly owned facility					

Section E: Electricity potential

1. In your opinion, what is your estimate of the electricity potential of the municipal solid waste in Nairobi County? Please tick as appropriate.

Power potential(MW)	
0-10	
11-20	
21-30	
31-40	
41-50	
51-60	
61-70	
71-80	
81-90	
>91	

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APPENDIX 2: DATA ANALYSIS

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.501
Bartlett's Test of Sphericity	Approx. Chi-Square	269.466
	df	136
	Sig.	.000

Communalities

	Initial	Extraction
Geographical location	1.000	.837
Environmental impact on location	1.000	.892
Stakeholder involvement in overall project	1.000	.751
Stakeholder involvement in early project stage	1.000	.844
Benefit articulation to stakeholders	1.000	.620
Stakeholder involvement in planning stage	1.000	.911
Buy in from all actors	1.000	.748
Community involvement	1.000	.583
Economic benefit	1.000	.920
Incentives to attract investors	1.000	.734
Policy for waste management	1.000	.837
Supporting regulatory framework	1.000	.795
generation of waste	1.000	.839
Collection and transportation	1.000	.738
Source separation and recycling	1.000	.765
political buy in	1.000	.928
political support	1.000	.933

Extraction Method: Principal Component Analysis.

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Component Matrix[a]

	Component					
	1	2	3	4	5	6
Geographical location	.456	.142	.273	.108	-.692	-.210
Environmental impact on location	.175	-.141	.428	.540		-.606
Stakeholder involvement in overall project	.602	.455	-.241		.348	
Stakeholder involvement in early project stage	.718	.290		.471	.139	
Benefit articulation to stakeholders	.409	.402	-.331		.349	-.236
Stakeholder involvement in planning stage	.771	-.507		-.141	.180	
Buy in from all actors	.208		-.678	.329	-.265	.260
Community involvement	-.342	.250	.137			.619
Economic benefit	.436	-.365		-.741	.213	
Incentives to attract investors	.567	.260	-.271		-.499	.128
Policy for waste management	-.311	.545	.599	-.283		
Supporting regulatory framework	.142	.664	.291	-.468		-.154
generation of waste	.129	.169	.327	.526	.544	.339
Collection and transportation	.701	.401	-.236	-.133		
Source separation and recycling	.521	.485	.340	.125	-.173	.311
political buy in	.589	-.561	.390		-.187	.273
political support	.790	-.437	.275	-.151		.115

Extraction Method: Principal Component Analysis.

a. 6 components extracted.

Component Transformation Matrix

Component	1	2	3	4	5	6
1	.648	.563	.448	-.140	.130	.162
2	-.591	.539	.322	.423	.199	-.195
3	.264	-.415	.157	.718	.385	.264
4	-.326	-.132	.137	-.495	.649	.437
5	.143	.402	-.802	.129	.396	.037
6	.186	-.202	.100	-.155	.466	-.821

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

APPENDIX 3: SUPPORT LETTER FROM SBS

Strathmore Business School

Wednesday, 15 April 2015

To Whom It May Concern:

Dear Sir/Madam,

FACILITATION OF RESEARCH – KOECH CAROL CHEPKEMOI

This is to introduce Koech Carol Chepkemoi, admission number MBA/73195/10 who is an MBA student at Strathmore Business School. As part of our Masters Programme, Carol is expected to do applied research and to undertake a project. This is in partial fulfilment of the requirements of the Master of Business Administration. The outcome would be of immediate benefit to the organizations she is researching on. To this effect, she would like to request for appropriate data from your organization.

Carol is undertaking a research paper on **'Entrepreneurial Opportunities for Converting Municipal Solid Waste to Electricity for Sustainable Waste Management'**

Information obtained from your organization shall be treated confidentially and shall be used for academic purposes only.

Our MBA seeks to establish links with industry, and one of these ways is by directing our research to areas that would be of direct usefulness to industry. We would be glad to share our findings with you after the research, and we trust that you will find them of great interest, if not of practical value to your organization.

We very much appreciate your support and are willing to provide any further information if required.

Yours sincerely,

Eliud Njogu

Ag.DIRECTOR – MBA Programs

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