BIOGAS PRODUCTION FROM ORGANIC SOLID WASTES IN KAMPALA CITY, UGANDA

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A Dissertation Presented to the College of Higher Degrees and Research, Kampala International University Kampala, Uganda, In Partial Fulfillment of the Requirements for award of the Degree of Master of Science in Environmental Management and Development.

DECEMBER, 2013.

I can confirm that the corrections were fixed
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DECLARATION

I, **Hussein Garelnabi Mohammed**, solemnly declare that, this dissertation was produced as a result of my own committed efforts and to the best of my understanding, its contents have not been presented for the award of a higher degree or any other professional award in this institution or any other institution of higher learning.

Signature Husseing Garelnabi

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Date 5th/12/2013

Dedication

This dissertation is dedicated to my parents Mr. Garelnabi Mohammed and my dear Mother Umkalthum Elshareif, and my brothers Mohammed, Elshareif, Saif, Mhgoob Siddeg, Elsadigg and Algazafi. In a special way my sisters, zhrah, Siham, Ibtisam, Inaam, Intsar, Insaf and Fatmah also all people who are concerned about the Environment.

Acknowledgement

In the name of Allah, most gracious, most merciful, praise be to God, the cherisher and sustainer of the world, I would like to appreciate the tireless efforts of my supervisor Dr. J.B. Nuwe who has played a key role in guiding, counseling and scrutinizing my work up to the final moment. Also my internal examiner Professor Dominic Byarugaba. I also extend my sincere gratitude to my parents Mr. Garelnabi and my dear Mama, together for constantly being by my side during the hard times. In a special way, I equally convey my utmost and heartfelt gratitude towards my brothers and sisters, also my friends Eniru Emmanuel Innocent for sacrificing a lot of his time, and other friends who supported me so much. I appreciate all those who supported me. Lastly, I would like to thank God for granting me good health, courage, wisdom, knowledge and hope that have made me encounter all the upcoming challenges.

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LIST OF ABBREVIATIONS

ADRA	Adventist Relief Agencies
AMREF	African Medical Research Foundation
CAMARTEC	Centre for Agricultural Mechanization and Rural Technology
CHDR	College of Higher Degrees and Research
CITC	Christian Intermediate Technology Center
CWAS	Child Welfare and Adoption Society
ERL	Environmental Resource Limited
GE	Jenbacher Gas Engines
GHG	Greenhouse Gas
GIZ	Deutsche Gesellschaft fur Internationale Zusammenarbeit
GTZ	German Technology Cooperation
HIP	Heifer International Project
HRT	Hydraulic retention time
KCC	Kampala City Council
KCCA	Kampala Capital City Authority
KIE	Kenya Industrial Estates
KWAP	Kenya wood fuel and Agro forestry Project
LFG	Land Fills Gas
LPG	Liquefied Petroleum Gas
MLHUD	Ministry of lands, housing and urban development
MSW	Municipal Solid waste
NEMA	National Environment Management Authority
NGO	Non-Government Organization
SEP	Special Energy program
SIDO	Small Industries Development Organization
SNV	Netherlands Development Organization
SPSS	Statistical Package for Social Sciences
TDBP	Tanzania Domestic Biogas Programme
VOCs	Volatile Organic Compounds

ABSTRACT

Biogas refers to a gas produced by the biological breakdown of organic matter in the absence of oxygen. Organic waste such as dead plant and animal materials, animal dung, and kitchen waste can be converted into biogas. The main objective of the study was to find out how biogas production process is well known by the local communities in Kampala, Uganda. The specific objectives were to find out the potential organic solid wastes used for biogas production, establish the benefits of using biogas as an alternative energy source, examine the factors affecting biogas generation from organic solid waste and also investigate the relationship between organic solid waste generation and biogas production. The methods used in the study are purposive and snowball sampling. The data collection instruments were the structured questionnaires and interview schedules. The data was analyzed using the Statistical Package for Social Scientists software. The Pearson's chi-square was used to analyze the hypothesis "the relationship between the generation of organic solid wastes and biogas production."

The study found out that the most commonly used types or potential of organic solid waste for the production of biogas are animal wastes, followed by household wastes, crop residues and industrial waste at lowest level. The benefits of biogas production are: it saves time for women and children, it provides a low cost energy source, it is also a clean fuel, further reduces deforestation and forest encroachment, produces an effluent called bio-slurry which is an excellent organic fertilizer, and finally it reduces air and water pollution in that it does not emit large quantities of greenhouse gases. The most common factors affecting the production of biogas are: the high initial investment costs, a relatively high degree of maintenance efforts, the storage and disposal of the bio-slurry, high cost of collecting wastes, and finally the water supply which should be good and constant within reach for the digester. There is a very weak relationship between the factors affecting biogas production and organic solid wastes generated hence the hypothesis was accepted.

The study recommended that a comprehensive biogas policy should be developed containing well stipulated regulatory standards and quality control must be enacted by the government, low cost biogas plants and building materials should be subsidized by the government for easy adoption, demonstration sites should also be set, people must be instructed to construct biogas plants where there is a nearby and reliable water source for ensuring constant water supply for the digestion chamber to function effectively. Also the local community's participation in different organic solid waste collection systems, storage and decision-making should be a priority, pilot fuel cells projects should be established, educates institutions and individuals of the potential of organic solid waste, and further increase the rate of creating awareness about biogas potential production from organic solid waste.

CHAPTER ONE: INTRODUCTION

1.1 Background of the study

Biogas typically refers to a gas produced by the biological breakdown of organic matter in the absence of oxygen. Organic waste such as dead plant and animal materials, animal dung, and kitchen waste can be converted into a gaseous fuel called biogas. Biogas originates from biogenic material and is a type of bio fuel biogas produced by the anaerobic digestion or fermentation of biodegradable materials such as biomass, manure, sewage, municipal waste, green waste, plant material and crops. Biogas comprises primarily methane (CH_4) and carbon dioxide (CO_2) and it may also have small amounts of hydrogen Sulphide (H_2S), moisture and siloxanes. The gases methane, hydrogen and carbon monoxide (CO) can be combusted or oxidized with oxygen. This energy release allows biogas to be used as a fuel. Biogas can be used as a fuel in any country for any heating purpose, such as cooking and thus providing and documenting baseline information about the benefits of biogas can further help people who live in Kampala and Uganda at large by benefiting schools, tertiary institutions, local communities and government agencies to reduce heavy reliance on fuel wood and Hydro Electric Power (HEP). It can also be used in anaerobic digesters where it is typically used in a gas engine to convert the energy in the gas into electricity and heat. Biogas can be compressed, much like natural gas, and used to power motor vehicles. In the United Kingdom, for example, biogas is estimated to have the potential to replace around 17% of vehicle fuel. Biogas is a renewable fuel, so it qualifies for renewable energy subsidies in some parts of the world. Biogas can also be cleaned and upgraded to natural gas standards when it becomes bio-methane (FAO, 1996).

Organic waste is a growing problem especially in urban and peri-urban areas in Uganda. This is largely due to increasing consumer demand for foodstuffs that are marketed in raw form (Ekere *et al.*, 2009). The marketing of raw unprocessed foods means that the task of processing them is carried out by the final consumers resulting into massive accumulation of organic waste in homesteads and urban areas.

Kampala City alone generates about 40,000 tones of household and market wastes annually with a collection of only 36% (Kampala City Council, 2002). In contrast, Mwesigye and Sabano (2003) found out that daily solid waste production by Kampala's population of about 1.2 million people, at about 900 metric tones with only a collection capacity of about 45%. Composting and burning of waste are the most common ways of managing waste in the rural areas (Ekere *et al.,* 2009) whereas sanitary landfills continue to be largely the common disposal method for urban waste. In Kampala City, for instance, land filling is the only formal way of waste disposal (Kampala City Council, 2002). However, such landfills inevitably generate waste management problems (Zamorano, 2005).

In addition, Kahn (1998) noted that developing new landfill sites or technical situations to waste disposal (such as incineration) treat only the symptoms of the problem but not the problem. Waste disposal in landfills can generate environmental problems such as water pollution, unpleasant odors, explosion and combustion, asphyxiation, vegetation damage, and greenhouse gas emissions (Department of the Environment UK, 1995). These problems render the whole waste collection operation unsustainable. Appropriate and sustainable solutions must therefore be devised to deal with the eminent problem of waste. One sustainable approach to manage the large quantities of organic solid waste and increase their value is to use them as an energy resource. Through appropriate conversion technologies, organic wastes can be a good source of raw materials for the generation of renewable energy which leads to the attainment of the twin objective of sustainable waste management strategy using the methods and approaches explained above and also increasing other energy sources such as biogas to foster socio-economic development of the country.

Biogas generation is the production of biogas for the purpose of generating alternative energy for electricity, car fuel and various other purposes. An odourless, inflammable gas, comprising mainly of methane and carbon dioxide, biogas is produced when organic matter is broken down by anaerobic bacteria digestion. The organic matter used for biogas generation includes human waste, animal manure, food waste, sewage, paper crops (FAO, 1996).

1.1.1 History of biogas production in Uganda

Nyendahayo (2011) narrated a story about a former Vice President of Uganda who was invited to China in the mid 80's to look at Chinese agricultural systems inspired me even more. He explained that "one day the Vice President was invited by the Chinese government and while there, he was taken to visit different families in different parts of rural China. He found the local people were using biogas out of bio digesters which actually used cow dung as raw material. They were able to use the same gas to power machinery, power lights, for cooking, refrigeration and even in incubators. Much of Uganda was still in the dark by then. By then, he said that very few people know about the above technology and he noted that much of rural Uganda goes pitch black by 7pm and only a few candle lights can be seen here and there".

Nyendahayo (2011) further explained that "Upon his amazement, the Vice President immediately requested the Chinese government to provide him with two experts to accompany him to Uganda and he expected them to help teach at least two Ugandans on how the biogas production technology worked. The duo arrived some time in 1985. Unfortunately the war was raging on at the time and so the two Chinese experts had very little time in Uganda. While sharing their expertise, the war became even intense and wanted to go back immediately. However, the Vice President became rather angry that the two Ugandans in the hands of the Chinese experts had not yet grasped the workings of biogas. They had only learned how to dig holes where the bio digesters would be built. On the contrary, although the rebels were then approaching Kampala (6 miles away from the city centre) the Vice President could not allow the Chinese to go back until the two Ugandans knew exactly what to do. The Chinese had no choice then apart from doing exactly what they had to do, that is teach the two Ugandans all they knew and get out of Uganda as soon as possible." Well, that was exactly how the very few Ugandans became introduced to biogas technology.

1.1.2 Benefits of biogas

By using biogas, many advantages arise. In Uganda, utilization of biogas would generate enough electricity to meet up to three percent of the country's electricity expenditure (Njendahayo, 2011). In addition, biogas could potentially help reduce global climate change. Normally, manure that is left to decompose releases two main gases that cause global climate change: nitrous dioxide and methane. Nitrous dioxide warms the atmosphere 310 times more than carbon dioxide and methane 21 times more than carbon dioxide. By converting cow manure into methane biogas via anaerobic digestion, the hundreds of cows in Uganda would be able to produce many kilowatt hours of electricity, enough to power hundreds of homes across Uganda (Njendahayo, 2011).

1.1.3 Cost for building bio digesters

Depending on size and location, a typical brick made for fixed dome biogas plant can be installed at the yard of a rural household with the investment of between UK £600-800. A high quality biogas plant needs minimum maintenance costs and can produce gas for at least 15-20 years without major problems and re-investment (Njendahayo, 2011).

1.2 Statement of the problem

There is a growing concern over the potential impact on environmental quality and socio-economic consequences caused by the generated wastes (Kampala City Council, 2002; Ekere *et al.*, 2009). The accumulation of the wastes and lack of safe waste handling practices creates environmental and health problems. Poor waste collection practices attract and promote the breeding of undesirable and potentially disease transmitting insects like cockroaches, house flies and mosquitoes and other pathogens like bacteria. (Zamorano, 2005)

Solid waste means any garbage, refuse, sludge from a wastewater treatment plant, water supply treatment plant, or air pollution control facility and other discarded materials including solid, liquid, semi-solid, or contained gaseous material, resulting from industrial, commercial, mining and agricultural operations, and from community activities, such household waste, human excreta but does not include solid or dissolved materials in domestic sewage, or solid or dissolved materials in irrigation return flows or industrial discharges that are point sources (MLHUD, 1993).

The main types of organic solid waste are domestic refuse, market refuse, commercial, industrial refuse, abattoir wastes and hospital waste. It is estimated that approximately 25,000 tones of solid waste are generated in Kampala every month, an average of 800 tons day (MLHUD, 1993). Only about 5,000 tones are collected per month and transported by then Kampala City Council and currently Kampala Capital City Authority (KCCA), to the dumping site at Mpererwe. This service in 1996 only covered 20% of the generated waste. Almost 80% of the generated wastes were not collected by Kampala City Council. As a result the unfortunate residents make their own arrangement to dispose of their waste. Some people bury it, others burn it, while others simply throw it on unauthorized sites like roadsides and public land. Some families have even established mini permanent dumping sites in their backyard or nearby location and such sites are often a source of littering, pollution and offensive smells and provide breeding grounds for rats, flies and mosquitoes (MLHUD, 1993). Each household in Uganda generates approximately 1 tone of domestic waste per year. Urban domestic waste management is drawing increasing attention, as citizens observe that too much garbage is lying uncollected in the streets, dustbins, causing inconvenience and environmental pollution, and being a risk for public health (MLHUD, 1993). Therefore the purpose of this research is to assess the best measures for producing biogas as a means of reducing on the large quantities of organic wastes within Kampala.

1.3 Research Objectives

1.3.1 General objective

The general objective of this study was to find out how biogas production process is well known by the local communities in Kampala, Uganda.

1.3.2 Specific objectives

The specific objectives of the study were;

(i) To find out the potential organic solid wastes used for biogas production.

(ii) To establish the benefits of using biogas as an alternative energy source.

(iii) To examine the factors affecting biogas generation from organic solid waste.

(iv) To investigate the relationship between generation of organic solid waste and biogas production.

1.4 Research questions

This study was guided by the following research questions:

(i) What are the potential organic solid wastes used for biogas production?

(ii) What are the benefits of using biogas?

(iii) What are the challenges involved in biogas generation from organic solid wastes?

(iv) Is there any relationship between generation of organic solid wastes and biogas production?

(v) Is there any policies containing the standards, quality and control of biogas?

1.5 Hypothesis

The hypothesis of the study was:

There is no significant relationship between the organic solid wastes generated and biogas production.

1.6 Scope of the study

Geographical scope: The study was conducted in Nsambya Central Parish specifically in Hospital zone and Nsambya Babies Home.

Content scope: The study focused on finding out the process of biogas production from organic solid wastes through the following objectives, finding out the potential organic solid wastes used for biogas production, establishing the benefits of using biogas as an alternative energy source, examining the factors affecting biogas generation from organic solid waste, and investigating the relationship between organic solid waste generation and biogas production.

Time scope: The study was carried out from June 2012-May, 2013.

1.7 Significance of the study

The result of the study will improve on the living conditions of the population and reducing indoor pollution, encouraging better access to information regarding electricity generation from biogas where by both the urban and peri-urban population can use this form of energy for domestic purposes such as watching television, lighting and cooking, among others.

It will also contribute to general knowledge about the production of biogas from organic solid waste and reduce the impact on environment towards better life. It will reflect on knowledge creation, as well as on technological or socio-economic value to the community.

The findings will equally help the legislators to come up with efficient energy policies and laws that facilitate proper management of solid wastes to reduce environmental degradation.

In addition, biogas could potentially help reduce global climate change. Normally, manure that is left to decompose releases two main gases that cause global climate change: nitrous dioxide and methane.

1.8 Operational definitions of key terms

Anaerobic digestion: is a series of processes in which microorganisms break down biodegradable material in the absence of oxygen it is used for industrial or domestic purposes to manage waste and/or to release energy.

Biogas: Biogas is about 20% lighter than air and has an ignition temperature in the range of 65^0C to 75^0C. It is odourless and colourless gas that burns with clear blue flame similar to that of liquefied petroleum gas (LPG).

Biogas generation: This is the production of biogas for the purpose of generating alternative energy for electricity, car fuel and various other purposes.

Biorest: A waste residue in liquid and solid forms is obtained after biogas generation.

Solid wastes: are any discarded (abandoned or considered waste-like) materials.

Organic solid waste: Organic solid waste such as dead plant and animal material, animal dung, and kitchen waste can be converted into a gaseous fuel called biogas.

Family-size: it is a model of biogas plants used in developing countries, there are two basic designs of family-size biogas plants: the floating drum type and fixed dome type.

Energy: Energy is the driving force for the universe and it is the ability to work.

Energy reserves: unused energy sources. Examples are coal, gas, and oil.

CHAPTER TWO: LITERATURE REVIEW

2.1 Concept of biogas

Biogas refers to a gas made from anaerobic digestion of agricultural and animal waste. The gas is a mixture of methane (CH_4) 50-70%, carbon dioxide 30-40%; hydrogen 5-10%, nitrogen 1-2%, hydrogen Sulphide (trace), water vapor 0.3%. The gas is useful as a fuel substitute for firewood, dung, agricultural residues, petrol, diesel, and electricity, depending on the nature of the task, and local supply conditions and constraints. Biogas is about 20% lighter than air and has an ignition temperature in the range of 65^0C to 75^0C. It is odourless and colourless gas that burns with clear blue flame similar to that of liquefied petroleum gas (LPG). Its caloric value is 20 mega joules (MJ) /m^3 and burns with 60% efficiency in a conventional biogas stove biogas systems also provide a residue organic waste, after anaerobic digestion that has superior nutrient qualities over the usual organic fertilizer, cattle dung, as it is in the form of ammonia.

Anaerobic digesters also function as a waste disposal system, particularly for human waste, and can, therefore, prevent potential sources of environmental contamination and the spread of pathogens (FAO, 1996).

2.2 Theoretical perspectives

For many years the rational behind using biogas technology was the search for renewable sources of energy. In the meantime, other environmental protection aspects gain additional importance. By using biogas, many advantages arise. In Uganda, utilization of biogas would generate enough electricity to meet up to three percent of the country's electricity expenditure (Njendahayo, 2011). This theoretical frame it would work best in the peri-urban areas especially slums in Kampala and other modern towns like Mbale, Mbarara, Maseka, Jinja, Lira and Gulu, among other with high demand for electricity in their duty activities.

It would further work best under livestock rearing because the livestock would product much cow dung to be used as raw material for construct product of good quality biogas especially for lighting and cooking. This can reduce the amount of organic solid wastes discharged or dumped into various undesignated part of the City or town.
Biogas can (i) provide a low cost energy source for cooking and lighting, because it's produced by readily-available animal dung and human waste, (ii) improve sanitation in the home, farmyard and surrounding environment,(iii) eliminate respiratory and eye diseases caused by indoor air pollution resulting from traditional cooking with wood, because it eliminates the need for an indoor wood fire, (iv) save time for women and children, because they do not need to collect wood,(v) create rural employment, particularly for biogas masons and entrepreneurs,(vi) produce an effluent called bio-slurry which is an excellent organic fertilizer,(vii) lessen the pressure on rangeland as biogas stimulates zero-grazing practices thus making the ecosystem becomes more resilient, (viii) reduce greenhouse gas emissions on a global level, (ix) and reduce deforestation and forest encroachment by providing a realistic substitution for fuel wood (Renard,1988).

Biogas production also has economic benefits, reducing energy production expenditure and benefiting communities, especially rural ones in developing nations. Biogas plants can create employment opportunities for the local populace and, aside from helping local farms cut down on electricity bills, the biogas system can also help farms make a profit from waste treatment, fertilizer manufacture and biogas energy sale (FAO, 1996).

2.2.1 Potential organic solid wastes used for biogas production.

Anaerobic digestion technology: Many studies have been conducted on biogas production and utilization as an alternative energy resource. A similarity with most of these studies is the emphasis of the importance of biogas as a source of energy (Adeoti *et al.*, 2000; Akinbami *et al.*, 2001; Gupta and Ravindranath, 1997; Ni and Nyns, 1996; Singh and Sooch, 2004; Taleghani and Kia, 2005; Yadvika *et al.*, 2004).

Biogas producing materials (substrates) range from animal dung to household, agricultural and industrial wastes. It is produced through the process of anaerobic decomposition and fermentation of cellulose containing biodegradable materials such as cattle dung, poultry droppings, pig excreta, human excreta, crop residues (Erdogdu, 2008). This results in the 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 vapors (Erdogdu, 2008; Singh and Sooch, 2004).

The structural set up in which the fermentation occurs is called the biogas plant - a technical facility in which the biogas production process takes place (Raven and Gregersen, 2005). Biogas is utilized mainly for cooking and lighting while the slurry provides a good source of manure for soil fertility improvement. For operational biogas plants, households use the slurry as fertilizer for their crops, especially vegetables and fruits (Walekhwa *et al.*, 2009). With proper location and construction of the biogas units, the slurry will freely flow downstream to gardens. Slurry occurs in the following common forms: (i) a light and rather solid fraction, mainly straw or fibrous particles which float to the top of the digester forming a scum (ii) a liquid, watery fraction remaining in the middle layer of the digester (iii) a viscous fraction below which is the real slurry or sludge, and (iv) heavy solids, mainly sand and soil particles, which settle at the bottom of the digester.

Biogas plant designs: There are many designs or models of biogas plants. However, each design is directly linked to its hydraulic retention time (HRT), which may be defined as the time period during which the biogas producing material stays in the digester to produce the biogas before being fully exhausted of its biochemical potential of producing biogas (Singh and Sooch, 2004). The HRTs of plants are different for different regions. In tropical countries, HRT varies from 30–50 days while in temperate countries it may go up to 100 days (Yadvika, 2004). The models of biogas plants used in developing countries are mainly small-scale ones and are commonly referred to as

family-size digesters (Singh and Sooch, 2004). There are two basic designs of family-size biogas plants; the floating drum type and fixed dome type.
The floating drum type plants, which are Indian designed, have an underground well shaped digester with inlet and outlet connections through pipes at its bottom on either side of a partition wall (Rijal, 1985). An inverted drum (gas holder), is placed in the digester, which rests on the wedge shaped support and the guide frame at the level of the partition wall. This drum can move up and down along a guide pipe with the accumulation and disposal of gas, respectively. The weight of the drum applies pressure on the gas to make it flow through the pipeline to the point of use (Singh and Sooch, 2004).

The need to have an alternative inexpensive design to bring it within the reach of the poor rural population, two types of fixed dome models of biogas plants, which are Chinese designed, have been designed (Kandpal *et al.*, 1991). In this case the digester and the gas holder are integrated parts of the brick masonry structure and the digester is made of a shallow well having a dome shaped roof on it. The inlet and outlet chambers are connected with the digester through large chutes. These chambers are above the level of the junction of the dome and the cylindrical well. The gas pipe is fitted on the crown of the masonry dome.

The second model is designed on the basis of the principle of minimization of the surface area of a biogas plant to reduce its installation cost without sacrificing its functional efficiency (Singh and Sooch, 2004). The design consists of two spheres of different diameters, joined at their bases. The structure thus formed acts as the digester or fermentation chamber, as well as the gas storage chamber. The digester is connected with the inlet pipe and outlet tank. The upper part above the normal slurry level of the outlet tank is designed to accommodate the slurry to be displaced from the digester with the generation and accumulation of biogas.

Biogas plant designs in Uganda: The plant designs used in Uganda are mainly the small-scale type commonly referred to as family-sized digesters (Kandpal *et al.,* 1991) with two basic designs: floating drum and fixed dome. The fixed dome is the most preferred biogas plant design in Uganda. The floating drum digester is not popular because it is very costly, Tanzania, is the most common digester in Uganda. Its installation cost ranges between US$ 700 and 1200, depending on the size (Kassenga, 1997).

Another type also referred to as the tubular or polythene or plastic digester has been recently promoted to reduce installation and operation costs further by using local materials. The type of plastic materials needed for this digester can be obtained locally, and construction requires relatively simple skills, thereby significantly lowering costs (Kassenga, 1997). However, this type of digester is unpopular in Uganda because it has a much shorter lifespan than the other types (Walekhwa *et al.*, 2009).

Most family-sized digesters promoted in Uganda have installed digester capacity volume of 8, 12 or 16 m^3 (Walekhwa *et al.,* 2009). Few community and institutional biogas plants with capacity of 30 or 50 m3 have also been installed. Cow dung for the zero-grazed cattle is currently the major feedstock for biogas digesters in Uganda. However, there is an abundance of other potential feedstock, including agro-industrial wastes and residues, municipal solid wastes and waste waters, forestry by-products and residues, crop residues and household food wastes (Walekhwa *et al.*, 2009). The biogas generated is for mainly household cooking and lighting while the slurry is used as a fertilizer in agricultural production.

Biogas energy production and utilization in Uganda: While the foregoing biogas energy production and utilization statistics show that biogas technology is a successful story in Europe and a number of Asian countries, this important waste management strategy and renewable energy source has not been fully harnessed in Africa however, data on the number and size of biogas plants and actual quantity of biogas generated in various African countries remains scanty (Akinbami *et al.*, 2001). The development of biogas technology in Eastern Africa is still at an embryonic stage although the potential is promising (Day et al., 1990; Mwakaje, 2008).

The history of biogas technology in Uganda is relatively old, dating back to the 1950s when the technology was first introduced by the church missionary society (Nabuma and Okure, 2004; Pandey *et al.*, 2007). In the 1960s some missionaries built one demonstration plant in Kotido district. The first extensively documented study on biogas technology in the country was a PhD (Doctor of Philosophy) thesis by Boshoff then based at Makerere University (Pandey *et al.*, 2007). He studied the biogas digester built at Kabanyolo University Farm for demonstration purposes. However, the technology did not go beyond the University farm gates.

Pandey *et al.,* (2007) further asserted that a baseline study of biogas technology in the central region of Uganda was conducted and recommended that biogas energy in Uganda was viable. However, implementation was not undertaken due to poor political climate at the time. Since then, there have been efforts by the government to promote the technology but with limited success.

In 1985, a Chinese biogas technical team carried out a feasibility study covering many districts in Uganda including private, government and co-operative firms (Pandey *et al.*, 2007). They concluded that the technology was most viable in small-scale private dairy farms with easy access to feedstock. A government pilot project was implemented by the then Ministry of Animal Husbandry and Fisheries with technical assistance from the Republic of China, in which seven digesters were installed in Eastern Uganda in 1985 (Kuteesakwe, 2001). However, because of inadequate technical capacity to monitor and maintain the digesters, only one digester was functional by 1987. Another Programme funded by the World Bank and implemented by the then Ministry of Natural Resources established 10 biogas digesters with a total gas capacity of 262 cubic meters. This programme did not also register much success.

In 1989, the government showed further interest in the technology, and several demonstration plants were constructed in the country (Pandey *et al.*, 2007). FAO carried out another study through the then Ministry of Energy, which led to the creation of a national biogas programme in Uganda. They recommended that the Chinese-type design be built in secondary schools as bio-latrine system using cow dung but with possibilities of incorporating human waste later. A number of secondary schools consequently built these plants such as Tororo Girls' secondary school, Kings College Budo, Busoga College Mwiri, Namagunga and Gayaza High Schools. Most of these schools did not have adequate livestock. The acquisition of feedstock became the main constraint coupled with inadequate knowledge of the technology (Kuteesakwe, 2001).

During the 1990s, a number of government and private initiatives were invested in development and popularization of biogas technology in Uganda. Between 1997 and 1998, the Chinese Government, through a memorandum of understanding with the Government of Uganda, committed about US$ 170,000 for construction of 20 demonstration biogas digesters and training of Ugandans in the design, construction and maintenance (Kamese, 2004). During this period an estimated 120-170 biogas units were constructed in the country. Out of these, about 50% were operational by 1999 (Kuteesakwe, 2001). Several demonstration biogas plants were built over a decade ago but the technology never went beyond the demonstration sites.

All these programmes demonstrate the government's attempts through funding from various donor agencies and private initiatives to disseminate biogas technology in the country. Biogas energy has been recently popularized mainly by nongovernmental organizations (NGOs) including Heifer International Project (HIP), Adventist Relief Agencies (ADRA), AMREF (African Medical Research Foundation) and Africa 2000 Network. Smaller technologies that do not require a lot of investment in costs of construction were introduced and are being promoted mainly by NGOs to boost dissemination of biogas technology in the country. In general, the development of biogas technology in Uganda has not been very significant. Pandey *et al.*, (2007) assert that the total theoretical biogas potential is about one billion m^3 per year, with energy potential equivalent to a 1,000 MW hydropower plant.

2.2.2 Establish the benefits of using biogas as an alternatives energy sources.

When biogas is used, many advantages arise. In North America, utilization of biogas would generate enough electricity to meet up to three percent of the continent's electricity expenditure. In addition, biogas could potentially help reduce global climate change. Normally, manure that is left to decompose releases two main gases that cause global climate change: nitrous dioxide and methane. Nitrous dioxide (NO_2) warms the atmosphere 310 times more than carbon dioxide and methane 21 times more than carbon dioxide. By converting cow manure into methane biogas via anaerobic digestion, the millions of cows in the United States would be able to produce one hundred billion kilowatt hours of electricity, enough to power millions of homes across the United States. In fact, one cow can produce enough manure in one day to generate three kilowatt hours of electricity, only 2.4 kilowatt hours of electricity are needed to power a single one hundred watt light bulb for one day. Furthermore, by converting cow manure into methane biogas instead of letting it decompose, we would be able to reduce global warming gases by ninety-nine million metric tons or four percent (FAO, 1996).

The 30 million rural households in China that have biogas digesters enjoy 12 benefits:(i) saving fossil fuels, (ii) saving time collecting firewood, (iii) protecting forests, (iv) using crop residues for animal fodder instead of fuel, (v) saving money, (vi) saving cooking time, (vii) improving hygienic conditions, (viii) producing high-quality fertilizer, (ix) enabling local mechanization and electricity production, (x) improving the rural standard of living, (xi) and reducing air and water pollution. Biogas can : (i) Provide a low cost energy source for cooking and lighting, because it's produced by readily-available animal dung and human waste, (ii) improve sanitation in the home, farmyard and surrounding environment , (iii) eliminate respiratory and eye diseases caused by indoor air pollution resulting from traditional cooking with wood, because it eliminates the need for an indoor wood fire , (iv) save time for women and children, because they

Major constraints to biogas technology dissemination include: (i) high initial investment costs compounded with lacking credit schemes, (ii) negative image caused by failed biogas plants, (iii) limited private sector involvement (Day *et al.*, 1990; Mwakaje, 2008).

2.3.2 Tanzania domestic biogas programme

Tanzania population of 37 million people is growing at 2% per year. Nearly 80% of Tanzanians live in rural areas where they meet 94% of their energy needs with biomass, particularly by burning wood. This dependency on fuel wood has led to a rapid deterioration of Tanzania's ecosystems. Collecting fuel wood requires difficult time-consuming work primarily done by children and women. Smoke from burning fuel wood also leads to respiratory and eye diseases. Renewable energy technologies, like domestic biogas, can improve the present situation. Biogas has a relatively long history in Tanzania and was initially introduced by the Small Industries Development Organization (SIDO) in 1975. Center for Agricultural Mechanization and Rural Technology (CAMARTEC) and GTZ carried this work forward in the 1980s-1990s by developing, promoting and providing training in the biogas sector. During those years, interested parties built around 6,000 biogas digesters. As a result, older generations of Tanzanians know the advantages of biogas.

Biogas is a feasible option for the domestic energy needs of Tanzania's rural population and offers the following socioeconomic and environmental advantages. Biogas: (i) provide a low cost energy source for cooking and lighting, because it's produced by readily-available animal dung and human waste, (ii) improve sanitation in the home, farmyard and surrounding environment, (iii) eliminate respiratory and eye diseases caused by indoor air pollution resulting from traditional cooking with wood, because it eliminate the need for an indoor wood fire, (iv) save time for women and children, because they don't need to collect wood, (v) create rural employment, particularly for biogas masons and entrepreneurs, (vi) produce an effluent called bio-slurry which is an excellent organic fertilizer, (vii) lessen the pressure on rangeland as biogas stimulates zero-grazing practices. As a result, the ecosystem becomes more resilient, (viii) reduce greenhouse gas emissions on a global level and (ix) reduce deforestation and forest encroachment by providing a realistic substitution for fuel wood (Renard , 1988).

Based on the 2007 feasibility study and 2008 programme implementation document, SNV estimates that the technical for domestic biogas in Tanzania is around 165,000 households, Kilimanjaro, Mbeya, Iring and Ruvuma are the areas with the most potential. SNV previously developed a commercially-viable method to promote domestic biogas in Asia, and we recently introduced this concept to a number of African countries, including Rwanda, Ethiopia, Kenya, Uganda, Senegal, Burkina Faso and Tanzania. This concept is based on a multi-stakeholder approach focused on involving the private sector to market and construct quality domestic biogas infrastructure and provide after sales services to the biogas households. The programmes promote single, standardized biogas digester designs to enable clear and robust quality management systems. (Kassenga, 1997)

The Tanzania Biogas Stakeholders Group opted for the modified CAMARTEC design in four different sizes to respond to the energy needs of individual households and the availability of animal dung. A major challenge is the relative high initial investment to build a biogas plant. The turnkey cost for a 6 m^3 digester can be as high as US$1,000. To stimulate demand, we are working to find a way to provide financial incentives like investment subsidies and special biogas loans. Rather than directly executing the biogas programme, SNV will assist CAMARTEC and other programme partners to implement the Tanzania Domestic Biogas Programme (TDBP). The main actor is the private sector providing construction and after-sales services. Financial support is obtained from the Netherlands Government through its Africa Biogas Partnership Programme.

Over the next five years, the first phase of the project, SNV and TDBP will work to improve the livelihoods and quality of life of rural farmers in Tanzania through exploiting the market and non-market benefits of domestic biogas. By the end of the first phase, the programme aims to; (i) Support the construction of 12,000 new biogas plants nationwide and keep at least 95% of the constructed biogas plants in continued operation, (ii) enable proper bio-slurry use by fitting 80% of the biogas plants with the needed facilities. The bio-slurry will transform 65 kilotons of organic matter into rich organic fertilizer that can significantly increase agricultural yields and may reduce the amount farmers spend on chemical fertilizers, (iii) fit all biogas plants with a second inlet pipe to allow a future toilet connection and help 2,400 households connect a toilet to their biogas installation to further improve the sanitary situation of the households, (iv) protect 8,000 hectares of forest from being deforested and reduce greenhouse gas emissions by 60 kilotons of Carbon Dioxide (CO2). Biogas generated by the plants will produce the equivalent of nearly 100 kilotons of biomass fuel, (v) benefit 72,000 people directly by eliminating the need to gather fuel wood, thereby reducing the daily workload of women and children by the equivalent of 2,003 human years of labor. Women and children will also chiefly benefit from the elimination of indoor air pollution, (vi) provide 16,800 days of user training and over 5,000 days of professional training. The programme will generate direct employment in rural areas equivalent to 840 human years. (Kassenga,1997)

SNV will strive to meet the above targets in the first phase of the programme, but long term, TDBP estimates it will need 10 dedicated years to establish a commercial viable domestic biogas market, with 100,000 domestic biogas digesters operating in Tanzania.

2.3.3 Biogas success worldwide

Leading countries include China, India, and Brazil. In the East African region, Tanzania has had the greatest success where successfully promoted and installed fixed dome biogas digesters. More than 1,000 digesters have been installed and are being maintained by a cadre of trained local technicians. The fixed biogas digesters cost between US$ 800 and 1, 300 for a local Tanzanian NGO is now promoting a simple low cost Tubular Plastic biogas digester costing approximately US$150. The gas produced is mainly used for cooking and lighting. These costs are likely to vary for other countries depending on labor and material costs (Renard, 1988).

In Europe, crop and animal wastes are being used to generate biogas energy. This, to a great extent, has reduced environmental problems associated with crop and animal wastes (Raven and Gregersen, 2005). The European Union is producing more than four million tones of oil equivalent (MTOE) of biogas each year (Refocus Report, 2005). In these countries, biogas is produced from several different sources, mainly from waste storage centers (rubbish dumps) and urban and industrial sewage treatment plants, municipal dump mechanization units, agricultural installations and collective co-digestion units (Raven and Gregersen, 2005).

Centralized biogas plants in Denmark, for instance, generate renewable energy, enable recycling of organic waste, play a role in manure distribution and storage, and improve the veterinary aspects of manure. These advantages make biogas plants a technology that is able to combine several environmental benefits across different sectors (Raven and Gregersen, 2005). Similarly in Asia, biogas production is an important waste management strategy and a vital source of household energy. For instance, the biogas digester is a popular project as a waste treatment system in Thailand. China, the biggest rural biogas user in the world, already had 5.7 million operational rural household digesters by the end of 1995 for cooking and lighting and in some cases for electricity generation (Ni and Nyns, 1996). In India, 35,647 biogas plants had been installed in the state of Himachal Pradesh alone by 1995 (Singh and Verma, 1996). By 1994, an estimated 285 million tones of net animal waste generated between 10,830 and 21,660 million m^3 of biogas per year in Pakistan (Ghaffar, 1994). In Nepal, over 37,000 biogas plants were established between 1992 and 1996, serving over 200,000 people (Biswas and Lucas, 1996).

2.3.4 Factors affecting biogas generation from organic solid waste.

Biogas as a source of domestic energy was introduced over 50 years ago with approximately 700 units installed in Uganda by 2008. As investigated in Dr. Kariko's report, biogas digesters did not meet the expectations in many cases: numerous plants are failing or under-performing due to (i) poor construction works, (ii) biological reasons, (iii) lack of regular maintenance, and (iv) socio-economic factors.

Therefore, to be able to run a biogas system in a successful way some requirements must be fulfilled. These include the following: (i) proper construction skills - The units must be built in a proper way to avoid leakages and other disturbing influences, (ii) feedstock - there must be access to organic agricultural and/or other type of waste, infrastructure like kitchen waste and food leftovers can also provide an excellent feedstock. Furthermore, certain substances may act as inhibitors to the system decreasing or completely stopping the gas production process, (iii) water supply - there should be a good constant supply of water within reach for the digester, (iv) human labour - to manage the biogas plant by feeding the digester regularly and carrying out maintenance, (v) reluctance towards the use of dung excrements as base for the cooking gas is to be overcome by awareness-raising and demonstration, (vi) experts are required for the design of the reactor and skilled labor is required for the construction of a gastight tank. Substrates need to contain high amounts of organic matter for biogas production slurry may have to be further treated before reuse for example composting (MUELLER, 2007).

2.3.5 Investigate the relationship between generation of organic solid waste and biogas production

In Kampala City alone domestic waste generation rates range between 0.5 kg and 1.1 kg per capita per day (KCC, 2002). The population of Kampala city and its suburbs is estimated at 1.5 million people. The estimate of waste per capita generation per day is 0.5 kg. This makes the total collection to be 1.5 million x 0.5 kg = 750,000 kg per day or 750 tones generated per day. Domestic waste generation is higher among high income earners populations. On average the collection is 45-50% of this and so on a daily basis collection amounts to 375 tons or 37,500 kg of waste collected a day from Kampala.

In composition, plastics under which polythene falls account for 1.6% with the highest being 73.8% for vegetable matter with the rest being tree cuttings, glass, metals, and paper, etc. Kampala City generates 750 tons of domestic waste per day. On the management however, the dumping is done by the K.C.C. at Mpererwe, a landfill made in 1996 after the former one at Lweza and Lubigi. A comprehensive study was carried out in 1990. The findings are contained in a report called solid waste disposal–Kampala final report which was prepared by environmental resource limited (ERL). This report led to the formulation of the solid waste component of Uganda first urban project.

Table 1: Waste composition according to ERL in Kampala was as below.

Type of waste	Percentage
Vegetable Matter	73.8
Paper	5.4
Sawdust	1.7
Plastic	1.6
Metal	3.1
Glass	0.9
Tree cuttings	8.0
Street debris	5.5

Source: *Solid waste disposal Kampala report 1990*

And the average per capita waste generation was 0.5 kg per person per day. Kampala City Council (KCC) is responsible for the solid waste management of Kampala, due to the local governments act, 1997. KCC is the district/urban local government in the city of Kampala. The KCC consists of an elected council headed by a chairperson as well as team of professionals headed by the chief executive. KCC is divided into five sub-counties, called divisions in Kampala. The divisions are all administrative units and they are responsible for solid waste collection and transportation of the solid waste in their own division. Solid waste disposal is the responsibility of the KCC headquarters. The solid waste is collected either by KCC itself or by private actors. The private actors accounted for around 10% of the waste delivered to the landfill in 2002 (KCC, 2002).

The private collectors can only collect waste from areas where people can afford to pay for the waste they generate. KCC prefer to delegate the responsibility of collecting the solid waste to as many private actors as possible. The reason is that KCC is not allowed to charge money for their work directly from each household. KCC gets its money from the taxes paid by the residents of Kampala. However, the private actors are allowed to charge their customers for the work they do. The private actors provide a door to door service of waste collection twice a week at Ugandan shillings 20,000 to 30,000 a month (KCC, 2002).

Because of the advantages of letting private actors take care of the waste collection, the KCC plan to extend the rate of using private contractors to collect the waste. Such an extension will imply specific costs for waste collection also for residents of medium and low income areas. Residents living in low income areas like Bwaise, Katwe, Kalerwe and Kinawataka will pay Ush 100 a day or Ush 2,500 a month according to a proposal made by Lubowa, the city secretary for health, hygiene and environmental improvement.

People living in the medium income areas like Najjanankumbi, Kitintale, Kabowa and Rubaga will be charged Ush 200 a day or Ush 5,000 Ush a month (Ntabadde, 2004).The KCC itself is responsible for collecting the remaining waste. For that purpose KCC has 20 trucks available to collect the waste from their 500 skips. These skips range from a capacity of 5 m^3 to a maximum of 15 m^3. The waste is transported to the landfill site of KCC, Mpererwe landfill. Currently only 40% of the waste generated in Kampala is collected (KCC, 2002). This praxis results in waste lying around in the streets of Kampala. The environmental awareness of the population of Uganda is not very high in general (Nicholas, 2003), which is one reason why there is waste lying around in the streets everywhere. Another reason is that the equipment used for waste collection is too few and in bad condition.

The skips are filled up too quickly and they are in bad condition. The skips are not filling the requirements of the need they are meant to cover anymore when there are holes in the walls of the waste container, but it seems like skips in such condition still are in use. The consequence is that some of the waste thrown away in the skip is falling out again and remains lying on the ground. The same is happening when the skips are overfull. A significant part of the waste is remaining on the sites where the containers are situated. Some waste is also falling of the trucks when they are transporting the skips to the landfill. The skips are only covered by a big masked net while transported, so some of the waste situated on the top easily falls off during transport (KCC, 2002).

The organic waste is generally processed, liquefied, and pasteurized to rid it of pathogens and make its breakdown easier for the anaerobic bacteria. These bacteria, commonly found in soil and water, first employ enzymes to convert the waste matter into amino acids and sugars and then ferment these into fatty acids. The fatty acids are then transformed into a gas that is mainly methane and carbon dioxide, or biogas. This whole process takes place in a sealed, waterproof chamber known as an anaerobic digester. The digester is generally cubical or cylindrical in shape and may be constructed of brick, concrete, steel or plastic. The liquefied organic waste is fed into the digester chamber through a pipe and exposed to the anaerobic bacteria that flourish there under optimum temperatures ranges between 95 degrees Fahrenheit (35 degrees Celsius) and 140 degrees Fahrenheit (60 degrees Celsius). The sealed nature of the biogas generator prevents the entry of oxygen and prevents the exit of the biogas once it is produced. The trapped biogas can then be diverted to a combined heat and power unit to be transformed into heat and electricity for various practical uses. A waste residue in liquid and solid form is obtained after biogas generation. It is called "digest ate" and it can be used as a soil fertilizer.

Using anaerobic digestion for biogas generation is a clean, environmentally friendly way of energy production. It effectively disposes of waste matter that might otherwise have littered and polluted the environment. It also provides alternative, renewable energy that does not add to the greenhouse effect. Biogas production also has economic benefits, reducing energy production expenditure and benefiting communities, especially rural ones in developing nations. Biogas plants can create employment opportunities for the local populace and, aside from helping local farms cut down on electricity bills, the biogas system can also help farms make a profit from waste treatment, fertilizer manufacture and biogas energy sale (FAO, 1996).

Biogas is practically produced as land fill gas (LFG) or digester gas. A biogas plant is the name often given to an anaerobic digester that treats farm wastes or energy crops. Biogas can be produced using anaerobic digesters. These plants can be fed with energy crops such as maize silage or biodegradable waste including sewage sludge and food waste. During the process, an air-tight tank transforms biomass waste into methane producing renewable energy that can be used for heating, electricity, and many other operations that use any variation of an internal combustion engine, such as GE Jenbacher gas engines. Landfill gas is produced by wet organic waste decomposing under anaerobic conditions in a landfill. The waste is covered and mechanically compressed by the weight of the material that is deposited from above. This material prevents oxygen exposure thus allowing anaerobic microbes to thrive. This gas builds up and is slowly released into the atmosphere if the landfill site has not been engineered to capture the gas. Landfill gas is hazardous for three key reasons. Landfill gas becomes explosive when it escapes from the landfill and mixes with oxygen. The lower explosive limit is 5% methane and the upper explosive limit is 15% methane. The methane contained within biogas is 20 times more potent as a greenhouse gas than is carbon dioxide. Therefore, uncontained landfill gas, which escapes into the atmosphere, may significantly contribute to the effects of global warming. In addition, landfill gas impact in global warming, volatile organic compounds (VOCs) contained within landfill gas contribute to the formation of photochemical smog (Zamorano, 2005).

CHAPTER THREE: METHODOLGY

3.1 Introduction

Under chapter three, a number of items were adopted to generate data. These items included: research design, area of study, sample population, sample method, administration of questionnaires and sources of data.

The study area: Nsambya is a hill in the center of Kampala. It is located approximately 4.8 kilometers (3.0 miles) south-southeast of the central business district of Kampala, along the road to Ggaba, a suburb of the city. The coordinates of Nsambya Hill are: 00 17 57N, 32 35 17E. Accordng to Matagi, (1998), the elevation is 4,000 ft (1,220 m).

Kampala, the capital city of Uganda is situated $0^{0}15$_N and $32^{0}30$_E ($0^{0}15$_N and $32^{0}30$_E) and is located 45 km north of the Equator. Kampala has a total area of 190 km^2. The city centre is situated 8 km north of Lake Victoria, the second largest inland fresh water lake in the world.

Rainfall: The city is 1,300 m above sea level and receives a mean annual rainfall of 1,200 mm. Despite its proximity to the equator, it has a tropical climate rather than a typical equatorial climate. This modified climate is due to the high altitude, long distance from the sea, relief and proximity to the large water mass of Lake Victoria (Matagi, 1998).

Topography: The topography of the city is characterized by a series of low lying hills with flat Hill tops typical of the Buganda Region, of central Uganda (Hickman and Dickens, 1981). These hills are surrounded by a network of wet valleys which are covered by papyrus swamps (MNR, 1992). Many of the papyrus swamps have been reclaimed and developed. They contain the central business district, slum dwellings and industrial zones. The hill tops have been reserved for institutional purposes such as universities and churches, prestigious buildings like State Lodge and other important installations like the Radio and Television masts, while the slopes have been utilized for various grades of commercial or official and residential buildings.

Economic activities: The major economic activity carried out in Kampala City is trade and commerce, and very little agricultural activities.

Population: The national census in 2002 estimated the population of the city at 1,189,142. The Uganda Bureau of Statistics (UBOS) estimated the population of Kampala at 1,420,200 in 2008. In 2012, UBOS estimated the mid-year population of the city at 1,659,600 with additional large numbers coming to work in the city daily with a current growth rate of 4.9% per annum (Matagi, 1998). The most common languages spoken in Kampala are Luganda, English and to some extent Kiswahili.

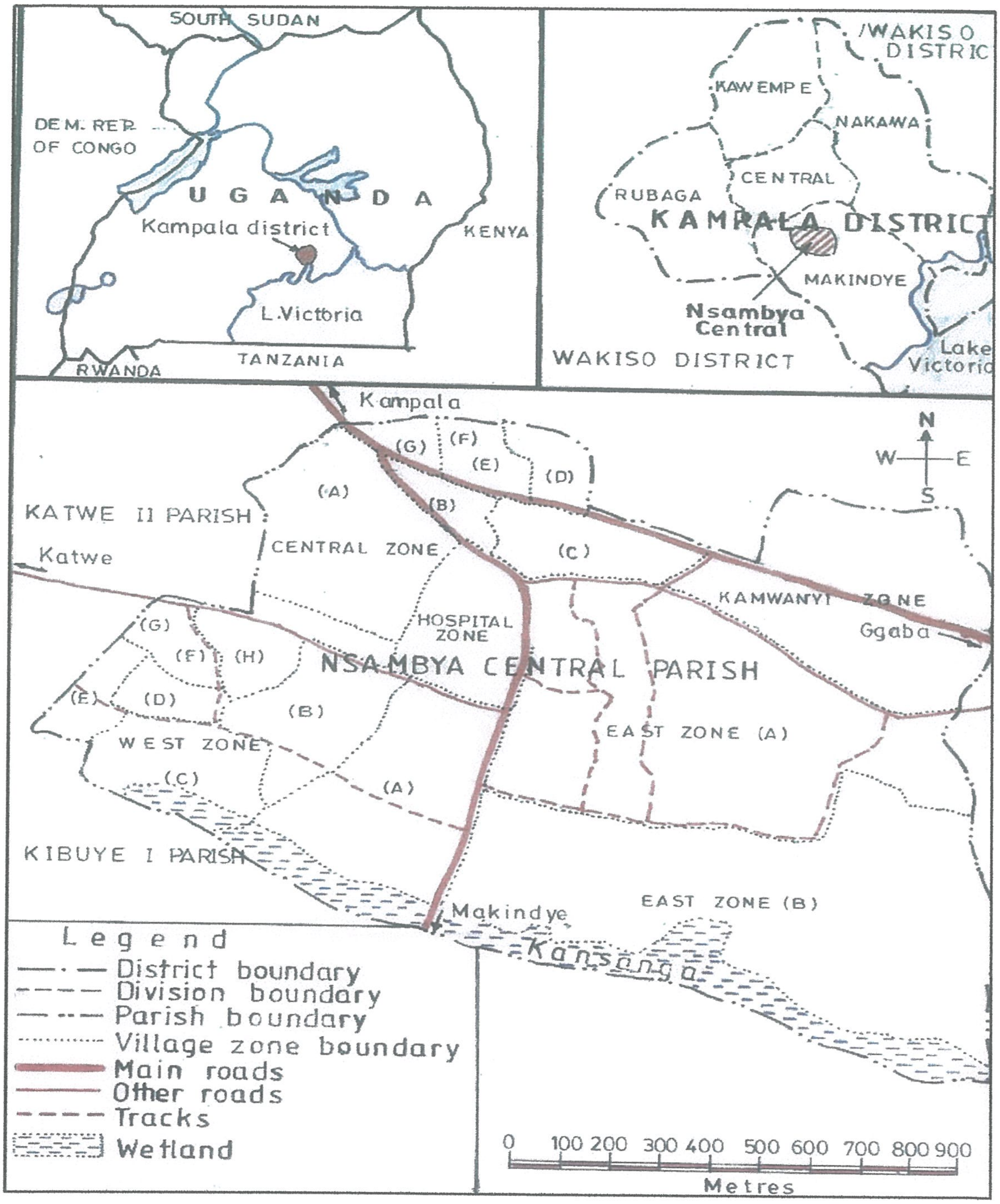

Figure 1: Map of Kampala District showing the study areas

3.2 Research design

This part of the research discusses the strategy that were used, a detailed description of how this research study was designed and conducted. The study employed both qualitative and to a lesser extent quantitative methods of data collection. Tools and means to collect data and analyze their impact were carefully collected and used. The methodology that was utilized in this research includes site exploration, documentaries related to the study, questionnaires and interviews with people.

3.2.1 Research population

The study targeted local leaders and professionals who were knowledgeable about biogas production and in position to influence this production with the local population who were direct beneficiaries of these services or innovations, and also the local people. The local people were sampled out mainly because they exist in the locale and use at least reasonable number of biogas production technologies. The experts were sampled out of the many Non-Governmental Organizations such as Child Welfare & Adoption Society (CWAS) at Nsambya Babies Home, Heifer International project (HIP), among others. The employees of the National Environment Management Authority (NEMA) as a government agency, also sampled because they are the over seers of all environmental aspects in Uganda. Also Ministry of Energy and Mineral Development. The local population and leaders were sampled from within. The Kampala Capital City Authority (KCCA) officials in the public health services and environment department were also sampled.

3.2.2 Sample size

Stratification of the sample size categories: The target population was obtained from the different organizations and was subjected to stratification in their respective strata in order to get representative sample that was included and used as a target sample population and sample size, as summarised in Table 2.

Table 2: Categorization of the representative target sample population

Target population	Number of Employees/people
CWAS	10
Heifer project international (HPI)	20
Ministry of energy	20
KCCA	20
Local leaders	10
Local people	60
NEMA	20
Total	160

Source: *Computed based on the Data obtained from Primary data*

Therefore stratification sampling function= $^{n}/_{N}$ OR: **n/N.**

Whereby: n= Sample size

N= Population size

$$\frac{160}{1.425} = 122.$$

Slovene's formula was also used to support and guide the sampling process for clarity as indicated below:

$$n = \frac{N}{1+Na^2}$$

Whereby; **n**= sample size, **N**= target population,

a= confidence level at 0.05

$$n = \frac{160}{1+160 \times 0.0025} = 1.425$$

$$= \frac{112}{160} = 0.7$$

CWAS	= 0.7 x 10	= 7
HIP	= 0.7 x 20	=14
Ministry of energy	= 0.7 x 20	=14
KCCA	= 0.7 x 20	=14
Local leaders	= 0.7 x 10	=7
Local people	= 0.7 x 60	=42
NEMA	= 0.7 x 20	=14

Therefore; 7+ 14+ 14 + 14+7+42+14 = **112 total number of respondents.**

Purposive sampling: Non-random sampling method used as the best judgment about the respondents to select and pick those that meet the purpose of the study at its best. Only those that have been considered relevant to the study were included, meaning that the respondents were chosen based on their experience and knowledge about the study. The researcher picked from the different categories to ensure effective representation. It therefore implies that, the CWAS, KCCA officials, HIP, Ministry of Energy and Mineral Development, NEMA, local leaders and local people were selected.

Snowball or network sampling: In addition, the snowball was also used in stages, therefore in the first stage; the researcher was identifying a few respondents who qualify to be in the sample. In the subsequent samples, the identified respondents acted as informers to help the researcher identify other possible elements to be included in the sample. This method was helping because most of the respondents that are not known. The researcher tried to win the confidence of the respondents they were requested to invite their colleagues.

3.2.3 Research instrument

A recommendation letter from the University administration authorizing the researcher to conduct the research was obtained for the visit and the assessment of the study area. To get all necessary information about the study the following methods were used:

General questionnaires: A questionnaire is a set of related questions designed for soliciting responses from respondents regarding a particular topic. A self-administered questionnaire was used whereby the respondents were required to read the questions and later on fill in the answers by themselves. However, guidance was to any of the respondents who may require clarification or assistance.

Interview: An interview is defined as face-to-face conversion between an interview and respondent for the purpose of obtaining information. The researcher used the convenience of an interview schedule which helped the researcher to get in-depth responses and good quality data.

Source of data: The research utilized two sources of data; the primary source of data and the secondary source of data. Primary data was gathered from the respondents through issuing the general questionnaires and conducting interviews; in addition the sits were visited and explored. The information obtained from published books, Newspapers, magazines, reports, websites, internet and research papers were gathered as secondary sources of data. All these were collected in order to get a basic understanding on the existing situation and also to study different approaches on the same kind problem.

3.3 Data analysis

In this part, the descriptive, quantitative and qualitative analysis was obtained from the samples and thereafter allow the reader a proper understanding by identifying the previous related study done by others and/or which is occurring. All data obtained from questionnaires, responses of text and the main information interviews were interpreted collectively between the general aims and the questions. After getting all data, they were interpret in diverse meaning and then explained into numerical figures so that the presented results were shown in percentages, graphs and pie-charts. The collected data was further analyzed using SPSS (Statistical package for social Sciences) software to get the different summary statistics relevant for analyzing the stated objectives, also the Pearson's chi-square was used to analyze the relationship between organic solid wastes generation and biogas production.

3.4 Ethical considerations

Before the study or data collection process began, the researcher obtained permission from the authorities in order to begin the study. After obtaining the transmittal letter from the high authorities of the school that is the administration of College of Higher Degrees and Research (CHDR), the research further acquired permission from the local government. The study was done without forcing the respondents hence it was their choice either to participate or not, and all their responses were kept with utmost confidentiality or as a top secret.

3.5 Limitations of the study

During the course of the research, inappropriate events occurred that perhaps interfered with the results. However, the researcher aimed at an early identification of such events and accordingly tried to deal with them.

The research instrument on biogas production from solid wastes is not standardized so problems of measurement for its appropriateness are bound to occur. Validity and reliability tests were used by the researcher to minimize them.

Some subjects dropped out of the study before the study was completed. The drop was systematic in a way that only subjects with certain common characteristics were left in the study that may be due to attrition or mortality. In most occasions, it was the less motivated; lower performing respondents who dropped out leaving behind more motivated and creative respondents. Therefore, here not all questionnaires were returned or attempts to retrieve the questionnaires turned out to be futile and other subjects opted to drop out of the study before it was completed thus the statistical correlations and conclusions drawn might be influenced by such uncontrolled situational events.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the analysis, interpretation and discussion of the research findings based on data obtained from the field about the process of biogas production from organic solid waste in Kampala. The analysis and interpretation of the data are descriptive, qualitative and quantitative.

4.2 Demographic characteristics of the respondents

The distribution of the respondents by age, gender, and education level are reflected in Tables 3, 4 and 5.

Table 3: Age of the respondents

Age bracket	Frequency	Percentage
20 - 29 years	21	19
30 – 39 years	53	47
40 – 49 years	25	22
50 – 59 years	13	12
Total	112	100

Table 3 indicates that respondents between the age categories of 30-39 years are the highest in terms of engaging in biogas production with 47% while the second group is that between 40-49 years with 22%. The third group is the category between 20-29 years with 19%, whereas the category between 50-59 years is the least in terms of production biogas with 12%.

Table 4: Gender of the respondents

Gender	Frequency	Percent	Cumulative Percent
Male	102	91	91
Female	10	9	100
Total	112	100	

According to Table 4, the males participate in the production of biogas with 91%, as compared to the female with 9%.

Table 5: Education level of the respondents

Education levels	Frequency	Percent	Cumulative Percent
Primary	8	7	7
O-level	20	18	25
A-level	25	22	47
University	54	48	95
Other Qualifications	5	5	100
Total	112	100	

From results in Table 5, it was noted that those with university level of education were the most respondents with 48%, and they were closely followed by those who acquired A-level (Advanced level) education with 22%, the ordinary level (O-level) respondents were 18%, Primary level were 7% while those with other qualifications from tertiary and/or technical institutions they were 5%.

4.3 Potential organic solid wastes used for biogas production.

Table 6, indicates that Uganda is rich of agricultural and horticultural activities especially when it comes to cattle in that it features a considerable amount of cow dung as the major form of animal waste and greatest source with a potential and actual capacity to produce biogas with 52%. This implies that for one to generate biogas one has to have a reliable and quality source of cow dung as biogas feedstock (raw material used for biogas production) from the cattle both local and exotic breeds. Household wastes are the second major supplier of biogas feedstock with 38% normally obtained from food remains and peelings from certain food stuffs such as potatoes, and bananas (matooke) among others. In addition, crop residues with 7% are the third in terms of usage as biogas feedstock and are normally got from the gardens such as weeds and maize stalk and leaves, among others. Industrial waste with 3% is the least used and includes fish scales and skin, animal hides and skins from abattoirs and homes. There are numerous homes, institutions such as boarding schools, prisons or health institutions that have large central kitchens for feeding hence biogas can be used to supplement cooking energy needs, boil water for cleaning or hygienic purposes, avoid hazardous emissions resulting from the combustion of traditional biomass, provide solid waste disposal and demonstrate fertilizer benefits in institutional gardens. All these potential organic solid wastes identified during the study are in agreement with the findings of Erdogdu (2008) of the organic solid wastes used for biogas production.

Table 6: Potential organic solid waste for biogas production

Organic solid wastes	Frequency	Percent	Cumulative Percent
Animal waste	58	52	52
Household waste	42	38	90
Crop residues	8	7	97
Industrial waste	4	3	100
Total	112	100	

4.4 The benefits of using biogas as an alternative energy sources

Table 7: Respondents views on benefits of biogas

Valid	Who say yes	Percentage for yes	Who say no	Percentage for no	Total for yes or no
Save time	99	88	13	12	112
Low cost	82	73	30	27	112
Clean fuel	43	38	69	62	112
Reduce deforestation	40	36	72	64	112
Organic fertilization	25	22	87	78	112
Reduce air and water pollution	8	7	104	93	112

Table 7, shows many advantages obtained from biogas and they include; biogas saves time for women and children with 88% as the biggest benefit also that related to the findings of Renard (1988) in spite of 12% rejecting. In addition, it provides a low cost energy source for cooking and lighting, and it is the second biggest benefit with 73%. The low cost is the equally important reason for people constructing biogas plants, because it is produced by readily-available animal and household waste which is in agreement with the findings of Renard (1988).

Thirdly, biogas is a clean fuel with 38% of respondent agreeing while 62% rejected. The rejection was because biogas also releases some carbon dioxide, methane and other GHGs in small quantities when burning to cook and also when released for lighting. The 38% who agreed was because it low risk of odours, eliminate respiratory and eye diseases caused by indoor air pollution resulting from traditional cooking with wood, and also reduces greenhouse gas emissions on a global level.

The fourth benefit is that biogas reduces deforestation and forest encroachment with 36% yes response because it lessens the pressure on rangeland, provides biodiversity in protected areas and national parks, and 64% disagreeing and this is also in agreement with Renard's (1988) findings.

Further more, biogas produces an effluent called bio-slurry with 22% who agreed to know about the benefits of bio-slurry which is an excellent organic fertilizer used for restoring soil fertility thus giving high crop yields is not very harmful to the soils and soil organisms while 78% disagreed. The least benefit is that biogas reduces air and water pollution with 7% concurring while 93% rejected. These benefits also concur with the findings of FAO (1996) with more emphasis on the reduction of GHGs thus reducing global warming.

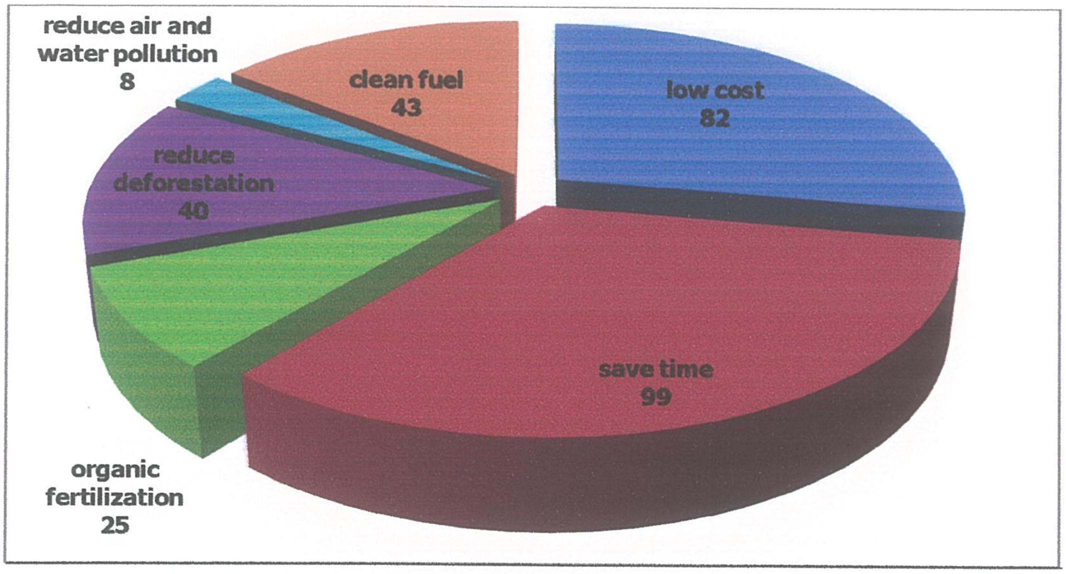

Figure 2: Respondents who said yes for benefits of biogas

Figure 2, shows that 99 of the respondents say yes to benefit of saving time, 82 low cost, 43 clean fuel, 40 reduces deforestation, 25 organic fertilizer, and 8 said that it reduces air and water pollution. This figure of respondents' views provides a clear back up for the percentages in Table 7 because it equally shows the benefits to the local people when they use biogas as an alternative energy source.

4.5 The factors affecting biogas generation from organic solid waste

Table 8: Respondent's views of the factors affecting biogas generation from organic solid waste

Valid	Who say yes	Percentage for yes	Who say no	Percentage for no	Total
High initial investment cost	103	92	9	8	112
High degree of maintenance	46	41	66	59	112
Storage and disposal of the bio-slurry	41	37	71	63	112
Cost of collecting organic wastes	10	9	102	91	112
Water supply-good constant supply	8	7	104	93	112

The results in Table 8 indicate that the most factors affecting biogas generation from organic solid waste are; High initial investment cost with 92% concurring with the response implying that they can not afford constructing a biogas, while 8% rejected because they could afford the investment costs in terms of the plant's design which is in agreement with the findings of Mwakaje (2008) and all this is attributed to the high poverty levels in Uganda which has made local people unable to afford the purchase as a way of adopting newer technologies especially alternative energy sources such as biogas production.

The high degree of maintenance of the biogas plant was agreed by 41% of the respondents. However, the quality of the plant in terms of maintenance requires facing high costs of which 59% of the respondents disagreed by saying that biogas plants do not require the high degree of maintenance in terms of quality and cost.

The storage and disposal of bio-slurry or sludge is the third factor affecting biogas production from solid wastes and 37% of the respondents agreed which is equally in agreement with the findings of Day *et al*, (1990) and Mwakaje (2008) who also found out that it was always difficult for the owners of the biogas plants to store the bio-slurry properly according to the required standards that avoid massive emission of GHGs and in terms of disposal, most of respondents find it challenging to dispose to well designated places to avoid eutrophication of nearby water sources and producing bad odour within the vicinity.

More to the above, the cost of collecting wastes (biogas feedstock) at 9% is usually too high especially when an individual does not have a reliable source of supply and access to organic solid waste like agricultural or other type of waste hence faces the costs of transportation, selection and purchasing of the raw material.

Ideally, with a biogas plant, one needs to have constant water supply which should be within the reach of the digester 7% of the respondents agreed to this because they do not have a reliable and nearby water sources to enable their activities which affects the rate at which their plants produce biogas and also discourages others from adopting the technology.

However, these findings disagreed with Somda *et al*, (2002) findings which stated that it is only the age of the farmers, education level, gender relationships of the male-female asset ownership and control in Africa, cost of kerosene and the number of cattle in a household that affect the production of biogas from organic solid wastes.

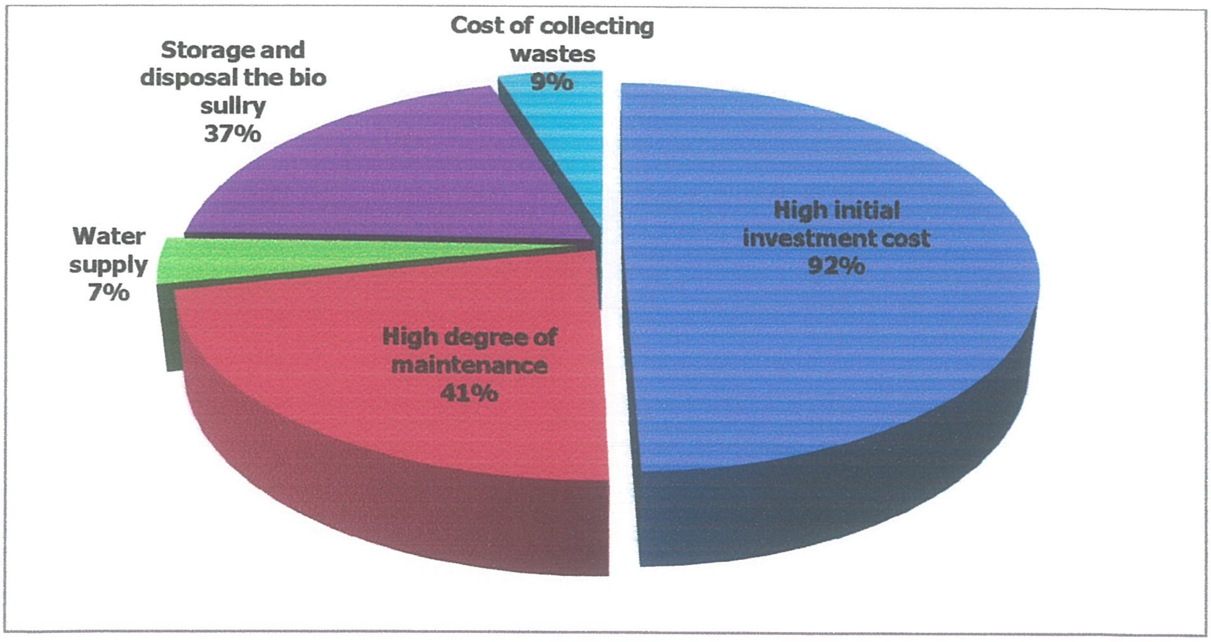

Figure 3: Respondent who said yes for the factors

4.6 The relationship between generation of organic solid waste and biogas production.

Table 9: Shows the relationship between the generation of organic solid waste and biogas production.

Response	Frequency	Percent	Cumulative Percent
Yes	77	69	69
No	35	31	100
Total	112	100	

The results in Table 9 show that 69% respondents said that there is a relationship between the amount of organic solid wastes generated and biogas production. This implies that the lesser the amount of organic solid wastes generated, the lesser the amount of biogas produced. One respondent described the relationship between organic solid waste and biogas production as efficient in that *"the more organic solid waste, the more biogas in the digester."* Another respondent said that *"a lot of biogas generation means hundreds of tons of organic solid waste disappear".* Therefore, based on the responses and narratives from the respondents, it is befitting to describe and acknowledge that there is a relationship between organic solid waste generation and biogas production. However, 31% of the respondents disagreed that there is no relationship between organic solid wastes generated and biogas produced because according to them, one can have less but quality organic wastes which can produce greater quantity and quality of biogas thus the relationship could be described as a negative, contrary or an opposite one.

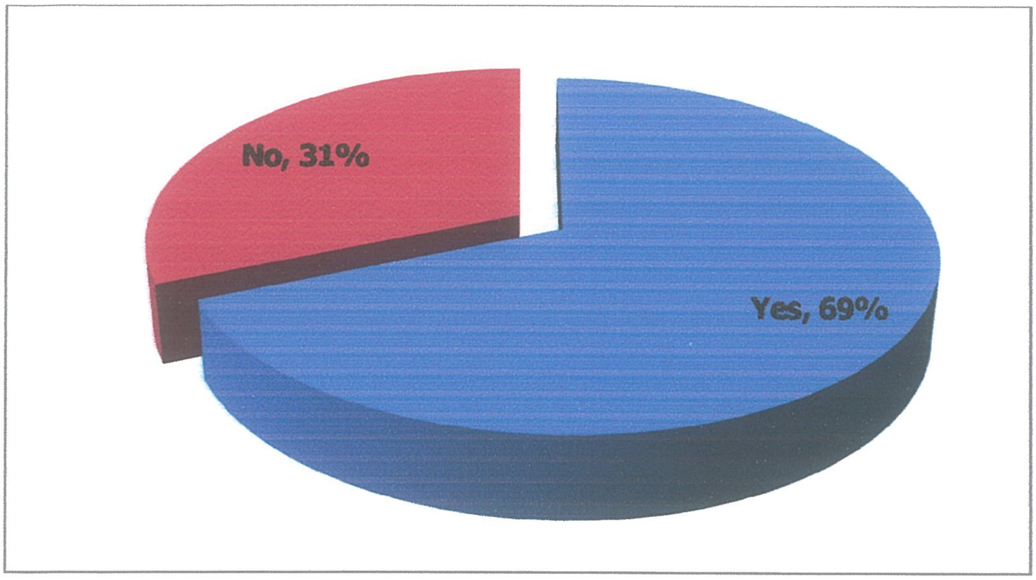

Figure 4: The relationship between organic solid waste generation and biogas production.

In the summary (Figure 4), a bigger percentage of respondents (69%) approved that there is relationship between organic solid waste generation and biogas production implying a positive relationship between organic solid wastes generation and biogas production.

Table 10: Results for Chi-square test analyzing the relationship between organic solid wastes generated and the biogas production.

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	1.120E2[a]	1	.000		
Continuity Correction[b]	107.394	1	.000		
Likelihood Ratio	139.123	1	.000		
Fisher's Exact Test				.000	.000
N of Valid Cases[b]	112				

Table 10 demonstrates that there is a very weak relationship between the organic solid wastes generated and the biogas production (X^2=0.000, at p=0.05). This could be attributed to the factors affecting biogas generation from organic solid wastes earlier on mentioned in Table 8 above such as high investment cost, high degree of maintenance, water supply (good constant supply), storage and disposal of bio-slurry, and cost of collecting the organic wastes. This implies that it is these factors that determine a specified amount of organic solid wastes generated for producing biogas and also determining the type of biogas plant also to be constructed.

CHAPTER FIVE: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter presents the summary of the findings, conclusions, recommendations and areas for further research based on this study. The conclusions are derived from the results of the study and therefore suggested recommendations are meant for ensuring the improved reliable approaches to the biogas production from organic solid waste following the study objectives. The areas for further research are also suggested here.

5.2 Summary of the findings

The study clearly indicated that the respondents between the ages of 30-39 are the greatest producers of biogas from organic solid waste at 47%, while those between 50 -59 are the least producing at 12%. The males are the most dominant producers of biogas from organic solid wastes at a rate of 91%. Meanwhile, those who have studied up to university are also the majority producing at a rate of 48% and the least are those with other qualifications implying the tertiary institutions with 5% of the respondents.

The findings show that the most commonly used types or potential of organic solid waste used to produce biogas are animal wastes (52%) which included (cattle dung, poultry droppings, pig excreta), followed by household wastes (38%) including (Kitchen waste, human excreta), in third level crop residues (7%) and at the last level industrial organic wastes with (3%) including (fish and meat industries).

The study revealed that using anaerobic digestion for biogas production is a clean and an environmentally friendly way of energy production with benefits based on responses from respondents who stated yes from the greatest to the least benefit such as; it saves time at 88%, low cost energy source with 73%, provides clean fuel with 38%, reduces deforestation and forest encroachment at 36%, good organic fertilizer with 22%, and finally reduces air and water pollution at 7%.

Biogas digesters or plants do not meet the expectations in many cases and the research findings indicate that the most common problems or factors affecting the production of biogas from organic solid wastes are: the high initial investment costs (92%), high degree of maintenance (41%), storage and disposal of the bio-slurry (37%), cost of collecting wastes (9%) and the least was water supply (7%).

According to the study, (69%) respondents said that there is a relationship between organic solid wastes generating and biogas production. From the analysis of the data (X^2=0.000, at p=0.05) the hypothesis had to be accepted leading to the conclusions that there is a very weak relationship between the organic solid wastes generated and the biogas production, clearly proving that it is not only the organic solid wastes that affect people's production of biogas but also other factors presented in Table 8.

5.3 Conclusions

The most commonly used types or potential of organic solid waste for the production of biogas are animal wastes, followed by household wastes, crop residues and industrial waste at last level.

The biogas production (i) save time for women and children hence they do not need to collect firewood from different and far places, (ii) provide a low cost energy source for cooking and lighting because it is produced by readily available animal wastes and household wastes, (iii) is a clean fuel because it does not emit large quantities of GHGs, (iv) reduce deforestation and forest encroachment because the burden of searching for firewood and cutting down trees is gradually eliminated by the cheap and locally available raw materials,(v) produce an effluent called bio-slurry which is an excellent organic fertilizer that is not very harmful to the soils and soil organisms, and finally (vi) reduce air and water pollution in that it does not emit large quantities of greenhouse gases (GHGs).

The most common problems or factors affecting the production of biogas are (i) the high initial investment costs, (ii) a relatively high degree of maintenance efforts which are indispensable for keeping the biogas system going, (iii) the storage and disposal of the bio-slurry, (iv) high cost of collecting wastes and finally (v) the water supply which should be good and constant within reach for the digester.

Given the fact that there is a very weak relationship between the factors affecting biogas production and organic solid wastes generated, the hypothesis was therefore accepted, and it was clearly proved that it is not only the organic solid wastes that affect people's production of biogas but also other factors presented in Table 8.

5.4 Recommendation

The utilization of biogas technology is no longer in doubt, for effective utilization of biogas technology (based on the study) the following recommendations have been made:

1. Creating awareness about biogas potential production from organic solid waste should be increased to reduce heavy reliance on fuel wood in a bid to save the disappearing forests and tree species.
2. People should be encouraged to use biogas from organic solid waste through evaluating the potential of the organic solid waste in reducing the amount of greenhouse gases in the atmosphere because biogas is hygienically excellent in terms of producing less effluents due to complete combustion thus it is good for use in the kitchen environment as it has less risks of health related problems especially respiratory diseases.
3. There is need to educate institutions and individuals of the potential of organic solid waste and increase their value as an energy resource in Uganda.

4. Local community's participation in different organic solid waste collection systems, storage and decision-making should be developed. So the local people must be encouraged to use organic solid waste for production biogas because there are many advantages for them such as generating electricity and heat. Biogas can be the best way to save energy and produce clean and safe energy as well by reducing global warming.

A comprehensive biogas policy that should contain well stipulated regulatory standards and quality control must be enacted by the government through its legislative arm or parliament on behalf of the energy sector. A private sector led policy should be developed to promote biogas production from organic solid wastes.

5.5 Further research

Biogas digesters did not meet the expectations in many cases; more research should be conducted in the following areas:

(i) Cost effective materials that can be acquired locally for the construction of biogas plants to increase on the adoption rates.

(ii) Establishment of all the factors affecting the adoption of biogas technology in developing and developed countries.

(iii) The specific amounts and measurement devices for organic solid wastes that are required to generate biogas for two or more households from one biogas plant with quality output for all the desired activities.

(iv) The amount of heat and electricity that is produced by the different types of biogas plants in that even the local people should be in position to calculate and derive figures or findings through consequent experiments when using the plant.

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OFFICE OF THE HEAD OF DEPARTMENT, ECONOMICS AND MANAGEMENT SCIENCES
COLLEGE OF HIGHER DEGREES AND RESEARCH (CHDR)

Date: 11, July, 2012

RE: REQUEST FOR HUSSEIN GARELNABI MOHAMED MEM/33354/111/DF TO CONDUCT RESEARCH IN YOUR ORGANIZATION

The above mentioned is a bonafide student of Kampala International University pursuing Masters of Science in Environment Management.

He is currently conducting a research entitled" **Biogas Production from Solid Waste in Kampala, Uganda."**

Your organization has been identified as a valuable source of information pertaining to his research project. The purpose of this letter is to request you to avail him with the pertinent information he may need.

Any information shared with him from your organization shall be treated with utmost confidentiality.

Any assistance rendered to him will be highly appreciated.

Yours truly,

Mr.Malinga Ramadhan
Head of Department,
Economics and Management Sciences,(CHDR)

NOTED BY:
Dr. Sofia Sol T. Gaite
Principal-CHDR

KAMPALA INTERNATIONAL UNIVERSITY
PRINCIPAL
P.O. BOX 20000 KAMPALA

The leaders of Nsambya
please accord him the necessary support in his research / dissertation work

KAMPALA CAPITAL CITY AUTHORITY
MAKINDYE DIVISION ... COUNCIL
18 JUL 2012
OFFICE OF THE TOWN CLERK
P.O. Box 7010, KAMPALA

Appendices II: Research Instruments, Kampala International University, College of higher degree and research, Master of Science in Environment Management programme.

Dear Sir/ Madam

Greetings

I am a post graduate candidate for the award of master in environment management of Kampala International University and currently pursuing a research study entitled **Biogas production from organic solid waste in Kampala, Uganda**. In view of this empirical investigation may I request you to be part of this study by answering my questionnaire. Rest assured that the information you provide shall be kept with utmost confidentiality and will be used for academic purposes only. Please respond to all the items in the questionnaire and do not leave any item unanswered.

Further I, and my research assistant to the entire questionnaire within three days from the date of distribution.

Yours faithfully,

HUSSEIN GARELNABI

In signing this document, am giving my consent to be part of the research study of HUSSEIN GARELNABI that will focus on **Biogas production from organic solid waste in Kampala, Uganda.**

I shall be assured of privacy, anonymity, and confidentiality and that I will be given the option to refuse participation and the right to withdraw my participation any time.

I have been informed that the research is voluntary and that result will be given to me if I ask for it.

Initials ______________________

Date ______________________

Face Sheet: Profile of the Respondents

1. Age ________________

2. Gender (please tick) Male ☐ Female ☐

3. Educational Qualification.

A. Primary ☐ B. O-level ☐ C. A-level ☐ D. University ☐

Other Qualifications ....

(i) The potential organic solid wastes used for biogas production.

4. What are the forms of the organic solid waste used to produce biogas?

A. Animal waste ☐ B. Household waste ☐ C. Crop residues ☐

D. Industrial waste ☐

5. Are you engaged in biogas production? Yes ☐ No ☐

6. How do you produce biogas from the organic solid wastes?
....

....

7. What are the uses of this biogas to you?

A. Cooking ☐ B. Lighting ☐ C. Charging ☐ D. Watching TV ☐

8. What was your major reason for starting up a biogas unit?

A. Domestic consumption ☐ B. Demonstration purposes ☐

C. Commercial purposes ☐

D. Others, please specify..

9. Is there demand for biogas? Yes ☐ No ☐
If no whey?
a) ....

b) ....

c) ....

10. Do you think biogas saves your costs as compared to Hydro electric power (HEP)?

Yes ☐ No ☐

If yes, give reasons to support your answer

a) ....

b) ....

c) ....

11. It is biogas best way to produce clean and save energy? Yes ☐ No ☐

12. What biogas plant design(s) do you own?

A. Fixed dome ☐ **B.** Floating drum ☐ **C.** Tubular ☐

Any other, please specify..

13. What is the installed capacity for the plant(s)? ....

14. Is the biogas plant(s) operational? 1. Yes. ☐ 2. No ☐

i) If No, has the biogas plant ever worked before breaking down? Yes ☐ No ☐

ii) For how long did it work before breaking down completely? ....years

iii) What are the reasons for the biogas plant not being operational?

a) ....

b) ....

c) ....

15. Are you aware of any other sources that can be used as substrate for biogas?

Yes ☐ No ☐

16. Is biogas has negative Impacts on household air quality? Yes ☐ No ☐

17. Is biogas cheaper than Charcoal and Firewood? Yes ☐ No ☐

(ii) The benefit of using biogas as an alternatives energy sources;

18. What is the benefit of biogas?

a) ....

b) ....

c) ....

(iii) The factors affective biogas generating from organic solid waste.

19. What are the challenges involved in biogas generation from organic solid waste?

a) ....

b) ....

c) ....

20. How much do the digesters cost? ....

21. Are they affordable? Yes ☐ No ☐

22. Who many families do you know they use biogas and why? ....

Cheep ☐ Available ☐ clean ☐

23. Is there any culture said something about the use of biogas? Yes ☐ No ☐

(iv) The relationship between organic solid waste and biogas.

24. Is there any relationship between organic solid wastes generation and biogas production?

Yes ☐ No ☐

i) If its yes how?

a) Is organic solid wastes generation increasing? Yes ☐ No ☐

b) Is biogas production increasing? Yes ☐ No ☐

25. is there any kind of pre-treatment is necessary before the biogas generation process?

Yes ☐ No ☐

If its yes what are they?

a) ....

b) ....

c) ....

26. What kind of organic solid waste is available?

a) ....

b) ....

c) ....

27. Which type of organic solid waste can the use of biogas reduce it?

a) ....

b) ....

c) ....

28. If organic solid waste is about 70% biogas plants can consume this amount?

Yes ☐ No ☐

29. How does organic solid waste generation affect biogas production?

a) ....

b) ....

c) ....

30. Is there any policy contain the standards and quality control of biogas?

a) ....

b)..

Thank you for your cooperation.

Appendices III: RESEARCHER'S CURRICULUM VITAE

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