THE ROLE OF BIOGAS USAGE ON THE CONSERVATION OF FORESTS IN UGANDA: A CASE STUDY OF GOMBE SUB-COUNTY, WAKISO DISTRICT

BY

ALI MOHAMED ABDULLE

2018-08-01794

A RESEARCH REPORT SUBMITTED TO THE SCHOOLOF NATURAL AND APPLIED SCIENCE IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF A MASTER'S DEGREE IN ENVIRONMENTAL MANAGEMENT OF KAMPALA INTERNATIONAL UNIVERSITY

NOVEMBER, 2021

DECLARATION

I, Ali Mohamed Abdulle declare that this research report on "The role of biogas usage on the conservation of forests in Uganda: A case study of Gombe Sub-County, Wakiso District" is my original work and to the best of my knowledge, has not been submitted for any award at any academic institution.

Signed: 

Ali Mohamed Abdulle

Student no. 2018-08-01794

Date: 02 November, 2021

APPROVAL

This is to confirm that this research report on "The role of biogas usage on the conservation of forests in Uganda: A case study of Gombe Sub-County, Wakiso District" was compiled under my supervision and is now ready for submission to the School of Natural and Applied Science of Kampala International University.

Dr. SUZAN LUYIGA

Signature: 

Date: 02 November, 2021

DEDICATION

I dedicate this work to my brothers Sharma and M. Sharaf, and my sister Farxiyo for their utmost effort towards my academic life. I am very grateful for the firm foundation that was laid by my family, may God bless you all abundantly.

ACKNOWLEDGEMENT

I extend my special thanks to the Almighty God for his wonderful blessing and guidance. Without God's intervention I would not have reached this far.

I am so grateful to my supervisors Dr. Suzan Luyiga and Dr. Maria Mbatudde for their professional advice and support rendered to me throughout this research project.

Special thanks go to my respondents who spared their time to give me the information I needed to accomplish this study.

I thank my parents, it's your financial support, care, advice and prayers that made me reach great heights.

Special thanks go to all my lecturers at Kampala International University and teachers in all schools I attended. Without all of you, finishing this course would not be easy. I will live to remember you. God bless you.

TABLES OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Conservation of forests in Uganda and across the globe is an environmental agenda that countries are engaged in, with efforts to improve the conservation of the environment. The pressure being exerted on the use of firewood and charcoal as the sources of energy for cooking has resulted to massive deforestation and as such posed serious threat in maintaining ecological balance in various communities. This study therefore, investigated biogas use as an alternative energy source within Gombe Sub-County, Wakiso District, where, 226 biogas using homesteads were considered for data collection using structure questionnaire and an experiment. Data collected was analysed using descriptive statistics and content analysis. Results revealed four major factors influencing the adoption of biogas use in Gombe sub-county, and these included; high cost of other sources of energy, low susceptibility to danger, cheap means of producing biogas, and less time consumption. Moreover, results showed that biogas use reduces wood fuel demand, improved livelihoods and contributed to tree and forest enhancements.

It is therefore, recommended that homesteads should be encouraged to adopt the use of biogas, due to its core value in tree-cover enhancement and environmental conservation.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Countries globally depend on traditional sources of fuels like wood, charcoal, dung and agriculture waste; as sources of energy are very high, close to 3 billion people in the world are changing solid fuels (Abukhzam and Lee, 2010). The usage of the traditional energies like firewood in developing states can be affiliated to the rural households. Nevertheless, conservation of forests in Uganda and across the globe is an environmental agenda that countries are engaged in their efforts to improve the conservation of the environment. Different efforts have been put forward especially aimed at reducing the usage of wood energy in a bid to conserve the forests through reduced tree cutting (Amare, 2015). Masinde and Karanja (2011) contend that having limited awareness on clean fuels and stoves is key hindrance to their adoption and use. Lack of knowledge and awareness on biogas as an alternative energy provides and hinders technology expansion concerning biogas. Bensah and Brew-Hammond (2011) contend that education improves beliefs and habits for the creation of favorable attitudes for accepting the new practices for conservation of forests. Fatona *et al* (2013) submitted that sources of energy are fundamental for the development of a state and drive the status for developments and the magnitude of its demand is a crucial indicator of the socio-economic development of a country. Bensah and Brew-Hammond (2011) established that technical problems have been associated with very large installations of biogas plants either by accident or design. This is due to the fact that at the start-up phase after the biogas plant has been installed, problems such as odor nuisance, low methane productions are experienced.

More importantly, in Africa, fuel wood contributes 5% to the world deforestation with 55% woods obtained from the forest were used as fuel. Wood is the main reason for deforestation in many African countries and in the Savanna areas (Africa Biogas Partnership Program, 2013). The lack of sustainable means of attaining the wood types contribute to the generation of soil erosion and land degradations that affects the ground for other cases of diversity loss. Meanwhile, approximately 68% of Uganda's energy demand comes from biomass which is predicted to remain the primary energy source in the country (Alphonse *et al*., 2013). Biomass energy demand, specifically wood fuel, has been steadily increasing with increasing

population in Uganda. Fire wood loss and its effect on continued prices are the reason for the household level loss because of poverty and few resources used as alternatives. The scarcity has exerted an imbalance in demand and supply, causing a lot of pressure on forests (Mengistu *et al*., 2015).

Moreover, unsustainable reliance on biomass fuel in Uganda has exerted a lot of pressure on forests with high negative effects on the environments; this among the many issues has led to decrease in plant trees cover. The current cover is at 6.07% that does not provide a recommended world standard of 10% coverage. To attain the end to the destruction of the forests resources, government of Uganda established a regulation that hinders the cutting of trees in national forests and protected reserves in the years 2005 (World Bank, 2010). Alternative biogas includes the usage of Kerosene and electricity. The ban results in serious deficits in wood fuel implying that, it is the only local available energy source that has high demands in the households, organizations and factories in many residential and operation areas of Uganda. It is noteworthy to state that in Uganda, biogas usage and production has proven as a key solution to the challenge of energy in rural areas (MNES, 2012). They can provide suppression to adverse social, economic and environment effects connected to conventional energy sources like the traditional biomass. The uses of the technologies for Uganda provide a slow and undistributed form of extension since due to many households providing awareness for the existed form of 50 years.

Promotions based on biogas making as an alternative energy source is appropriate for Wakiso district favours adopting the technologies that are available locally. For example the dairy farms in the areas are hence a continuous available source of cow dung that is good and improves or substitutes biogas. Water is hence required in producing biogas (World Bank, 2010). The use of biogas technologies in Uganda is low and many parts of Uganda and some systems that could be adopted are still under installation.

In Wakiso district particularly Gombe Sub-County, biogas has helped to improve the quality of life and livelihoods of the residents by utilizing the many benefits of biogas production rather than cutting down the trees for fire wood (Tobin, 2011).

While feasibility studies indicate that the long-term benefits of biogas outweigh the upfront cost of a biogas system as well as a cultural bias against biogas as a fuel for cooking remain barriers to biogas uptake. The taking and use of biogas is hence of high value when it comes to development of a sustainable mechanism for the development of the people in the rural environments. Despite the different studies on role of biogas usage on the conservation of forests, there are minimal studies conducted in Uganda and specifically focusing on the role of biogas usage on the conservation of forests in Gombe Sub-County, Wakiso District.

1.2 Statement of the Problem

Energy is a basic tool for development. Firewood and charcoal have been and are still, the major sources of energy for daily use by the population of Gombe Sub-County, Wakiso district. This total dependence on firewood and charcoal as the sources of energy for cooking has resulted in deterioration of the quality and quantity of forests and has posed a serious threat in maintaining ecological balance, thereby manifesting various problems like deforestation, flood, global warming, soil erosion and climate changes (Abukhzamand, 2010). The pressure on forest resource for energy fulfillment is considerably increasing due to high population growth in the area causing scarcity of energy for cooking. As a consequence, many people in the rural areas are burning livestock dung and other agricultural residues as an alternative for timber. This has been one of the factors deteriorating environment and soil fertility (Bensah and Brew-Hammond, 2011).

However, it becomes very imperative to look for alternative energy source such as biogas energy. Biogas is an alternative or substitute energy source. As viable eco-friendly alternative technology, it can substitute firewood for cooking, heating fuel and kerosene for lighting. Thus, it reduces the over-dependency on forests and increases greenery leading to an improved environment (Fatona *et al* (2013).

Biogas as a product of animal refuses and plant residues that are available to farming communities, as well as a source of energy, has wider socio-cultural implications, particularly for women and children. It has many other direct and indirect uses. Chemically, biogas is just methane gas. Meanwhile, as forest accounts for 78% of energy consumption in Wakiso district, alternative energy source such as biogas is necessary to reduce pressure on forests. This study,

therefore, filled the gap by investigating the role of biogas usage on the conservation of forests in Uganda particularly Gombe Sub-County, Wakiso district.

1.3 Objectives of Study

1.3.1General Objective

- To examine the role of biogas usage on the conservation of forests in Gombe Sub-County, Wakiso District.

1.3.2 Specific Objectives

1) To determine the factors influencing the adoption of biogas usage by households in Gombe Sub-County, Wakiso District.
2) To examine the contributions of biogas usage to financial and time saving and how the two factors improve livelihoods at household level in Gombe Sub-County, Wakiso District.
3) To determine how the adoption of biogas usage reduce wood fuel demand and contribute to tree cover enhancement in Gombe Sub-County, Wakiso District.

1.4 Research Questions

1. What are factors influencing the adoption of biogas usage by households in Gombe Sub-County, Wakiso District?
2. What are the contributions of biogas usage to financial and time saving at households' level?
3. How does the adoption of biogas usage reduce wood fuel demand and contribute to tree cover enhancement in Gombe Sub-County, Wakiso District?

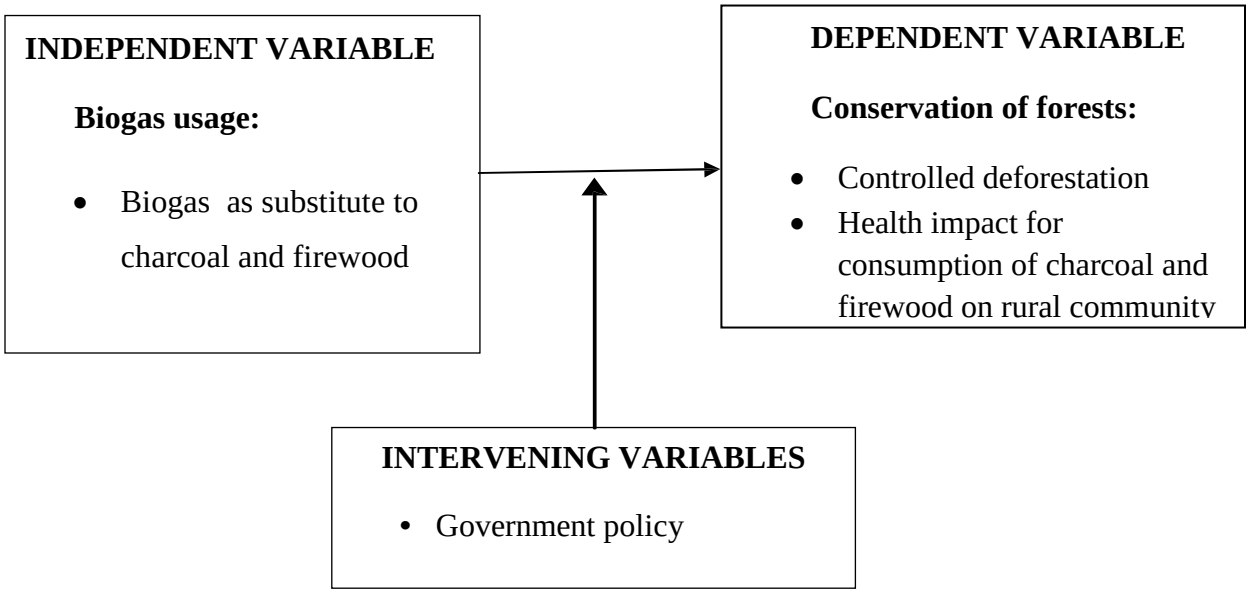
1.5 Significance of the Study

There is need to provide guidance and support towards the promotion and increase of usage and adoption of renewable energies in Uganda to enable energy crisis management most especially in the rural areas.

The study is to facilitate the development of better comprehension in handling the challenges hindering the usages of biogas technology and further more provide a guide to policy makers in

the local governments and other organizations in promoting the biogas technology and many related energy technologies

1.6 Conceptual framework



The conceptual framework shows the independent variable, dependent variable and intervening variable of the study. Biogas use substitute's charcoal and firewood conserving of forests, through controlled deforestation. The substitution also improves the health of rural community by eliminating the smoke. As an intervention, government is called upon to ensure the implementation of its policies to influence forest cover and conservations.

CHAPTER TWO

LITERATURE REVIEW

2.0 Biogas and its uses

Biogas is a mixture of gases produced through anaerobic degradation of organic materials like agriculture waste, manure, municipal waste and plant materials, sewage, green waste and food (Anushiya, 2010). Biogas is a renewable energy source that is produced through anaerobic digestion of biodegradable materials in a closed system that facilitates usage in cooking in an environmentally friendly manner.

Biogas is therefore, considered a green technology with the environment values. The technology of biogas facilitates the usage of accumulated animal waste from food production and solid waste production in the greenhouse gas known as methane. It is an efficient combustion that replaces methane with carbon dioxide. Methane is almost 21 times more effective in trapping the heat in the environment than carbon dioxide, and biogas combustion provide results in the reduction of the green houses emissions (FAO, 2010). In additions, biogas production reduces odour and pathogens connected to traditional manure piles. Biogas is environmentally friendly and a renewable form of clean energy. The over flow of landfills spread foul smell and allow toxic liquids to drain the underground water sources. The effect is another form of using biogas in generating the water quality reducing the soil water pollutions and the attained value is green biogas generations (FAO, 2010).

2.1 History of Biogas use

Globally, with many values of biogas, it has becomes a popular source of energy. In 2003 the USA consumed or used 147 trillion of British Thermal Units (BTU) for energy and from the landfills with close to 0.6% for the USA natural gas used and has a high contribution to conservations for the forests in a bid to generate improved cooperation and management of the forested environment to support the existence of the forests for human and natural consumption in the country (Arthur et al., 2011).

Methane biogas is attained from cow dung and has been tested in USA. The methane biogas is being used to prove the effect on reducing the 99 million metrics of tones of greenhouses gases and emissions for close to 4% for the green houses gas attained in USA and protecting the forests from exploitations. In Germany use of biogas have developed highly for the last 20 years. The reason is the legal created framework. Government supports for energy starts in 1991 with electricity Fed-in act (FAO, 2010). The law provides that production of energy from renewable energy is fed to the public power grid through the companies being forced to make productions of energies in the private production for the green energy and hence play a key role towards forests conservations in countries and attaining a global agenda on green energy (Arthur *et al*., 2011).

The African continent has high usual natural occurrence for the energy sources like biogas used in the occurrence of deep lakes like Kivu from Rwanda and Democratic Republic of Congo (DRC) (Arthur *et al*., 2011). The lake produces biogas that is a combination of actions of anaerobic microorganisms at the deep of decays for the organic matter alongside the process connected to geothermal activities and the major focus to conserve the forests across the countries. Additionally the form of natural biogas that is presented in the mine sites in South Africa. The gas has a typical extraction from ventilation system that has flared the aid of ensuring that work safety is used in the provision of values for the fuel and generations other than cutting the trees for charcoal and hence conservation for forests. Africa can use the available different organic materials for the making of renewable decentralized powers (Bensah and Brew-Hammond, 2011).

In Uganda, traditionally, biogas is the main contributor of energies balance for the country with close to 90% energy needed being the traditional biomass, this is not sustainable for it highly accounts for the exhaustion of the country's forests and drought leaving populations homeless (FAO, 2010). The fuel are used for lights and heat in the houses and institutions like schools and hospitals, commercial settings like hotels and restaurants and small scale factories. Many of these are systems that are constructed in the country for manures are the major source for subtrate systems existence.

Biogas technology has a long history in Uganda particular emphasis on Wakiso district. As per the report on Uganda domestic biogas program (UDBP, 2010), biogas technology has provided a districts with 1950 and 2008 with estimated systems for the close to 800 improvements for over the estimates of existed since 1990. The same sources also provide that failure to use the estimates for the 15-20%, the key cause is usually failure to have skills by the constructors and prevalence of inadequate operations as well as maintenance for the households in the district. In Gombe Sub-County, Wakiso District, the driving factor is that biogas has potential for meeting energy needs of the population if well managed. This is added to the fact that manures and anaerobic digestions provide a better quality system that biomass waste provides leading to good agricultural yields and hence boosting the food supplies and economic development in long run as a factor that can endure and facilitate development (Fatona *et al*., 2013).

2.2 Biogas use and conservation of forests

Biogas development has substantial role in forest conservation. Direct effect can be attributed in the reduction in forest use for firewood. Some studies have indicated that about 65% reduction of firewood demand after installation of biogas plant.

Biomass attainment has a key function in conserving the forests. Direct effects are attributed to the reduction of forests use in firewood. Many studies have shown that close to 65% reductions for firewood demand after installation in biogas plants (FAO, 2010). Furthermore, it was revealed that approximately 34.7% of the households have completely stopped collection of wood from the forest because of changes from traditional to biogas. Biogas developments change livestock raring acts (Mwirigi *et al*., 2014). The forests develop in countries like Nepals are affected through grazing, development for biogas and reduction of grazing and eventually forests generations. According to Fao (2010) 76% houses need firewood hence account for destructions of forest covers. The needs can’t be reduced unless alternatives to traditional fuels are developed enhanced and devised as a means to develop effective work for resource usage in the environment of waste management’s, controls and effective tributes to the generation of a cleaner environment.

2.3 Factors influencing the adoption of biogas usage by households

Awareness

Masinde and Karanja (2011) contend that having limited awareness on clean fuels and stoves is key hindrance to their adoption and use. Lack of knowledge and awareness on biogas as an alternative energy provides and hinders technology expansion concerning biogas (Anushiya, 2010). It is fundamental that education on the explanation demonstrations for technology and rural community development is crucial. In Kenya biogas is not so new, the adoption process though remain low coupled with limited knowledge and poor infrastructure for the technology among people who could derive for great values in the organization (Hamlin, 2012).

Impact of Installation and operational problem

Technical problems have been associated with very large installations of biogas plants either by accident or design (Bensah, and Brew-Hammond, 2011). This is due to the fact that at the start-up phase after the biogas plant has been installed, problems like odor nuisance, low methane productions are experienced. Under-collection of dung was associated with underfeeding of cattle and also the cattle being overworked in the field that has led to reduction in biogas fuel production. Elsewhere, studies indicated that trained masons in biogas plant constructions were not involved because they were considered to be costly and instead cheaper labour was opted for hence to poor quality work. Production of biogas fuel was affected by change in temperature especially during the cold seasons. This contributed towards challenges like gas leaking, blockages and maintenance. The main reason for failure is poor observation to biogas plant maintenance and insufficient technical support (FAO, 2010).

Other challenge includes the accumulated slurry at the bottom of the digester which required regular removal. This made the work so involving whereas in the case of slurry being considered for use as manure, it required space where to deposit it. In cases where space is available then its storage was a challenge and cost must be involved (FAO, 2010). Furthermore, frequent monitoring was necessary due to formation of scum and rusting of drum- reactors. In other studies, presence of heavy metals present in the substrate can have an inhibitory or toxic effect on the anaerobic digestion process. Heavy metals are not biodegradable, so they accumulate in

the bioreactor and at higher concentrations they can avert or completely impair the enzyme function of some bacteria groups by binding with certain groups on protein molecules. Heavy metals also might displace the natural metals in enzymes making it non efficient (Bensah and Brew-Hammond, 2011).

Economic Problems

Food and Agricultural Organization, embrace efforts to cub food insecurity, energy poverty and clearing of vegetation cover hence promoting sustainable livelihoods. Sources of energy are fundamental for the development of a state and drive the status for developments and the magnitude of its demand is a crucial indicator of the socio-economic development of a country (Fatona *et al*. 2013). The energy sector has a very strong impact on mitigation of poverty through income, health, education and gender. At present any country that embraces the use of green energy, has fewer challenges in reducing poverty, since clean and safe energy have a great impact on a country's economy (FAO, 2010). Therefore, provision of adequate, affordable, efficient and reliable energy services with minimum negative effect on the environment is crucial. In Kenya, the demand for energy has been continuously increasing whereas its supply has been going down.

In other studies, energy poverty continues to place a disproportionate burden on women and children (especially girls). Biomass being the primary source of energy, women who are expected to take care of the house chores spend most of their time gathering firewood for fuel. Wood land degradation of community biomass ecosystems so to satisfy their cooking requirements (Bensah and Brew-Hammond, 2011). As a result, women have often resorted to using poorly dried wood (green wood fuel), cow dung and sawdust. Other desperate and alarming solutions include using old plastic utensils, cooking with such toxic low calorific fuel means that meals are undercooked and nutritional value is severely curtailed. Further, women who are thought and expected to be taking care of the home spending most time with home chores, need modern, friendly, efficient and available energy so as to improve their quality of life.

Others factors

Lack of sufficient water and manure is among the important issues that hinder the biogas use since the requirements in some cases hold possession for inadequacy of the cows and water through nature and grazing systems developed for nomadic semi-norms and freezing for grazing and systems that make cows dung collection as a tiresome tasks (FAO, 2010).

Other factors that influence the technology uptake for biogas are education, awareness, age, sex for the households and the characters of the people in capacity for obtaining the information through knowledge and perceptions for the technology use and flips for the effect on the decisions for using the biogas. Education hence improves beliefs and habits for the creation of favorable attitudes for accepting the new practices (Bensah and Brew-Hammond, 2011).

2.4 Biogas use and its implications on the finances and time saving at household level

The technologies used in production of biogas are quite cheap and easy. It is easy to setup and needs little investments when small scale. Small bio-digesters are used in right quantities in homes using kitchen and animal manure (Masinde and Karanja, 2011). The house hold system provides a pay level for the materials usage in generation of the system absolute. The gases provide a manifest of the usage and directly for cooking and generating the electricity.

Financial contributions

Biogas technology is cheaper than other forms of energy such as firewood since has no complications in establishments with little investments needed (Fatona *et al*. 2013). Small bio-digesters are used in homes for kitchen waste and animal manure for instance in Kampala the cheapest form of charcoal goes to 90 UG shillings, the expansion of the urban population pushes the demands for the charcoal to highs (Mwirigi *et al*., 2014). Biogas technology hence is taken as key replacements to the energy in Uganda. Uganda national charcoal survey 2015-2016 contend that 94% of the Ugandans use biomass for cooking, this provides to a translated form of estimations to 115 football fields for cooking in a day (FAO, 2010).

Time saving in cooking

Biogas generations save women and children from the tasks of firewood collections. The result is that much time is left for the cooking and cleaning. The important function is cooking on stove as for the ovens and fire presenting families from the exposure and smoke in the Kitchens hence helping the prevention of deadly respiration diseases (Anushiya, 2010). Actually 4.3 million people die yearly from premature births due to sickness affiliated to household air pollutions caused by the insufficient solid fuels for cooking.

During use in cooking fuel, it provide better combustion for the less efficiency in cooking and fuels such as wood, that is compared to clean and hygiene due to bacteria and other pathogens that are destroyed through anaerobic treatments (FAO, 2010). Substantially reducing the drudgery for the women in doors for smoke in hotels and respiration infections for biogas digestion and improved health reductions for medical expenditures hence saving the time for people to waste

On contrast, small farms in developing countries collect and use most traditional fuel from fertilizers like wood, harvest residues and cows (Fatona *et al*. 2013). There exist no direct savings for the attribution and usage of biogas in bio-fertilizers. The money value used for biogas is hence attributed to the time saved in collecting the fuels and money values for bio fertilizers through expected increases in crop yields.

A shortage in energy is firewood that provides a reflection of less market price for the time in houses and especially women and children need to collect the fuels (FAO, 2010). The time is hence spent on collecting the many varieties in the many hours in the week for a day. In some places in Africa and Asia, firewood collection is a single avenue for time consumption activity were a house wife saves time. The opened fire has to be provided and attend to in the flows for grades of fuel like cow dung to avoid burning (Fatona *et al*. 2013). In addition to the works caused to soot of the open fire, the shining pots are provided in the symbol of many cultures compared to the time needed for operation of the plants in a normal low and case considered to saving as realized in the organization values. In some places in Africa and Asia, firewood collection is a single avenue for time consumption activity were a house wife saves time.

2.5 Reduction in wood fuel demand and enhancement of tree cover

Reduction of wood fuel

Biogas can aid in the reduction of forests cutting in Africa through provision of sources of energy that can otherwise be done through wood. However, the connection between deforestation and usage of wood fuel at the world level is weakly analysed due to fuel being always attained from the fallen wood and sources of cut trees for construction and clearance of land (Anushiya, 2010). Unfortunately, wood fuel production and usage in Africa is on the increase overtime.

Biogas is also taken to be a cheap form of energy to the low income people. Although the practice for charcoal and wood production leads to cutting of trees responsible for increase in carbon emissions in the atmosphere (FAO, 2010). Additionally women and children spend long hours getting firewood that has a high value in reducing the farm production and productivity. Apart from this, the usage of firewood can lead to smoky cooking environment that has negative effect on children and women.

Unfortunately, charcoal provides a functional role in energy sectors of many African countries. It provides a considerate form of employment in rural areas that allow for quick returns on investments. Although inefficiently produced and used, charcoal places a heavy strain on the local wood resource that lead to severe environment effects. In most developing countries, the use of charcoal is blamed on the occurrence of deforestation that is seen in form of deserts due to loss of thousands of species (Mohamed ElmiAbdullahi 2001). Biogas can be a good solution to wood fuel since cattle keeping, as a source of organic matter, is a key aspect of the many households.

Contribution to tree cover enhancement

Unsustainable reliance on biomass fuel in Ethiopia has exerted a lot of pressure on forests causing adverse forms of effects on the environment. The main focuses are the factors that result in loss of tree covers. The prevailing trees cover provide an effect on the environment at 6.07% which does not yet meet the world's recommendation of 10% coverage (Fatona *et al*. 2013).

The biogas technology is very important in reducing the cutting down of forest cover and scaling down usage of firewood which has caused a positive impact on environment. Furthermore, the by- products from the technology such as manure have improved the quality of soils hence improved agricultural produce (Bensah and Brew-Hammond, 2011). As a result, vegetation cover also improves hence improved rainfall patterns and livelihoods. The biogas fuel is commonly known for its efficiency during consumption. It is used in place of petroleum products like kerosene oil, solid waste from agricultural products and wood fuel. Replacement of biomass with biogas energy would mitigate loss of forest cover. This would cause an improvement on ecosystems and environment by reducing land erosion.

Installed domestic biogas provides value to the field of energy supply, agriculture, health, sanitation, gender, sanitation and environment (Sassi 2014). For instance in Tanzania, with an average consumption rate of 15 million tonnes of firewood annually by 80% Tanzanian families living in rural areas, the estimated 33.5 million hectares of forest and woodland are under a threat of disappearing (National forest policy, 1998). This calls for urgent interventions to introduce most Tanzanian households relying of firewood and charcoal to other sustainable energy sources such as biogas to meet their energy demand for cooking.

2.7 Research gap

Many researchers such as Rogers, (2003) recount biogas technology as a powerful and sustainable source of alternative energy for people in rural areas of developing nations to improve their livelihoods. However, Rogers (2003) did not clearly articulate the factors that can influence the adoption of biogas usage by households. According to Smith, (2005), firewood gathering consumes much of household time for millions of people worldwide, particularly women and children. This exercise occurs on a regular basis hence denying this group an opportunity to empower themselves either economically or socially. However, Smith, (2005) did not mention how biogas usage contributes financially to the households as it is time saving. Winrock International (2007), IFAD-supported biogas program put up about 23,000 biogas tanks in China an initiative that helped around 30,000 poor households improve their living conditions and forests were protected. However, Winrock International (2007) did not mention how adoption of biogas usage reduces wood fuel demand and contributes to tree cover enhancement.

Authors	Findings	Gaps
Bensahand Brew-Hammond, (2011)	Bensahand Brew-Hammond, (2011) recount biogas technology as a powerful and sustainable source of alternative energy for people in rural areas of developing nations to improve their livelihoods. Energy scarcity is perceived as one among other elements affecting well-being and livelihoods of communities.	However, Bensahand Brew-Hammond, (2011) did not clearly articulate the factors that can influence the adoption of biogas usage by households
Mengistu et al., (2015)	Mengistu et al., (2015) noted that firewood gathering at the local level normally occurs on a small scale and most of the material collected is deadwood although the rate at which collection takes place is higher than the regeneration rate.	However, Mengistu *et al*., (2015) did not mention the contributions of biogas usage to financial and time saving and how the two factors are important to households
Abukhzamand Lee, (2010)	Globally, dependency on traditional fuels such as wood, charcoal, dung, and agricultural residues, as a source of energy is very high with around 3 billion people all over the world combusting solid fuels (Abukhzamand Lee, 2010).	However, Abukhzamand Lee, (2010) did not mention the how adoption of biogas usage reduces wood fuel demand and contribute to tree cover enhancement

CHAPTER THREE
MATERIALS AND METHODS

3.0 Study Area

Gombe sub-county is 23 Km North of Kampala, the capital city of Uganda. The coordinates are latitude: 0°29'19.0" (0.4888599) North; longitude: 32°28'50.0" (32.480550) East; at an elevation of 900 to 1340 meters above sea level. The total number of households within Gombe Sub-County is 83,567. This sub-county has over twenty government forest reserves with a total area of 773 hectares. This forest area has experienced illegal clearance, with activities like burning of charcoal, farming, encroachment, pit swaying and firewood. Gombe sub-county was used as the study area because of the continued depletion of its forest reserves despite the production of biogas.

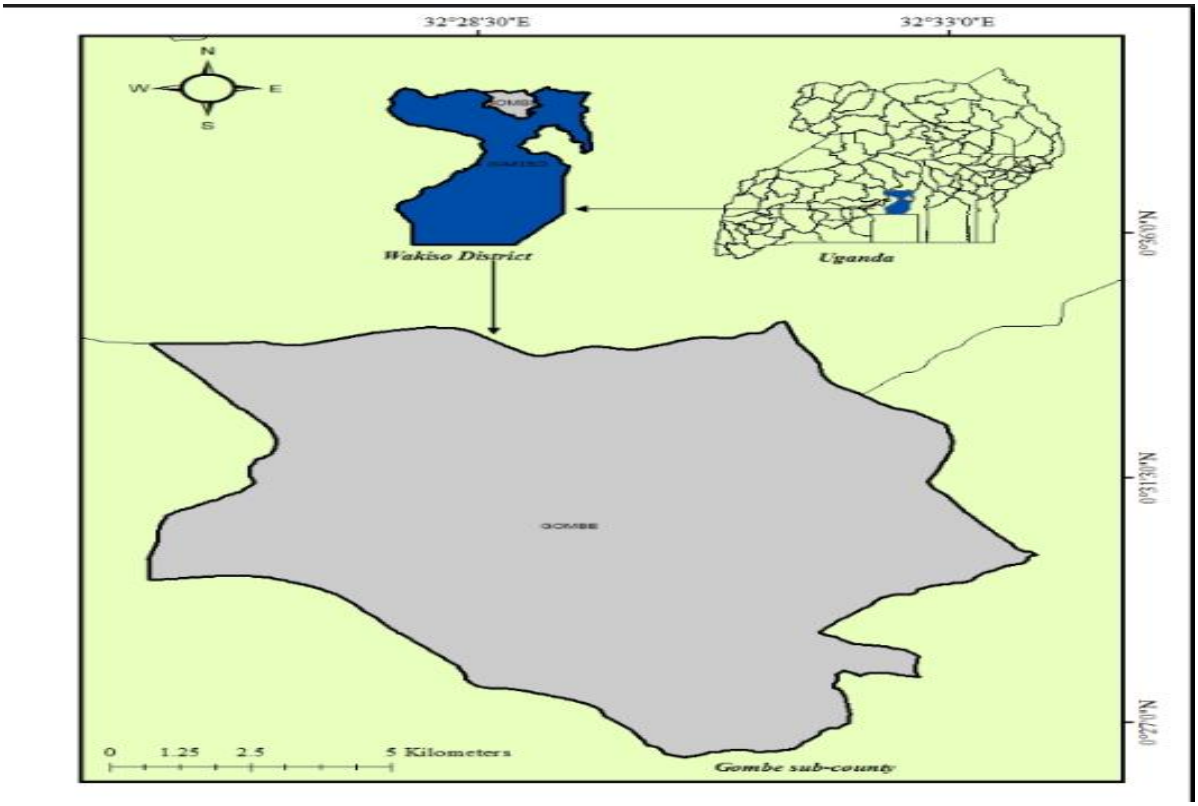


Figure 3.1: A Map of Gombe Sub-county in Wakiso District

Figure 3. 1: Gombe sub-county and the studied areas A, B, C, D and E.

3.1 Data Acquisition

Gombe Sub-county has a reported number of 83,567 households (UBOS, 2018), of which only 0.27% use biogas (UBOS, 2018). Using these facts, the target number of homesteads using biogas (N) was calculated as:

$$N = \frac{0.27}{100} * 83567$$

N=225.63~226

Therefore, the target number of homesteads was 226.

3.2 Sample size

The sample size (n) was determined using Sloven's formula as shown below:

Sloven's formula states that: $n = \frac{N}{1+N(\alpha)^2}$

Where: n = Sample size

N = Total number of homesteads using biogas

0.05 = Level of significance

Therefore, $n = \frac{226}{1+226(0.05)^2}$

$$n = \frac{226}{1 + 226(0.0025)}$$

$n = 144$ respondents

Table 1: showing target respondents and sample size

Category	**Target population**	**Sample size**	**Sampling techniques**
District environmental officers	2	1	Purposive sampling
Officials from National Forestry Authority	3	2	Purposive sampling
Biogas users who produce biogas	20	11	Purposive sampling
Other biogas users	201	130	Random sampling
Total	226	144	

Source: Primary Data (2019)

3.3 Sampling techniques

During this study, a survey research type of non-experimental design was employed. However, multi-stage sampling procedure was employed, using purposive sampling in the selection of district environmental officers, officials from National Forestry Authority and Biogas producers and users who are believed to have vital information regarding the role of biogas use on the conservation of forests. While random sampling was used in the selection of other biogas users.

3.4 Data sources

Primary data

Primary data were obtained using a questionnaire and an experiment. This data was gathered using self-administered questionnaires to representatives per considered homestead. Also, an

experiment was conducted to gather information on the amount of charcoal used per capita, which was converted to the number of sacks and then to number of trees destroyed for this cause.

Secondary data

The secondary data was attained from the documents and other published forms of literature related to biogas use and forest conservation.

3.5 Data Collection Methods

3.5.1 Utilized methods of data collection

Qualitative and quantitative data were collected for the study. The data collection techniques used included the following:

a) **Self-administered Questionnaire**

Questionnaires were administered to respondents directly. The respondents were the household heads or spouses and local government officials. Here the researcher used questionnaires as the key tool for collection of data. Close and open ended questions were used for obtaining data from the respondents. The instruments used were purposely to enable and seek for personal views of the respondents and hence enable respondents use their knowledge in providing a wide range of information in detail.

b) **Survey Observational**

I. **Charcoal burning**: To establish the number of trees destroyed per capita via charcoal burning, an experiment involving five holes of charcoal burning was conducted within the study area. The average number of charcoal bags per cut tree was established by counting the number of tree stumps at a newly piled hole and the number of bags that are harvested from that particular pile. The average weight of a charcoal bag was obtained by weighing 30 randomly selected bags from a nearby charcoal market.

II. **Charcoal consumption: '**Charcoal consumption per household' experiment involved five homesteads of charcoal plus biogas users which were randomly selected from the study area. A known weight of charcoal was given per household, depending on the size of family, for use within 24 hours. After this time, the remaining charcoal was weighed establishing the

amount used. The number of people within a homestead was also recorded, and this was used in the estimation of charcoal use per capita.

III. **Firewood consumption:** The 'firewood consumption per household' experiment involved five randomly selected homesteads of the firewood and biogas users who were selected randomly from the study area. Weighed bundles of firewood were given to each homestead depending on family size, and the balance after a day's use was weighed again to establish the consumption.

IV. **On site Pictures:** These were also taken from important sites for appreciation.

3.6 Data analysis

Quantitative data analysis was used in this study. Analyses were carried out with the aid of the Statistical Package for Social Sciences, (SPSS Version 19.0). Descriptive statistics were used to describe the data and to accurately characterize the variables under observation within a specific sample (Marczyk, DeMatteo, & Festinger, 2005).

3.7 Validity and reliability of the Instrument

According to Joppe (2000), reliability is the extent to which results are consistent over time and an accurate representation of the total population under study is referred to as reliability and if the result of the study can be reproduced under similar methodology, then the research instrument is considered reliable. While, validity determine whether the research truly measures that which it was intended to measure or how truthful the research result are.

In other words, researchers generally determined validity by asking a series of questions, and often look for the answers in the research of others (Golafshani, 2003).

3.7.1 Validity of the Instrument

The coefficient of Validity of the Instrument (CVI) was computed using the following formula:

$$CVI = \frac{\text{No of items declared valid}}{\text{total no of items}}$$

Table 2: Determination of the validity of the instrument

	Relevant items	**Not relevant**	**Total**
Rater 1	22	3	25

Rater 2	23	2	25
Rater 3	20	5	25
Total	**65**	**10**	**75**

$$CVI = \frac{65}{75} = 0.866$$

Thus, since the CVI computed is above 0.7, the Standard Cronbach Alpha, the instruments were considered valid this is also in line with Amin (2005) who noted that the overall CVI for the instrument was calculated by computing the average of the instrument and for the instrument to be accepted as valid the average index should be 0.70 or above.

3.7.2 Reliability of the Instrument

Reliability measures the degree to which research instruments can attain consistent data repeated. The study uses Cronbach Alpha Value (Steven, 2013), for the instrument is good when the value exceed 0.9, and at 0.8 it is acceptable. Any value below 0.5, the instrument is poor and unacceptable.

Table 3: Reliability

Variable	**Items**	**Cronbach Alpha Value**
Factors	5	0.832
Biogas and implications	5	0.782
Adoption reduce fuel	5	0.750
Production, operation and durability	6	0.821
Mean Average		**0.796**

Source: Primary data

Table 3: above displays the reliability indices/coefficients for all instruments used in the study. All alpha reliabilities (α) for all scales computed were above 0.5, ranging from 0.750 to 0.832, meeting acceptance standards for research (Nunnally, 1978).

3.8 Ethical Considerations

The study was conducted in the full knowledge and authorization of the local leaders in Gombe sub-counnty and top authourities in Wakiso district.The researcher first of all acquired an introductory letter from Kampala International University for use, eliminating suspcision. The respondents were then selected, questionnares delivered and time of picking them agreed.In addition, appointments for interviews fixed. Confidentiality with collected data was paramount.

CHAPTER FOUR

DATA PRESENTATION, ANALYSIS AND INTERPRETATION

4.0 Introduction

The chapter deals with the presentation, analysis, and interpretation of data collected from the field to examine the role of biogas usage on the conservation of forests in Gombe Sub-County, Wakiso District. The study objectives were (i) to determine factors influencing the adoption of biogas use by households, (ii) to determine the contributions of biogas usage to financial and time saving as well as improving livelihoods at household level and (iii) to determine how the adoption of biogas usage reduces wood fuel demand and contribute to tree cover enhancement in Gombe Sub-County, Wakiso District. The presentation, analysis and interpretation was done based on these specific research objectives.

4.1 The demographic structure of the respondents

Demographic characteristics considered included: gender, age, marital status, education level and occupation of the respondents.

4.1.1: Gender of respondents

Table 2: Gender of respondents

Table 4: Gender of respondents

	Frequency	**Percentage**
Male	89	61.8
Female	55	38.2
Total	**144**	**100.0**

Source: Field data, 2020.

Results (Table indicate that majority of the respondents were male constituting 61.8% while female were 38.2%. The high number of male is based on the fact that the study was a household survey and in most cases the man in each household was responsible for the installation and maintaince and therefore, was majorly left to fill the questionnaire by the woman. The participation of the women (38%) indicate that data was collected accross gender hence meets the gender tests.

4.1.2: Age of respondents

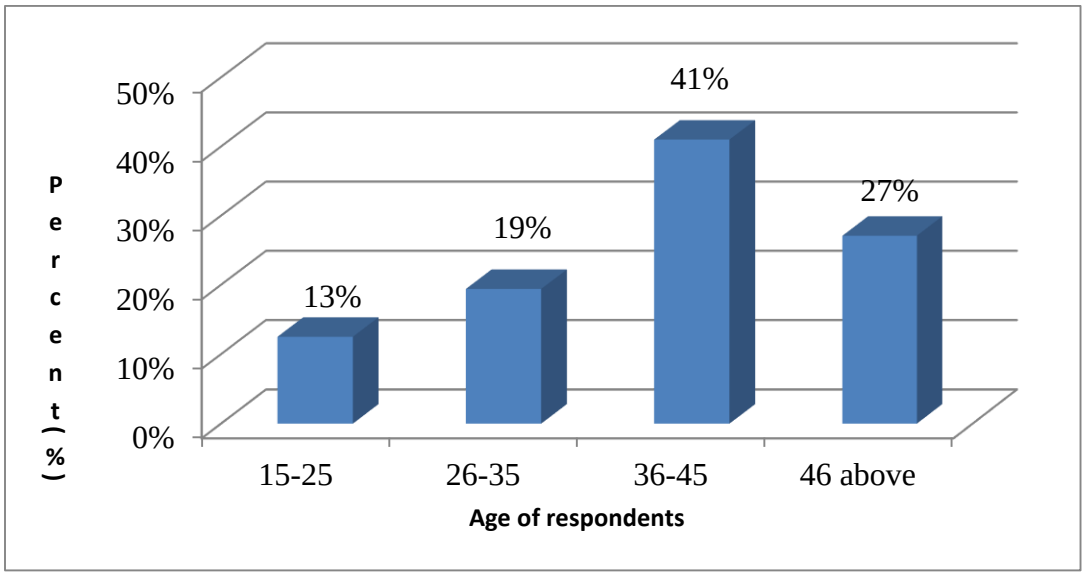


Figure 4.1: Age of respondents (n=144)

Figure 4.1 above shows that the majority of the respondents were in the age bracket of 36-45 years (41%), followed by those of 46 and above with 27%, while those aged 26-35 years were 19% and the minority (13%) were in the age bracket of 15-25 years. This reveals that the information/data was collected from adults 36 and above indicating reliability.

4.1.3 Marital status of respondents

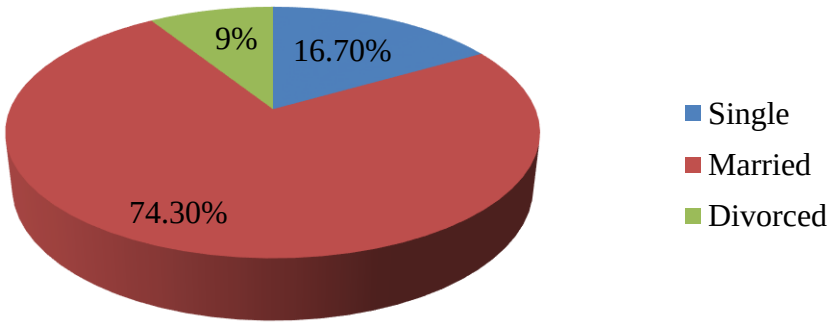


Figure 4.2: Pie chart Shows the Marital status of respondents (n=144)

Figure 3 reveals that majority of the respondents (74.3%) were married. Those who were single were 16.7% while the separated or divorced constituted 9%. The study findings indicate that majority of the respondents were married.

4.1.4 Level of education

Table 2: Level of education of respondents

Education	Frequency	Percent
Primary	21	14.6
Secondary	51	35.4
Tertiary	35	24.3
Informal	37	25.7
Total	**144**	**100.0**

Source: Field data, 2020

Table 2 presents the level of education of respondents, and reveals that the majority of the respondents attended up to secondary school level (35.4%), while tertiary level is achieved by 24.3%. Those with informal skilling were 25.7% and the primary level were the least with 14.6%. It is therefore, indicated that majority of the respondents were educated hence information attained from them concerning biogas production and usage is deemed sufficient for the study.

4.1.5 Occupation of respondents

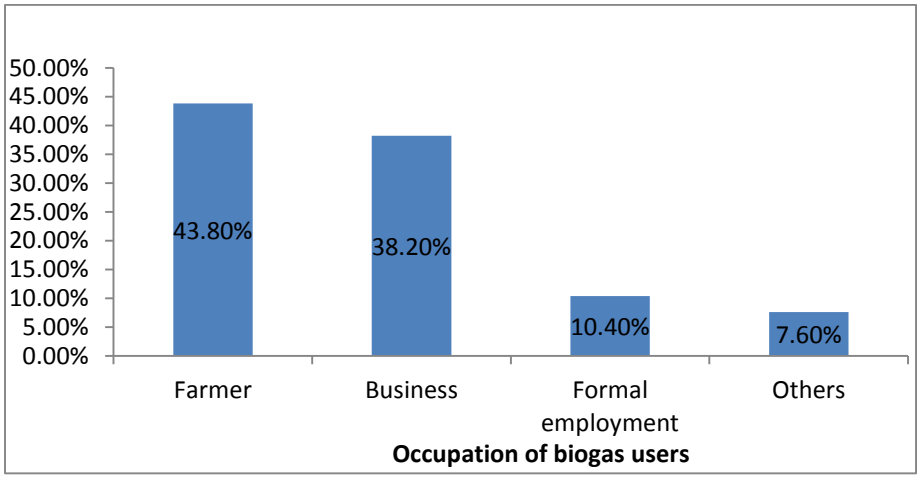


Figure 1.3: The occupation of biogas users in Gombe sub-county

Farmers constituted the majority (43.8%) of the biogas users in Gombe sub-county, followed by business people (38.2%), then those formally employed (10.4%) and the informally employed were only 7.6% (Figure 1). Most of the households depend on farming and business, and were working within the sub-county.

4.2 Factors influencing the adoption of biogas usage

Factors influencing the adoption of biogas usage by households in Gombe Sub-County, were investigated. Collected data is presented under three sub-themes as follows:

4.2.1 Forms of energy used in Gombe sub-county

Table 3: Forms of Energy used within households in the study area

Energy used	**Frequency**	**Percentage**
Biogas only	0	0
Biogas & Charcoal	10	6.9
Biogas & Firewood	20	13.9
All forms	114	79.2
Total	**N=144**	**100**

Source: Field Data, 2020

Table 3 shows the forms of energy utilized by the biogas-using-households in Gombe sub-county. Three forms of energy i.e biogas, charcoal and firewood, were mostly recorded among the respondents during the study. These three forms of energy were used in combination i.e. no house hold was found utilizing only biogas. Most of them (79.2%) utilized all the three forms of energy, and 13.9% used biogas in combination with firewood, while the rest (6.9%) were using biogas and charcoal.

4.2.2 Advantages of biogas use over other forms of energy.

Table 4: Suggested advantages of biogas use over other sources of energy by different respondents

Advantage of biogas usage	Frequency	Percent (%)
Low cost of biogas production	15	10.4
Biogas use is more efficient	50	34.7
Biogas saves time	6	4.2
Biogas is very safe	31	21.5
Biogas is environmentally friendly	42	29.2
Total	**144**	**100**

Source: Field Data, 2020

From the Table 5 above, six advantages of biogas use over other sources of energy were identified. The efficiency of biogas use as a source of energy (34.7%) followed by environmental friendliness (29.2%) stood out as the major advantages driving the adoption of biogas use in Gombe sub-county. Other advantages included the biogas safety (21.5%), the low cost of production (10.4%) and the time saving characteristic of its use (4.2%).

4.2.3 Duration of biogas use per household

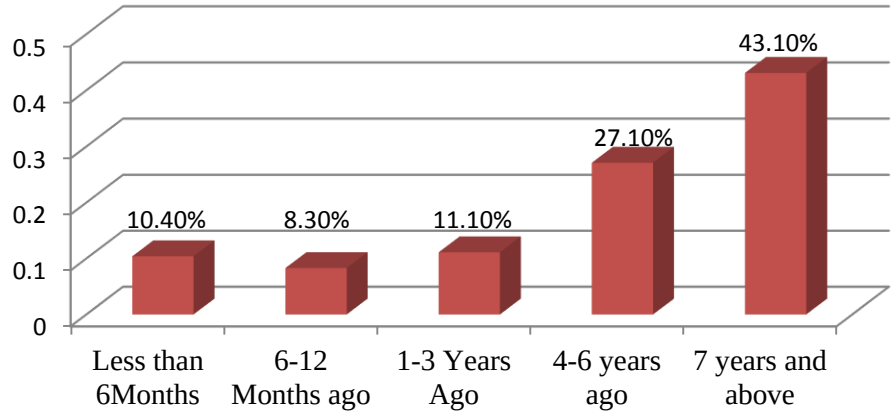


Figure 2: The evolution of biogas use in Gombe subcounty

The results reveal that the majority of respondents started using biogas 7 years and above (43.1%) followed by those who started 4-6 years ago (27.1%), and the rest were less than 3 years (Figure 2). This finding indicates that the recruitment to biogas use by the Gombe community is falling consistently, yet the biogas users are only 0.27% of the sub-county population.

4.2.4 Limitations of biogas use in Gombe sub-county

Figure 6 presents the major reasons as to why biogas usage in Gombe sub-county is limited. Lack of sensitization concerning biogas use and related benefits appears to be the main limiting factor. Information concerning the value of biogas use is lacking amongst the community, and this came out prominently (38.9%) as the major reason for the poor adaptation. A good number of homesteads (29.2%) were so much attached to traditional sources of energy in form of biomass (firewood and charcoal). Fearing the installation cost (16.7%) and the long generation time during production (15.3%) deterred a big number of homesteads from using biogas.

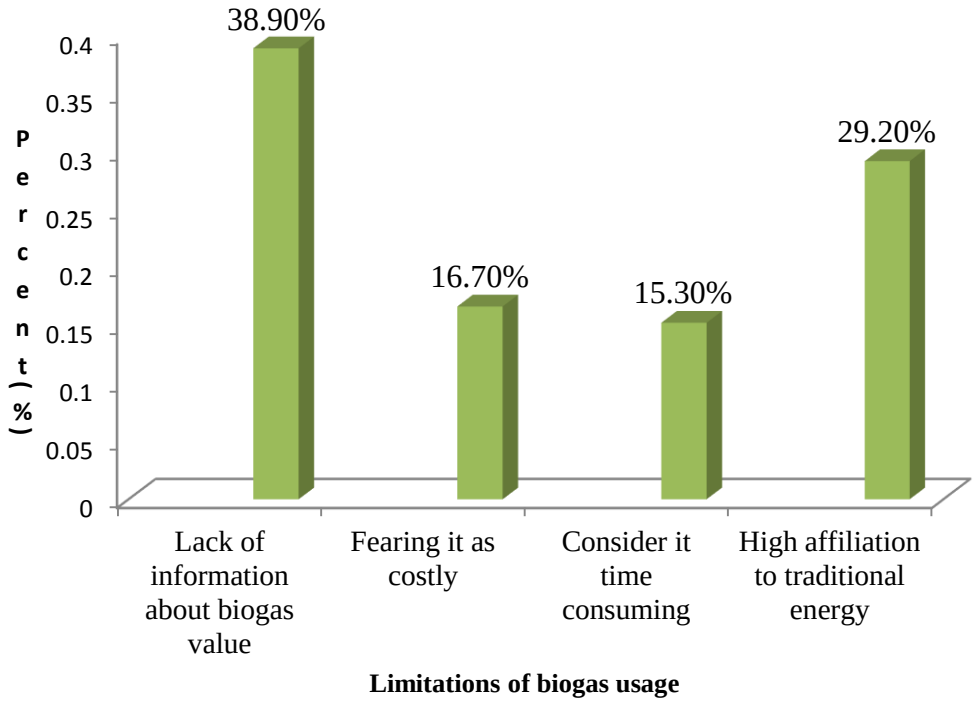


Figure 3: Reasons for low biogas usage in Gombe Sub-county

4.3 Biogas usage and contribution to financial and time resources in house holds

This constituted the second research objective which was to determine the contributions of biogas production and use to the financial and time saving in a house hold of Gombe Sub-County, as a mode of improving their livelihoods. The results concerning this objective are presented below.

4.3.1Cost of biogas compared to other forms of energy

Table 5: Whether biogas is cheaper than other forms of energy

Responses	Frequency	Percent (%)
Yes	116	80.6
No	28	19.4
Total	**144**	**100.0**

Source: Field Data, 2020

Table 6 shows the comparative cost of biogas and other available sources of energy. The majority (80.6%) of the respondents agreed that biogas is a cheaper source of energy than other available sources. The main reason as to why biogas was considered cheaper is that the installation is done once and used for a long time, and the raw materials (such as organic matter –dung and agricultural residues) are readily available. The convenience during use also encourages users as clean source of energy. Those who considered biogas use as an expensive venture, however, revealed that the cost of installation is high and it takes a lot of time to operate. They also complain of the management and maintenance costs of the biogas system. This finding indicated that there is a need to sensitize the Gombe community on the financial benefits of biogas use.

4.3.2 Time saving through biogas use

Table 6: Responses on whether biogas saves time

Response	Frequency	Percent
Yes	107	74.3
No	37	25.7
Total	**144**	**100.0**

Source: Field Data, 2020

Table 7 indicates that the majority (74.3%) of the respondents agreed that biogas use saves time. Time saving was majorly through reduced cooking time as gas cooks faster, and no need to prepare the fire before cooking. This saves time for other social and economic activities such as networking, farming and other domestic chores.

4.3.3 Financial benefits of biogas use

Table 7: Whether biogas use saves money

Responses	Frequency	Percent
Yes	104	72.2
No	40	27.8
Total	**144**	**100.0**

Source: Field Data, 2020

The majority of the respondents (72.2%) agree to the fact that biogas use saves money at house hold level. It encourages saving compared to charcoal and fire wood use, as there is no wastage of residual fire after cooking. Secondly, the unit cost of charcoal and fire wood usage is higher than that of biogas use. The 27.8% of the respondents believed otherwise as they considered biogas use expensive as they had free access to fire wood from the nearby forest. There is also, the aspect of cultural belief that Matooke is only cooked well using fire wood, hence the combined use of gas and fire wood.

4.3.4 How Biogas save finances

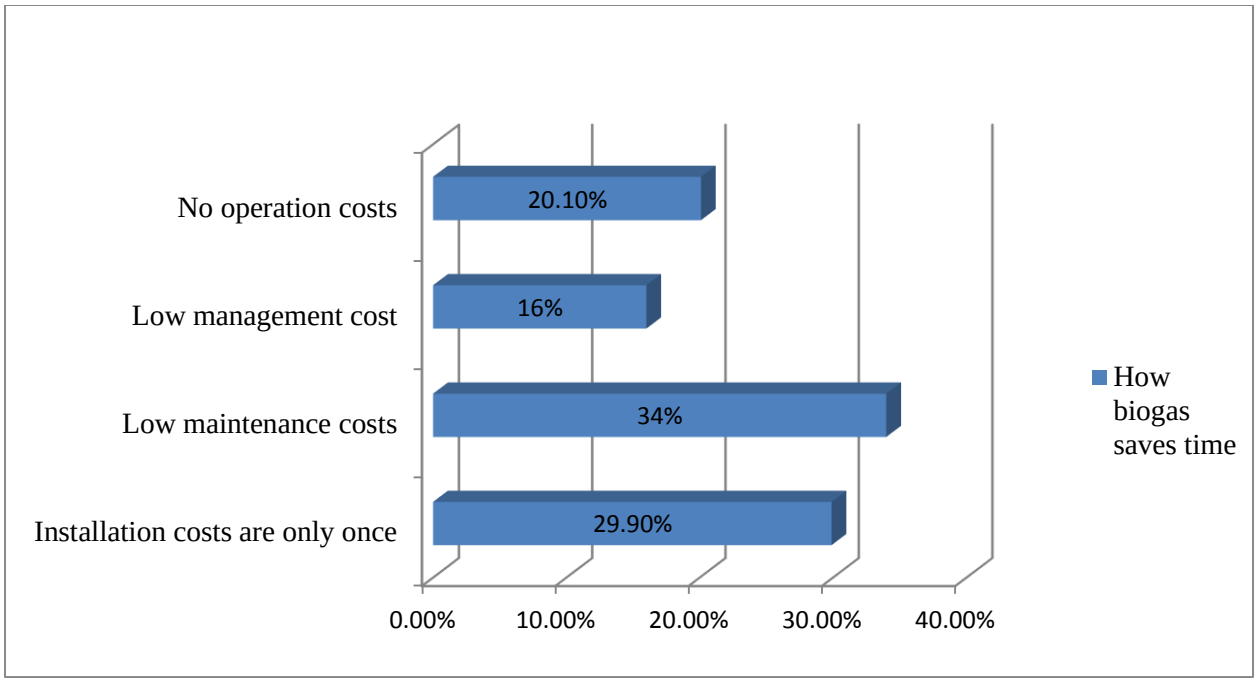


Figure 7 The different ways by which biogas use saves money in Gombe sub-county

Biogas users in Gombe sub-county maintain that low maintenance costs (34%) and the one time installation costs (29.90%) are the major factors responsible for the financial saving in biogas use. Absence of operation costs (20.10%) and low management costs (16%) were also among the suggested ways by which biogas use saves finances of the users. The saved finances therefore, can be used for health care, education and other domestic demands.

4.4 Biogas usage and its contribution to tree cover enhancement

The third research objective was to determine how adoption of biogas use reduces wood fuel demand and contribute to tree cover enhancement in Gombe Sub-County, Wakiso District. To achieve this objective, questionnaires were administered to homesteads utilizing biogas with either charcoal or firewood to assess their opinion concerning the benefits of using biogas for the conservation of biogas. In addition, an experiment involving the estimation of the extent of tree clearance due to charcoal and firewood consumption was carried out.

4.4.1 An assessment of the benefit of biogas use in forest conservation

Table 9: A summary of the assessment of the significance of biogas use in the conservation of forests (n=144)

Concern	Response	Frequency	Percent
a. Biogas use saves forests	Agreed	103	71.7
	Disagreed	41	28.5
b. Biogas use reduces tree cutting	Agreed	85	59
	Disagreed	59	41
c. Biogas can be used as an alternative to wood fuel (Charcoal & firewood)	Agreed	92	63.9
	Disagreed	52	36.1

Source: Field Data, 2020

Results in Table 9 indicate that the residents of Gombe sub-county clearly understand the importance of biogas use in the conservation of forests. This is so because the majority agreed to the fact that biogas use saves forests (72%), as it reduces tree cutting (59%) and can be used as an alternative to charcoal and firewood use (64%). However, referring to Table 4 in Section 4.2, the majority of the considered homesteads (79%) utilized all three forms of energy (i.e. charcoal, fire wood and biogas) and none was singly utilizing biogas. Indeed a good number of the respondents believed that biogas cannot be singly used for cooking due to different cooking modalities. This clearly meant that as long as there is still open access to firewood and charcoal, biogas users would still use these two sources of energy.

So, the study also assessed the benefits of using biogas over wood fuel and results are as presented in Table 9 below. It was quite clear that the respondents knew the environmental benefits of using biogas as the energy source instead of wood fuel, in addition to cooking faster and cost effectiveness.

Table 10 Benefits of biogas use over wood fuel

Advantage of biogas use over wood fuel	Frequency	Percentage
Biogas cooks faster	44	30.5
Biogas is less costly	46	31.9
Biogas use reduces environmental degradation	54	37.5

Source: Field Data, 2020

This finding reveals that biogas can be a sustainable alternative and can easily substitute wood fuel. It's important to argue that continued usage of biogas can reduce wood fuel demand and enhance forest conservation.

The contribution of biogas use to forest cover enhancement was another point of assessment, and the results are as indicated in Table 11.

Table 11: contribution of biogas to tree cover enhancement (n-144)

Biogas use benefit	Frequency	Percent
Reduces tree cutting	56	38.9
Controls bush burning	46	32.1
Reduces environmental degradation	42	29.2

Source: Field Data, 2020

To ascertain these findings, household level experiments were carriedout as in the following section (Section 4.4.2).

4.4.2 The experiment to ascertain the benefits of biogas use in forest conservation

Quantification of the number of trees utilized as wood fuel per capita in Gombe sub-county was done in a household-based experiment involving ten households utilizing biogas in addition to wood fuel (but for the experiment, convinced to use only wood fuel for a day). Five households utilizing charcoal and biogas, and another five households utilizing fire wood and biogas, were randomly selected from the study area for the experiment.

4.4.3 Charcoal burning and number of sacks

Table 12: Charcoal burning and number of sacks per hole

Holes of burning	No. of trees	No. of sacks	Average sacks/hole
Hole (A)	5	12 Sacks	2.4
Hole (B)	4	13 Sacks	3.25
Hole (C)	9	18 Sacks	2
Hole (D)	7	5 Sacks	0.71
Hole (E)	3	10 Sacks	3.3
Total	**28 Trees**	**58 Sacks**	**2.3**

Charcoal burners reported to produce most frequently 11-12 sacks of charcoal for one firing cycle. One cycle from cutting of the wood to removing the charcoal from the kiln takes an average of 10-15 days. It is therefore estimated that with the traditional kiln, a charcoal burner can produce two cycles per month. This gives an estimate of 30 sacks of charcoal per month or 360 sacks of charcoal per year.

4.4.4 Charcoal consumption per person

Table 13: Charcoal use per capita

Selected house hold	No. of people per house hold	Charcoal use (kg)	Use per person per day(kg)
House hold (A)	6	4kg	0.67
House hold (B)	4	2kg	0.5
House hold (C)	6	3.5kg	0.58
House hold (D)	3	2kg	0.67
House hold (E)	7	4.5kg	0.64
Total	26 Members	16kg	0.612

Source*:* Field data, 2020

The average number of people per charcoal consuming household within the study area was 5 members, who consume on average 3.2kgs of charcoal per day, with each member using 0.612 kg. Each tree on average, produces 2 ± 03 sacks of charcoal (n = 4 burning holes) whose average weight is 58±2 kg per sac.

Assuming that all households within the study area utilize charcoal as a source of fuel, then: The 83,567 households in Gombe Sub-county, with an average daily use of charcoal of 3.2kg, we will have a total consumption of (83,567*3.2) Kg of charcoal used in the whole of Gombe sub-county per day.

Converting this to number of trees consumed per day within the sub county:

= (83,567 households * 3.2 kg) = 267,414.4 Kg of charcoal consumed per day

= each tree produces 116 Kg of charcoal on average (i.e. 58 Kg * 2 sacks)

Therefore, Dividing 267,414.4 Kg by 116 Kgs gives 2,305.3 trees per day.

Converting this to annual consumption, then the number of trees comes to 841,433.24 trees/year (i.e. 2,305.3 * 365 days).

Therefore, Ggombe as a sub-county is capable of destroying 841,433 trees annually as a source of wood fuel.

4.4.5 Number of household and firewood consumption

Table 14: Firewood use per capita

Selected households	No. of people per household	Firewood use per day (kg)	Average use per person per day
House hold (F)	3	3	1
House hold (G)	5	3	0.6
House hold (H)	6	3.5	0.58
House hold (I)	5	4	0.8
House hold (J)	4	3	0.75
Average per household	**4.6**	**3.3**	**0.746**

Source: Field Data, 2020

An average household size in the study area was 5 members who consume an average of 0.75 kg of firewood per capita. An average amount of firewood used by each household was 3.3 kg of wood per day.

PLATE 1: Weighing of charcoal sacks using hang scale in one of the stacking stolls in Gombe sub-County.

Plate 1 depicts the kilogram of charcoal used by each member of the household. It was estimated that 0.64kg of charcoal was used per person while 3.2kg was used per household respectively. Also, a particular household destroyed one tree in one month (4 weeks) while a person destroyed four trees in a year.

CHAPTER FIVE

DISCUSSION OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.0 Introduction

5.1 Discussion of Findings

This section was further organized into three subsections with respect to the research objectives that guided the study.

5.1.1 Factors influencing the adoption of biogas usage by households in Gombe Sub-County, Wakiso District.

The study reveals that the high costs of wood fuel could not deter households from using this source of Energy. The poor adoption of biogas use in Gombe Subcounty, according to this research, was the insufficient supply due to lack of awareness (installation and management). The community was aware of the health and environmental advantages of using biogas, but could not generate the gas due to lack of technical know-how, and yet they had the raw materials. The study findings are in agreement with the previous authors (Bensah, and Brew-Hammond, 2011) who argued that technical problems have been associated with very large installations of biogas plants either by accident or design. This is due to the fact that at the start-up phase after the biogas plant has been installed, problems like odor nuisance, low methane productions are experienced. Under-collection of dung was associated with underfeeding of cattle and also the cattle being overworked in the fields that have led to reduction in biogas fuel production. Elsewhere, studies indicated that trained masons in biogas plant constructions were not involved because they were considered to be costly and instead cheaper labour was opted for hence to poor quality work. The study results are in agreement with the findings of FAO (2010) who argue that involving whereas in the case of slurry being considered for use as manure, it required space where to deposit it. In cases where space in available then its storage was a challenge and cost must involve.

5.1.2 Contributions of biogas usage to financial and time saving and how the two factors are important to households of Gombe Sub-County.

Compared to traditional wood fuel, biogas has positive implications on time and finance as the time for the people is saved especially the collection and cooking time. The study further establishes that the biogas system functions at reduced costs with low costs of installation that is

done once, low maintenance and operational costs compared to fuel hence the need for the maintenance of the system. The majority of respondents agreed that biogas save costs in terms of financing the installation since it is a onetime activity and there is no need for operation fares or costs and low cost of management. Even Fatona et al (2013) contend that Biogas technology is cheaper than other forms of energy such as firewood since has no complications in establishments with little investments needed. Small bio-digesters are used in homes for kitchen waste and animal manure for instance in Kampala the cheapest form of charcoal goes to 90 UG shillings, the expansion of the urban population pushes the demands for the charcoal to highest FAO (2010) argued Biogas technology hence is taken as key replacements to the energy in Uganda. Uganda national charcoal surveys 2015-2016 contend that 94% Ugandan use biomass for cooking, this provides to a translated form of estimations of 115 football fields for cooking in a day.

On the other hand, a great majority (74.3%) of the respondents agreed that biogas use saves time. This finding provided that the current biogas use saves cooking time amongst the people of Gombe Sub-county. Anushiya, 2010) contend biogas generations save women and children from the tasks of firewood collections. The result is that much time is left for other domestic chores like cooking and cleaning. The important function is cooking on stove as for the ovens and fire presenting families from the exposure and smoke in the Kitchens hence helping the prevention of deadly respiration diseases. The provided results are in agreement with those of FAO (2010) who argued that during use in cooking fuel, it provide better combustion for the less efficiency in cooking and fuels such as wood, that is compared to clean and hygiene due to bacteria and other pathogens that are destroyed through anaerobic treatments

5.1.3 How adoption of biogas usage reduces wood fuel demand and contributes to tree cover enhancement in Gombe Sub-County.

The study revealed that 2,305 are needed every day to provide charcoal for Gombe sub-county. Implying that the sub-county is capable of destroying 841,433 trees annually as a source of wood fuel. Definitely, these numbers of trees are not within the sub-county, and the lack of sustainable supply will contribute to the clearance of vegetation cover/ trees within the sub-county leading to deforestation, increase in soil erosion and land degradation that turns to affect the biodiversity.

Meanwhile, approximately 68% of Uganda's energy demand comes from biomass which is predicted to remain primary energy source in the country for next few years (Alphonse et al,2013). Like in Uganda, the scarcity of wood fuel in Gombe sub-county will exert an imbalance in demand and supply, causing a lot of pressure on forests (Mengistu et al, 2015). Moreover, unsustainable reliance on biomass fuel in Uganda has exerted a lot of pressure on forests with high negative effects on the environments. This, among, many other issues, has led to degrease in plant trees cover.

In Uganda, the current tree cover is at 6.07% (Whole Bank, 2010), and that does not provide a recommended world standard of 10% coverage.to be able to end the destruction of the forests resources, the government of Uganda must enforce the 2005 regulation on the cutting of trees in national forests and protected reserves. It is worth noting that in Uganda, biogas usage and production has proven as a key solution to the energy challenge in rural areas (MNES, 2012). It reduces forest cleaning through provision of an alternative source of energy to wood fuel encouraging, tree prevalence (Anushiya, 2010). It is therefore, imperative to state that Gombe sub-county should be encouraged to adopt biogas use in place of wood fuel. This would save more than 2,000 trees per day, and what a "think forest" the sub-county and its neighbors would be after a year!

Unfortunately, the connection between deforestation and usage of wood fuel at the world level is weak due to fuel being attained from the fallen wood and source of cut trees for construction and clearance of land. On the other hand, Fatona et al, (2013) contend that biogas technology is very important in reducing the cutting down of forest cover and scaling down usage of firewood that has caused a positive impact on the environment and public health. Furthermore, the by-products from the biogas technology such as manure have improved the quality of soils hence improved vegetation cover.

5.2 Conclusion

The study set to examine the role of biogas usage on the conservation of forests. The study set to investigate the factors influencing the adoption of biogas usage by households in Gombe Sub-County. To determine the contributions of biogas usage to financial and time saving and how the two factors are important to households of Gombe Sub-County, to determine the how adoption of biogas usage reduces wood fuel demand and contribute to tree cover enhancement in Gombe Sub-County, Wakiso District.

- The study reveals that the high costs of wood fuel could not deter households from using this source of Energy. The poor adoption of biogas use in Gombe Sub-county, according to this research, was the insufficient supply due to lack of awareness (installation and management). The community was aware of the health and environmental advantages of using biogas, but could not generate the gas due to lack of technical know-how, and yet they had the raw materials.

- The study established that biogas has, compare to traditional wood fuel, positive implications on domestic time and finance. Time is saved on the collection of wood fuel and cooking time, for it takes less time when cooking with biogas. In terms of finances, the onetime installation and local availability of raw materials reduces the operational costs making biogas use a cheap venture compared to wood fuel use.

- Biogas usage reduces wood fuel demand and it is an alternative energy source instead of charcoal and firewood. The adoption of biogas use in Gombe sub-county would save about 841,433 trees every year within and out of the sub-county.

5.3 Recommendations

Biogas use is highly appreciated within the study area, and more homesteads should be encouraged to adopt it through creation of awareness. It is therefore, imperative to argue that biogas usage is fundamental for improved environmental management.

Improved development and usage of biogas, as a time saving and financial saving entity, will improve the livelihoods of the rural community in Gombe sub-county.

Implement the regulations of wood harvesting through effective adoption of biogas use as an alternative to wood fuel.

5.4 Areas of further study

The study was set to investigate the role of biogas usage on the conservation of forests in Uganda: a case study of Gombe sub-county, Wakiso district. The study explored the importance of biogas use in forest conservation, the following area need to be addressed in any subsequent study:

- Why people continue to use charcoal and firewood even with access to biogas
- Government's role in the implementation of renewable energy resources
- Community mobilization in management of forest resources

REFERENCES

Abbasi, T., Tauseef, S. M., &Abbasi, S. A. (2012). Biogas Energy. *Biogas Energy*, 11–22. https://doi.org/10.1007/978-1-4614-1040

Abukhzam, M., and Lee, A. (2010). Workforce Attitude on Technology Adoption and Diffusion. The Built and Human Environment Review. Vol. 3: 60 -71.

Africa Biogas Partnership Programme (2013). News: ABPP hits 29,500 digesters mark! Retrieved 29

Alphonse, N., Isaac, E., and Alphonsine, M. (2013). Comparative Study on Charcoal Yield Produced by Traditional and Improved Kilns: A Case Study of Nyaruguru and Nyamagabe Districts in Southern Province of Rwanda. Energy and Environment Research, 3 (1).

Amare, Z. Y. (2015). The benefits of the use of biogas energy in rural areas in Ethiopia: A case study from the Amhara National Regional State, Fogera District, *9*(4), 332–345. https://doi.org/10.5897/AJEST2014.1838

Anushiya, S. (2010) Prospect of Biogas in terms of Socio-Economic & Environmental benefits to rural communities of Nepal. A case of Biogas Project in Gaikhur VDC of Gorkha District

Arthur, R., Baidoo, M.F., and Antwi, E. (2011). Biogas as a potential renewable energy source: A Ghanaian case study. Renewable Energy, 36:1510–6.

Bensah, E., and Brew-Hammond, A. (2011) Biogas technology dissemination in Ghana: history, current status, future prospects, and policy significance. Int. J. Energy Environ, 1(2), 277-94.

Change, C. (2011). Household Cookstoves, Environment, Health, and Climate Change: A New Look at an Old Problem, (May).

FAO. (2010) Global Forest Resources Assessment 2010 (FAO Forestry Paper 163) Rome: FAO

Fatona P., Abiodun, A., Adetayo, O., (2013). "Viewing Energy, Poverty and Sustainability in Developing Countries Through a Gender Lens". In Hasan, A., and Ibrahim, Y. New Developments in Renewable Energy.

Hamlin, A. (2012). Assessment of Social and Economic Impacts of Biogas Digesters in Rural Kenya. Independent Study Project (ISP) Collection. Paper 1247.

Kiunsi, W. B., &Mkini, R. I. (2015). Evaluating the Adoption of Biogas Technology as an Alternative Sustainable Energy for Cooking In Tanzanian Households. *Engineering Research and Reviews*, *3*(1), 34–39.

Kumar, R., & Engineering, M. (2014). Biogas production by two-stages thermophilic and mesophilic bio-digestion of kitchen waste.

Masinde, S., and Karanja, L. (2011). Climate Change, the Plunder of Kenya's Forests. Global Corruption Report 2011: pp 280-282.

Mengistu, M.G., Simane, B., Eshete, G., and Workneh, T.S. (2015). "A review on biogas technology and its contributions to sustainable rural livelihood in Ethiopia", Renewable and Sustainable Energy Reviews.

MNES (2012). Exploring institutional failures and embeddedness. Journal of International Business Studies 43, 332-341.

Mugo, F., and Gathui, G. (2010). Biomass Energy Use in Kenya. A Background Paper Prepared for the International Institute for Environment and Development (lIED) for an International ESPA Workshop on Biomass Energy. Nairobi, Kenya.

Mwirigi, J., Balana, B.B., Mugisha, J., Walekhwa, P., (2014). Socio-economic hurdles to widespread adoption of small-scale biogas digesters in Sub-Saharan Africa: a review. Biomass Bioenergy, 70:17–25.

Sassi, C. (2014). Technology Transfer and Farm-based Renewable Energy Sources: The Potential of Biogas Technology for Rural Development in Tanzania, 0–19.

Tobin, C.M. (2011). The Root of the Problem. Washington D.C.: Union of Concerned Scientists.

Vasiliki, G., Vasiliki, K., Nikolaos, B., and Georgios, A. (2012), "Economic evaluation of strategic biogas investment options- case study in the region of Larisa."

World Bank (2010). Energy intensive sectors of the Uganda economy: Path to low carbon development.

Ziemiński, K., & Frąc, M. (2012). Methane fermentation process as anaerobic digestion of biomass: Transformations, stages and microorganisms, *11*(18), 4127–4139.

APPENDICES

APPENDIX I: QUESTIONNAIRE

Dear respondent,

I am **ALI MOHAMED ABDULLE,** a student at Kampala International University, studying a Master of Science Environmental Management. This questionnaire is intended to collect information on "**The role of biogas production and use on the conservation of forests in Uganda: a case study of Gombe sub-county, Wakiso district.** The information obtained will be strictly for academic purposes and it will be treated with at most confidentiality. I kindly request you to fill this questionnaire.

Yours faithfully ……..

SECTION A: Socio Demographic Data

1. Gender
   a) Male ☐ b) Female ☐
2. Age
   a) 15-25 ☐ c) 36-45 ☐
   b) 26-35 ☐ d) Above 46 ☐
3. Marital status
   a) Single ☐ c) Divorced ☐
   b) Married ☐ d) Widowed ☐
4. Education level
   a) Primary ☐ c) Tertiary ☐
   b) Secondary ☐ d) None ☐
5. Occupation
   a) Farmer ☐ c) Formal employment ☐
   b) Business ☐ d) Other (specify) ☐

SECTION B: Factors influencing the adoption of biogas usage by households

6. What forms of energy do you use?
   a) Biogas ☐
   b) Biogas &Charcoal ☐
   c) Biogas &Firewood ☐
   d) All of them ☐
7. What are the factors influencing the adoption of biogas production and use?
   a) Low cost of biogas production
   b) High cost of other forms
   c) Biogas saves time
   d) Biogas is very safe
   e) Biogas is environmentally friendly
8. When did you start using biogas?

   ---
9. What are the limitations of biogas usage?
   a)…….
   b)…….
   c)……..
   d)…….

SECTION C: Biogas use and its implications on the finances and time saving at household level

10. Do you think biogas use is cheaper than other forms of energy such as firewood?
    a) Yes ☐ If yes why?

    ---
    b) No ☐ If no why?

---

11. Do you think that using biogas has helped you save time?
    a) Yes ☐ b) ☐
12. Does biogas use save money?
    a) Yes ☐ b) ☐
13. What are The different ways by which biogas use saves money?
    a)……..
    b)……
    c)…….....**.....**
    d)……..

SECTION D: How adoption of biogas usage reduce wood fuel demand and contribute to tree cover enhancement

14. Do you think that using biogas saves forests?
    a) Yes ☐ If yes how?

    ---

    b) No ☐ If no why?

    ---

15. Do you believe that biogas can be a sustainable alternative to wood fuel?
    a) Yes ☐
    b) No ☐
16. What are the benefits of biogas use over wood fuel?
    a)…….
    b)…….
    c)…….

17. Are aware that biogas use can reduce tree cutting?

a) Yes ☐ If yes why do you say so

b) No ☐ If no why do you say so

18. How biogas uses enhance tree cover?

a) Reduces tree cutting ☐

b) Controls bush burning ☐

c) Reduces environmental degradation ☐

Thanks for your responses

END