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OSINDE Anthony

INFLUENCE OF SOCIAL FACTORS ON ENERGY RECOVERY OPTIONS FROM SOLID WASTE GENERATED IN MARKETS:

A Case of Central Division of Kampala.

Defended on 11/11/2020 before the following committee:

Chair: Prof. Hassan Qudrat-Ullah (SAS, Toronto, Canada)

Supervisor: Eng. Dr. Swaib Semiyaga (Makerere University, Uganda)

External examiner: Prof. Tawfik Benabdallah (ENPO, Oran)

Internal examiner: Dr. Abdellah Benyoucef (PAUWES, Tlemcen)

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A thesis submitted to the Pan African University Institute of Water and Energy Sciences (including Climate Change) in partial fulfilment of the requirements for the degree of Master of Science in Energy (Policy option).

By

Anthony OSINDE (B.Eng. Civil)

Supervisor: Eng. Dr. Swaib Semiyaga

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DISSERTATION APPROVAL PAGE

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Submitted by

OSINDE ANTHONY	____________________	19/11/2020
Name of Student	*Signature*	*Date*

Approved by Examining Board

____________________	____________________	________________
Name of Internal Examiner	*Signature*	*Date*
____________________	____________________	________________
Name of External Examiner	*Signature*	*Date*

DEDICATION

I dedicate this piece of work to my beloved parents, wife and children your unconditional love and advise have taken me this far.

PAN AFRICA UNIVERSITY

STATEMENT OF THE AUTHOR

By my signature below, I declare that this dissertation is my work. I have followed all ethical principles of scholarship in the preparation, data collection, data analysis, and completion of this dissertation. I have given all scholarly matter recognition through accurate citations and references. I affirm that I have cited and referenced all sources used in this document. I have made every effort to avoid plagiarism.

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Student

Name: Anthony OSINDE Signature: ____________________________

Date: **19/11/2020**

Academic Unit: Energy (Policy Track)

PAU Institute: PAUWES

Supervisor

Name: Eng. Dr. Swaib Semiyaga Signature: ____________________________

Date: **28th November 2020**

Department of Civil & Environmental Engineering

Makerere University

BIOGRAPHICAL SKETCH

Anthony Osinde is one of the few Ugandan who have been privileged to obtained a fully paid scholarship at Pan African University Institute for Water and Energy Sciences (PAUWES) through the African Union Commission (AUC). He was born and raised in the Eastern part of Uganda (Kigandalo, Mayuge district). He holds a Bachelor's degree in Civil Engineering from Ndejje University in Uganda. Anthony has served as a volunteer at the Energy Research and Development Centre, Ndejje University from August 2014 to September 2015. He later served as a Laboratory Technician as well as Research Assistant in the Renewable Energy Lab at Ndejje University from 2015 to 2018. He also served as a Teaching Assistant at the same University focusing his teaching on Renewable Energy technologies, Introduction to Engineering and Engineering Mathematics. Anthony's interest in Energy policy was drawn from his passion for clean cooking and unregulated cooking energy supply which has led to rapid deforestation. He strongly hopes to contribute to the clean cooking sector upon completion of his studies at PAUWES. During the course at PAUWES, in 2019 Anthony undertook a two months' career internship with Ministry of Energy and Mineral Development (MEMD). He also recently participated in a study to investigate the impact of Covid-19 lockdown on Energy access in Uganda. He is currently involved in a study to determine the technical and economic feasibility of Bamboo briquettes as an alternative energy source for cooking needs in Uganda.

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ACRONYM AND ABBREVIATION

AD – Anaerobic Digestion

AHP - Analytical Hierarchy Process

CBOs - community Based Organisations

GGGI - Global Green Growth Initiative

ISNAD - International Support Network for African Development

KCCA – Kampala Capital City Authority

LFG - Landfill Gas

MCDM - Multi-Criteria Decision Making

MRP - Mentoring for Research Programme

MSW – Municipal Solid Waste

MSWM - Municipal Solid Waste Management

NEMA – National Environment Management Authority

NGOs - Non – Government Organisation

NIMBY - Not-in-my-back-yard

OFMSW - Organic Fraction of Municipal Solid Waste

WBA - World Bioenergy Association

WtE - Waste-to-Energy

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ABSTRACT

Sub-Saharan African cities have faced problems associated with poor Municipal Solid Waste Management (MSWM) as well as inadequate electricity access. This has brought about several economic, social, environmental and health issues. The organic fraction of municipal solid waste (MSW) is relatively high in developing countries as compared to the developed countries. The development and implementation of sustainable solid waste management system is a viable aspect when based on an integrated and holistic approach. Depending on the purpose of the waste treatment, nature and composition of the waste, there are several integrated systems such as; incineration, landfilling, gasification, recycling and anaerobic digestion technologies. Given the fact that MSW in Kampala city (Uganda) has over 73% organic fraction, this study aimed at determining the **Influence of social factors on energy recovery options from solid waste generated in markets: a case of Central division of Kampala.** It entailed comparative analysis of energy recovery technologies such as Gasification, Anaerobic digestion, Landfill gas recovery and incineration.

The required primary and secondary data from the study areas of Nakasero market, Owino market and Usafi market were collected by use of survey questionnaires, face-to-face interviews, and through direct observation. The results were analysed using Kobo tookbox, and Superdecision software (MCDA, AHP). From collected data, the solid waste from the markets were mostly composed of 36.41% were plastics (bottles, polythene bags among other), 32.04% (spoilt fruit and vegetables), 31.55% peelings (cassava, potatoes, bananas among others). The technology evaluation, the Landfill gas recovery has the highest score of 0.3264 which makes it the most suitable technology option followed by Anaerobic digestion (0.2870), incineration (0.2480) is the third preferred option while Gasification has the least score (0.1384). This appropriate integration of technologies is expected to result into improved sustainability (economically, socially and environmentally) for the entire MSWM system, increase on the energy supply, reduction on the overall GHG emission from the waste, bio slurry for the urban farmers, several employment opportunities and evidence based decision and policy making.

This study also further recommends that more emphasis is put in capacity building and sensitizing communities especially market vendors on the value and benefits of proper waste management including the 4Rs (Reduce, Reuse, Recycle and Rethink). Sensitization directly impacts of social wellbeing and behaviour of waste generators and handlers hence facilitating Energy Recovery process as well as enhancing Public Private Partnership.

Résumé

Les villes d'Afrique subsaharienne ont été confrontées à des problèmes liés à une mauvaise gestion des déchets solides municipaux (GDSM), ainsi qu'à un accès insuffisant à l'électricité. Cela a entraîné plusieurs problèmes économiques, sociaux, environnementaux et sanitaires. La fraction organique des déchets solides municipaux (DSM) est relativement élevée dans les pays en développement par rapport aux pays développés

Le développement et la mise en œuvre d'un système de gestion durable des déchets solides constituent un aspect viable lorsqu'ils sont basés sur une approche intégrée et holistique. En fonction de l'objectif du traitement des déchets, de la nature et de la composition des déchets, il existe plusieurs systèmes intégrés tels que; technologies d'incinération, de mise en décharge, de gazéification, de recyclage et de digestion anaérobie.

Étant donné que les DSM dans la ville de Kampala, en Ouganda, ont plus de 73% de fraction organique, cette étude visait à déterminer l'influence des facteurs sociaux sur les options de récupération d'énergie à partir des déchets solides générés sur les marchés: le cas de la division centrale de Kampala. Elle impliquait une analyse comparative des technologies de récupération d'énergie telles que la gazéification, la digestion anaérobie, la récupération des gaz d'enfouissement et l'incinération.

Les données primaires et secondaires requises de la zone d'étude (marché de Nakasero, marché d'Owino et marché d'Usafi) ont été collectées à l'aide de questionnaires d'enquête, d'entretiens individuels et d'observation directe. Les résultats ont été analysés à l'aide du logiciel Kobo takebox et Superdecision. D'après les données collectées, les déchets solides des marchés étaient majoritairement composés à 63,03% de plastiques (bouteilles, sacs en polyéthylène entre autres), 55,46% (fruits et légumes avariés), 54,62 épluchures (manioc, pommes de terre, bananes entre autres). L'évaluation de la technologie, la récupération de gaz de décharge a le score le plus élevé de 0,3264, ce qui en fait l'option technologique la plus appropriée suivie de la digestion anaérobie (0,2870), l'incinération (0,2480) est la troisième option préférée tandis que la gazéification a le moindre score (0,1384).

Cette intégration appropriée des technologies devrait entraîner une amélioration de la durabilité (économique, sociale et environnementale) pour l'ensemble du système MSWM, une augmentation de l'approvisionnement énergétique, une réduction de l'émission globale de GES des déchets, du lisier biologique pour les agriculteurs urbains, plusieurs emplois les opportunités et la prise de décisions et de politiques fondées sur des données probantes.

1. INTRODUCTION

1.1 Background

The rapid increase in urban population of African cities is projected to triple from 470 million in 2015 to about 1.2 billion by 2050 (United Nations., 2014). This growth in population has led to future projections of annual waste generation to increase by over 60% in East African countries by 2030 (Aryampa, Maheshwari, Sabiiti, Bateganya, & Bukenya, 2019). A study by (Alam & Ahmade, 2013 ; Khajuria, Yamamoto, & Morioka, 2010) also attributes the increasing rate of waste generation globally to urbanisation and population growth which also doubles as a problem of Municipal Corporation. The generation of MSW is an issue of worldwide concern with its management becoming a noteworthy concern within the government departments, pollution control agencies, regulatory bodies and general public in the developing countries (Khajuria *et al*., 2010). Globally, in 2017 over 2.01 billion metric tonnes of MSW was generated, with projections in annual generation to reach 3.40 billion metric tonnes by 2050 (Panigrahi & Dubey, 2019).

The per capita solid waste generation in Kampala has increased from 0.34 to 0.38 kg/capita/day with associated annual waste quantity in the span of 4 years (2014 to 2018) (Global Green Growth Institute, 2018). The rate of solid waste generation in Kampala in 2015 was estimated at 3,206 tons per day and expected to increase to 4,739 tons per day by 2030, however, only 45 to 50% of the generated waste is collected and disposed to Kiteezi landfill (Global Green Growth Institute, 2018). Kiteezi landfill is the only official facility for waste disposal for Kampala city but it is currently full to capacity even after being subjected to expansion from the initial designed total surface area of 0.04 km^2 to 0.11 km^2 (Kinobe, Niwagaba, Gebresenbet, Komakech, & Vinnerås, 2015). In the analysis of the waste collected in 2012, it was estimated that 9% and 18% of the solid waste was generated from markets and institutions (schools and upscale residential areas), respectively (Kinobe *et al.*, 2015).

The high annual population growth rate at 4.03% and annual urbanisation rate of 5% in Kampala (UBOS, 2017 ; United Nations., 2014), signifies continuous rise in waste management challenge if no integrated waste management system is adopted. As developing countries still face challenges with waste management, the developed countries are already exploiting MSW as a renewable energy resource (Moya, Aldás, López, & Kaparaju, 2017)

Adoption of integrated solid waste management approach, including resource recovery with limited landfilling, the urban centres, public places (such as markets) and institutions will sustainably manage the waste with minimal costs and limited environmental damages

(Aryampa *et al*., 2019). As stated in the global sustainable development goal 7, the energy recovery process is a forward step towards ensuring access to affordable, reliable, sustainable and modern energy for all. With application of proven waste to energy technologies, and green economy concepts, the high concentrations of wastes can be turned into renewable energy resources and or compost for plant nutrients. However, these resource recovery options are dependant and largely influenced by the social factors such as level of education, income, age, religion, marital status among others (Hammed, Wahab, & Sridhar, 2016 (Rahardyan, Matsuto, Kakuta, & Tanaka, 2004). Zurbrügg *et al*., (2013) noted that relying on technological solutions alone is not enough since the understanding of social aspects is very significant in determining rate of adoption, benefits, and impacts of technology use. An integrated approach which considers social, economic, institutional, legal, technical and environmental issues and tries to balance these to obtain best practicable means to manage waste is necessary. This study therefore aims at examining how the social factors influence the adoption of energy recovery options from MSW generated in markets.

1.2 Problem Statement

Public places such as markets have high solid waste intensity which is associated with high population density (Aye & Widjaya, 2006). The solid waste from such areas in Kampala have high fractions of organic content estimated at over 90% and high moisture content (Schoebitz, Nguyen, Tran, Dang, & Strande, 2014). It is also noted that the waste from these markets are more uniform, more concentrated and less hazardous given the activities leading to generation of these wastes (Aye & Widjaya, 2006). The high intensity of moist solid waste is not only bulky to handle but also pose high management challenges and costs which leads to management inefficiencies and irregularities.

On the other hand, there is an increase in urban energy consumption due to an increase in population (Mukwaya, 2016; Li & Yao, 2009 and Karekezi & Majoro, 2002). The energy requirements range from household to commercial or industrial in form of heat and or electricity for lighting, cooking among other uses. There are various processes through which this energy can be recovered from solid wastes such as anaerobic digestion, landfill gas recovery, gasification and or incineration. The success for uptake of these processes/technologies depends on various factors including social, cultural, economic among others (Gakungu, Gitau, Njoroge, & Kimani, 2012). However, the knowledge, attitudes and social practices of people form a very crucial part in the selection of the technology to be applied. This research therefore looked at how the social factors influence energy recovery options from solid waste generated in markets within Kampala Central division.

1.3 Main objective

This study is aimed at determining the influence of social factors in establishing the energy recovery options from solid waste generated in markets in the Kampala central division.

1.4 Specific Objective

i. To examine the current status of solid waste management in markets in Kampala central division.
ii. To assess people's attitude about energy recovery options from solid waste.
iii. To evaluate the suitable and applicable energy recovery option from the solid waste.
iv. To recommend strategies for effective solid waste management in markets.

1.5 Research questions

i. What waste management strategy exists? What are some of the weaknesses and strengths of the existing strategy towards solid waste management?
ii. How do people perceive and understand the options of energy recovery from solid waste?
iii. What is the most suitable technology option for waste-to-energy conversion for market wastes

1.6 Significance of the study

The social and economic understanding of a technology is in most cases paramount in determining the significant benefits, impacts and costs mounting to utilisation of the technology (Ni & Nyns, 1996). The rate of adoption, development and management of the waste to energy (WtE) technologies is more inclined to social aspects in relation to human behaviour and less of a pure technical aspects (Zurbrügg *et al*, 2013), adding that the users acceptance and perception of the technology influences successful and durable performance. Singh & Sooch, (2004) reports that the full potential of the biodegradable material may not be harnessed just because of lack of awareness about the suitable type of WtE technology to be used. However, the technical considerations of WtE technologies are more less the same for different countries while the social aspects vary for different societies (Yap & Nixon, 2015).

Kampala being the only capital city and the largest city as well as the economic engine of Uganda, her population is full of diverse ethnic groups all with different origins from different parts of the country and even from the neighbouring East African Countries (Uganda Bureau of Statistics, 2016). The emphasis of this study enlighten the uniqueness of the social aspects of age, income, education level, marital status among others in Kampala Central division. Without determining the influence of social aspects in energy recovery, the feasibility and viability of WtE technologies will still remain unrealistic to ascertain.

1.7 Scope of work

1.7.1 Content Scope

This study is grounded on the energy recovery options from Municipal Solid Waste (MSW) in markets, understanding how the social factors influence these recovery options. It as well involves examining the status of waste generation, collection, transportation, disposal and the associated challenges. The attitude and perception of the market occupants/venders which forms a basis on energy recovery is as well assessed in this study.

1.7.2 Geographical Scope

This research was conducted in the Central division of Kampala city. The coordinates of the division are: 0°19'00.0"N, 32°35'00.0"E (Latitude:0.316667; Longitude:32.583333). The division is one of the 5 administrative divisions of Kampala Capital City. The city harbours many people with different origins who move to the city for various reasons including socio-economic needs, business, formal and informal jobs, and or better life style among others. This movement of people is one of the factors contributing to the urban population growth which translates to increase in solid waste generation. In order to keep a clean and attractive city, proper waste management including energy recovery is an option to consider.

1.7.3 Time Scope

The time scope of the study is between September 2019 to August 2020. This time is based on the university program for research work. This study period also comes in time when Kampala is experiencing rapid population growth and urbanisation, harbouring over 80% of the country's industrial and commercial activities and contributing more than a half of Uganda's GDP (Wang *et al*., 2019).

1.8 Structure of the Report

This report is structured and contains five chapters including chapter one: Introduction, chapter two: Literature review, chapter three: materials and methods of the study, chapter four: results and discussion, chapter five: Summary, conclusion and recommendation.

2 LITERATURE REVIEW

2.1 Introduction

This section gives the overall conceptual understanding and review of the related studies that have been conducted regarding energy recovery options and how they are influenced by the social factors.

2.2 Definition of Key Terms

Some of the key terms used in relation to this study are defined as below: -

i. Municipal solid waste (MSW)

MSW can be defined as the aggregate of the discarded unwanted materials, which are generated from the daily activities of man as they interact with their environment. These solid waste includes all domestic refuse and non-hazardous wastes such as commercial, industrial and institutional wastes (Speight, 2015)

ii. Solid waste management (SWM)

Referred to as the process of collecting, disposing and treating of solid waste materials that has served the purpose and are no longer useful. SWM involves the activities required to manage waste from its generation to its final disposal. This includes the collection, transportation, treatment and disposal of waste, together with monitoring and regulation of the waste management process (Zurbrügg, 2013)

iii. Sanitary landfill

Is a well designed and built structure where the solid waste is disposed of and isolated from the surrounding environment. It has a bottom liner that protects the groundwater from the leachate coming from the decomposing wastes and it involves daily covering of the waste disposed with a layer of soil (Lee *et al*., 1994)

iv. Social factors

This can be defined as the facts and experiences that influence individuals' personality, attitudes and lifestyle. Example includes; wealth, religion, social class, education level, family size and structure and population density among others (Ali & Siong, 2016).

v. Energy recovery

Also known as waste-to-energy (WTE) is defined as the conversion of non-recyclable waste materials into usable energy in various forms of heat, electricity, or fuel through several processes such as incineration/combustion, gasification, pyrolization, anaerobic digestion, and or landfill gas (LFG) recovery (Moya *et al*., 2017).

2.3 Municipal solid waste management

Municipal solid waste management is one of the major challenges faced by most cities especially in developing countries. Most urban centres in developing countries lack effective waste collection and disposal mechanisms. In developed countries, well mechanized and efficient systems facilitate the collection and proper disposal of over 90% of the waste generated while in developing countries less than 50% of the waste generated is collected (Malinauskaite *et al*., 2017). As such, most people in developing regions do not access adequate waste management services and therefore use rudimental methods to dispose their wastes.

2.3.1 Municipal solid waste management strategy

Human activities create waste, but it is the way in which these wastes are handled, stored, collected, and disposed of that can pose a risk to the environment and public health. In places with intense human activities such as urban centres, appropriate and safe solid waste management is of great importance in providing healthy living conditions for residents. Though most governments in developing countries acknowledge this fact, many municipalities struggle to provide even the most basic of services (Zurbrügg *et al*, 2013). Zurbrugg further argues that the importance of ensuring proper SWM is well perceived and recognised as one essential element of sustainable development.

Solid waste generation is a part of every human and human activity. The limited and or distant disposal infrastructure has always slowed down the daily efforts of collection and disposal of municipal solid waste. As discussed by (Aliu, Adeyemi, & Adebayo, 2014), the visible municipal service of urban solid waste collection is associated not only with large expenditures but also with challenging operational setup such as investment for vehicle fleet, operational costs and environmental cost (emission, noise, and traffic congestion). Waste collection problems in sub Saharan African countries have been attributed to insufficient public awareness, insufficient legislation, inappropriate technology, poor infrastructural maintenance, education, corruption among others (Ufoegbune & Oyedepo, 2012).

In most African cities and their suburbs, different waste generation points use baskets, sacks, plastic bags, among others which are then picked by waste collectors using push carts to the temporary storage / transfer site for the pick up by trucks to the final disposal site. Frequencies and regularity of solid waste collection according to (Mohammed, & Elias, 2017) is poorly maintained and this is mainly attributed to poor pay and inadequate labourers. It is also noted that in most of African cities, one of the notable challenges have been shortage of waste containers and poor handling of the waste before final disposal. This challenge therefore hinders the proper collection of solid wastes leaving the nearby residents in unsuitable environment.

As it is for every city, municipality or town to have an authority for waste management, in Uganda KCCA is authorised under Section 5 of The Public Health Act, Cap. 281 and Local Government Act of 1997 to ensure collection and management of MSW (Komakech *et al*., 2014). KCCA further contracted several private companies to assist her in solid waste collection, transportation and disposal within the 5 divisions (Makindye, Nakawa, Rubaga, Central and Kawempe division). (Daniel Hoornweg and Perinaz Bhada-Tata, 2015.) reveals that in urban areas, the quantity of MSW is growing even faster than the rate of urbanisation. The growth indicates an increase from 2.9 billion residents who generated 0.68 billion tonnes per year to 3 billion residents generating 1.3 billion tonnes per year. Kampala Waste Treatment and Disposal PPP project, per capita waste generation increased by 12% since 2014 from 0.34kg to 0.38kg in 2018. Kampala Capital City Authority (KCCA) and other 35 licenced waste collectors can manage to collect up to 45% of the total waste generated and transport it for disposal at Kiteezi, the official landfill (Global Green Growth Institute, 2018). At the landfill are several scavengers who pick items with some market value such as paper, metal, and plastics.

The collected solid waste in the city is heterogeneous in nature since they are composed of mixed paper, plastic, cloth, metal, glass and organic matter among others being generated from households, institutions, commercial establishments and markets

2.3.2 Transportation and disposal practices of solid waste

The heterogeneous waste collected from various generation points such as households, commercial setups, schools and markets composed of organic matter, mixed paper, plastic, cloths, metal scraps and glass. According to (Zurbrügg *et al*, 2013) there exists a big difference between the quantity and type of waste generated at different places depending on the living standards, consumption pattern and economic activities.

The improper transportation and disposal practices of solid waste leaves a polluted environment in the form of polluted air, land, and water. A study by (Kinobe *et al*., 2015) points out that the process of waste transportation involves solid waste preliminary treatment to enable recycling purpose or transformation at various levels. The recyclable materials, reusable materials and materials with some market value have to be separated for final disposal. The impacts of improper waste collection, transportation, and disposal only get worse with increase in population (Aryampa *et al.*, 2019). This adversity is further pointed by (Lee et al., 1994) as hazardous chemicals and contaminants are always released at the landfill and other disposal sites.

Disposal of solid waste generated in a community is the ultimate step in a solid waste management system (Ufoegbune & Oyedepo, 2012). According to (Zurbrügg *et al*, 2013) municipalities in most of the low income economies often lack sufficient equipment for transportation and management of waste. The various types of waste disposal according to (Ufoegbune & Oyedepo, 2012) have been classified as uncontrolled open dump sites, controlled dumpsite and sanitary landfill.

In Kampala, the solid waste collected from all the five divisions are transported by trucks owned by either KCCA or private waste collectors to Kiteezi landfill, located about 12 km from the city centre. The waste is then spread and scattered using a crawler truck to facilitate decomposition and spread with insecticide to kill off flies before a soil layer is added for covering.(Komakech *et al*., 2014). However, there has been reports of complaint by the residents near the landfill due to bad odour, water pollution by leachate, mosquitoes and flies, scattering of waste by scavengers and wind and this all together makes the place undesirable for residence as well as loss of value of the surrounding land (Komakech *et al*., 2014 ; Mwiganga & Kansiime, 2005).

2.4 Energy recovery from solid waste

Energy recovery from waste (Waste to Energy conversion) is gaining widespread recognition and acceptance worldwide due to its ability to greatly reduce volumes of waste at the same time harnessing the energy embedded in the waste for useful purposes. Biodegradable waste among other solid wastes can be of a pivotal role in energy production through several options of biochemical transformation, thermochemical, and conventional combustion (Nzila, Dewulf, Spanjers, Kiriamiti, & van Langenhove, 2010). A study by (Tan, Hashim, Lee, Taib, & Yan, 2014) also postulates that energy generation from the waste is recognised as a promising alternative to overcoming waste generation problem and a potential renewable energy source. (Yuan *et al*., 2019) notes that energy recovery practices have competitive advantages including small land occupation, good volume reduction effect, stability and minor secondary pollution and also regarded as one of the most effective means of disposal currently and in the near future

2.4.1 Energy recovery technology options

Energy is recovered from the waste either in the form of electricity and/or heat, biogas and other transportation fuels mainly after the primary treatment of waste. There exist various technology options for energy recovery from MSW which mainly include thermal conversion processes (incineration, pyrolysis, gasification, production of Refuse Derived Fuel (RDF)), biochemical conversion (composting, bio-methanation and anaerobic digestion) and chemical conversion (esterification, ultrasonic reactor method, supercritical processes) (R. P. Singh, Tyagi, Allen, Ibrahim, & Kothari, 2011). Within the thermo-conversion route, incineration is currently the most utilized technology for energy recovery from waste, with generation of electricity and heat and also a decrease in the volume of the produced waste. Gasification and pyrolysis are alternatives for the production of chemical products from wastes. The biological route is an alternative for the utilization of the organic fraction of solid waste. The anaerobic processes enable the production of biogas and of bio slurry used as a fertilizer in the farm. More than one technology can be combined for a better energy usage of waste and it is dependent on the size of the population, composition of waste, and products to be obtained (Palacio *et al*., 2018.). The characteristics of waste are greatly considered in selecting the choice of WtE technology to be applied. Other variables for efficient energy recovery is the quality of waste (Komakech *et al*., 2014)

2.4.1.1 Biochemical conversion technology

This technology process is based on enzymatic decomposition of organic matter by microbial action to produce methane gas or alcohol. The biochemical conversion processes are preferred for wastes having high percentage of organic (biodegradable) matter and high level of moisture/ water content, which aids microbial activity.

Anaerobic digestion

Anaerobic digestion consists of a set of processes in which microorganisms consume the organic matter present in organic waste in the absence of oxygen. The process results into production of a combustible gas containing 40–70% methane, 30–40% carbon dioxide, 1 –5% hydrogen and traces of nitrogen, hydrogen sulphide, oxygen and water vapours. The anaerobic process also occurs naturally in some types of soil and in the sediments settled on the bottom of a water body including rivers, lakes, oceans, and swamps where oxygen cannot penetrate (Palacio *et al*., 2018.) There are several chemical reactions associated with conversion processes, which are in chemical balance. Generally, although some authors classify the anaerobic digestion process in two or even three steps, it is more common to utilize four steps to describe the process, as depicted in the table 2.1 below.

Table 2.1. Description of the anaerobic digestion phases. Source: (Palacio *et al*., 2018.)

Sn.	Step	Description
1	Hydrolysis	Organic polymolecules are cracked into standard molecules such as sugar, amino, and fatty acids with the addition of hydroxyl groups. This is accomplished by hydrolytic bacteria.
2	Acidogenesis	Sugars, fatty and amino acids are converted into smaller molecules, with the formation of volatile fatty acids (acetic, propionic, butyric, and valeric acids) and production of ammonia, carbon dioxide, and H_2S as sub products.
3	Acetogenesis	The molecules produced during acidogenesis are digested, producing carbon dioxide, hydrogen, and acetic acid.
4	Methanogenesis	Formation of methane, carbon dioxide, and water.

The process of anaerobic digestion can occur in controlled environments, such as in bio-digesters, which recover energy from waste, and in sanitary landfills. Sanitary landfills are locations for the controlled disposal of waste, reducing its negative environmental impact, and for the control of lixiviate material. Some landfills generate electricity from the biogas produced. Anaerobic digestion (AD) is one of the most promising technologies for waste-to-energy conversions of organic waste to bioenergy including methane-rich gas and bio-slurry (a fertilizer product) (Zulkifli *et al*., 2019.).

Landfill gas recovery

Landfill gas (LFG) is formed when organic wastes decompose anaerobically in a landfill. Although LFG gas is generated under aerobic and anaerobic conditions, the initial aerobic phase is short-lived and produces a gas with a much lower energy content than does the long-term anaerobic phase which follows. For the estimation of the amount of biogas that can be produced, there are several models developed. According to (Kamalan H, Sabour M, Shariatmad N, 2011.) the models are categorised into the following;

Zero order model; in this model, the biogas generated doesn't change with time. The age and type of waste under this model has no influence on the gas production

First order model; this order considers the quality of the waste including moisture and carbon content, age of waste and its ability to be biodegraded.

Second order model; using largely the first order model, the second order model describes the reactions occurring during the degradation of waste.

Numerical and mathematical models; consider the different variables involved in the process, and require a higher number of inputs.

2.4.1.2 Thermo-chemical conversion technology

The thermochemical process involves thermal decomposition of non-biodegradable organic matter to recover either heat energy or gas or fuel oil. It is also associated with lower masses (75% weight reduction) and volumes (90% reduction) of waste, reduced landfill space, destruction of organic pollutants (halogenated hydrocarbons) and reduced emission of GHG for open decomposition of waste (Begum, Rasul, & Akbar, 2012) ; (Palacio *et al*., 2018.). under this WtE technology options there are different categories including Combustion, Gasification, Pyrolysis and Incineration (Begum et al., 2012). For the case of incineration, the energy value embedded in the waste can be recovered through a sequence of exothermic chemical reactions, however, for pyrolysis and gasification it is the chemical value of waste that is recovered. The derived chemical products, in some cases, can be utilized as inputs in other processes or as secondary fuels (Palacio *et al*., 2018.). Figure 2.1 below indicates thermochemical conversion processes, the products involved, and energy and material recovery systems

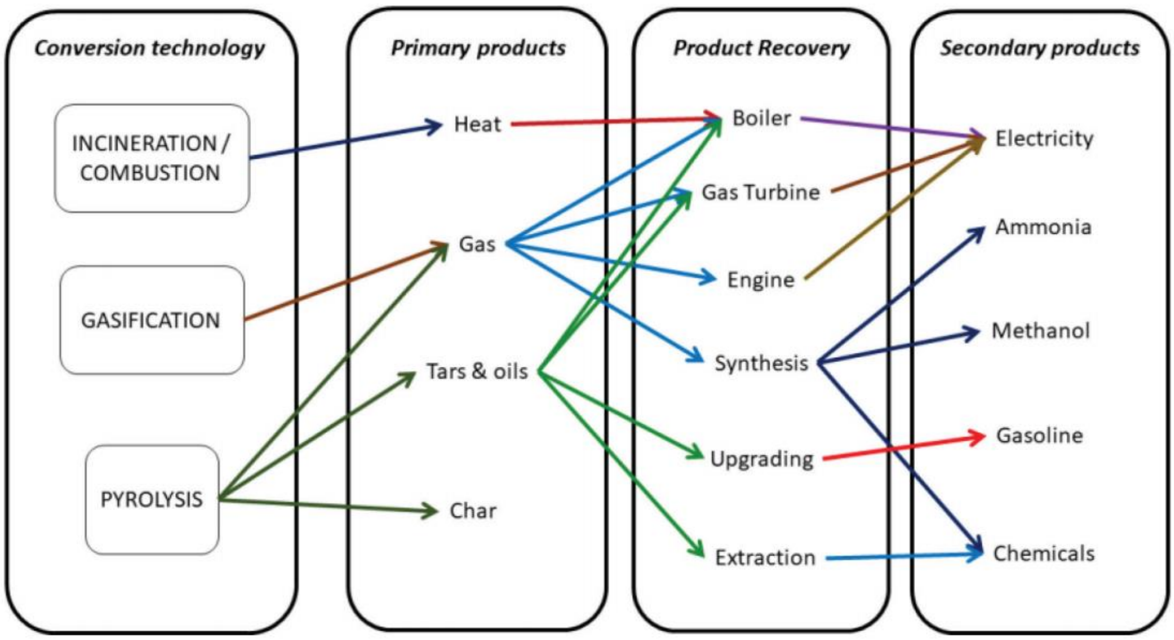

Figure 2.1: thermochemical conversion technology, processes and products. Source (Begum *et al*., 2012)

Incineration

Incineration is a controlled burning / combustion process aimed at size reduction of solid, liquid, and or gaseous combustible waste into carbon dioxide, water vapour, heat (thermal energy) and other gases. It is widely applied in waste management for both hazardous and non-hazardous waste. The relatively small non-combustible residue can then be processed for other purposes or landfilled in an environmentally convenient way (Begum *et al.*, 2012). During the incineration process, there are possibilities of recovering mineral, energy and chemical content of waste for other processes.

Under combustion, there are different processes applied for thermal treatment of waste such as fluidized bed combustion, grate combustion and rotary furnace or rotary kiln. Grate combustion (mass burn combustion) is the most utilized option due to its ability to handle larger objects with crushing only required for the oversized materials (Palacio *et al.*, 2018.).

Gasification

Gasification is defined as the thermal conversion process of a solid or liquid carbon based material into a mixture of combustible gaseous products including syngas. Gasification is applied not only in converting coal and coke to gas but also solid biomass material. By means of high temperature, the chemical structure of biomass is changed through the thermal chemical conversion processes (Begum *et al.*, 2012). In comparison with combustion and pyrolysis, gasification process is more technologically complex and it involves relatively high temperatures above 700°C, partial oxidation process (using air, pure oxygen, hydrogen), produces electricity and fuels such as methane, hydrogen, ethanol, synthetic diesel) and other chemical products.

The gasification process is broadly characterised by the following stages (Puig-arnavat, Bruno, & Coronas, 2010) ; (Begum *et al.*, 2012).

- Drying; the moisture content of the solid biomass is reduced at this stage. The reduction in moisture content from the typical range of 5% - 35% is reduced to less than 5% at a temperature about 100 - 200°C
- Devolatilisation (pyrolysis); this stage involves the thermal decomposition of the biomass/ solid waste in absence of air or oxygen. The volatile matter in the biomass is also reduced at this stage resulting into release of hydrocarbon gases from the feedstock material (biomass)
- Oxidation; here the reaction between solid carbonised biomass and oxygen occurs resulting in formation of CO_2. The available hydrogen in the biomass is also oxidised to generate water.
- Reduction; in the absence of oxygen and at a temperature range of 800 – 1000°C, several reduction reactions take place and these are mostly endothermic reactions.

The gasification of biomass (solid waste) is an effective energy recovery option in reducing the amount of waste in a relatively faster manner than the conventional processes. The process of integrated gasification and combustion emits dioxin and furan within acceptable limits established by national and international agencies (Thakare & Nandi, 2016).

Pyrolysis

Pyrolysis is one of the energy recovery options from solid waste. It involves thermal degradation of organic matter in an oxygen-deficient (limited oxygen) atmosphere at a temperature range of 400 – 900°C releasing gas, liquid and solid products. The quality and quantity of products of pyrolysis are dependent on waste type, reactor system, gas residence time, heating rate, temperature and presence of catalyst (Velghe, Carleer, Yperman, & Schreurs, 2011)

2.5 Evaluation of the energy recovery technologies

As the sustainable alternatives for WtE technologies grow in number and complexity, the need of a suitable decision-making model for effective evaluation of these technology options is more emphasized. Various decision making models have been established to deal with the selection of the most appropriate and suitable alternative for energy recovery from MSW (Khoshand, Kamalan, & Rezaei, 2018). Following diverse criteria which are partially or completely conflicting for assessing different technology options, models based on the use of multi-criteria decision-making (MCDM) methods could be considered as appropriate techniques. Among the various MCDM methods, Analytic Hierarchy Process (AHP) is the most popular MCDM method which is widely adopted for analysing decision problems in a several disciplines such as waste management and renewable energy and waste to energy (Nixon, Dey, Ghosh, & Davies, 2013).

2.5.1 The Analytical Hierarchy Process (AHP)

The AHP is a multi-criteria decision making tool, quite often used to solve complex decision making problems in various disciplines including waste management, manufacturing industry, power and energy industry, environmental management, transportation industry, construction industry, among others (Stefanovi, Dassisti, Markovi, & Vu, 2014). The AHP employs a mathematical approach to structure and analyse relevant information which helps in obtaining the best option from many alternatives. The mathematical computations done in the AHP involve, first and foremost, pairwise comparisons. These comparisons are crucial for obtaining pertinent data suitable for use in the AHP tool. By carrying out pairwise comparisons of the evaluation criteria, the weights of importance of the criteria can be obtained with the higher weight showing the more important criterion. Then, for each criterion, the relative performance of each technology option is also obtained.

In solid waste management, the AHP method is used to evaluate options for energy recovery from municipal solid waste (Yap & Nixon, 2015) ; (Khoshand *et al*., 2018). It has been also used to evaluate solid waste treatment technology (Nixon *et al*., 2013) and to select between different waste management plans to implement in Boston, USA (Contreras, Hanaki, Aramaki, & Connors, 2008). In a study conducted (Khoshand *et al*., 2018), the energy recovery from MSW in Tehran, Iran was assessed using AHP model. The results indicated that anaerobic digestion is the most suitable alternative due to the associated comparative advantages of better environmental and economic aspects while LFG energy was ranked as the least preferred alternative due to associated environmental challenges. The most of applications of AHP method indicates that AHP is a powerful decision tool assisting the decision makers to solve complex problems with multiple conflicting and subjective criteria in simplified way.

The AHP hierarchical structure allows decision makers to easily comprehend problems in terms of relevant criteria and sub-criteria. Furthermore, if necessary, it is possible to compare and prioritize criteria and sub-criteria in the AHP practice, and one can effectively compare optimal solutions based on the information (Stefanovi *et al*., 2014).

Table 2.2: Basic scale of pairwise comparison

Intensity of importance	Definition	Explanation
1	Equally important	Two elements have equal importance regarding the objective
3	Weak importance of one over another	Experience or judgment slightly favour one element over another
5	Essential or strong importance	Experience or judgment strongly favour one element over another.
7	Demonstrated importance	An activity is strongly favoured and its dominance is demonstrated in practice
9	Extreme importance	The highest order dominance of one element over another
2,4,6,8	Intermediate values between the two adjacent judgements	When compromise is needed

Adopted from (Saaty's, 1977)

The AHP tool is implemented in three steps as mentioned below.

Step 1: Determining the criteria weight vector

Step 2: Determining the matrix of alternative priority scores

Step 3: Determining the rank of the alternatives

Checking for consistency

The existence of a large number of evaluation criteria and alternative options poses a challenge of maintaining consistency while carrying out a large number of pairwise comparisons. To determine whether the judgements for the comparisons are consistent, the AHP involves the determination of the consistency index, CI, given by:

$CI = \frac{(\lambda - m)}{m-1}$, where λ is the Eigen value, which is a scalar quantity that is determined from the built matrices, and *m* is the number of decision criteria.

For a given evaluation to be perfectly consistent, CI should be equal to zero. However, small inconsistencies in the evaluation are tolerated. As indicated by (Saaty., 1977), if CI/RI < 0.1, the inconsistencies can be tolerated and the results from the AHP are expected to be reliable. RI is the Random Index, which is the consistency index when the entries of a given matrix are completely random. Below is a table with RI values.

Table 2.3: RI table values

Size of matrix (m)	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

2.6 Influence of Social Factors on WtE

Influence of social factors on waste generation, collection, transportation and disposal

The term *social* implies individual well-being as well as the interaction between different individuals. Depending on a society’s level of development, an individual member of society aspires to different levels of needs as articulated in Maslow’s hierarchy of needs. These needs translate into waste (Assefa & Frostell, 2007). Sustainable development of energy systems is becoming increasingly more important for policy and decision makers worldwide. It is also noted that the sustainable development of energy systems requires considerable attention to all the three sustainability dimensions such as economic, environmental and social (Santoyo-castelazo & Azapagic, 2020).

Within the mainstream social impact assessment, (Assefa & Frostell, 2007) summarises social impact as changes to peoples: way of life (how they live, work, play), culture (shared beliefs, customs, values), community (stability, cohesion, services, and facility), political systems (participation in decision), environment (availability, quality and access), health and well-being, personal and property rights, fears and aspirations. The author also adds that acceptance of technology is a function of different indicators such as knowledge, perception, and fear. Knowledge indicates the public's knowledge of the different aspects of the technologies in focus, the purpose of using perception as an indicator is to gather information on what respondents think about the physical and psycho-sociological health implications of different aspects of the technologies, fear as an indicator expresses the level of fear of the technologies being considered.

The attitude and awareness towards energy recovery varies widely with different socio-demographic factors such as age of the respondents, education and income (Yuan *et al*., 2019). In order to promote energy recovery practices, (Yuan *et al.*, 2019) also adds that respective governments should conduct mass sensitization to create more awareness. It is also noted that people with older ages above 50 years, people with low income and low level of education lack the awareness and knowledge about waste-to-energy.

2.6.1 Education

A study conducted by (Masoud, Ghasem, Omrani, Karbassi, & Fakheri, 2012) noted that level of education was negatively correlated with the generation of solid waste. Kendall cohesion coefficient, and linear regression analysis was applied in the study. In the other hands, (Sujauddin, 2008) shows a positive correlation between the level of education and solid waste produced. He further noted that with higher education level, the individuals' consumption pattern changes which finally influences the nature and quantity of waste generated.

2.6.2 Attitude / awareness

The stronger the intention to engage in an activity or behaviour, the more like should be its performance in attitudes and awareness (Ali & Siong, 2016). Behaviours are not only guided by motivation but also the individual's attitude and awareness to engage in that behaviour. It is noted that lack of public awareness and understanding of energy recovery practice can lead to not-in-my-back-yard (NIMBY) syndrome (Heras-Saizarbitoria, Zamanillo, & Laskurain, 2013). Protests by local residents was reported in WtE project in Guangzhou which led to the project call off despite the fact that it had passed the required official environmental impact assessment (Yuan *et al*., 2019). Similarly, Siting of an incinerator as a policy instrument for waste disposal in Taiwan was also reported to have faced vigorous protest from the community based protest movement (Hsu, 2006). This is an indication that public awareness and attitude is crucial in implementation of WtE projects as well as addressing NIMBY phenomenon.

2.6.3 Age

An average age in a community is reported to have a negative correlation to waste generation (Sankoh, Yan, Mohamed, & Conteh, 2012). This implies that quantity of waste generation decreases with advancement in age.

2.6.4 Income

Positive correlation between individuals' monthly income with the quantity and composition of waste generated has been reported in several studies, more monthly income implies more waste generation (Bandara, Wirasinghe, & Pilapiiya, 2007) people's standard of living, consumption and pattern changes with increase in the income level. High income level influences the purchasing power which directly impacts not only the waste generation but also the energy recovery options. However, some studies, (Masoud, Ghasem, Omrani, Karbassi, & Fakheri, 2012; Sankoh, *et al*, 2012) found out the contrary that level of income has no influence on the total generation in a municipal solid waste. It is also shown that the quantity and nature of waste generated by a country is proportional to its population and the mean living standards of the people which is related to the income levels of people (Sankoh *et al*., 2012).

2.7 Summary of the Literature Review

The literature view that is been conducted in this study indicates that the topic of social factors and their influence towards energy recovery practices vital and multi-faceted. The reviewed literature also shows that there has been limited/ no research conducted in the field of energy recovery options being influenced by social factors. The table below therefore shows the most recent and relevant academic literature on social factors in energy recovery practices.

It has been noticed that the previous studies mainly focused on application of MCDM tools in evaluation of waste management alternatives and there are only limited recommendations in the literature with regards to the evolution of energy recovery from MSW in markets by applying AHP technique. This study therefore, focuses on addressing the aforementioned knowledge gaps given the fact that several studies have used AHP for the same.

3 MATERIALS AND METHODS

3.1 Introduction

This section describes the methods, procedures and systematic approach for conducting the research. The study area, the research design, the research approaches, the sample and sampling procedure, data collection, data quality control, the sources of information, data processing and data analysis that will be used for conducting this research work is also discussed in this section.

3.2 Study Area

Central division among the five administrative divisions of Kampala Capital City Authority was chosen for the study. It is located in the centre of Kampala City. It is a division around which all the other divisions are built resulting into high population growth and urbanisation that leads to increase in solid waste generated. Kampala Central division is chosen for the study mainly because it encompasses 4 out of the 13 major food markets in Kampala that is to say Nakasero, Owino, Kiseka and Kamwokya markets and all the waste generated is almost organic with 2% being the inorganic fraction (Kinobe *et al*., 2015; Schoebitz *et al*., 2014).

The figure 3.1 below shows the parishes in Kampala, market locations and market waste collection points as developed by (Schoebitz *et al*., 2014) Out of the 20 Parishes in the central division, the study will focus on the four (4) main food markets located in 4 Parishes of Nakasero, Kiseka, Kiseny II and Kamwokya II. The markets include Nakasero market, Kamwokya market, Kiseka market, and St. Balikudembe market (Owino). The markets considered for the study therefore included Nakasero market, Owino market and Usafi market being one of the populated and busy food markets within the Central division of Kampala.

During data collection period, the researcher visited the case study areas to collect primary information. The site visits were aimed at examining the current status of solid waste management in food markets within the study area. Three of the proposed four food markets were visited including the Nakasero market, Owino (St. Balikudembe) market and Usafi market. The visited markets share some features in common as well as some differences as highlighted below.

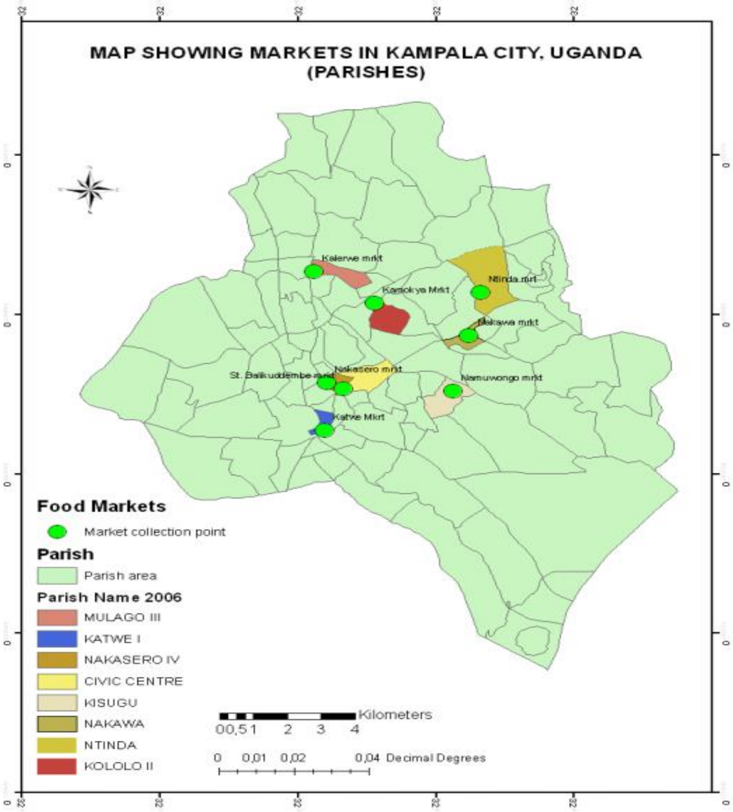

Figure 3.1: showing the parishes in Kampala, market locations and market waste collection points Source ; (Schoebitz *et al*., 2014)

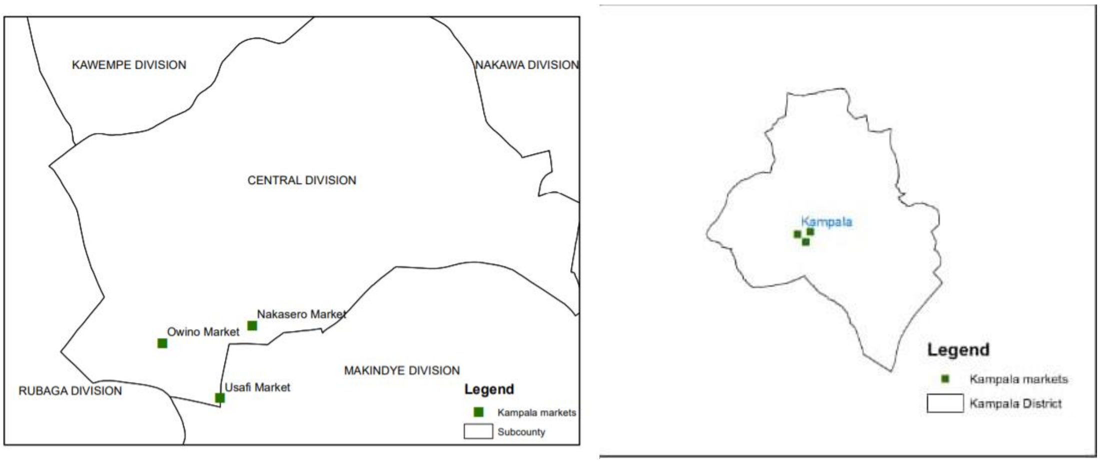

Figure 3.2: Map of Kampala, Uganda indicating location of markets considered for the study

3.2.1 Nakasero Market

Nakasero market is one of the biggest markets in Kampala city central business district located at the foot of Nakasero hill. It is mainly a home of fresh foods, textiles, shoes, building tools and some electronic. Nakasero market is the oldest market in the capital having been established in 1895. It provides employment to over 10,000 people both directly and indirectly from across Uganda and East African region. The employees range from vendors, traders, hawkers, service providers who all potentially contributes to the waste generated.

Nakasero market is divided into two categories; the open area and the closed area. The open area is partially covered and mainly occupied by fresh farm produce while the closed area has an old building where textiles, shoes, tourist items and other hardware materials are sold. The market is under the management of Nakasero Market Vendors and Traders Association Ltd.

Figure 3.3 showing Nakasero market

3.2.2 Owino Market

Owino market also known as St. Balikudembe market is the largest open market in Uganda located within Kampala central business district. It was established in 1971 following the relocation of 320 vendors from Nakasero market by the Kampala City Council and it occupied about 7 hectares of land in Kampala by then. The vendors/ traders in Owino market are estimated to be over 50,000 of whom about 70% are women. Owino market is mainly famous for its second-hand clothes, but almost every household item is available in the market ranging from food stuff/ fresh farm produce, herbs to shoes among others.

3.2.3 Usafi Market

Usafi market was constructed in 2013 as one of the mechanisms to get hawkers and vendors off Kampala streets. However, several vendors deserted the market citing lack of customers. The market has a capacity of 3000 vendors. Usafi market has about 1200 stalls and 108 lock-ups. Vendors pay for the stalls and lock-ups on a monthly basis.

Figure 3.4 showing Usafi market

3.3 Research design

The research design adopted for this study is cross-sectional design. The independent variables in this case include the nature, quantity of waste generation and social factors such as level of education, income, age, knowledge and awareness while the dependent variable is the energy recovery option. The technology option applied is largely dependent not only on the nature of waste generated but also on the social aspects of the stake holders in the waste management chain. A cross-sectional survey design is imperative in investigating, explaining and describing the phenomenon of interest through obtaining different views of the stakeholders relating to the study objectives (Hasheela, 2009).

An empirical research which is both qualitative and quantitative was conducted for this study. It is qualitative in nature since the study envisions exploring the existing situation concerning waste management (Symeou & Lamprianou, 2018) as well as the possibility of energy recovery options. The quantitative methods were also used in order to provide numerical and statistical data about solid waste.

3.4 Sample Size

The sample size was determined using the Yamane's sample size formula. This formula considers mainly two key parameters namely the level of precision and the confidence level in determination of sample size (Johnson & Shoulders, 2019). The formula assumes a ±5 % level of precision and a 95% confidence level. The formula is as below; -

$$n = \frac{N}{1+N(e)^{\wedge}2}$$

Where; n = sample size

e = level of precision (0.05)

N = Population size. (63,000 traders and vendors in Nakasero, Owino, Usafi markets)

$n = \frac{63000}{1+63000(0.05)^2}$ = 397.4 ………………………………………………………….. i)

n = 398 market vendors and traders.

Basing on the current situation related to covid-19 pandemic, most of the markets are working to approximately half capacity. This scenario limits the opportunity of data collection on how the waste is handled when the markets are at full capacity as well as the opinions/ survey responses from other venders are missed out.

In the 3 markets, the samples were distributed according to the percentage population of each of the market such as Owino with the highest population (50,000) took 79% of the samples, Nakasero (10,000) took 15.9% of the sample and Usafi (3,000) had 4.8% of the sample computed from the estimated total of 63,000 market venders and traders.

3.5 Sampling Technique

Markets with high population and hence high waste generation rate were selected to fill the survey questionnaire. Representative samples from markets were selected for the interviews through both purposive and random sampling technique. The participants for the survey questionnaire and interview included the stakeholders in waste management in the markets such as the administrators, market waste generators (traders and vendors), waste collection companies and KCCA administrators. Purposive sampling enabled the researcher to reach respondents with rich information and knowledgeable about solid waste management, while random sampling gave opportunity to those stakeholders who would not be met using the purposive sampling. This information obtained from the randomly picked respondents can also be used to make generalisation of the collected data (Cohen *et al*., 2007)

3.6 Data Collection Methods

For this research, both the primary and secondary sources of data collection were applied. The two approach were used in order to complement each other and also for reliability of the data.

3.6.1 Secondary Sources of Data Collection

Secondary data was collected from Journal papers, text books, News Papers, reports as well as KCCA records and internet. The literature on the existing energy recovery options and associated operation challenges and success also guided the study. In order to rectify any potential errors and or out datedness in the literature, field study for primary sources of data was conducted (Maschinen, Investition, Beschaffungen, Ersatzbeschaffungen, & Mittelherkunft, 2012.).

3.6.2 Primary Sources of Data Collection

The first-hand information was collected through key informant interviews, researcher facilitated questionnaires and direct observations.

Questionnaires surveys

A mixture of both closed and open-ended questions were designed in the semi-structured questionnaire in order to capture both the qualitative and quantitative data from the respondents was conducted. The survey questionnaire in a softcopy form using a phone was conducted and filled by the researcher basing on the response from the vendors and traders with in the markets. Measuring of social attitudes, commitments, beliefs and feelings of the respondents on SWM was considered in the questionnaires (Salkind, 2012). As indicated in Appendix 6.1, the questionnaire was structured to obtain information about the status of SWM and the attitudes of the respondents towards energy recovery options from SWM.

Key informant Interviews

The interview targeted the key informants on the waste management waste to energy processes. This includes KCCA representatives, Kampala Central division leaders (representatives), representatives from waste collection company, market authorities' representatives. The interview guide in Appendix 6.2 was used to gather information about the existing waste management strategies including collection, transportation, treatment and disposal and the awareness about the energy recovery options such as anaerobic digestion (AD), gasification, Incineration and landfill gas recovery.

Direct Observations

Direct observation as a method was used to enable the researcher gain some insight on the current situation regarding SWM including, the nature of waste generated, how waste is collected, transported, recycled, treated and disposed as well as the equipment and tools used in the management process. This on-site visit and observation enabled validation of data collected through interviews and questionnaires. The structured observation checklist (Appendix 6.3) was used to guide the researcher as well as recording the findings and taking photography of the existing situation.

3.7 Status of SWM in markets in Kampala central division.

At the case study area, the researcher used the designed survey questionnaire and sought the response from the randomly selected market vendors. The questions in the questionnaire were categorised into 4 different sections including social demographics and general information, Information on solid waste generation, collection and disposal, Knowledge about energy recovery possibilities, awareness and attitude about energy recovery options. Different respondents gave their opinion on how waste is currently managed and these opinions varied from poor to good as indicated in the next chapter. The survey questionnaires were directly administered and facilitated by the researcher, this approach was used so as to create rapport and obtain extra information resulting from different views and explanations given by the respondents.

Direct observation notes recorded about the status of SWM was also used to supplement information obtained through survey questionnaire. Similarly, the Key informant interview with KCCA also gave a hint on the general perspective on the state of SWM within Kampala central division

3.8 Attitude About Energy Recovery Options from solid waste.

The attitudes of the MSWM stakeholders was obtained through the survey questionnaires under the section of "awareness and attitude about energy recovery options" within the questionnaire. The KII also obtained information concerning the attitude of the stakeholders about the energy recovery options. In the next chapter, the gathered information will be discussed in details.

3.9 Identification of most suitable energy recovery Option from MSW generated in the market

From the literature reviewed (Chapter 2), a characteristic table indicating the selected features of various technology alternative for energy recovery from waste in India and UK is given below. The table highlights the different aspects and features of each of the technology option. It also highlights on the cost implications, social, environmental and technical aspects of the technologies. In this study, the information in the table was referred to in developing the AHP model.

Table 3.1: WtE technology characteristics; technical review

Feature	Description	Units	Anaerobic digestion	LFG recovery	Incineration	Gasification
Capital cost	Initial cost of facility	$/kW	-	15,000	890-1780	445 - 534
Operation and maintenance (O&M) cost	% of capital cost	$/kW	4-7.5	0.4-0.7	6.5-7.5	11.5
Resource potential	The quantity and quality of raw material required		low	medium	High	High
Operational life	Duration of the technology plant					
Overall efficiency (net electric output)	How efficient is the system in energy production	%	10 -20	10	18 – 26	18 – 30
Prominence/ maturity of technology	Is it a proven technology on market		Most prominent	Low prominence	Low prominence	Emerging
Pre-treatment requirement	Chain of activities to be done in treating the waste	-	Segregation /shredding	none	none	Segregation/shredding
Public acceptance	Attitude of the public towards the technology	-	high	low	medium	low
Employment opportunity	How many opportunities can be created by the technology	-	medium	medium	low	average
Occupational health and safety	Health and safety aspects of the technology		low	low	medium	low
CO_2 emission reduction	Ability to reduce the emission of CO2		Net positive environmental gain	1 -1.2 kg CO_2 /kWh	0.22 kg CO_2 /kWh	0.11 kg CO_2/ kWh
Volume reduction of MSW	Capacity to reduce volume of waste	%	38 (75% OFMSW)	Low	90	50 - 90
Land requirement for the plant	Space requirement for setting up the plant	hectares	2	Over 10	0.8	0.8

3.9.2 Identification of major criteria and sub-criteria for AHP model

The major criteria and sub sub-criteria used in this study for developing the AHP model were derived from related studies (Khoshand *et al*., 2018; Nixon *et al*., 2013; Yap & Nixon, 2015) while others were identified during the online discussion and meeting with leaders and WtE experts. The major four identified criteria include Technical, Economical, Environmental and social factors. These criteria are in line with the Draft National Energy policy 2019 and Renewable energy Policy 2007 (MEMD, 2018). For further enrichment of the model, thirteen (13) sub-criteria have been identified having direct influence on the selection of the WtE technology. The criteria are briefly described in the table below as supported by other authors in similar studies.

Table 3.2: Criteria description

Sn	Criteria	Sub-criteria	Description
1.	Economical	Capital cost	Expenditure on setting up, equipment, installation
		Operation and maintenance (O&M) cost	Level of O&M requirement and costs involved
		Resource potential	Availability and sustainability of solid waste supply
		Operational life	Number of years of operation before decommissioning
2	Technical	Overall efficiency (net electric output)	Alternative technology with higher efficiency is preferred.
		Prominence/ maturity of technology	A technology widely used and available commercially
		Pre-treatment requirement	if there is a need for any waste treatment before use in the technology
3	Social	Public acceptance	The public perception and mind-set about a particular type of technology.
		Employment opportunity / Job creation	Job creation potential as a result of the technology. The number of new jobs created in waste management depends on waste treatment technology employed.
		Occupational health and safety	Hygiene, potential hazards and physical injury associated with technology

4	Environmental	GHG (CO_2) emission reduction	Capability of the technology to alleviate emissions of CO2
		Volume reduction of MSW	The volume of waste that remains after energy is recovered.
		Land requirement for the plant	For physical installation of the WtE plant and its components

3.9.3 Data from the MSWM stakeholders on energy recovery possibilities

In a way to develop a credible decision preference for the chosen evaluation criteria, eight experts (4 from public sector and 4 from academia / private sector) who specialize in energy recovery technologies were involved in a survey to gather their opinion. The data collected from both the technical review and experts is then used into an MCDM model. The data is used to evaluate and compare the suitable WtE technology for waste generated from Markets in Kampala Central division. The average scores based on the survey responses were then used to complete the pair-wise comparisons, and SuperDecisions software was used to compute the priority weighting. The software has been widely used by several scholars in different studies relating to Multi Criteria Decision Analysis (MCDA) (Yap & Nixon, 2015; Khoshand et al., 2018; Nixon et al., 2013).

3.9.4 Tool for determining most Suitable Energy Recovery Option from MSW generated in the market

The MCDM tool known as Analytical Hierarchy Process (AHP) was be used because it has been widely used and popular for evaluating technology alternatives in both MSW management and energy planning projects (Soltani, Hewage, Reza, & Sadiq, 2015 and Saaty, 1977). AHP is a multi-criteria decision making tool which employs scientific properties to support effective decision making on different issues where the existence of many criteria and alternatives make the decision making process complex. The AHP model formulated in this study consists of four different hierarchal levels. At the top level is the goal of the model/ study followed by the major criteria at level two, sub-criteria at level three and the alternative WtE technologies at level four. With the data gathered from the literature review table 3.1, the preference of each WtE technological alternative for each criterion was then determined. This was achieved through pair-wise comparisons of the alternatives with respect to each sub-criterion in every major criterion.

3.9.6 Modelling the AHP structure

Both the major criteria and sub-criteria plus the technology alternatives are considered in modelling the AHP structure. The criteria are grouped in four clusters as economical, technical, social and environmental factors. The technical criteria are related to the performance and design characteristics of the technology while the economic criteria take into account the financial aspects and costs involved in a particular technology. Social criteria are mainly about the impact of the technology on the immediate community including employment opportunity, public acceptance among others while environmental criteria highlight the impact of technology on the environment in terms of emissions, land coverage among others. In the model, each of the criterion is connected to the goal while each of the alternatives are also connected to each criterion so as to do a pairwise comparison.

The AHP structure model for selecting a sustainable waste to energy alternative technology is shown in the figure 3.2 below;

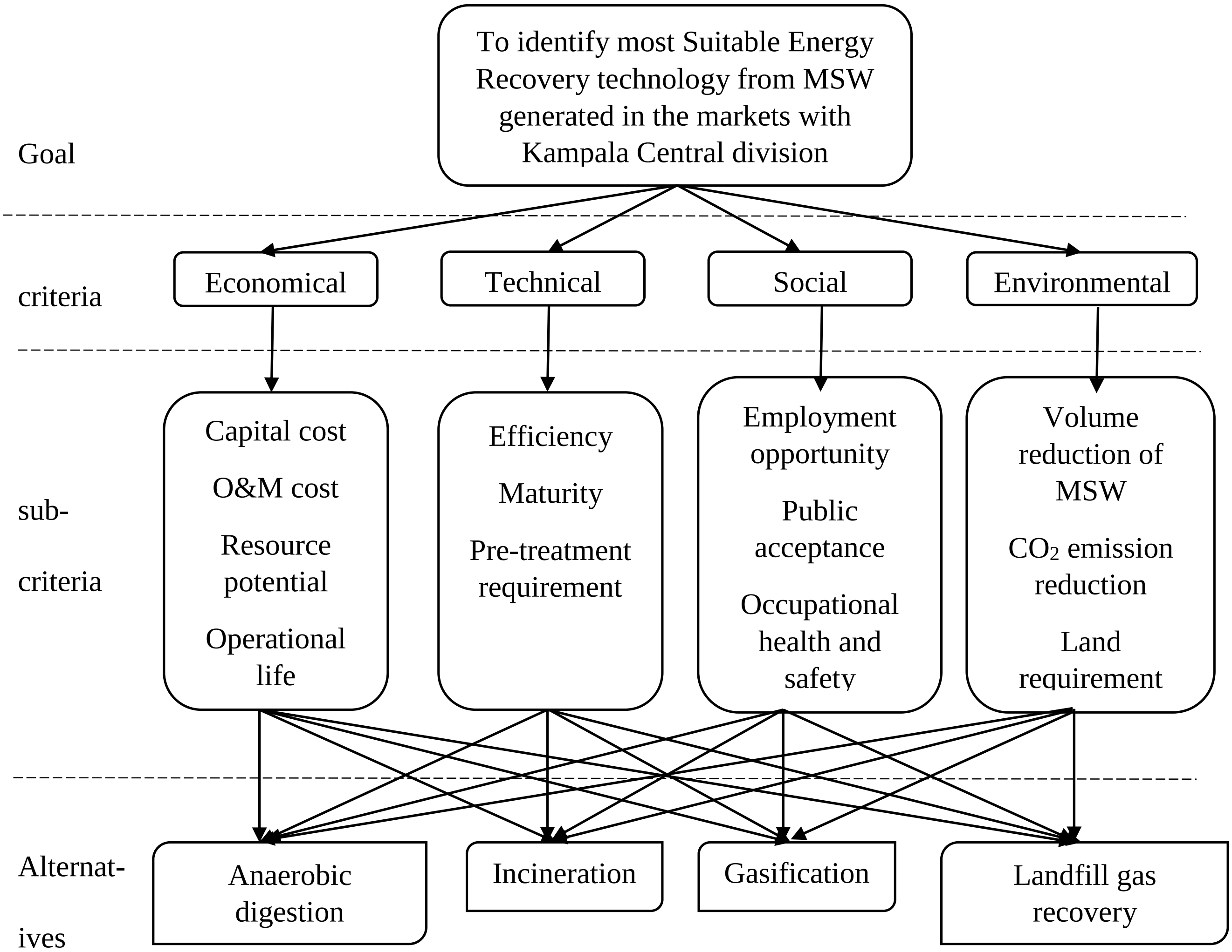

Figure 3.5: The AHP structure for selecting a suitable waste to energy technology alternative

3.9.7 Sensitivity analysis

To find the impacts of each criterion on the obtained results, the sensitivity analysis was conducted. The results of AHP analysis are always dependent on the preferences and experience of the experts and any change in the relative importance of the various criteria and alternatives assigned by the experts can highly influence the results of AHP analysis. This Therefore calls for sensitivity analysis, the consistency of the obtained results as well as the stability of the ranking.

3.10 Data Analysis

Self-administered questionnaires and interviews were reviewed and processed to check for any errors, completeness, accuracy and consistency of responses. The collected data was coded and analysed using MS excel, Kobo toolbox and Superdecision soft wares. The data was then processed and presented into statistical charts and tables for further interpretations.

3.11 Data Quality Control

3.11.1 Validity

To ensure internal validity, the questionnaire was derived from validated items from available literature related to the objectives of this research. The pilot test to ensure respondents fully comprehend the questionnaire was considered to observe validity of the instrument.

3.11.2 Reliability

Test –retest reliability was conducted where the response from the same individual/ location will be taken twice in a lapse of two weeks before carrying out the study.

4 RESULTS AND DISCUSSION

4.1 Introduction

This chapter is a representation of this research findings which are presented in various forms of graphical, tabular and photographic information for analysis and interpretation. It starts with the social demographics and general information about the respondents, the current status of MSWM in markets within Kampala central, attitude of the stakeholders about energy recovery options from solid waste, followed by the evaluation of the most suitable energy recovery option from the solid waste.

4.2 Social- demographics and General Information about the respondents

The bio-data of the respondents is presented in this sub-section by gender, age, highest level of education attained, main occupation and monthly income range. The presentation begins with gender as shown in the figure 4.1 below.

4.2.1 Gender of the respondents.

The gender of the respondents was identified as a way to observe how the response varies with gender. The outcome is as below.

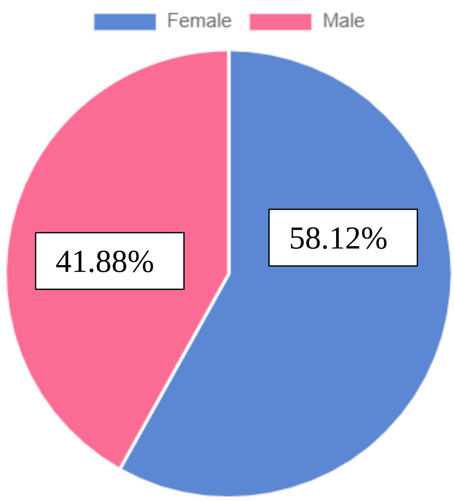

Figure 4.1: gender of the respondents

The bar chat in figure 4.1 indicates that 57.14% of the respondents were female and 41.18% were male. The high number of female respondents is as a result of females dominating the market as compared to the male. It is also due to high number of females available in the market during this period of partial lockdown (Corona pandemic) as they are mostly dealing in food stuffs. Some studies conform with this result as the quantity of waste generation does not only depend on the population size but also the population structure (Talalaj & Walery, 2015).

4.2.2 Age

Age was yet another feature considered to describe the respondents as presented below. The respondents were asked to identify their age range and the outcome is represented in the table 4.1.

Table 4.1: Age of respondents

Age range	Frequency	percentage
18 - 29	47	39.5
30 – 39	60	50.42
40 – 49	10	8.4
50 – 59	1	0.84
60 and above	0	0
Total	**118**	**100**

The information in the table above shows that 39.5% of the respondents were in the age group of 18 – 29 years, 50.42% were in the age group of 30 – 39 years, 8.4% in the age group of 40 – 49 years, 0.84 % were found in the age range of 50 – 59 years and there was no respondent with age above 60 years. Since solid waste generation increases with increasing number of people, this data implies that waste generators in the market are mainly youths below 40years of age. After 40 years, the waste generation is seen to decrease with increasing age. This reveals that waste to energy practice can easily be implemented by targeting the young population. However, these can easily be mobilised into a sustainable way of solid waste management. Furthermore, it can also be noticed that the waste generation is not so much discriminative by age as it is spread throughout the different age brackets. The study conducted about Age Structure and Municipal Waste Generation and Recycling in Czech Republic (Struk & Soukopová, 2016.) also found out that the highest waste generation was in age group of 30-39 due to their activeness and the ability to participate in various activities.

4.2.3 Level of education attained

The respondents were also asked to identify their highest education level attained. The results from the analysis is presented in the figure 4.2.

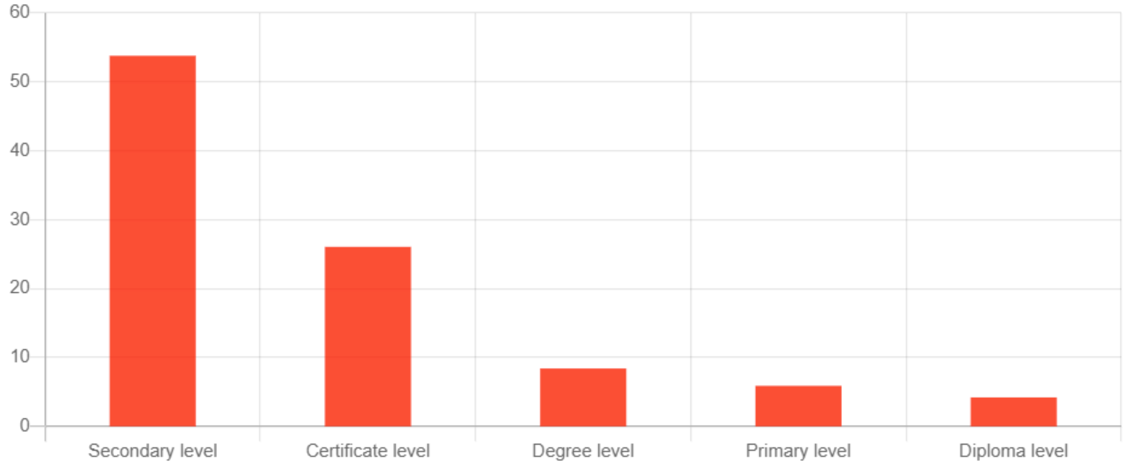

Figure 4.2: Highest education level attained

As depicted in Figure 4.2, the majority of the respondents (53.78%) were identified with secondary education (high school) as their highest education level attained followed by 26.05% of the respondents with certificate level as the highest education level, 8.4% were also identified with degree as the highest level attained. The fourth category of the respondents (5.88%) had Primary level. The least respondents (4.2%) were diploma holders. The data distribution is associated with the fact that the respondents were purely the market vendors who on daily basis are responsible of the waste generation and collection at source. The highest population is below degree level as a result of many people failing to raise money for school and resort to self-employment ending up in the market. The information on the education level is vital in proper waste management and energy recovery process. In a way to sensitize and work with this group of people, verbal communication through radios and recorded tapes (audio and video) can be effective in disseminating any information to them (vendors).

4.2.4 Main occupation

Due to the wide variety of items and activities conducted within the markets, the respondents were asked to identify their main occupation within the market. The results obtained are indicated in the figure 4.3.

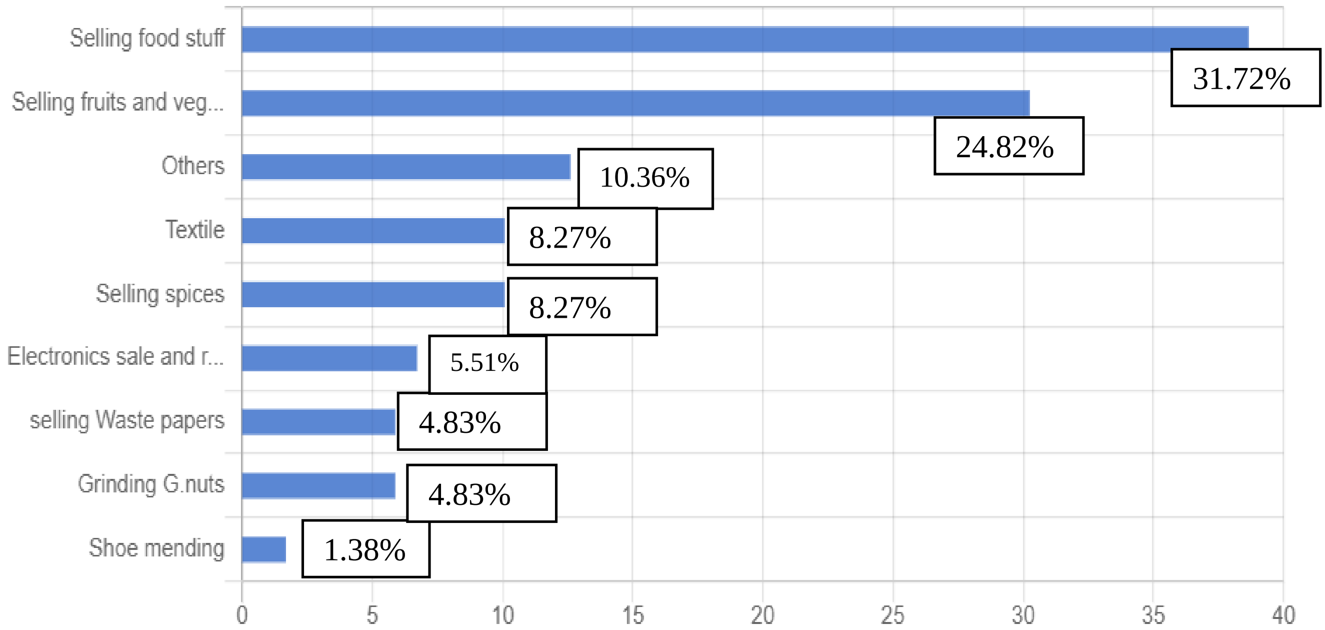

Figure 4.3: Main occupation of the respondents in the market

Following the primary data presented in figure 4.3 above, the respondents had different occupations with most of them (38.66%) dealing in food stuff, 30.25% were involved in selling fruits and vegetables, 10.08% were involved in textile business, 10.08% in selling spices, 6.72% electronic sales and repair, 5.88% involved in selling waste papers, 5.88% in grinding and selling groundnut paste while 1.68% were shoe menders. It was also observed that different occupations contributed differently to the nature, quantity and composition of solid waste generated within the wastes.

4.2.5 Monthly income

In order to understand the rate of waste generation within the markets, it was paramount to identify the monthly income of the respondents. The level of income affects the life style and expenditure hence the quantity of waste generated. The finding denoting the monthly income is presented in the table 4.3 below.

Table 4.2: Monthly income of the respondents

Income (Ugx)	Frequency	Percentage
Less than 200,000	5	4.23
200,000 – 400, 000	27	22.88
400,000 – 600, 000	41	34.75
600,000 – 800,000	30	25.42
Above 800,000	15	12.71
Total	**118**	**100**

As illustrated in the table 4.3 above, the bulk number of respondents (34.75%) earned a monthly income in a range of Ugx 400,000 to 600,000, followed by the range of Ugx. 600,000 to 800,000 at 25.42%, 22.88% in the range of Ugx 200,000 – 400,000. Those respondents earning above Ugx 800,000 were 12.71% and less than Ugx 200,000 shared a percentage of 4.23%. The level of income was dependent on the nature of business / occupation conducted in the market.

4.3 The Current Status of MSWM in Markets within Kampala Central

In this study, one of the objectives was to examine the current status of solid waste management in markets in Kampala central division. In the data collected, this was categorized into waste collection, transportation, and disposal mechanism as elaborated in the sub-sections below.

4.3.1 Solid waste generation and collection

4.3.1.1 Composition of solid waste generated in Kampala markets

During the data collection process, the researcher aimed at finding out the sources and composition of waste including how the generated waste is collected on site. This sub-section therefore will elaborate the results obtained from the field visit.

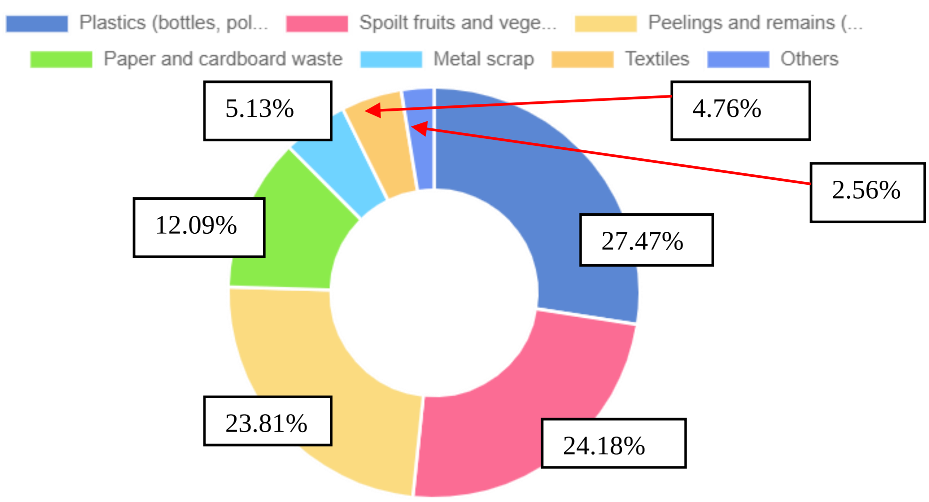

Figure 4.4: Type / composition of waste generated in the markets

The information provided in figure 4.4 above indicates that the majority respondents (27.47%) were plastics (bottles, polythene bags etc), 24.18% respondents indicates that the waste has spoilt fruits and vegetables, 23.81% revealed that the waste generated includes peelings, remains (cassava, potatoes, banana among others), 12.09% indicated paper and cardboard waste, 5.13% indicated metal scrap, 4.76% Textile and 2.56% were other wastes (including groundnut shells, electronic waste, food waste). The high quantity of the vegetable and food wastes reflects the nature of occupation of market vendors who mainly deal in food supplies. This is in conformity with the study conducted in sierra Leone where food waste dominated the household and market waste (Sankoh *et al*., 2012). The high volume of plastics is attributed to the fact that it is the default packaging material with in the market, making it (plastics) commonly used and widely littered. Given the high volumes of organic waste (spoilt fruits, vegetables and peelings), the suitable technology option would be anaerobic digestion and or landfill gas recovery since the process involves bacteria action on the organic waste (Yap & Nixon, 2015)

4.3.1.2 Means of solid waste collection/ onsite storage

The figure 4.5 highlights how the generated waste is collected at point of generation.

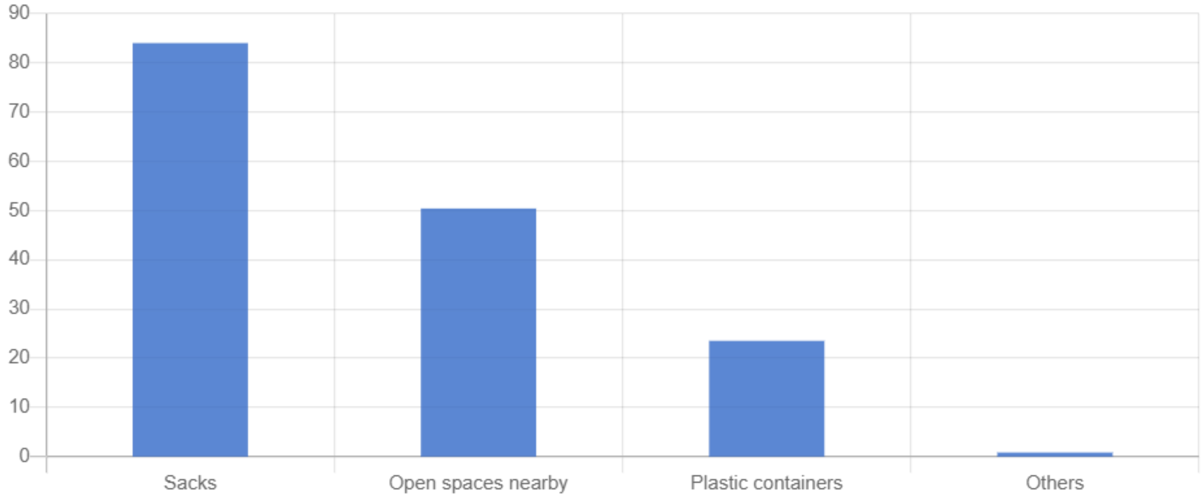

Figure 4.5: solid waste collection at source.

As depicted on Figure 4.5, majority of the respondents (84.03%) mentioned using sacks as a way of waste collection at source, 50.42% of respondents indicated that the waste is dumped in the nearby open spaces within the market where it is later swept and taken to the public bin. 23.53% mentioned use of old buckets as collection methods for the solid waste while 0.84% indicated other means for waste collection such as wheelbarrow, baskets among others. Most market vendors use sacks for waste collection because they are readily available and relatively cheap costing about USD 0.32, easy to handle among other factors. Open dumping is the second in choice since it is used in market areas with relatively bigger space / corridors and the collected waste is ensured to be swept and collected regularly.

4.3.1.3 Frequency of solid waste collection

The figure 4.6 indicates the frequency for which the collected waste is picked from the transfer site to the final disposal.

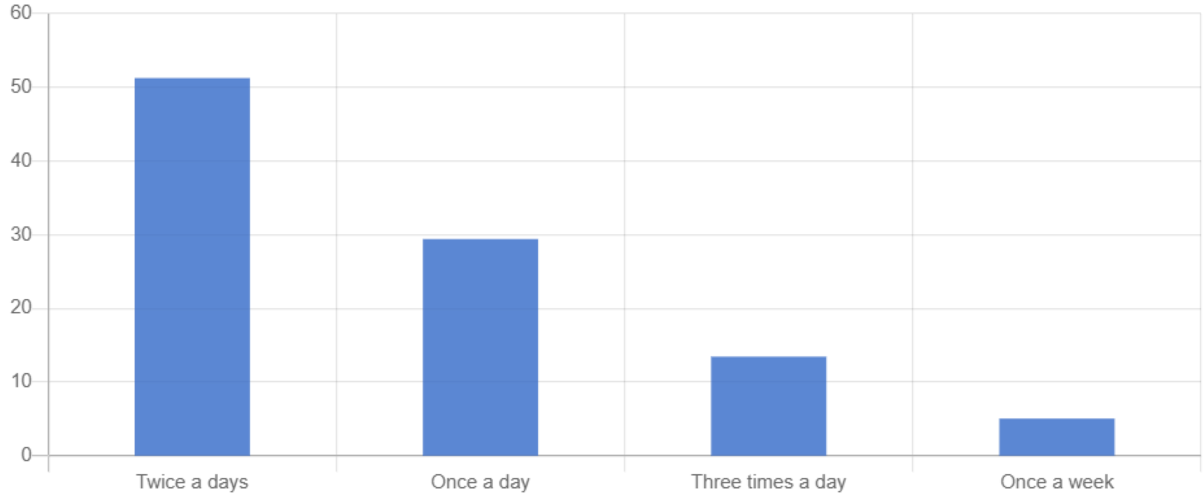

Figure 4.6: Frequency of waste picking from the generation site.

As indicated in the figure 4.6, 51.26% of the response indicated that the collected solid waste is picked and taken to the final disposal site twice a day. 29.41% indicated that the waste is taken once a day while 13.45% of the respondents said the waste is collected three times a day to the final disposal. The remaining responses (5.04%) indicated otherwise for the frequency of picking the collected waste. The waste is mostly picked twice a day not only as a result of large numbers of sales but also to discourage rotting and smell from the temporary transfer site within the market. In most busy days (deliveries) such as Monday, Wednesday and Friday for the case Nakasero market, there are full 3 trucks of garbage being collected. This large volume of waste is experienced due to the disposed packaging materials from the supplied products. The packaging materials include polythene bags, cardboard, dry leaves and grass among others. However, the Nakasero market authority started to encourage the suppliers to collect and take all the packaging waste during the supplies and also to adopt to reusable packaging material like wooden boxes, high density polythene.

4.3.2 Solid waste transportation

4.3.2.1 Transportation within the market

During the data collection process, it was found that the transportation of waste within the market (from different points) is different to that outside the market. Solid waste transportation to the temporary disposal site/ transfer site is by either head lifting, hand lifting, bicycle or wheelbarrow while transportation to the final disposal site is done by the dumping trucks and open pickup vehicles (specific for waste collection) as indicated in the figure 4.7

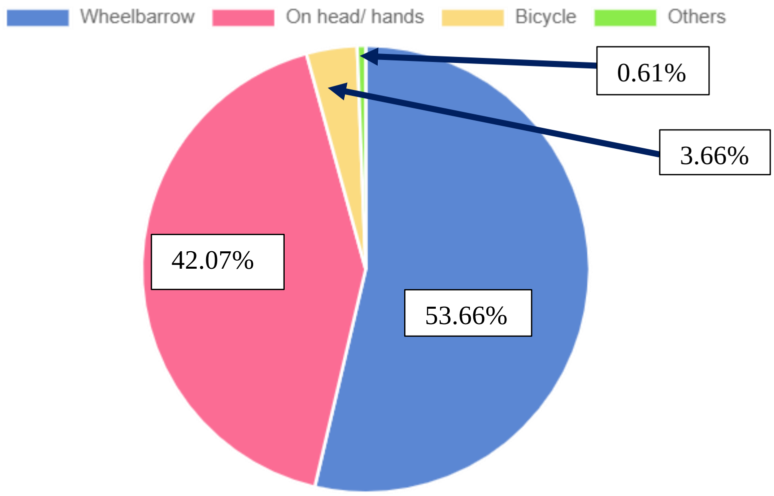

Figure 4.7: waste transportation within the markets

As indicated in Figure 4.7, the majority of the respondents (53.66%) agreed that solid waste is carried on wheelbarrow, followed by 42.07% who indicated that the waste is carried by lifting with head/ hands to the transfer site while only 3.66% indicated that bicycle is used for waste transportation, other means (0.61%) included picking by the scavengers for the items with market value and animal feeds directly from the collection point. Wheelbarrow is most preferred since it is easy and faster to use within the market, it also carries relatively large volume of waste compared to the other methods

4.3.2.2 Transportation to final disposal

The transportation of waste from the transfer site to the final disposal is done by dump trucks and other specialised vehicles. The waste is picked at different intervals for different markets either once, twice or thrice a day, basing on the quantity of waste generated in a single day. The figure 4.8 indicates the means of waste transportation. In most cases, there are 2 to 3 trucks loaded on daily basis from each of the markets to the final disposal site. The waste transporters face big challenges of high traffic and poor road conditions to the disposal site especially during rainy season. This result is in agreement with what was found it another study conducted in Kampala (Komakech *et al*., 2014). This study also established that the private companies and contracted by the government and paid by the market authorities per the garbage truck loaded and taken for disposal.

Figure 4.8: waste transportation from Nakasero market waste transfer site to the final disposal

4.3.3 Solid waste disposal

Within the markets, there exists a temporary disposal site also known as transfer site where the collected waste is temporarily kept before the final disposal.

In a way to ascertain disposal mechanism of the generated waste, the respondents were asked if they knew where the waste was being taken for the final disposal. The table 4.5 presents the response given.

Table 4.3: Response on where the waste is taken

Response	Frequency	Percentage
Yes	69	57.98
No	49	41.18
Total	**118**	**99.16**

The findings presented in the table above indicates that 57.98% of the respondents knew where the waste is taken for the final disposal while 41.18% did not know where the waste is disposed.

The figure 4.9 presents the information on the disposal mechanism used.

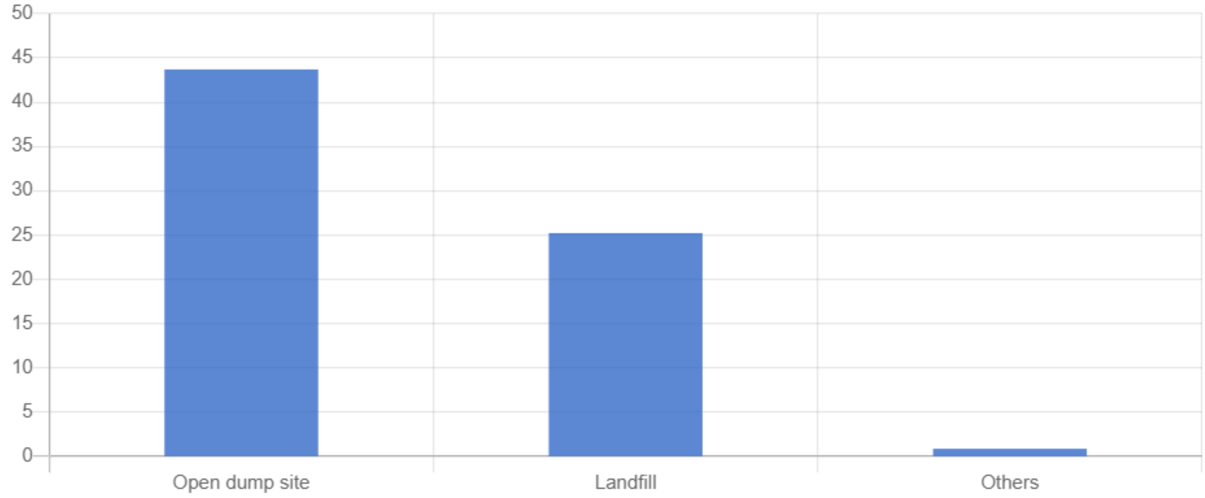

Figure 4.9: Disposal mechanism

From the graph in figure 4.7, it is indicated that most the respondents (43.7%) know that the disposal mechanism used is open dump site while 25.21% know about landfill as the disposal mechanism where waste is taken for final disposal. This study also found out that the final disposal sites are designated and maintained by the government except the unauthorised / illegal dumpsite. The disposal mechanism also determines what kind of technology to apply, for instance with a sanitary landfill, landfill gas recovery is suitable, whereas open dumping may require more efforts in sorting and preparing the waste

Furthermore, in a way to get the opinion of the respondents on how they rate the status of SWM within the market, the following data is presented in the figure 4.10

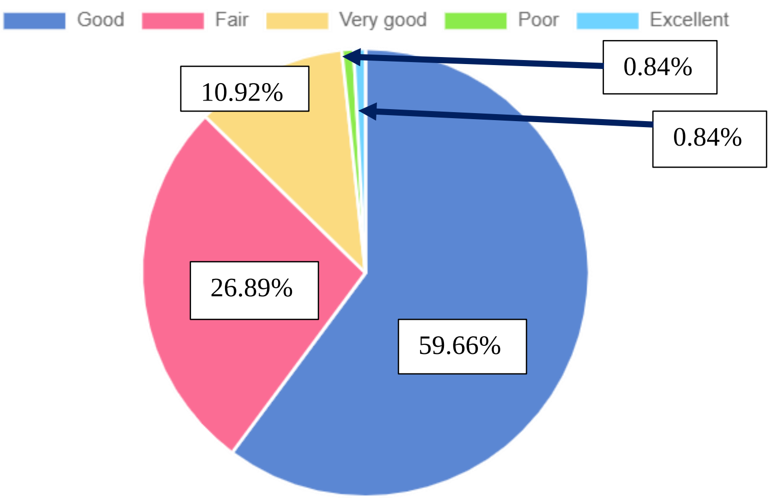

Figure 4.10: Rating the SWM status within the market.

The findings presented in the figure 4.10 depicts that the majority of the respondents (59.66%) said the status of SWM within the market was good, 26.89% said the status is fair, 10.92% rated the status as being very good. Only 0.84% of the respondents rates the state of SWM as

Excellent and 0.84% rated it poor. With the majority appreciating the status of solid waste, this implies that the energy recovery process gets more simplified with a proper solid waste management chain.

4.4 Attitude about Energy Recovery Options from Solid Waste.

Assessment of people's attitude about energy recovery options from solid waste generated from the markets in Kampala central division was yet another objective of this study. Through the survey responses, the data obtained about the attitudes is presented in the sub sections below.

Table 4.4: WtE as a way to address MSWM and energy challenges in the market

Response	Frequency	Percentage
Yes	80	67.23
No	5	4.2
Not sure	33	27.73
Total	**118**	**99.16**

From the table 4.4, it is indicated that 67.23% agreed that energy recovery from market waste is one way to address MSWM challenges as well as energy challenges faced with in the market and the surrounding areas. 27.73% of the respondents were not sure whether WtE can address the waste management and energy challenges within the market. 4.2% did not agree that WtE is a way to address the MSWM and energy challenges in the markets. With the majority respondents consenting that energy recovery is a way to address MSWM, it implies that the venders have positive attitude and awareness about WtE processes.

Similarly, the respondents also attributed the importance of energy recovery to different benefits as shown in the figure 4.8.

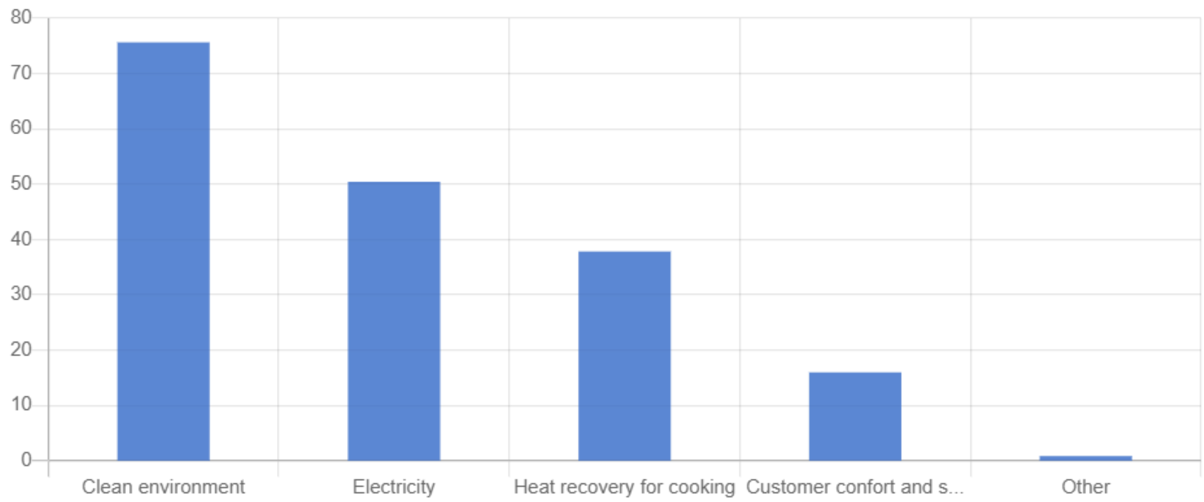

Figure 4.11: importance of energy recovery to the market and surrounding area.

As depicted in the figure 4.11, all the respondents (75.63%) attribute the importance of energy recovery to maintaining of clean environment which also gives customers and market visitors comfort. In addition to clean environment, 50.42% of the respondents mentioned electricity production as one of the benefits of energy recovery, 37.82% of the respondents added the importance of heat recovery for cooking, only 15.97% added mentioned about customer comfort and the rest (0.84%) indicated otherwise who were not sure about how important is energy recovery. Energy recovery from waste can be one of the key to a circular economy that enables the value of materials, products, and resources to be kept on the market for as long as possible, minimising waste and conserving environment. This study agrees with the results obtained from other studies (Komakech *et al*., 2014)

The involvement of the respondents in the energy recovery process was also investigated and the results are indicated in the figure 4.12.

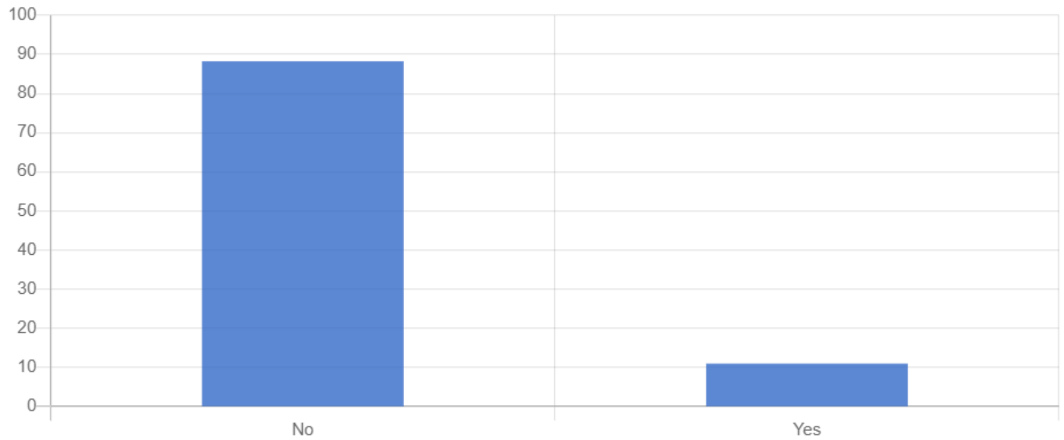

Figure 4.9: level of involvement of the participation in energy recovery

From figure 4.12, it shows that most of the respondents (88.24%) had not yet engaged directly in any energy recovery practice from solid waste. Some respondents claimed that they had followed some media show about briquettes and biogas. However, only 10.92% of the respondents had actively got involved in the WtE process. The most involved in practice was briquette production from dry solid waste and most of the respondents who knew WtE practice have tested/ used briquettes from solid wastes for cooking at their households.

When the respondents were asked about the benefits of waste-to-energy process to the market, the following the response was received as recorded in the figure 4.13

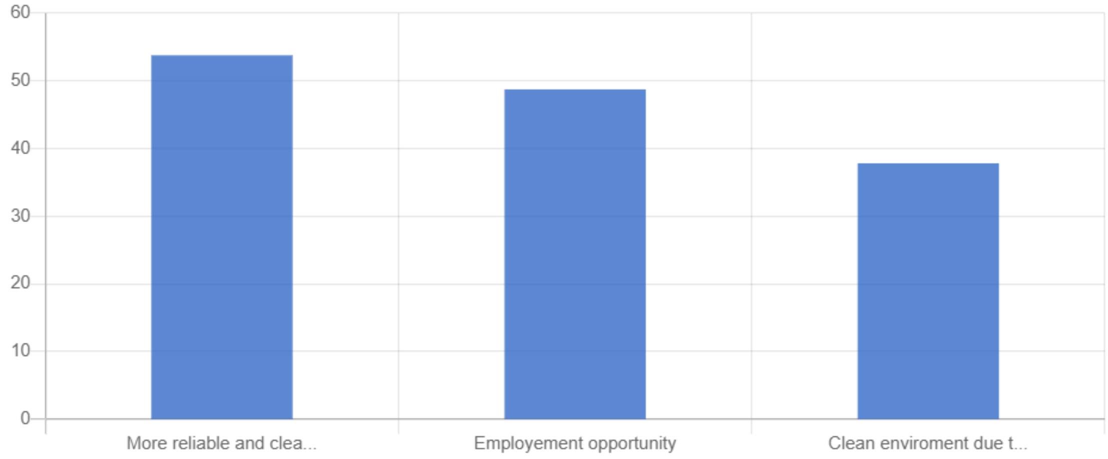

Figure 4.13: benefit of WtE process to the market

From the graph above, most of the respondents (53.78%) mentioned more reliable and clean energy as the benefit expected from the WtE processes, this majority response depicts the level of awareness and attitude towards energy recovery. 48.74% of the response talked about employment opportunity as a benefit and 37.82% responded with clean environment as the benefit of energy recovery from solid waste.

The attitude of the respondents was generally positive towards energy recovery practices since they attributed the practices to several benefits such as reliable and clean energy, employment opportunities and job creation, hygiene and sanitation among others. The prevailing attitude of the vendors and traders towards solid waste collection, transportation and disposal or treatment is positive. Every stall owner/ vendor takes up the initiative to collect and transport waste to the transfer site since they are very much aware that buyers needs a clean environment. The researcher also observed that the market authority together with the city authority work hand in hand in ensuring that the entire market is free from garbage.

4.5 Most suitable and applicable energy recovery option from the market solid waste in Kampala central division

The attributes / criteria as indicated in table 3.2 were identified during focused group discussions and literature review. The criteria are grouped into:

4.5.1 Criteria and sub criteria weightings

Weighting criteria is essential for achieving informed decision making. The weights of the criteria or sub-criteria show the importance attached to each particular criterion or sub-criterion by the decision maker based on the decision maker's subjective opinion. Basing on the responses from individual assessments carried out by each respondent (expert), the average values of the assessments were obtained, these were then used in developing pairwise comparison matrices for the criteria/sub-criteria.

Weight of criteria

The assessment of the importance of economic, technical, social and environmental criteria were done by WtE experts. The average values and calculated weights from the pairwise comparison are shown in Table 4.5 below

Table 4.5: Weights of the major criteria

Name	Normalized	Idealized
1 Economical	0.52153089938449149	1.0
2 Technical	0.27646153408863661	0.53009617342887128
3 Social	0.059950196565300103	0.11495042122346551
4 Environmental	0.14205736996157181	0.27238533733902881

Inconsistency 0.09535

The normalized weight of economic criterion which is 0.5215 is the highest followed by technical criterion (0.2764), environmental criterion (0.1420) and social criterion (0.0599) has the least normalized weight. This variation indicates that economic consideration is much more important in choosing a suitable WtE technology plant. Since the plant requires to run sustainably generating revenue to support the production costs, economic criterion is worth taking the highest weight followed by the technical consideration. The comparison is indicated to be consistent given that the inconsistency ratio is 0.09535 which is less than the recommended10%.

Weight of sub-criteria

Economic criteria

Under the economic criterion, the importance of sub-criteria including capital cost, O&M cost, Resource potential and operating life are compared as indicated in the table 4.6.

Table 4.6: Weights of the sub-criteria under economic criteria

Name	Normalized	Idealized
1 Capital cost	0.17038188458449718	0.35454513901932583
2 O&M cost	0.48056471753011359	1.0

3 Resource potential	0.26194333124857316	0.54507399668216183
4 Operational life	0.08711006663681603	0.18126604692188508

Inconsistency 0.09088

From table 4.6, O&M cost with weight of 0.4805 is considered to be of higher importance under the economic criterion. Due to a long value chain attributed to WtE processes, there are several operation and maintenance practices that have to be done to ensure effectiveness of the plant. Some of the O&M practices include waste collection and sorting equipment repairs among others. The cost of maintenance is always high and recurring as compared to the investment (capital cost) which is a lump sum cost at the start of the project. The comparison of the sub-criteria under the economic criteria is equally consistent with given the ratio of 0.09088 which is below 10%.

Technical criteria

Under technical criteria, the importance of the different sub-criteria efficiency, maturity, pre-treatment was compared and the mean results from the experts were used to obtain the weights in the table 4.7.

Table 4.7: Weights of the sub-criteria under technical criteria

Name	Normalized	Idealized
1 Efficiency	0.26836845261639286	0.43678994117456243
2 Maturity	0.11722075785230751	0.19078564349712807
3 Pre-treatment requirement	0.61441078953129968	1.0

Inconsistency 0.07069

From the results in the table 4.7, pre-treatment requirement (0.6144) has higher weight as compared to plant Efficiency (0.2683) and technology Maturity (0.1172). The pre-treatment requirement includes the activities performed on the waste before feeding into the plant for energy recovery. The pre-treatment requirement is in most cases unique for each technology option. The higher the pre-treatment requirement the higher the cost of energy recovery process.

The system efficiency is considered to be the second most important sub criterion with weight of 0.2683. the efficiency determines whether the energy recovery is economically viable and technically fulfilling. The high system efficiency of the technology makes it attractive. The comparison also shows the consistence ratio of 0.07069 which is below 10% and it confirms that the comparison was done consistently.

Social criteria

Under social criterion, employment opportunity, public acceptance, occupational health and safety and public acceptance were compared and the results obtained are indicated in the table 4.8.

Table 4.8: Weights of the sub-criteria under social criterion

Name	Normalized	Idealized
1 Employment opportunity	0.36429151063958953	0.6786044041478726
2 Public acceptance	0.53682455995409062	1.0
3 Occupational health and safety	0.098883929406319862	0.18420157493311493

Inconsistency 0.09040

From the table above, public acceptance is considered to be of higher importance with weight of 0.5368, followed by employment opportunity (0.3642) and occupational health & safety (0.0988) had the least weight. In any social setting, the public acceptance of a project is very vital for the successful operation of that particular location. The attitude of the people surrounding the plant / technology has the ability to promote or discourage the project.

Environmental criteria

Under the environment criterion, the sub criterion volume reduction of MSW, CO_2 emission reduction and land requirement were compared to determine their level of importance. The results are indicated in the table 4.9

Table 4.9: Weights of the sub-criteria under social criterion

Name	Normalized	Idealized
1 Volume reduction of MSW	0.27968738584745578	0.44628833586211814
2 CO_2 emission reduction	0.62669660704255081	1.0
3 Land requirement	0.093616007109993502	0.14938010842563451

Inconsistency 0.08247

From the results in table 4.9, CO_2 emission reduction is considered more important with highest (0.6266) as compared to the volume reduction of MSW (0.2796) and land requirement (0.0936). This high weight for CO_2 emission reduction is attribute to the global concern to reduce global warming. The energy recovery technology selected should ensure great potential in reduction of global warming agents. The volume reduction of MSW is the second in weight as this is associated with space requirement in solid waste management.

Land requirement is the least in weight under the environment criterion. It involves the space requirement for the plant, waste (raw material) storage and processing. For technology options with less pre-treatment requirement, it also translate to less space requirement as well as upfront costs. The comparison of the three sub-criteria is consistent as indicated by the consistence ratio of 0.08247 which is below 0.1.

4.5.2 Final combined priority scores and ranking

The summary of results for criteria weights, sub-criteria weights and alternative priority scores are shown in Table. These summarised results were used to calculate the final combined priority scores of the alternative technology options using the Superdecision software version 3.2.0-. The final scores were then used to rank the energy recovery technologies in order identify the most suitable technology out of the four alternatives.

Table 4.23: Summarised results of criteria weights and alternative priority scores from Superdecision software

Sn	Criteria	Sub-criteria	Alternatives	Priority score
1	Economic (0.522)	Capital cost (0.170)	Anaerobic digestion	0.529
			Incineration	0.285
			Gasification	0.105
			Landfill gas recovery	0.079
		O&M cost (0.481)	Anaerobic digestion	0.259
			Incineration	0.157
			Gasification	0.093
			Landfill gas recovery	0.489
		Resource potential (0.262)	Anaerobic digestion	0.420
			Incineration	0.263
			Gasification	0.224
			Landfill gas recovery	0.093
		Operational life (0.087)	Anaerobic digestion	0.372
			Incineration	0.103
			Gasification	0.123
			Landfill gas recovery	0.402
2	Technical (0.276)	Efficiency (0.268)	Anaerobic digestion	0.432
			Incineration	0.078
			Gasification	0.187

			Landfill gas recovery	0.303
		Maturity (0.117)	Anaerobic digestion	0.431
			Incineration	0.267
			Gasification	0.121
			Landfill gas recovery	0.181
		Pre-treatment requirement (0.614)	Anaerobic digestion	0.072
			Incineration	0.428
			Gasification	0.072
			Landfill gas recovery	0.428
3	Social (0.059)	Employment opportunity (0.364)	Anaerobic digestion	0.268
			Incineration	0.163
			Gasification	0.497
			Landfill gas recovery	0.073
		Public acceptance (0.537)	Anaerobic digestion	0.559
			Incineration	0.134
			Gasification	0.197
			Landfill gas recovery	0.109
		Occupational health and safety (0.098)	Anaerobic digestion	0.575
			Incineration	0.102
			Gasification	0.064
			Landfill gas recovery	0.258
4	Environmental (0.142)	Volume reduction of MSW (0.279)	Anaerobic digestion	0.107
			Incineration	0.516
			Gasification	0.339
			Landfill gas recovery	0.038
		CO2 emission reduction (0.627)	Anaerobic digestion	0.090
			Incineration	0.235
			Gasification	0.056
			Landfill gas recovery	0.619
		Land requirement (0.094)	Anaerobic digestion	0.206
			Incineration	0.438
			Gasification	0.255
			Landfill gas recovery	0.099

From the results obtained by the use of Superdecision software as indicated in the table 4.23, the overall weight for all the compared technologies are indicated in the figure 4.11. Landfill gas recovery has the highest score of 0.3264 which makes it the most suitable technology option when considering all the major and sub-criterion. Gasification has the least score (0.1384) making it least preferred of the four technologies. Anaerobic digestion is considered the second with score of 0.2870 slightly below the highest score, while the incineration is the third preferred option with relatively competitive score of 0.2480.

Name	Graphic	Ideals	Normals	Raw
1 Anaerobic digestion		0.879573	0.287098	0.095699
2 Incineration		0.760042	0.248082	0.082694
3 Gasification		0.424054	0.138414	0.046138
4 Landfill Gas Recovery		1.000000	0.326406	0.108802

Figure 4.11: overall priority score of the WtE technology options for market waste in Kampala central division

5 SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Summary and discussion of research findings

Solid waste management and energy recovery are not new interventions for the cities and municipal authorities. These interventions have been evolved with man for a long period of time. Over the time, human activities have been associated with waste generation and disposal to the environment. Similarly, methods for collection, transportation and disposal of the wastes have also been evolving over time. For a clean city, it has been observed that the collection, transportation and disposal of the solid waste is jointly managed by both the market vendors and Kampala capital city authority. Due to increasing population and economic growth, more efforts and sustainable approach to waste management is vital in maintaining a garbage free and clean market.

5.2 Current status of solid waste management in food markets in Kampala central division.

The study findings established various ways of solid waste collection, transportation and disposal practices. It was found that the different categories of waste generated are collected in various ways including sacs, old buckets and open spaces near the stalls. At the end of each day, the vendors pick or hire someone to pick and take the sacks to the transfer site. The market authority employees also sweep and collect the openly dumped waste onto the wheelbarrow, bicycle or on head to the transfer site. It was also observed and noted that the collected waste around the stalls were collected and taken away on a daily basis to the transfer site. The quantity of waste varies from market to market depending on the quantity of the products supplied to and from the market. Waste generation starts with the packaging materials of the supplied agro products, peelings, rotting fruits and vegetables, textiles, cardboards and paper waste.

The study found out that from the transfer site, the waste is picked and transported regularly to the final disposal. In Nakasero market, there are peak days in the week including Monday, Wednesday and Friday when the quantity of waste collected is high as the market receives agro supply from different parts of the country and East African region. In the peak days, the waste is transported three times a day by the dump track for the final disposal while in the other days the waste is picked either twice or once from the transfer site. This finding is contrary to the findings in the study by Mohammed and Elsa (2003 *ibid*) who found it hard for municipalities, households and SWM bodies to regularly and frequently collect solid waste due to the less number of labourers with their low payments. This difference in findings indicates that the attitude and awareness of people about waste management and its benefit is vital in the frequency of SWM. The waste collected at the transfer site is ensured that it doesn't accumulate to decomposition and bad smell since it may bring complaints from the different classes of people visiting the markets.

The study also found out that in Nakasero and Owino markets the waste is collected and transported by the private companies to the final disposal while for Usafi market it is transported by KCCA dump trucks. The private companies are employed by KCCA to ensure a clean and garbage free market and other places. It was noticed that the private companies engage appropriate equipment including dump tracks and lorries that carry the waste to the disposal site. The study also found that the transfer sites are regularly emptied to discourage decomposition and bad smell in the market as shown in figure 5.1 below. A study by Sharholy *et al* (2008) noticed that despite different methods used in transportation of the solid wastes, cities in low-income countries often lack sufficient transportation and appropriate equipment to collect wastes and transport such waste in suitable manner. This has been of no exception for the case of the markets in the central division in Kampala city

The study also found that market authorities are only responsible for waste management within the market. Anything outside the market is not their role such as final disposal sites. However, from the data collected, it was observed that the market traders and vendors are generally satisfied by how the waste is managed within the market. The satisfaction comes as result of positive cooperation between the authority, waste collectors and the vendors who regularly ensure their stalls are clean and tidy.

Other strategies employed by different markets in managing the wastes.

During the study field visit, the following interventions towards a proper solid waste management was found in different markets as mentioned below.

Nakasero market

The study The market authority advises the suppliers to adopt reusable packaging materials during supply of the agro-products. The packaging material may include wooden/plastic trays, sacks among others which can be taken back for instead of using grass or leaves which would be left in the market as waste.

The suppliers are also asked to sort and take back the spoilt supplies (fruits and vegetables) so as to minimise on the quantity of waste generated in the market.

The market also has a community radio / public address system used for daily communication and sensitization of the vendors and traders about proper waste management and its benefits. This intervention has helped increase the level of awareness and attitude towards proper solid waste management.

Usafi market

Monthly communal clean-up organised by the market authority on the 30th or 28th of each month. The clean-up involves different stakeholders such as local leaders, community based organisations (CBOs), NGOs, KCCA, market vendors and traders among others. The activities include sweeping, collecting and sorting of waste wastes, community sensitization about the benefits of proper SWM, possibilities of energy recovery through briquette making, possibilities of recycling plastics among others.

The study found a specific collection point for plastics near Usafi market which is privately owned by the Slum dwellers Kampala Central Division with support from KCCA. The plastics are collected on daily basis by different people who are paid. At the collection centre, plastics are further sorted basing of the type and colour. The sorted plastics are later taken for recycling at different bottling and plastic companies.

The study also noted that the vegetable wastes and food remains are collected and sorted from the kitchen department for sale. The food left overs, peelings (banana, beans, cassava, potato) are taken for animal feeds.

Briquette production and training is yet another initiative in progress by the private individuals near the market. The study found that the briquettes are made from dry biomass and charcoal remains collected from the market.

5.1.1 Attitude towards energy recovery options from solid waste.

From the study, the researcher found that most respondents (67.23%) agreed that energy recovery is a suitable strategy in addressing both the SWM and energy challenges in the market. The response obtained clearly indicates a positive attitude towards energy recovery practices. Just like it is with metal scraps and plastics, whenever value is attached to a waste product it will always be taken away hence minimising waste accumulation. It was also note that most of the respondents mentioned heat recovery for cooking and electricity as the preferred energy from waste.

The researcher also found out that most respondents who have ever engaged in WtE have been in briquette production either for small scale commercial or household / own use while others have watched other WtE practices on television.

5.1.2 Evaluation of the suitable and applicable energy recovery option from the solid waste.

Findings from the study and the expert opinion reveal that the landfill gas recovery is the most suitable energy recovery technology for the market waste generated with in Kampala central division. The findings considered four major criteria and several sub-criteria, the relative importance was obtained from which the overall priority score for technologies was determined.

5.2 Conclusion

Social demographic factors of the market vendors such as age, level of education, level of income among others did not have direct influence on the energy recovery technology option. This can be associated to the existing waste management structure where the waste is collected, transported and disposed by an authorised body.

The solid waste management strategy in the three market are similar. All the markets have a transfer site from which the waste is picked with either dump tracks or lorries to the final disposal sites at kiteezi landfill.

Energy and resource recovery is crucial in institutional waste management as it has the ability to minimise waste as well as enhancing production in terms of energy generated. KCCA and the market institutions are missing out on the potential to boost income and minimise expenditure in waste collection and transportation through energy recovery.

5.3 Recommendation

In order to reduce the quantity of solid waste generation and improve on solid waste management practices, there is need to adopt and improve on existing community sensitization and capacity building on proper solid waste management. This can be done through regular community meetings, radio programmes about dangers of poor SWM, benefits of proper SWM, involvement of the CBOs and NGOs in community sensitization meetings among others.

There is need to adopt the 3Rs approach (Reduce, Reuse, Recycle) which is very vital in minimizing waste as well as providing social and economic benefits such as hygiene and revenue from the recyclable materials.

Segregation at source and specific collection for resource recovery is needed in a way to promote integrated SWM. WtE facilities may be built close to the disposal site for easy and efficient disposal of the residual wastes from the facility.

There is need to consider Public private partnership in integrated SWM approach to allow either co-funding of the energy recovery practices. This can be done by opening up and inviting academia, private persons and companies with vast experience and interest in WtE practices.

Need for clear stipulated policies governing private power production so as to encourage private entities in energy recovery sector. In most case, private companies are discouraged to invest in energy generation in countries without clear policy frame works on energy generation. The feed-in tariff and feed-in agreement should also be designed in a way that encourages and favours entry of private companies in energy recovery from waste.

5.4 Possibilities for further research

i. Techno-economic assessment of the energy recovery process in Kampala and Uganda as a whole
ii. Comparative advantages of using energy from waste as opposed to fossil
iii. Studies on integrated solid waste management in Institutions and industries in Uganda

References

1. Alam, P., & Ahmade, K. (2013). Impact of Solid Waste on Health and the Environment. *International Journal of Sustainable Development and …*, *2*(1), 165–168. Retrieved from http://irnet.sg/irnet_journal/IJSDGE/IJSDGE_doc/IJSDGE_V2I1,2_papers/31.pdf
2. Ali, N. E. H., & Siong, H. C. (2016). Social Factors Influencing Household Solid Waste Minimisation. *MATEC Web of Conferences*, *66*, 1–8. https://doi.org/10.1051/matecconf/20166600048
3. Aliu, I. R., Adeyemi, O. E., & Adebayo, A. (2014). *Municipal household solid waste collection strategies in an African megacity : Analysis of public private partnership performance in Lagos*. https://doi.org/10.1177/0734242X14544354
4. Aryampa, S., Maheshwari, B., Sabiiti, E., Bateganya, N. L., & Bukenya, B. (2019). Status of Waste Management in the East African Cities: Understanding the Drivers of Waste Generation, Collection and Disposal and Their Impacts on Kampala City's Sustainability. *Sustainability*, *11*(19), 5523. https://doi.org/10.3390/su11195523
5. Assefa, G. Ã., & Frostell, B. (2007). *Social sustainability and social acceptance in technology assessment : A case study of energy technologies*. *29*, 63–78. https://doi.org/10.1016/j.techsoc.2006.10.007
6. Aye, L., & Widjaya, E. R. (2006). *Environmental and economic analyses of waste disposal options for traditional markets in Indonesia*. *26*, 1180–1191. https://doi.org/10.1016/j.wasman.2005.09.010
7. Bandara, N. J. G. J., Wirasinghe, S. C., & Pilapiiya, S. (2007). *Relation of waste generation and composition to socio-economic factors : a case study*. 31–39. https://doi.org/10.1007/s10661-007-9705-3
8. Begum, S., Rasul, M. G., & Akbar, D. (2012). *An Investigation on Thermo Chemical Conversions of Solid Waste for Energy Recovery*. 624–630.
9. Cohen, L., Manion, L., Lecturer, P., Morrison, K., & Lecturer, S. (2013). *Research Methods in Education*.
10. Contreras, F., Hanaki, K., Aramaki, T., & Connors, S. (2008). *Resources , Conservation and Recycling Application of analytical hierarchy process to analyze stakeholders preferences for municipal solid waste management plans , Boston , USA*. *52*, 979–991. https://doi.org/10.1016/j.resconrec.2008.03.003
11. Gakungu, N. K., Gitau, A. N., Njoroge, B. N. K., & Kimani, M. W. (2012). *SOLID WASTE MANAGEMENT IN KENYA : A CASE STUDY OF PUBLIC TECHNICAL TRAINING INSTITUTIONS*. *5*(3), 127–138.
12. Hammed, T. B., Sciences, H., Sciences, H., Wahab, B., & Planning, R. (2016). *Enhancing solid waste collection and transportation for sustainable development in the ibadan metropolis, nigeria*. *4*(7), 23–32.
13. Hasheela, R. (2009). Municipal Waste Management in Namibia : The Windhoek Case Study Universidad Azteca Municipal Waste Management in Namibia : The Windhoek Case Study Universidad Azteca. *Waste Management*, (October).
14. Heras-Saizarbitoria, I., Zamanillo, I., & Laskurain, I. (2013). Social acceptance of ocean wave energy: A case study of an OWC shoreline plant. *Renewable and Sustainable Energy Reviews*, *27*, 515–524. https://doi.org/10.1016/j.rser.2013.07.032
15. Hsu, S. H. (2006). NIMBY opposition and solid waste incinerator siting in democratizing Taiwan. *Social Science Journal*, *43*(3), 453–459. https://doi.org/10.1016/j.soscij.2006.04.018
16. Johnson, D. M., & Shoulders, C. W. (2019). *Beyond Magic Words and Symbols : Rethinking Common Practices in Quantitative Research*. *60*(3), 291–303.
17. *Kampala Municipal Solid Waste Value Chain Mapping Global Green Growth Institute*

2018. (2018). Retrieved from www.gggi.org
18. Karekezi, S., & Majoro, L. (2002). *Improving modern energy services for Africa ' s urban poor*. *30*, 1015–1028.
19. Khajuria, A., Yamamoto, Y., & Morioka, T. (2010). Estimation of municipal solid waste generation and landfill area in Asian developing countries. *Journal of Environmental Biology*, *31*(5), 649–654.
20. Khoshand, A., Kamalan, H., & Rezaei, H. (2018). Application of analytical hierarchy process (AHP) to assess options of energy recovery from municipal solid waste : a case study in Tehran ,. *Journal of Material Cycles and Waste Management*, *0*(0), 0. https://doi.org/10.1007/s10163-018-0736-3
21. Kinobe, J. R., Niwagaba, C. B., Gebresenbet, G., Komakech, A. J., & Vinnerås, B. (2015). Mapping out the solid waste generation and collection models: The case of Kampala City. *Journal of the Air and Waste Management Association*, *65*(2), 197–205. https://doi.org/10.1080/10962247.2014.984818
22. Komakech, A. J., Banadda, N. E., Kinobe, J. R., Kasisira, L., Sundberg, C., Gebresenbet, G., & Vinnerås, B. (2014). Characterization of municipal waste in Kampala, Uganda. *Journal of the Air and Waste Management Association*, *64*(3), 340–348. https://doi.org/10.1080/10962247.2013.861373
23. Lee, G. F., Ph, D., Jones-lee, A., Ph, D., Lee, G. F., & Macero, E. (1994). *Impact of Municipal and Industrial Non-Hazardous Waste Landfills on Public Health and the Environment : An Overview*.
24. Li, B., & Yao, R. (2009). Urbanisation and its impact on building energy consumption and efficiency in China. *Renewable Energy*, *34*(9), 1994–1998. https://doi.org/10.1016/j.renene.2009.02.015
25. Malinauskaite, J., Jouhara, H., Czajczyńska, D., Stanchev, P., Katsou, E., Rostkowski, P., … Spencer, N. (2017). Municipal solid waste management and waste-to-energy in the context of a circular economy and energy recycling in Europe. *Energy*, *141*, 2013–2044. https://doi.org/10.1016/j.energy.2017.11.128
26. Maschinen, B., Investition, A., Beschaffungen, G., Ersatzbeschaffungen, B., &
27. Masoud, S., Ghasem, M., Omrani, A., Karbassi, A., & Fakheri, F. (2012). *The effects of socioeconomic parameters on household solid-waste generation and composition in developing countries (a case study : Ahvaz , Iran)*. 1841–1846. https://doi.org/10.1007/s10661-011-2082-y
28. MEMD. (2018). *Ministry of Energy and Mineral Development Draft MINING AND MINERAL POLICY FOR UGANDA*. (October), 1–58.
29. Mohammed, A., Elias, E., Science, E., & Ababa, A. (2017). *solid waste management environmental impacts in Addis Ababa city*. *4*(1), 194–203.
30. Moya, D., Aldás, C., López, G., & Kaparaju, P. (2017). Municipal solid waste as a valuable renewable energy resource: A worldwide opportunity of energy recovery by using Waste-To-Energy Technologies. *Energy Procedia*, *134*, 286–295. https://doi.org/10.1016/j.egypro.2017.09.618
31. Mukwaya, P. I. (2016). *Urban Adaptation to Energy Insecurity in Uganda*. (March), 69–84.
32. Mwiganga, M., & Kansiime, F. (2005). The impact of Mpererwe landfill in Kampala - Uganda, on the surrounding environment. *Physics and Chemistry of the Earth*, *30*(11-16 SPEC. ISS.), 744–750. https://doi.org/10.1016/j.pce.2005.08.016
33. Ni, J. Q., & Nyns, E. J. (1996). New concept for the evaluation of rural biogas management in developing countries. *Energy Conversion and Management*, *37*(10), 1525–1534. https://doi.org/10.1016/0196-8904(95)00354-1
34. Nixon, J. D., Dey, P. K., Ghosh, S. K., & Davies, P. A. (2013). Evaluation of options

for energy recovery from municipal solid waste in India using the hierarchical analytical network process. *Energy*, 1–9. https://doi.org/10.1016/j.energy.2013.06.052
35. Nzila, C., Dewulf, J., Spanjers, H., Kiriamiti, H., & van Langenhove, H. (2010). Biowaste energy potential in Kenya. *Renewable Energy*, *35*(12), 2698–2704. https://doi.org/10.1016/j.renene.2010.04.016
36. Palacio, C. E., Carlos, J., Palacio, E., Renó, L. G., Luiza, M., Renó, G., … Carvalho, M. (2019). *Municipal Solid Waste Management and Energy Recovery José*. https://doi.org/10.5772/intechopen.79235
37. Panigrahi, S., & Dubey, B. K. (2019). A critical review on operating parameters and strategies to improve the biogas yield from anaerobic digestion of organic fraction of municipal solid waste. *Renewable Energy*, *143*, 779–797. https://doi.org/10.1016/j.renene.2019.05.040
38. Philadelphia, S., & Pennsylvania, W. (1977). *A , A ,. 281*, 234–281.
39. Puig-arnavat, M., Bruno, J. C., & Coronas, A. (2010). Review and analysis of biomass gasification models. *Renewable and Sustainable Energy Reviews*, *14*(9), 2841–2851. https://doi.org/10.1016/j.rser.2010.07.030
40. Rahardyan, B., Matsuto, T., Kakuta, Y., & Tanaka, N. (2004). Resident's concerns and attitudes towards Solid Waste Management facilities. *Waste Management*, *24*(5), 437–451. https://doi.org/10.1016/j.wasman.2003.11.011
41. Salkind, N. (2012). "Technique for the Measurement of Attitudes, A." *Encyclopedia of Research Design*. https://doi.org/10.4135/9781412961288.n454
42. Sankoh, F. P., Yan, X., Mohamed, A., & Conteh, H. (2012). *A Situational Assessment of Socioeconomic Factors Affecting Solid Waste Generation and Composition in Freetown , Sierra Leone*. *2012*(July), 563–568.
43. Santoyo-castelazo, E., & Azapagic, A. (2020). Sustainability assessment of energy systems : integrating environmental , economic and social aspects. *Journal of Cleaner Production*, *80*(2014), 119–138. https://doi.org/10.1016/j.jclepro.2014.05.061
44. Schoebitz, L., Nguyen, V.-A., Tran, H. H., Dang, T. H., & Strande, L. (2014). *RRR-Project From Research to Implementation Component 1 – Waste Supply and Availability Report – Hanoi*. 1–58.
45. Singh, K. J., & Sooch, S. S. (2004). Comparative study of economics of different models of family size biogas plants for state of Punjab, India. *Energy Conversion and Management*, *45*(9–10), 1329–1341. https://doi.org/10.1016/j.enconman.2003.09.018
46. Singh, R. P., Tyagi, V. V, Allen, T., Ibrahim, M. H., & Kothari, R. (2011). An overview for exploring the possibilities of energy generation from municipal solid waste (MSW) in Indian scenario. *Renewable and Sustainable Energy Reviews*, *15*(9), 4797–4808. https://doi.org/10.1016/j.rser.2011.07.071
47. Soltani, A., Hewage, K., Reza, B., & Sadiq, R. (2015). Multiple stakeholders in multi-criteria decision-making in the context of Municipal Solid Waste Management : A review. *Waste Management*, *35*, 318–328. https://doi.org/10.1016/j.wasman.2014.09.010
48. Speight, J. G. (2015). Waste gasification for synthetic liquid fuel production. *Gasification for Synthetic Fuel Production: Fundamentals, Processes and Applications*, 277–301. https://doi.org/10.1016/B978-0-85709-802-3.00012-6
49. Stefanovi, G., Dassisti, M., Markovi, D., & Vu, G. (2014). *Multi-criteria analysis as a tool for sustainability assessment of a waste management model*. https://doi.org/10.1016/j.energy.2014.05.056
50. Struk, M., & Soukopová, J. (2016). *Age Structure and Municipal Waste Generation and Recycling – New Challenge for the Circular Economy*. 1–9.
51. Sujauddin, M. (2008). *Household solid waste characteristics and management in*

Chittagong , Bangladesh. *28*, 1688–1695. https://doi.org/10.1016/j.wasman.2007.06.013
52. Symeou, L., & Lamprianou, I. (2018). *Chapter 3 : Approaches of Research and Methodology*. (January 2008).
53. Talalaj, I. A., & Walery, M. (2015). The effect of gender and age structure on municipal waste generation in Poland. *WASTE MANAGEMENT*. https://doi.org/10.1016/j.wasman.2015.03.020
54. Tan, S., Hashim, H., Lee, C., Taib, M. R., & Yan, J. (2014). Economical and environmental impact of waste-T o-energy (WTE) alternatives for waste incineration, landfill and anaerobic digestion. *Energy Procedia*, *61*, 704–708. https://doi.org/10.1016/j.egypro.2014.11.947
55. Thakare, S., & Nandi, S. (2016). Study on Potential of Gasification Technology for Municipal Solid Waste (MSW) in Pune City. *Energy Procedia*, *90*(December 2015), 509–517. https://doi.org/10.1016/j.egypro.2016.11.218
56. UBOS. (2017). *Ugandan Bureau of Statistics. (2017). National Population and Housing Census 2014 Area Specific Profiles Kampala Capital City Authority, (April). Retrieved from www.ubos.orgNational Population and Housing Census 2014 Area Specific Profiles Kampala Capital*. (April). Retrieved from www.ubos.org
57. Ufoegbune, G., & Oyedepo, J. (2012). *Disposal Sites and Transport Route Selection Using Geographic Information System and Remote Sensing in Abeokuta , Nigeria Disposal Sites and Transport Route Selection Using Geographic Information System and Remote Sensing in Abeokuta , Nigeria*. (July 2015).
58. Uganda Bureau of Statistics. (2016). National Population and Housing Census 2014 - Main Report, kampala. Uganda. *Uganda Bureau of Statistics*, 1–105. https://doi.org/10.1017/CBO9781107415324.004
59. United Nations, & Nations, U. (2014). *World Urbanization Prospects: The 2014 Revision, CD-ROM Edition.* 1–20.
60. Velghe, I., Carleer, R., Yperman, J., & Schreurs, S. (2011). Journal of Analytical and Applied Pyrolysis Study of the pyrolysis of municipal solid waste for the production of valuable products. *Journal of Analytical and Applied Pyrolysis*, *92*(2), 366–375. https://doi.org/10.1016/j.jaap.2011.07.011
61. Wang, X., Rafa, M., Moyer, J. D., Li, J., Scheer, J., & Sutton, P. (2019). *Estimation and Mapping of Sub-National GDP in Uganda Using NPP-VIIRS Imagery*. 1–14. https://doi.org/10.3390/rs11020163
62. Yap, H. Y., & Nixon, J. D. (2015). A multi-criteria analysis of options for energy recovery from municipal solid waste in India and the UK. *WASTE MANAGEMENT*. https://doi.org/10.1016/j.wasman.2015.08.002
63. Yuan, X., Fan, X., Liang, J., Liu, M., Teng, Y., Ma, Q., … Zuo, J. (2019). Public perception towards waste-to-energy as a waste management strategy: A case from Shandong, China. *International Journal of Environmental Research and Public Health*, *16*(16). https://doi.org/10.3390/ijerph16162997
64. Zulkifli, A. A., Zulkhairi, M., Yuso, M., Manaf, L. A., Zakaria, M. R., Roslan, A. M., … Hassan, M. A. (n.d.). *Assessment of Municipal Solid Waste Generation in Universiti Putra Malaysia and Its Potential for Green Energy Production*.
65. Zurbrügg, C. (2013). *Assessment methods for waste management decision-support in developing countries*. Retrieved from Zurbrugg@eawag.ch

6 APPENDIX

6.1 A Survey questionnaire

24/09/2020 Institutional waste to energy survey

Institutional waste to energy survey

Survey preparation

I am Anthony Osinde a student of Pan African University Institute of Water and Energy Sciences (Including Climate Change) - PAUWES, Algeria. I am undertaking a MSc. In Energy Engineering (Policy track). This research is about "INFLUENCE OF SOCIAL FACTORS ON ENERGY RECOVERY OPTIONS FROM SOLID WASTE GENERATED IN SCHOOLS AND MARKETS: A Case of Central Division of Kampala. I therefore kindly request you to fill this questionnaire honestly and truthfully. The information obtained will be kept and used anonymously and confidentially for only academic purpose of writing this research report.

Survey hint; This survey is about SWM and WtE; Participation is voluntary; Seeks for your honest and accurate response; Information obtained is highly confidential; The survey will last for about 15 minutes;

Do you have any general question about this survey process before we can proceed?

Would you wish to participate in this survey?

- (x) Yes
- ( ) No

GPS coordinates of this location

latitude (x.y °)

longitude (x.y °)

altitude (m)

accuracy (m)

Social demographics and general information

Institution name

Choose one

- ( ) Owino (St. Balikuddembe) Market
- ( ) Nakasero Market
- ( ) Usafi Market

https://kf.kobotoolbox.org/#/forms/ayJfMEFsfGnAbWuZfcAEzu/landing 1/11

Age

- ◯ 18 - 29
- ◯ 30 - 39
- ◯ 40 - 49
- ◯ 50 - 59
- ◯ 60 and above

Gender

- ◯ Male
- ◯ Female

Highest education level attained

- ◯ Primary level
- ◯ Secondary level
- ◯ Certificate level
- ◯ Diploma level
- ◯ Degree level
- ◯ Others

(Specify other) highest education level attained

____

Main occupation within the market

choose all that apply

- ☐ Selling food stuff
- ☐ Selling fruits and vegetables
- ☐ selling Waste papers
- ☐ Selling spices
- ☐ Shoe mending
- ☐ Grinding G.nuts
- ☐ Textile
- ☐ Electronics sale and repairs
- ☐ Others

(Specify others) main occupation

____

Monthly Income range

- ◯ Less than ugx. 200,000
- ◯ Ugx 200,000 to 400,000
- ◯ Ugx 400,000 to 600,000
- ◯ Ugx 600,000 to 800,000
- ◯ Above Ugx 800,000

We are now going to ask you a bit about your knowlegde on how solid waste is handled in this area

---

Information on solid waste generation, collection and disposal

What type of waste is generated in this area?
choose all that apply

- ☐ Peelings and remains (cassava, banana, cabagges, potatoes)
- ☐ Spoilt fruits and vegetables
- ☐ Paper and cardboard waste
- ☐ Metal scrap
- ☐ Plastics (bottles, polythene bags)
- ☐ Textiles
- ☐ Others

(specify other) type of waste generated in the area

How is the generated waste collected? in;
choose all that apply

- ☐ Sacks
- ☐ Plastic containers
- ☐ Open spaces nearby
- ☐ Others

(specify others) how the generated waste is collected

Are there any nearby temporary disposal /transfer site for the collected waste around the market?

- ◯ Yes
- ◯ No

How is the collected waste transported to the temporary disposal site

choose all that apply

- [ ] Wheelbarrow
- [ ] Bicycle
- [ ] On head/ hands
- [ ] Others

(Specify others) How is the collected waste transported to the temporary disposal site

---

How often is the collected waste picked from the temporary storage/ transfer site?

- ◯ Once a day
- ◯ Twice a days
- ◯ Three times a day
- ◯ Once a week
- ◯ Other

(specify others) how often is the collected waste picked from the temporary storage?

Do you know where the collected waste is taken for final disposal?

- ◯ Yes
- ◯ No

How is the waste disposed?

choose all that apply

- [ ] Landfill
- [ ] Open dump site
- [ ] By the roadside
- [ ] Any open field
- [ ] Others

(specify others) where is the waste disposed

How can you evaluate the status of solid waste management in this area?

- ◯ Excellent
- ◯ Very good
- ◯ Good
- ◯ Fair
- ◯ Poor

Mark the degree of agreement or disagreement with the following statement	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Vendors regularly collect and take their waste to the disposal site	◯	◯	◯	◯	◯
The collected waste always take long before it is picked for final disposal	◯	◯	◯	◯	◯
People are satisfied with how waste is handled in the market	◯	◯	◯	◯	◯
Bad smell and flies from the collected waste is a challenge	◯	◯	◯	◯	◯

How is the waste transported to the final disposal?
choose all that apply

- ☐ Specialised tracks for waste transportation
- ☐ Any open vehicle
- ☐ Others

(specify others) why you think proper solid waste management is important

---

We are now going to talk about energy use and possibilities of resource recovery from solid waste

---

Knowledge about energy recovery possibilities

Which forms of energy are commonly used in this market?
choose all that apply

- ☐ Electricity
- ☐ Charcoal
- ☐ LPG (gas for cooking)
- ☐ Biogas
- ☐ Briquettes
- ☐ Firewood
- ☐ Kerosene
- ☐ Others

(Specify others) form of energy commonly used in the market

For what purpose are the energy used?
choose all that apply

- [ ] Cooking
- [ ] Lighting
- [ ] Refrigerators
- [ ] Electronic repairs and charging (Television, Radios, Phones)
- [ ] Powering motors (grinding machines)
- [ ] Entertainment / Music system
- [ ] Others

(specify others) for what purpose are the energy used?

____

Which activities consume most energy in the market?
choose all that apply

- [ ] Cooking
- [ ] Lighting
- [ ] Refrigerators
- [ ] Entertainment / music system
- [ ] Powering engines / motors
- [ ] Others

(specify others) which activities consume most energy in the market?

____

Rank the following forms of energy according to their order of preference for energy use in the market.
Rank from most preferred to least prefered

____

1st choice

- ( ) Electricity
- ( ) Charcoal
- ( ) LPG (gas for cooking)
- ( ) Biogas
- ( ) Briquettes (for cooking)

2nd choice

- ( ) Electricity
- ( ) Charcoal
- ( ) LPG (gas for cooking)
- ( ) Biogas
- ( ) Briquettes (for cooking)

3rd choice

- ( ) Electricity
- ( ) Charcoal
- ( ) LPG (gas for cooking)
- ( ) Biogas
- ( ) Briquettes (for cooking)

4th choice

- ◯ Electricity
- ◯ Charcoal
- ◯ LPG (gas for cooking)
- ◯ Biogas
- ◯ Briquettes (for cooking)

5th choice

- ◯ Electricity
- ◯ Charcoal
- ◯ LPG (gas for cooking)
- ◯ Biogas
- ◯ Briquettes (for cooking)

Why do you prefer the selected form of energy?

choose all that apply

- ☐ Readily available
- ☐ Relatively cheaper
- ☐ Environmental friendly
- ☐ Easy and convinient to use
- ☐ Well developed technology
- ☐ Other

(specify others) why do you prefer the selected energy form?

____

From what sources are the preferred energy obtained?

choose all that apply

- ☐ Hydro electric power
- ☐ Solar
- ☐ Fossil fuels (diesel/ petrol generators)
- ☐ Firewood
- ☐ Charcoal
- ☐ Solid waste
- ☐ Other

(specify other) from what sources are the preferred energy obtained?

____

Have you ever faced any challenges with the preferred form of energy in the market?

select one

- ◯ Yes
- ◯ No

What energy challenges do you face?
choose all that apply

- [ ] Frequent power outages
- [ ] Disconnections
- [ ] Not reliable
- [ ] High maintainance cost
- [ ] Not readily available
- [ ] Associated environmental issues
- [ ] Other

(specify other) what energy challenges do you face with the preferred form of energy?

How have you always addressed the energy challanges ?
choose all that apply

- [ ] Mixing with other forms of energy
- [ ] Use of energy efficient appliances (energy saving appliances)
- [ ] Change to other alternative forms of energy
- [ ] Report to the service providers.
- [ ] Mobilise and encourage other members to pay for the bills in time
- [ ] Other

(specify others) how have you always addressed the energy challenges?

What do you think should be done to address the energy challenges?

- [ ] Subsidizing the energy tariffs / costs
- [ ] Create awareness about energy efficiency practices
- [ ] Subsidize the costs of energy efficient appliances
- [ ] Routine maintenance of the power plants by the utility
- [ ] Explore other forms of renewable energy
- [ ] Others

(specify others) what do you think can be done to address the energy challenges?

Do you think waste-to-energy practice is one way to address energy challenges in the market?

- ○ Yes
- ○ No
- ○ Not sure

In which ways do you think energy recovery practice can be useful to the markets and the surrounding areas?

choose all that apply

- [ ] Heat recovery for cooking
- [ ] Electricity
- [ ] Clean environment
- [ ] Customer confort and satisficiation in a clean environment
- [ ] Other

(specify others) in which way can energy recovery process be useful

---

I can support the energy recovery process through;
choose all that apply

- [ ] Waste sorting at source
- [ ] Paying for the energy generated
- [ ] Pay for waste collection
- [ ] Encourage other vendors to use the energy generated
- [ ] Other

(specify other) I can support energy recovery process through;

Mark the degree of agreement or disagreement with the following statement	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
There is need to subsidize on the cost of energy	◯	◯	◯	◯	◯
Energy supply is reliable in the market	◯	◯	◯	◯	◯
There is need for alternative energy source in the market	◯	◯	◯	◯	◯

We are going to check the level of awareness and attitude about energy recovery

---

Awareness and attitude on energy recovery options

Have you ever been involved directly or indirectly in a waste-to-energy conversion process?

◯ Yes

◯ No

What was the involvement about?

choose all that apply

- [ ] Briquette production from waste
- [ ] Biogas production process
- [ ] Gasification process
- [ ] Incineration process
- [ ] Pyrolysis
- [ ] Others

(spacify others) Your involvement in any waste-to-energy process

---

Have you had any engagement / training about energy recovery?

- ( ) Yes
- ( ) No

Which energy recovery option did you engage/ train in?

- [ ] Anaerobic digestion (Biogas production)
- [ ] Incineration
- [ ] Gasification
- [ ] Landfill gas recovery
- [ ] Slow pyrolysis (carbonisation for briquette production)
- [ ] Other

(specify others) Which energy recovery option did you engage/ train in?

Rank the energy recovery options in your knowledge from MOST awareness to LEAST awareness.

1st choice

- ( ) Anaerobi digestion
- ( ) Landfill with Gas recovery
- ( ) Incineration
- ( ) Gasification
- ( ) Pyrolysis

2nd choice

- ( ) Anaerobi digestion
- ( ) Landfill with Gas recovery
- ( ) Incineration
- ( ) Gasification
- ( ) Pyrolysis

3rd choice

- ( ) Anaerobi digestion
- ( ) Landfill with Gas recovery
- ( ) Incineration
- ( ) Gasification
- ( ) Pyrolysis

4th choice

- ◯ Anaerobi digestion
- ◯ Landfill with Gas recovery
- ◯ Incineration
- ◯ Gasification
- ◯ Pyrolysis

5th choice

- ◯ Anaerobi digestion
- ◯ Landfill with Gas recovery
- ◯ Incineration
- ◯ Gasification
- ◯ Pyrolysis

What do you think should be done to promote energy recovery practices in institutions?

choose all that apply

- ☐ Mass sensitization
- ☐ Soft loan to investors
- ☐ Promote public private partnership
- ☐ Put in place regulations and policy governing energy recovery sector
- ☐ Others

(specify other) What do you think should be done to promote energy recovery practices in institutions?

____

What do you think can be the benefit waste-to-energy process to the market

- ☐ Clean enviroment due to value attached to waste
- ☐ More reliable and clean energy supply
- ☐ Employement opportunity
- ☐ Others

(Specify others) How do you think you can benefit from the waste-to-energy process

____

THE END,

____

Thanks a lot for your cooperation

____

6.2 Key Informant Interview Guide

The key informant's representatives from

- Kampala Capital City Authority (KCCA)
- Political leaders in Kampala central division
- Waste collection company

Sn	Main question	Sub questions
1	Introduction	Tell me about your profession and what you do? Can you talk briefly about KCCA and its mandate on MSW
	The mandate of KCCA	Do you think the mandate is achievable? Please specify
	Solid waste	What do you think are the challenges associated with solid waste? Which group of people are most affected by the challenges? Which strategies have you developed to manage them? Are there any noticeable changes in the situation over the recent past?
	Waste collection	How is the waste collected? How often are the temporary storage bins emptied? How do you describe the cooperation between the collectors and the public? How is the safety and health of waste collectors ensured? Are there scavengers in the SWM value chain? How do you rate/describe the solid waste collection process
	Solid waste management strategies	What is the SWM strategy in use by KCCA? What initiatives have been put in place for waste reduction? (composting, recycling, resource recovery) What significant factors affects the initiative? Do you think there is a challenge with acquiring land for public waste disposal? How do you handle the challenge? What are some of the factors that influence the choice of the location? Are the facilities and funds sufficient for proper SWM? How do you describe the SWM strategies available?
	Public awareness and environmental impact	Is there training/ sensitization available about SWM? How do you describe the level of awareness about SWM in institutions (Schools and markets)? Which initiatives are in place to motivate the public towards proper SWM Do you notice any air, water or land pollution from the solid waste? Are there any health issues associated with solid waste?
	Energy recovery options	How do you understand energy recovery from waste? Do you think WtE is a better way of practicing waste reduction? Is there any willingness by KCCA to adopt and promote integrated MSWM including energy recovery? What are some of the energy recovery options in place? Has there been any attempt to recover energy from waste in KCCA

		What do you think the government can do to promote energy recovery in institutions?

Division leaders

Sn	Main question	Sub questions
1	Introduction	Your profession and what you do? How do you describe your support to SWM in Kampala
	Solid waste management strategies	How is your concern towards SWM? Do you think KCCA has a good SWM strategy? How do you view the public attitude towards SWM? Do you think there is sufficient cooperation of public in SWM, give a reason? How do you describe the level of awareness of the public? Do you understand the impacts of solid waste challenges to the environment?
	Public awareness and environmental impact	Have you noticed any impacts of solid waste on environment? What strategies are you putting in place to mitigate the challenges? Do you think the public cares about these environmental impacts?
	Energy recovery options	Have you heard of energy recovery from waste? How do you think it is important? Do you experience complaints and challenges associated with energy access and affordability? How can you describe your support to wards energy recovery process?

Non-government organisations and waste collection company representatives

Sn	Main question	Sub questions
1	Introduction	Tell me about your profession and what you do? Briefly describe the service your organisation does?
	Solid waste management strategies	How is our concern towards MSWM? Do you think KCCA has good strategy for solid waste management. How do you see the public attitude towards SWM? Do you think the public has sufficient information and awareness about SWM? How do you describe the SWM in Kampala central division.
	Public awareness and environmental impact	What are some of the impacts of SWM you know? How do you support in mitigating the potential impacts caused by the solid waste?

	Energy recovery options	How do you understand energy recovery from waste? Do you think WtE is a better way of practicing waste reduction? What are some of the energy recovery options you know? How do you explain the relations ship between energy recovery and sustainable development

6.3 Observation Checklist

Date:……./……./2020				Area: ………………………..
ACTIVITY		SUSTAINABLE	UNSUSTAINABLE	COMMENT
Nature/ category of waste generated	Organic waste (dry / carbonaceous)			
	Organic waste(moist/wet)			
	Inorganic such as plastics, polythene bags, metal scraps, tin,			
Frequency of waste collection *(are there any information about SWM, how is the collection, efficiency and effectiveness, interaction between waste collectors and the waste generators, strategy, equipments?)*				
Handling of waste at source *(are there waste in open spaces, trenches, drainage channels?)*				
Waste separation at source *(Is there any sign / evidence of waste sorting/separation)*				

Transportation of waste *(By which means is waste transported from the source till the final disposal)*			
Disposal of waste *(state of public waste bin)*			
Reuse of waste as an input for other processes *(is there any possibility of waste recycling)*			
Ambience/ atmosphere at the disposal site			
Evidence of Integrated solid waste management system			

Additional Information

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6.4 KCCA Permission Letter for Data Collection

DIRECTORATE OF PUBLIC HEALTH AND ENVIRONMENT

KCCA
KAMPALA CAPITAL CITY AUTHORITY
For a better City

REF: ***DPHE/KCCA/201/17***

12th June, 2020

Eng. Dr. Swaib Semiyaga
Makerere University
Department of Civil and Environmental Engineering
College of Engineering Design, Art and Technology
P.O. Box 7062
KAMPALA

RE: PERMISSION TO CARRY OUT RESEARCH ON STUDY TITLED, "INFLUENCE OF SOCIAL FACTORS ON ENERGY RECOVERY OPTIONS FROM SOLID WASTE GENERATED IN SCHOOLS AND MARKETS; A CASE STUDY IN CENTRAL DIVISION KAMPALA"

Reference is made to your E-Mail dated 11th June, 2020, This is to inform you that permission has been granted to **Mr. Osinde Anthony** a student from ***Pan African University, Institute for Water and Energy Sciences (Including Climate Change)*** to conduct research on the above-mentioned study at Central Division for a period of 1 Months with effect from 15th June to 15th July, 2020.

The above permission is granted to you on the following conditions: -

1. Participation in your research is voluntary and the informed consent process should be observed at all times.

2. Provision of a report to the office of the Director of Public Health and Environment.

By copy of this letter, the Town Clerk and Solid Waste Management Officer of Central Division are requested to accord you all the necessary Support during the Study period.

P. O. Box 7010 Kampala- Uganda
Plot 1-3 Apollo Kaggwa Road
Tel: 0414 231 446 / 0204 660 000
Web: www.kcca.go.ug, Email: info@kcca.go.ug
f: facebook.com/kccaug, t: @KCCAUG

Najib B. Lukooya (Ph.D)
FOR: AG. DIRECTOR PUBLIC HEALTH AND ENVIRONMENT SERVICES

Cc: Mr. Osinde Anthony (Student)
Cc: Officer Solid waste Management, Central Division KCCA
Cc: Town Clerk, Central Division KCCA

2

6.5 Alternative priority comparison

The pairwise comparison of the different energy recovery technologies in Kampala, Uganda was carried out individually by the selected WtE experts.

Economic criteria

Capital cost

Table 4.10: WtE technology comparison and priority score for capital cost sub-criterion

Name	Normalized	Idealized
1 Anaerobic digestion	0.529789003724337232	1.0
2 Incineration	0.28537100266490878	0.53865029409590337
3 Gasification	0.10499264258332219	0.19817822160375681
4 Landfill Gas Recovery	0.079847351027396735	0.15071538002124724

Inconsistency 0.07854

O&M cost

Table 4.11: WtE technology comparison and priority score for O&M cost sub-criterion

Name	Normalized	Idealized
1 Anaerobic digestion	0.25953052509798918	0.52969427829985394
2 Incineration	0.15707657126813701	0.32058872852924397
3 Gasification	0.093430040657521404	0.19068800457644219
4 Landfill Gas Recovery	0.48996286297635239	1.0

Inconsistency 0.08779

Resource potential

Table 4.12: WtE technology comparison and priority score for resource potential sub-criterion

Name	Normalized	Idealized
1 Anaerobic digestion	0.4203738789622013	1.0
2 Incineration	0.26307049542492894	0.62580124168129725
3 Gasification	0.22395806350865294	0.53275922866936876
4 Landfill Gas Recovery	0.092597562104216796	0.22027430042232207

Inconsistency 0.10909

Operational life

Table 4.13: WtE technology comparison and priority score for operation life sub-criterion

Name	Normalized	Idealized
1 Anaerobic digestion	0.37280022264991469	0.92756673137934664
2 Incineration	0.1025257928823092	0.25509511209499597
3 Gasification	0.12276196020237511	0.30544485556697287
4 Landfill Gas Recovery	0.40191202426540101	1.0

Inconsistency 0.08663

Technical criteria

Efficiency

Table 4.14: WtE technology comparison and priority score for Efficiency sub-criterion under technical criteria

Name	Normalized	Idealized
1 Anaerobic digestion	0.43249838932137713	1.0
2 Incineration	0.077694030212823645	0.17964004521434515
3 Gasification	0.18727744752092404	0.43301305194402362
4 Landfill Gas Recovery	0.30253013294487524	0.6994942418619593

Inconsistency 0.08874

Maturity of technology

Table 4.15: WtE technology comparison and priority score for Technology maturity sub-criterion under technical criteria

Name	Normalized	Idealized
1 Anaerobic digestion	0.43088420127730442	1.0
2 Incineration	0.26670029510254528	0.61896048709129814
3 Gasification	0.1211382542088083	0.28113876965019491
4 Landfill Gas Recovery	0.1812772494113421	0.42070990041864492

Inconsistency 0.09760

Pre-treatment requirement

Table 4.16: WtE technology comparison and priority score for pre-treatment requirement sub-criterion under technical criteria

Name	Normalized	Idealized
1 Anaerobic digestion	0.07229526705187117	0.16903076583921037

2 Incineration	0.42770466589782574	0.99999972581665597
3 Gasification	0.072295283882949715	0.1690308051913037
4 Landfill Gas Recovery	0.42770478316735344	1.0

Inconsistency 0.01063

Social criteria

Employment opportunity

Table 4.17: WtE technology comparison and priority score for employment opportunity sub-criterion under social criteria

Name	Normalized	Idealized
1 Anaerobic digestion	0.2680846926417817	0.53979756927371769
2 Incineration	0.16250106575602011	0.32720137593494658
3 Gasification	0.49663931055206872	1.0
4 Landfill Gas Recovery	0.072774931050129499	0.146534777863702

Inconsistency 0.07009

Public acceptance

Table 4.18: WtE technology comparison and priority score for public acceptance sub-criterion under social criteria

Name	Normalized	Idealized
1 Anaerobic digestion	0.55904746577524522	1.0
2 Incineration	0.13444207548297141	0.24048418732484045
3 Gasification	0.19652099747597351	0.35152828607040171
4 Landfill Gas Recovery	0.10998946126581	0.196744405438427

Inconsistency 0.07444

Occupational health and safety

Table 4.19: WtE technology comparison and priority score for occupational health and safety sub-criterion under social criteria

Name	Normalized	Idealized
1 Anaerobic digestion	0.57542867931274599	1.0
2 Incineration	0.1018879495221012	0.17706442724368454
3 Gasification	0.064513778403029534	0.11211429100141573
4 Landfill Gas Recovery	0.25816959276212331	0.44865610985963372

Inconsistency 0.09008

Environmental criteria

Volume reduction of MSW

Table 4.20: WtE technology comparison and priority score for volume reduction of MSW sub-criterion under environmental criterion.

Name	Normalized	Idealized
1 Anaerobic digestion	0.10653893494833577	0.20649629069901629
2 Incineration	0.51593631337244794	1.0
3 Gasification	0.33983849720713727	0.65868303586883237
4 Landfill Gas Recovery	0.037686254472079066	0.073044392292801907

Inconsistency 0.08005

CO2 emission reduction

Table 4.21: WtE technology comparison and priority score for CO2 emission reduction sub-criterion under environmental criterion.

Name	Normalized	Idealized
1 Anaerobic digestion	0.090326779867406892	0.14581798740467442
2 Incineration	0.2346756995506131	0.37884598843761308
3 Gasification	0.055548703086427773	0.089674403304235262
4 Landfill Gas Recovery	0.61944881749555225	1.0

Inconsistency 0.09402

Land requirement

Table 4.22: WtE technology comparison and priority score for CO2 emission reduction sub-criterion under environmental criterion.

Name	Normalized	Idealized
1 Anaerobic digestion	0.20648310214870741	0.47089274641981466
2 Incineration	0.4384928494197311	1.0
3 Gasification	0.25520096895932898	0.58199573675384442
4 Landfill Gas Recovery	0.099823079472232526	0.22765041574641634

Inconsistency 0.09724