

**ATTITUDES INFLUENCING ADOPTION OF BIOGAS FUEL AMONG  
WORKERS AND LEARNERS IN SELECTED CHRISTIAN BASED  
TRAINING INSTITUTIONS IN NANDI COUNTY, KENYA**

**BY**

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## DECLARATION

This thesis is my original work and has not been presented for a degree in any other university or any other academic award.

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### **DEDICATION**

I dedicate this work to my husband who supported me financially, socially and spiritually and my colleagues Mr. Mayora, Mrs. Wahungu and Mr. Chemitei for their wise advice throughout this process. I also dedicate it to my prayer group members for their spiritual support.

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## TABLE OF CONTENTS

DECLARATION .....	ii
DEDICATION .....	iii
ACKNOWLEDGEMENT .....	iv
TABLE OF CONTENTS .....	v
LIST OF TABLES .....	viii
LIST OF FIGURES.....	ix
LIST OF PLATES.....	x
ABBREVIATIONS AND ACRONYMS.....	xi
ABSTRACT.....	xii
CHAPTER ONE: INTRODUCTION .....	1
1.1 Background Information.....	1
1.2 Statement of the Problem.....	5
1.3 General Objective of the Study .....	6
1.4 Specific Objectives .....	6
1.5 Research Questions.....	7
1.6 Hypotheses .....	7
1.7 Significance of the Study.....	7
1.8 Limitations of the Study.....	8
1.9 Conceptual Framework.....	8
1.10 Definition of Terms .....	9
CHAPTER TWO: LITERATURE REVIEW .....	11
2.1 Preview .....	11
2.2 Global Energy Consumption and Sources of Energy .....	11
2.3 Biogas Energy .....	13
2.4 Global Diffusion of Biogas Energy .....	15
2.4.1 Diffusion of Biogas Energy in Kenya.....	15
2.5 Biogas Energy Production Process.....	17
2.5.1 Hydrolysis .....	18
2.5.2 Acidogenesis.....	18

2.5.3 Acetogenesis .....	18
2.5.4 Methanogenesis .....	18
2.6 Attitudes and Awareness of Biogas Technology .....	20
2.7 Factors Influencing Diffusion of Biogas Technology .....	21
2.7.1 Impact of Technical Problems .....	21
2.7.2 Economical Problems .....	22
2.7.3 Benefits of Biogas Energy.....	25
2.8 Improvement of Environmental Quality .....	29
2.9 Health Benefits of Biogas Fuel .....	30
CHAPTER THREE: METHODOLOGY .....	34
3.1 Study Area.....	34
3.2 Research Design .....	37
3.4 Sampling Procedure.....	38
3.5 Data Collection Instruments.....	38
3.5.1 Documentary Records.....	39
3.6 Validation of Research Instruments .....	40
3.7 Reliability of Research Instruments .....	40
3.8 Data Collection Procedure .....	41
3.8.1 Research Instrument.....	41
3.8.2 Administration of Research Instruments.....	41
3.9 Data Analysis .....	41
CHAPTER FOUR: RESULTS AND DISCUSSION .....	43
4.0 Preview .....	43
4.1 Background Information of the Respondent .....	43
4.1.1 General Characteristics of the Population Sampled .....	43
4.1.2 Respondents' Distribution by Gender.....	43
4.1.3 Age and Level of Education for the Students.....	45
4.1.4 Institution's Main Fuel.....	48
4.2 Attitude of Adopters and Non Adopters of Biogas Fuel .....	49

4.3 Factors Influencing Adoption and Use of Biogas Fuel .....	53
4.4 Awareness and Utilities of Biogas Energy .....	60
4.5 Hypothesis Testing .....	62
CHAPTER FIVE: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS .....	64
5.1 Summary of Findings .....	64
5.2 Conclusions .....	65
5.3 Recommendation .....	67
5.5 Areas for further research .....	68
REFERENCES.....	69
APPENDICES .....	81
APPENDIX I: LETTER OF INTRODUCTION FROM UNIVERSITY .....	81
APPENDIX II: LETTER TO THE PRINCIPALS OF THE INSTITUTIONS .....	82
APPENDIX III SELF-INTRODUCTION TO RESPONDENTS.....	84
APPENDIX V: QUESTIONNAIRE FOR THE TUTORS .....	88
APPENDIX VI: QUESTIONNAIRE FOR THE STUDENTS .....	90
APPENDIX VII: QUESTIONNAIRE FOR THE NON TEACHING STAFF .....	92
APPENDIX VIII: RELIABILITY ANALYSIS .....	93

## LIST OF TABLES

Table 2. 1 General features of biogas fuel.....	13
Table 2. 2 Features of biogas energy and their expected benefits .....	14
Table 2. 3 Equivalent energy and cost for 1 m <sup>3</sup> of biogas energy.....	27
Table 4. 1 Respondent distribution by category, college and gender .....	44
Table 4. 2 Association between age and gender .....	45
Table 4. 3 Association between students' level of study and age.....	46
Table 4. 4 Association between level of study and age of respondents .....	47
Table 4. 5 Association between age (yrs) and length of stay in the institution (yrs) .	47
Table 4. 6 The institution's main type of fuels.....	48
Table 4. 7 Use of biogas fuel in training institutions .....	49
Table 4. 8 Factors for adoption of biogas fuel .....	51
Table 4. 9 Univariate Chi square Statistics on Factors.....	52
Table 4. 10 Contingency table of biogas use and attitude .....	53
Table 4. 11 Factors influencing adoption and use of biogas fuel in learning institutions.....	54
Table 4. 12 Awareness about biogas fuel .....	61
Table 4. 13 Chi-square tests of hypothesis - Effect of biogas fuel on health .....	63

**LIST OF FIGURES**

Figure 1.1 Conceptual Framework.....	8
Figure 2. 1 Fixed dome digester.....	20
Figure 4. 1 Attitude of the tutors towards biogas adoption .....	52
Figure 4. 2 Challenges faced in the uptake of biogas technology in the study area ...	55
Figure 4. 3 Availability of raw materials for production of biogas fuel .....	58
Figure 4. 4 Institutional and individual decision to adopt biogas fuel .....	58
Figure 4. 5 Challenges of Using Biogas Technology at CITC .....	59
Figure 4. 6 Utilities of biogas fuel compared to other sources of energy .....	62

## LIST OF PLATES

Plate 3. 1 Part of Biogas Plant at CITC Photo 15/01/2014 near biogas demonstration plant .....	35
Plate 3. 2 Plate 3. 2 Biogas Plant at CITC, Kapsabet: Taken Photo 15/01/2014 near biogas demonstration plant .....	35
Plate 3. 3 Map of Kapsabet Municipality .....	36
Plate 4. 1 A Photo of biogas plant at CITC taken on 1/15/2014. (Authorised by CITC Management).....	50
Plate 4. 2 A cook at CITC attempting to light biogas burner. Photo taken on 1/15/2014 at CITC. (Authorised by CITC Management) .....	50
Plate 4. 3 Part of Biogas plant at CTIC. Photo of the researcher taken on 1/15/2014 at CITC .....	50

## ABBREVIATIONS AND ACRONYMS

<b>AD</b>	Anaerobic Digestion
<b>BSP</b>	Biogas Support Programme
<b>CHP</b>	Combined Heat and Power
<b>CITC</b>	Christian Intermediate Technology Centre
<b>COPD</b>	Chronic Obstructive Pulmonary Disease
<b>ERC</b>	Energy Regulatory Commission
<b>FAO</b>	Food Agricultural Organization
<b>GOK</b>	Government of Kenya
<b>GHG</b>	Green House Gases
<b>GTZ</b>	German Agency for Technical Cooperation
<b>HHs</b>	House Holds
<b>IEA</b>	International Energy Agency
<b>IFAD</b>	International Fund for Agricultural Development
<b>IGAD</b>	Inter Governmental Authority on Development
<b>IPCC</b>	Intergovernmental Panel on Climate Change
<b>JICA</b>	Japanese International Corporation Agency
<b>KENDBIP</b>	Kenya National Domestic Biogas Programme
<b>KIPPRA</b>	Kenya Institute for Public Policy Research and Analysis.
<b>KFS</b>	Kenya Forest Service
<b>KVIC</b>	Khadi and Village Industries Commission
<b>LFG</b>	Land Fill Gas
<b>MDG</b>	Millennium Development Goals
<b>NEMA</b>	National Environment Management Authority
<b>NO<sub>x</sub></b>	Nitrogen Oxides
<b>PAH</b>	Poly-Aromatic Hydrocarbons
<b>RES</b>	Renewable Energy Source
<b>SPTC</b>	St. Paul' Theology College
<b>TSPs</b>	Total Suspended Particles
<b>UN</b>	United Nations
<b>UNDP</b>	United Nations Development Programme
<b>UNEP</b>	United Nations Environment Programme

**UNFCCC United Nations Framework Convention on Climate Change****ABSTRACT**

Over-dependence on unsustainable wood fuel and other forms of biomass energy as the primary source of fuel to meet household energy needs has contributed to environmental drawbacks. Adoption of biogas as alternative source of energy has many advantages including conserving trees, being cheap and clean. Biomass energy contributes 68% of the national energy requirements and is expected to remain the main source of energy in the foreseeable future. The main purpose of the study was to assess attitudes influencing adoption of biogas fuel among workers and learners in selected Christian based training institutions in Nandi County. The specific objectives of the study were to compare the attitude of adopters and non-adopters of biogas towards adoption and utilization of the fuel as a source of sustainable energy in the training institutions, to determine factors influencing adoption and use of biogas fuel, and to establish the level of awareness and utilities of biogas fuel in the training institutions. The population of this study was made up of twelve tertiary institutions of middle level college. The sample comprised workers and learners of the two training institutions both located at Kapsabet town. Purposive sample selection (Census sampling) and descriptive case study research design were involved where 318 respondents participated in the study. The respondents were students, non-teaching staff, tutors and head teachers of the selected Christian based training institutions. A structured questionnaire was administered to obtain data on respondents' attitudes as well as opinion on adoption and use of biogas fuel as alternative source of energy. Data were statistically analyzed using SPSS version 20 and results presented in tables, graphs and charts. This research assessed the attitude of respondents including learners, cooks, tutors and head teachers of Christian Intermediate Technology Centre and St. Paul's Theology College in Nandi County as well as factors that influences adoption of biogas fuel as alternative source of energy. Results show that a significant proportion of all respondents have not used or adopted biogas energy; tutors ( $\chi^2 = 22.091$ ,  $df=1$ ,  $n=33$ ,  $p\text{-value}=0.000$ ), non-teaching staff ( $\chi^2 = 5.261$ ,  $df=1$ ,  $n=23$ ,  $p\text{-value}=0.022$ ) and students ( $\chi^2 = 100.8$ ,  $df=1$ ,  $n=260$ ,  $p\text{-value}=0.000$ ). Results also show that a significant proportion of the respondents (96.0%) had a negative attitude towards use of biogas fuel. In addition, there was significant difference in respondents' attitude towards biogas fuel adoption ( $\chi^2 = 10.667$ ,  $df = 1$ ,  $p = 0.001$ ). Further, the study results revealed that several factors including conservation of environment, being a clean energy and need for small space for installation influenced adoption of biogas fuel. In addition, there is availability of the common raw materials including animal, agricultural, human and kitchen waste. The findings of the study will be important to policy makers to turn around attitude towards biogas fuel use as alternative source of energy and save the environment.

## **CHAPTER ONE: INTRODUCTION**

### **1.1 Background Information**

In our daily activities, energy is very important in providing crucial services. Some of these services especially domestic are considered to be basic for instance energy for cooking, heating and lighting. Also energy is essential to run industrial processes such as food production and also in transport sector. However, energy production and supply varies from one region to the other. In urban areas it is not difficult to access energy whereas in rural areas, communities find challenges in accessing energy (FAO, 2006). Following the above mentioned gap in energy between rural and urban areas, approximately 2.5 billion people in developing countries mainly depends on biomass for basic energy. Such biomass includes coal and animal dung cakes since they are readily available.

In Sub-Saharan Africa and some parts of Asia, a large percentage of local communities mainly rely on biomass as a source of primary energy (IGAD, 2007). The latest report on energy globally by International Energy Agency showed that the present world trends in energy supply and demand are very high compared to its supply (IEA, 2008). In relation to the above report, two major global energy challenges have been identified. These challenges include securing supply of sustainable and cost friendly energy and to implement a fast transformation of clean energy. To meet the above challenges, discouraging use of oil and biomass have been focused on by most countries in the world. Presently, clean and friendly energy such as biogas are the commonly and widely used among households although the percentage globally is small (IEA, 2008).

In Sub-Saharan Africa, many households still depends on biomass energy in its raw form as basic and economic energy in order to meet primary energy needs. Most of the energy used in Sub-Saharan Africa according to the United States Department of Energy is obtained from wood and is mainly for cooking. This challenge is expected even to rise by 2030 and as a result poses a high risk for human and climate security. This prevents mitigation of poverty and economic growth in the region (KIPPRA, 2010). In Kenya, consumption of energy from biomass is very high among rural communities and also among town dwellers (GOK, 2012a; 2012b).

The gazette Kenya forest covers an area of 3.456 million hectares (5.9% of the total land). This cover is considered to be far much below the minimum recommended coverage of 10% (GOK, 2011). Heavy use of biomass has led to loss of vegetation cover hence serious threats to the sustainability of environment and also compromise efforts towards mitigation of poverty and hunger (UNDP, 2013). From the total area, the percentage of indigenous vegetation has drastically gone down both in community and private lands (KFS, 2009).

In Kenya, vegetation cover plays a big significance economically, environmentally, socially and culturally and contributes about 1% in the monetary terms to GDP (Winston, 2011) and contributes to a large percentage of local energy requirements and will remain a major source of fuel even in the future (Mugo and Gatheha, 2010). Mugo and Gatheha further indicated that in the year 2000, a big volume of biomass was consumed for energy and was mainly in the form of firewood. Studies according to Masinde and Karanja (2011) indicated that too much dependency on biomass energy has caused exploitation of forest covers leading to negative environmental impacts.

This menace has caused the country's vegetation cover to reduce to 1.7 percent which is far much below the minimum ten percent recommended globally. Due to the mentioned challenge, there has been a decrease in the levels of water in water bodies resulting to unreliable power supply. However, even with the use of energy generated from petroleum in order to reduce the use of biomass, there has been no lasting solution due to challenges including fluctuations in global market prices of crude oil, and the climate impacts of increased GHG emissions. Further, it has been indicated that transportation of petroleum over long distances is dangerous and also its leaks contributes to rise in green house gas emissions (IEA, 2008).

Studies according to IGAD (2007) further indicate that heavy use of biomass for energy has greatly contributed to loss of vegetation cover (UNEP, 2012). As a result of the heavy use of biomass by local communities, Kenya lost about 12,000 hectares of the forest cover per year (FAO, 2010). Across Kenya, negative impacts of climate change are clearly noted in supply of energy where demand is very high whereas

supply is very low (UNDP, 2009). Continued dependence by rural communities on biomass energy being used as major source of energy for domestic and other important uses has caused serious negative effects on natural forest cover resulting to loss of forest cover, erosion of the soils, pollution of the atmosphere and global warming (IGAD, 2007). Further studies showed that there is increase in the use of firewood and is likely to rise by the year 2030 to over 137% while that of charcoal will go up by over 5 times the 1970 base rate. This portrays a serious condition since production of charcoal requires more wood compared with that of producing firewood so as to generate energy (IGAD, 2007).

Furthermore, livelihoods' opportunities have been disadvantaged as a result of extensive loss of vegetation cover. This loss has occurred due to consumption of forest cover for firewood, obtaining fodder for animals, extracting timber for construction of shelter and burning trees for charcoal. The loss of vegetation cover has accelerated loss of top soils, contamination of surface water and destruction of natural habitats. It is therefore foreseen that there will be many people in African continent who will be depending on wood fuel as primary source of energy to meet their daily basic needs (IEA, 2008).

In Kenya, a case study of the Moiben River system of Cherengani forest by Cheboiwo, showed that there is excessive clearing of vegetation cover mainly for use as wood fuel and erecting of houses (Cheboiwo *et al.*, 2010). Due to the negative challenges encountered, biogas energy which is a clean and sustainable energy was identified. This energy can be produced and utilized hence reducing the negative challenges such as climate change and air pollution. The use of sustainable energy can lead to an improvement in the health and living standards of the people using biomass energy as the primary source of energy (Azhar and Baig, 2012).

However, like in many developing countries, there has been continuous increase need for energy which is not proportionate to its supply (Cheng *et al.*, 2009). Attempts to increase energy supply in a bid to match the increasing energy demand are needed and therefore biogas energy technology is such one option. Introduction of biogas energy in Kenya was done in the mid twentieth century by farmers who

were from Europe and soon after that a number of biogas plants were constructed. However, most of these plants were not effectively following challenges such as plant designs that were not effective, lack of attention towards the biogas digesters, failure by sponsors to oversee the running of the technology and government not participating by incorporating energy policy (Abeeku and Edem, 2008). Access to clean and safe energy has been considered to be the base for all the Millennium Development Goals by the United Nations and by addressing energy, it is a way of managing hunger, improving access to clean water for drinking hence mitigating the burden of illnesses including death of children and mothers.(UN, 2010).

In Kenya, sustainable energy is also an emerging issue which has drawn a lot of attention with the intention to address climatic challenges that hinder production of green energy (Okello *et al.*, 2013). To address the above issue of green energy, it was noted that solid garbage in big towns can be utilized to produce clean and safe energy. Studies according to Rotich *et al.* (2007) showed that the cumulative solid matter of Nairobi City council is approximately more than half percent of the daily solid waste deposited in the dump sites. The case of Nairobi is more less the same as other large cities and towns in East Africa.

Considering the large volumes of garbage deposited, the solid waste can be separated into organic and inorganic matter. The organic residue can be recycled in order to obtain energy for domestic consumption, fodder for animal feed and organic manure which is rich in nutrients. Following this, a pilot project was initiated in Nairobi in the early 2010 with the objective of harnessing energy for local consumption, obtaining fodder for animals and manure. The project was supported by Nairobi City Council, United Nations Environmental Programme and Japanese International Corporation Agency (Rotich *et al.*, 2007).

At present, the number of firms and organizations that support biogas plants already put in place are not many. Considering the existing plants, it is only a few that are running successfully and are mainly not affordable to the local community because of private ownership. However, donors have put much effort to ensure technical and monetary support yet still there have been challenges which have hindered the

growth of biogas technology in Kenya (Azhar and Baig, 2012). The part of the technical support incorporated included provision of fixed dome, floating drum and plastic tubes used as digesters. This technology was mainly designed to support local community mainly in the rural areas. This is because in the rural areas raw materials for production of biogas energy are readily available. These raw materials include animal and human manure remains from agricultural products (Von *et al.*, 2010).

## **1.2 Statement of the Problem**

In Kenya, continuous over reliance on biomass as main primary source of energy in order to meet basic energy needs among communities (Masinde and Karanja, 2011) has led to clearance of vegetation cover hence causing environmental challenges ; (Okello *et al.*, 2013; Abbasi, 2012). This loss of vegetation cover has contributed towards change in climate and unreliable rainfall patterns (UNDP, 2009). Further, extensive use of biomass fuels among communities as basic source of energy has also led to poor health due to partial burning of biomass in houses in rural areas that have not been well ventilated (Drabez *et al.*, 2009) and negative environmental impacts such as soil erosion (Mugo and Gathea, 2010).

Due to the above problems, there is need to have alternative source of energy that would be economically efficient, socially equitable (NEMA, 2009) and is environmentally sound (Drabez *et al.*, 2009). Biogas fuel compared to traditional biomass energy is a clean form of energy that has the potential to counteract many adverse health and environmental impacts connected with the use of wood fuel in Kenya. It will help in reducing environmental energy poverty which poses as one of the greatest challenges in global scale, especially for developing countries (Susanne, 2011) and overcoming the problem is directly linked with achieving the Millennium Development Goals.

Studies according to ERC (2010) noted that energy poverty is directly related with gender issues for instance in rural areas, women and young girls are typically responsible for providing the household with biomass energy. They have to walk long distances and for several hours a day to collect heavy wood fuel loads. This

cause health problems and stress to them keeping them away from other important productive, social and educational activities (Mwakaje, 2008). Additionally, the indoor burning of traditional biomass fuels, such as firewood, coal and cow dung, causes emission of harmful fumes (ERC, 2010) that are implicated with health issues that range from mild respiratory illnesses to lung cancer, with infants, children and pregnant women being the most affected (Katuwal and Bohara, 2009). Therefore, this study sought to address attitudes influencing adoption and use of biogas fuel as an alternative sustainable energy in training institutions in Nandi County (IGAD, 2007) view that at present, many homes and institutions have not adopted biogas technology due to many factors that hinder it and therefore this study explored on factors that influence adoption and use of biogas fuel in the training institutions.

### **1.3 General Objective of the Study**

Due to excessive cutting of trees to obtain biomass for fuel by local communities, there has been loss of vegetation cover at an alarming rate which has subjected the environment to long term damage (IGAD, 2007). As a result of this menace, basic needs such as provision of food, health services and access to clean and safe drinking water are placed at risk. This study sought to assess attitudes influencing adoption of biogas fuel among workers and learners in selected Christian based training institutions in Nandi County so as to cut down the cost of wood fuel and also to enhance environmental quality and health.

### **1.4 Specific Objectives**

The specific objectives of the study were:

1. To compare the attitude of adopters and non-adopters of biogas fuel towards adoption and utilization of the fuel as a source of sustainable energy in the training institutions.
2. To determine factors influencing adoption and use of biogas fuel in the training institutions.
3. To establish the level of awareness and utilities of biogas fuel in the training institutions.

### **1.5 Research Questions**

1. What is the attitude of adopters and non-adopters towards adoption and utilization of biogas fuel as a source of energy in training institutions?
2. Which factors influence adoption and use of biogas fuel in training institutions?
3. What is the level of awareness and utilities of biogas fuel in training institutions?

### **1.6 Hypotheses**

**H<sub>1</sub>:** Adoption and utilization of biogas fuel has adverse effects on environment

**H<sub>2</sub>:** Adoption and utilization of biogas fuel has adverse effects on human health

### **1.7 Significance of the Study**

The findings of this study will be of great importance to training institutions in Nandi County as it will impact on the choice of biogas fuel as an alternative source of energy. This is because the fuel is considered to be clean and the raw materials for production are readily available within the locality.

The results of the study will be useful to promoters and other stakeholders of biogas fuel in the energy sector enhancing understanding of the attitudes influencing adoption and use of biogas fuel as well as making decision and strategic actions of individuals and training institutions in Nandi County. The outcomes of the study were to be used to recommend the use of biogas fuel in training institutions in Nandi County because the researcher believes that adoption of biogas fuel will help mitigate environmental challenges, cut down cost of cooking fuel and also provide an alternative clean source of energy that is sustainable.

The results of the study will be important to promoters and other stakeholders in the energy sector since an understanding of the attitudes influencing the adoption of biogas fuel is very important in the decision making and strategic actions of individuals and training institutions.

### 1.8 Limitations of the Study

This section indicates challenges anticipated by the researcher that influenced the scope of the study:

- (i) The results from analysis were limited to the two institutions and therefore may not be generalized to all training institutions in Nandi County.
- (ii) The respondents selected generated information only related to their respective training institutions and not any other in Nandi County.
- (iii) Since the selected training institutions were located in the urban area, its findings may not be generalized to all other training institutions in Nandi County.
- (iv) The researcher assumed that there was very little on adoption of biogas technology and therefore the findings of the study will enhance awareness of the technology among training institutions in Nandi County.

### 1.9 Conceptual Framework

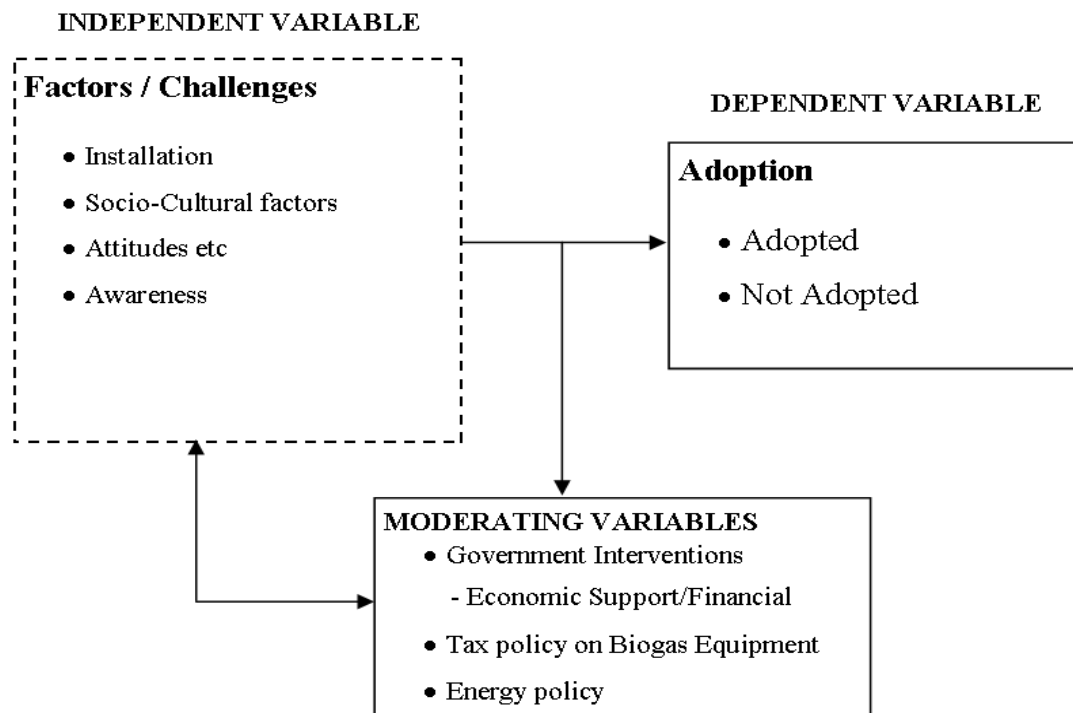


Figure 1. 1 Conceptual Framework

The conceptual framework in figure 1.1 was been generated and used by the researcher to relate biogas fuel and factors that influences its adoption as an alternative source of fuel. This research pursued three objectives: to compare

attitude of adopters and non-adopters of biogas energy as a source of energy, to determine factors influencing adoption and use of biogas fuel and to establish the level of awareness and utilities of biogas fuel as an alternative source of energy that could lead to the improvement of environmental quality in training institutions in Nandi County.

As demonstrated in figure 1.1, adoption and use of biogas fuel is directly influenced by technical, economic and social related factors. Technical factors such as installation cost of biogas plants, cost of hiring trained masons in biogas plant constructions, maintenances of the plant and storage of the biogas energy directly influenced adoption and use of biogas technology. Furthermore, emissions of greenhouse gases, storage of biogas fuel, significant water requirements and availability of raw materials are some of the social and economic factors influencing adoption of biogas fuel.

Attitude and awareness towards adoption and use of biogas fuel also influence adoption and utilization of biogas technology because it is perceived that biogas fuel is clean, friendly and less costly. It was further perceived that due to the above characteristics of biogas energy, embracing of the technology would enhance; improved health, improved rainfall pattern, improved food security, improved forest cover, provision of fodder for animals and manure from bioslurry. When people are aware and informed of the benefits of biogas technology, they may be compelled to opt for it as an alternative source of energy. As this factors play out in determining whether adoption will be there or not, there exist moderating variables such as government interventions - economic support and tax policy and energy policy.

### **1.10 Definition of Terms**

**Attitudes:** The opinion about biogas fuel

**Awareness:** The understanding of biogas fuel

**Biomass energy:** Natural organic fuels such as wood, charcoal, agricultural residues and animal waste

**Biodigester effluent:** The liquid by-product from an anaerobic digester.

**Biodigester:** Is a sealed container that facilitates anaerobic Digestion

**Biogas fuel:** A bio-fuel derived from organic matter containing methane and carbon dioxide.

**Biogas fuel adoption:** Use of biogas fuel

**Dependent Variables:** Are variables that will be measured and will be affected during the experiment

**Diffusion of Biogas fuel:** The spread of biogas fuel among its users

**Digestate:** Ordinary animal waste

**Independent variables:** Are variables that will affect the dependent variable

**Methane:** Primary constituent of fossil-fuel natural gas

**Moderating variables:** Modifies the relationship between the independent and the dependent variables

**Utilization of biogas fuel:** Use of biogas fuel

**Wood fuel:** The wood removed for energy production purposes, regardless whether for industrial, commercial or domestic use (FAO, 2010).

## **CHAPTER TWO: LITERATURE REVIEW**

### **2.1 Preview**

The chapter reviews various studies conducted in the area of biogas technology from global to local scenario. This literature will provide an overview of how biogas energy is used around the world, the various sources of biogas energy, and its history and extend it has spread in Kenya. The last section is on the biogas production process, attitudes and awareness of biogas technology, technical, social and economic factors influencing diffusion of biogas technology, benefits of biogas energy in relation to health and environment.

### **2.2 Global Energy Consumption and Sources of Energy**

A major challenge in this century will be that of implementing sustainable development and meeting the primary requirements of the continuously rising world's population. According to the International Energy Agency (2008), about 2.4 billion people of the total world's population heavily depend on biomass to meet their energy needs. Moreover, predictions over consumption of biomass to meet energy needs will be very high in 2030. This is according to the present trends in energy (IGAD, 2007).

The African continent has already encountered an energy challenges both traditional and commercial sources. The traditional sources include mainly biomass while commercial sources include natural gas, electricity and petroleum products (Parawira, 2009). Parawira further continued to note that, the energy consumption and demand of the African continent is estimated to grow continuously, at rates even faster than developed countries. The factors that contribute to this increase include growth in population, energy demands from various domestic sectors and the demand for improving quality of life. In order to meet the United Nations Millennium Development Goals on reduction of extreme poverty and hunger, quality and magnitude of energy services in the developing world must be addressed (Parawira, 2009).

Biomass energy, being considered a wide range of natural organic fuels like wood, charcoal, agricultural residues and animal waste, is mainly consumed without being processed to a better form of sustainable energy. There have been negative effects related to energy production, distribution and consumption which affects environment through air pollution locally, regionally and globally (UN, 2005). Global consequences of unsustainable use of biomass energy by local communities for fuel are responsible for partial clearance of world's vegetation cover (UNFCCC, 2010).

In addition, the World Health Organization (2009) highlight that, two million deaths annually are associated with the indoor burning of solid fuels in unventilated kitchens in which some 44 % of these deaths are in children and among adults. Moreover, burning of biomass energy releases unfriendly gases such as carbon dioxide, methane and other greenhouse gases resulting to global warming (WHO, 2009). As a result, the energy sector plays an important role in mitigating damages caused to environment through introduction of sustainable, clean and safe energy.

The World Bank has observed that most energy policies in developing countries have traditionally focused on large capital investments in the generation and transmission of electricity, gas and petroleum products, so enabling the commercial development of energy supply industries (World Bank, 2007). These policies are designed mainly for the needs of industry, transport and urban infrastructure, and thereby focus most attention on urban populations, whilst rural populations and their energy requirements are frequently overlooked. However, many rural areas do have local access to other sources of energy, such as solar energy and biogas technology. There are opportunities for these resources to be tapped using existing technologies and thereby release a range of useful services and meet the energy needs of the rural communities. Climate change, together with an increasing demand for energy, volatile oil prices, and energy poverty have led to a search for alternative sources of energy that would be economically efficient, socially equitable, and environmentally sound. Cleaner energy systems are needed to address all of these negative effects and to contribute to environmental sustainability (NEMA, 2009).

Kenya is currently in an energy deficit position both for commercial and non-commercial energy source. The majority of Kenyans live in rural areas where traditional biomass; mainly wood fuel, has remained the leading source of energy both for cooking, and at times for lighting (UNDP, 2009). According to Renwick *et al.*, (2007), high incidence of poverty is a major constraint to shifting from traditional to modern renewable energy utilization. The main challenge is how to mitigate overdependence on use of biomass energy among the local communities who cannot access alternative sustainable sources of energy. Biogas is an energy technology that has the potential to counteract many adverse health and environmental impacts connected with traditional biomass energy in the country.

### 2.3 Biogas Energy

Biogas fuel in this thesis is a type of bio-fuel, which primarily consists of methane and carbon dioxide. It originates from bacteria in the process of bio-degradation of organic material under anaerobic (without oxygen) conditions. Biogas energy is generated from biogenic material (Muhammad, 2009; Farooq *et al.*, 2012) and is a mixture of gases that is composed chiefly of methane (CH<sub>4</sub>): 55-70 vol. %, carbon dioxide (CO<sub>2</sub>): 30-45 vol. % (Deublein, 2008), other gases that are contained in biogas in minor concentrations are hydrogen (H<sub>2</sub>), hydrogen sulphide (H<sub>2</sub>S), nitrogen (N<sub>2</sub>), ammonia (NH<sub>3</sub>) and water in gas phase (H<sub>2</sub>O): 1-5 vol. % (Seadi *et al.*, 2008).

Table 2. 1 General features of biogas fuel

<b>Composition</b>	<b>55 - 70% Methane (CH<sub>4</sub>) 30 - 45% Carbon Dioxide (CO<sub>2</sub>) Traces of Other Gases</b>
Energy content	6.0 – 6.5 kWh/m <sup>3</sup>
Fuel equivalent	0.60 – 0.65 L oil/m <sup>3</sup> biogas
Critical pressure	75 – 89 bar
Critical temperature	– 82.5° C
Normal density	1.2 kg/m <sup>3</sup>
Smell	Oduorless
Molar Mass	16.043 kg/kmol

**Source:** (Deublein, 2008)

Biogas fuel is colourless, odourless and flammable gas due to presence of methane and hydrogen (Jørgensen, 2009) which has an energy content of 37.3 MJ/m<sup>3</sup>. The biogas does not produce smoke, it is clean and easy to use compared with other solid fuels. During its production of biogas fuel, the process includes three stage biochemical processes that is hydrolysis, acetogenesis and methanogenesis. (Ofoefule *et al.*, 2010). It can be distributed as in a gaseous form or in a liquefied form through pipelines, either separate or existing grid for natural gas, if it is upgraded (Lantz *et al.*, 2007).

Table 2. 2 Features of biogas energy and their expected benefits

- It is a locally produced fuel.	- It contributes to securing energy supply of the country and promotes local development.
- It is a renewable fuel.	- There is no risk of future depletion.
- The carbon content in biogas comes	- It does not add net GHGs to the atmosphere.
- From nature's own photosynthesis.	
- Liquid digestate is produced as a by-product.	- It can be utilized as fertilizer.
- The emissions of NOx, hydrocarbons and particles are much less than conventional fuels.	- Less air pollution is generated.
- It can be produced from various substrates.(sewage sludge, different organic wastes, energy crops, forest and agriculture residue, etc)	- It reduces a country's dependency on imported energy. It contributes to more sustainable waste management and provides a chance to agriculture industry.
- Biogas is released into the atmosphere in case of leakage because it is lighter than air.	- It does not pollute land and groundwater.

**Source:** Eriksson and Olsson (2007); Lantz *et al.*, (2007); Mårtensson (2007); Swedish Biogas Association (2008)

## **2.4 Global Diffusion of Biogas Energy**

Biogas energy was used long time ago in Assyria around the tenth century and was mainly used for heating water bath. It was obtained from decaying organic matter. At around late nineteenth century, biogas technology had spread and its dispersion was more in urban compared to rural areas. Studies according to Ni and Nyns (1996) noted that elsewhere in China, a good number of households had already constructed biogas digesters that were operational. The rapid spread of biogas technology in Asia, Latin America and Africa took place in late nineteenth century (He, 2010).

In Pakistan, the first ever documented biogas plant running with farmyard manure was built in 1959 in Sindh (Panhwar and Muhammad, 1959). In India, the early plants developed were not affordable to the local communities and also were not reliable and as a result of that biogas technology was not suitable for implementation (KVIC, 1993). In 2002 in India, there were small scale biogas plants which were then engaged and were useful to the local communities (Khapre, 1989). Studies according to Bond and Templeton (2011) showed that fast spread of biogas technology took part around late nineteenth century in India and China respectively.

Elsewhere in Europe the development of renewable energies on anaerobic digestion was as a result of first oil crisis in 1973 (Willinger *et al.*, 1988). During the recent years, increasing environmental problems and air pollution catastrophes has led to increased diseases of the respiratory organs, and to dying forests. This has led to studies on alternative energy application. One of these alternative energies is biogas fuel (Willinger *et al.*, 1984).

### ***2.4.1 Diffusion of Biogas Energy in Kenya***

The history of biogas fuel production and utilization in Kenya began in 1954 (O'Keefe *et al.*, 1984).

Biogas production in Kenya has been problematic for many years because of various reasons, including inappropriate design, construction and maintenance, water unavailability, substrate produced far away from the plant and needed to be transported, labor-intensive operation and poor social acceptability. In 1983 the

Kenyan Ministry of Energy launched a campaign for the promotion of biogas production and utilization under the Kenyan Special Energy Program (SEP) and with the assistance of the German Gesellschaft für Internationale Zusammenarbeit (GIZ) the ministry offered training programs for biogas plant builders. Consequently there was a raise in the numbers of installed biogas plants and by 1997 the number exceeded 500 all over the country (Laichena and Wafula, 1997).

In more recent years, the Kenyan government has actively put biogas in the national energy agenda. Their intentions are to a) raise awareness regarding the benefits and potential of biogas technology, b) promote research, development and demonstration of the appropriate technologies, c) facilitate local construction of biogas reactors and equipment by introducing rebates and waivers, d) introduce empowerment programmes that provide skills through polytechnics and technical institutions on how biogas plants are installed, managed and maintained, and e) develop guidelines for registration and regulation of biogas contractors/technicians (KENDBIP, 2011). Further, the government is in the forefront in implementing programmes that offers opportunities in investment and commercial. This was to help design efficient and effective biogas plants among households (Pandey *et al.*, 2007). This technology was considered as a tool to improve livelihoods, gender and also sanitation. The main aim of the government in supporting this technology was to construct many digesters by 2030 (KENDBIP, 2011).

The Kenyan Ministry of Energy has also issued a feed in tariff instrument for the promotion of the generation of electricity from renewable energy sources including electricity generated from biogas. For biogas projects with capacity from 0.2 up to 10 MW the standard fit in tariff is 0.1 US\$ / kWh and it applies for 20 years from the date of the first commissioning of the biogas plant (KENDBIP, 2011). In 2009, a study from the GIZ mapped and identified the theoretical biogas energy of agro industrial wastes for commercial scale biogas generation as well as biogas potentials from wastewaters in Kenya, which were published in a report (Fischer and Pigneur, 2010). Some of the national organizations that take action in the field of biogas promotion are the Kenya National Federation of Agricultural Producers (KENFAP), the Kenya National Domestic Biogas Program (KENDBIP), Africa Biogas

Partnership Program (ABPP) and National Environment Management Authority – Kenya (NEMA).

In relation to biogas production, some of the bodies responsible for the promotion and distribution of the technology are Kenyan governmental agencies such as Special Energy Programme (SEP) - Kenya and collaborating partners, Ministry of Energy and Regional Development (MOERD), Ministry of Livestock Development (MOLD), Kenya Industrial Estates (KIE) and private sector organizations such as Tunnel Technology Limited (TTL), Biogas Africa, Kentainers Limited, SEP trainees and individual entrepreneurs, the Christian Intermediate Technology Centre (CITC) and Kenya Wood fuel and Agroforestry Programme (KWAP) (Gitonga ,1997).

A study report of Kenya Institute of Public Policy Research and Analysis (KIPPRA, 2010) noted that there are so many households that depend on biomass and paraffin for cooking and lighting and this was varied from one place to the other (ERC, 2010) . Due to the above challenges, a sustainable and reliable source of energy can be harnessed through digesting solid waste mainly accumulated in urban areas (Kenya National Energy Policy, 2012).

In Kenya, the Africa Biogas Partnership Programme is currently being implemented by the Kenya National Domestic Biogas Programme (KENDBIP) between the periods of 2009 to 2013 (KENDBIP, 2009).The overall goal of the Programme is to improve livelihoods of rural farmers through benefits of domestic biogas and development of a commercially viable, market oriented biogas sector. According to KENDBIP (2011) report, the programme has built over a total of 2399 biogas plants in the country against a target of 2200 plants. Central and Rift valley regions; leading in installation of plants with 43% and 38% of the plants respectively (KENDBIP, 2012).

## **2.5 Biogas Energy Production Process**

Biogas energy is a product of decomposition organic material bacteria. This process takes place in an anaerobic environment which is conducive for production of biogas. The metabolic processes take place in four stages namely: hydrolysis,

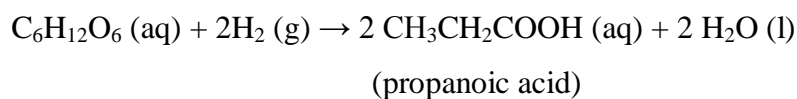
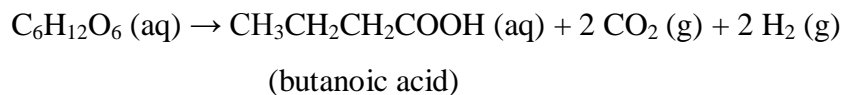
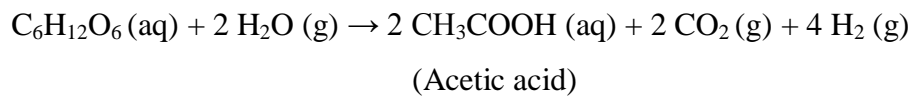
acidogenesis and acetogenesis (Gautam and Ghimire, 2009). The experiments on anaerobic decomposition of organic matter was conducted by Erlend Lausund in the the Gortner laboratory at the St. Paul campus, University of Minnesota (UMN) in the year 2011.

### **2.5.1 Hydrolysis**

This is a process where the anaerobic bacteria breaks large molecules of proteins, carbohydrates, fats and cellulose into small molecular substances such as amino acids, fatty acids and (Grady *et al.*, 2011).

### **2.5.2 Acidogenesis**

This is a process where decomposition of organic materials is accelerated by bacteria. Here the bacteria cause molecules to penetrate into bacteria cells for more transformation to occur. The organic material undergoes decomposition in absence of oxygen hence production of methane. The following are chemical reactions involved (Grady *et al.*, 2011).



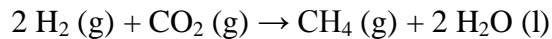
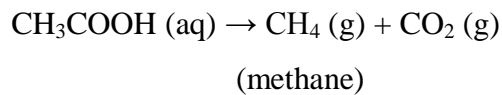
### **2.5.3 Acetogenesis**

Afterwards acid-forming bacteria act on organic acids which forms initial products for methane formation: acetic acid, carbon dioxide and hydrogen. For vital functions of these bacteria that consume hydrogen, stable temperature mode is very important. The chemical processes that take place include conversion of acetic acid to ethanoic acid, carbon dioxide and hydrogen gas and also butanoic acid to ethanoic acid and hydrogen.

### **2.5.4 Methanogenesis**

This last step involves production of methane, carbon dioxide and water from methanoic acid as shown in the chemical reactions below. Methane producing

microorganisms occurs to the extent that anaerobic conditions are provided. At this stage, 90% of methane yield from acetic acid takes place. Thus acetic acid formation (3rd step) is the factor that defines the speed of methane formation as cited by Ivet (2008) and illustrated by chemical reactions shown below.



The reactions above explain how methane gas is produced from ethanoic acid in an anaerobic condition. Other studies including Santosh *et al.*, (2004) and Xinshan *et al.*, (2005) consider biogas fuel as a product of breaking organic material in absence of oxygen. Biogas fuel can be obtained by subjecting organic materials such as animal waste, agricultural residues to aerobic or anaerobic processes.

Biogas fuel produced is a mixture of methane and carbon dioxide (Woodard, 2006). This type of fuel can be used directly to produce energy for domestic use (Gassanova *et al.*, 2006). Also biogas energy can be converted into other useful forms of energy (Jenssen *et al.*, 2009.) This is because the energy is considered by many experts to be an excellent tool for improving life, livelihoods and health in the developing world (Rieck and Onyango, 2010).

According to Wrapai (2009), biogas fuel can be harnessed from sewage works and used to produce energy that can be used in cooking and heating sewage works, cooking, and water heating. This fuel is sustainable and the raw materials for its production are readily available.

Other by products of biogas systems include slurry which contain rich nutrients that perform better compared with artificial fertilizers. The residue which is obtained as a by- product in the digester can also be used as fodder for animals and poultry due to the nutrients present. The handling of the slurry does not require skilled labour (Mwakaje, 2008).

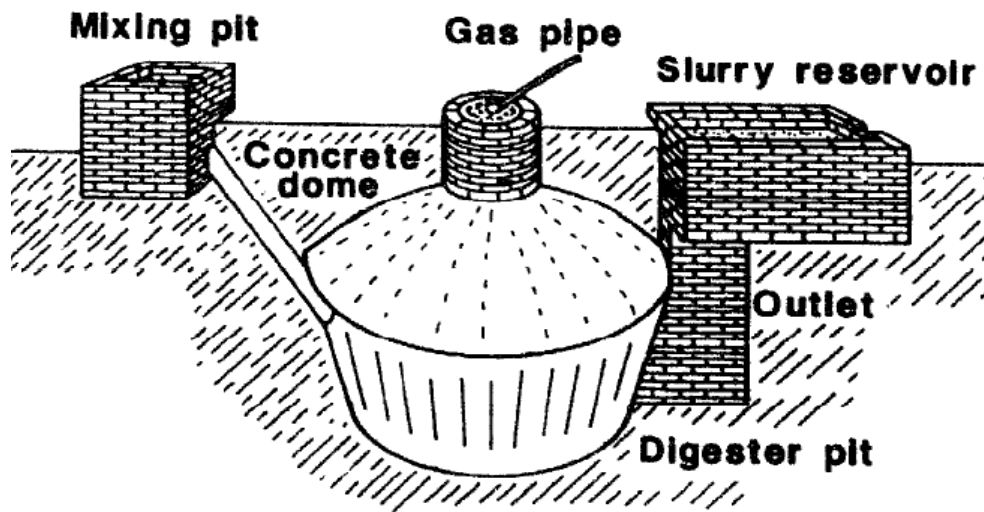


Figure 2. 1 Fixed dome digester (Fulford, 1988, May 13)

The fixed dome digester (figure 2.1), commonly known as the “Chinese model”. The digester is closed and has a dome shape. It is also connected to a mixing pit and a slurry reservoir. It is usually constructed underground in order to be protected and for space saving reasons. There are no movable parts or parts that can be subjected to erosion, so the construction costs are low and the lifetime of the digester is quite extended (Kossmann and Uta, 2008).

## 2.6 Attitudes and Awareness of Biogas Technology

Biogas fuel is described as an excellent tool for improving life among local communities (Raskovic *et al.*, 2009) and is investment, advanced one of many biomass energy sources which require more technology and resources than basic bio-digesters provide (Jury *et al.*, 2010). This technology is a very good solution to local energy needs and provides significant benefits to human and ecosystem’s health. The technology is also considered as a means leading to rural development (Raskovic *et al.*, 2009).

Biogas plants do not require big capital to set up and offer solutions to existing environmental problems and many unexpected benefits besides (Drabez *et al.*, 2009). In other studies, a critical factor for rural communities in order to adapt to

climate change effects is to develop human and financial capacity through the delivery of energy that is both affordable and reliable (Casillas and Kammen, 2010).

The potential environmental and economic benefits of bioenergy, in the form of biomass, biodiesel, bioethanol and biogas, have been gaining worldwide popularity and it has been suggested that if developing economies actively invest in the spreading of this kind of renewable energy technologies the benefits will include sustainable energy production, food security and improved livelihoods (Msangi, *et al.*, 2007). Namely biogas technology has the potential to improve sanitation, reduce greenhouse gas emissions, provide nutrient rich organic fertilizer and replace traditional fuels in cooking, thus improving indoor living conditions and reducing deforestation, while being financially attractive, in the sense that the investment costs can be paid back in a short term, when good design and operation and maintenance conditions are applied (Brown, 2006).

## **2.7 Factors Influencing Diffusion of Biogas Technology**

### ***2.7.1 Impact of Technical Problems***

Technical problems have been associated with very large installations of biogas plants either by accident or design (Magid *et al.*, 2006; Quadir *et al.*, 2010). 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 (Van Der Werf, 2010).

Studies according to UNDP (2009) showed that under-collection of dung was associated with underfeeding of cattle and also the cattle being overworked in the fields 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 (Yadvila *et al.*, 2008). Further, it was also noted that production of biogas fuel was affected by change in temperature especially during the cold seasons. This contributed towards challenges such as gas leakage, blockage and short of maintenance. The major reason for failure is considered to be poor

observation to biogas plant maintenance and insufficient technical support (Bond and Templeton, 2011).

Other challenge includes the accumulated slurry at the bottom of the bottom of the digester which required regular removal. This made the work so involving (Heeb, 2009) 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 (Hoop *et al.*, 2011). Furthermore, frequent monitoring was necessary due to formation of scum and rusting of drum- reactors (Mang and Jurga, 2005).

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 (Chen *et al.*, 2008).

### ***2.7.2 Economical Problems***

Food and Agricultural Organization, embrace efforts to curb food insecurity, energy poverty and clearing of vegetation cover hence promoting sustainable livelihoods (FAO, 2009). Energy is an important ingredient for the development process of any country (Okello *et al.*, 2013) and the magnitude of its demand is a crucial indicator of the socio-economic development of a country. The energy sector has a very strong impact on mitigation of poverty through income, health, education and gender (Sayigh *et al.*, 2005).

At present any country that embrace use of green energy, has fewer challenges in reducing poverty (Rao *et al.*, 2009), since clean and safe energy have a great impact on a country's economy (Amigun *et al.*, 2008). 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 (Chen *et al.*, 2009).

In other studies (Mugo and Gathea, 2010), 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 (Mwakaje, 2008). Mwakaje further indicates that wood fuel collection has become a very time and energy consuming as distances become longer due to deforestation and woodland degradation of community biomass ecosystems so to satisfy their cooking requirements.

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 (Denton, 2005). 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 (Muchiri, 2008).

Biogas fuel is a sustainable source of energy that is able to meet household energy needs effectively. Poor communities may improve their livelihoods with the consumption of biogas energy obtained from animal manure which is readily available and less costly. Use of this safe and clean energy in their homes help them utilize the time and energy in other useful activities that will make them get money and also help in mitigating release of harmful gases to the atmosphere hence preventing global warming (Mwakaje, 2008). Many countries have successfully utilized agricultural wastes like manure to provide energy at the household energy. For example, in China and India biogas plants have been promoted because of its importance to humanity. Such benefits include manure for agriculture, fodder for animals and improving health (Gautam and Ghimire, 2009).

Studies have also shown that women important in the community because their responsibility at homes such as struggling to get fuel for cooking or heating. They have suffered abuses because of endless effort to gather firewood for use at home as fuel (Denton, 2005; Omer and Fadalla, 2009). Further, Denton observes that women

often face difficulties accessing land, labour, water, capital technologies and other services and as much as they are agents of social and economic development have often being devalued.

Installation of biogas plants with the aim of providing safe and renewable energy has been accompanied by challenges for instance maintenance of large biogas plants for local community use and production of manure is costly (Balsam, 2006; van der Werf, 2010). As a result of slow process during anaerobic digestion, a long hydraulic system is needed to boost the process (Yang and Ren, 2007) In the rural places, communities cannot afford the high cost for investment of the digester (Jonusauskait, 2010) while in areas where there is scarcity of water, communities encounter difficulties of meeting the cost of water used (Frederickson *et al.*, 2006) whereas high impact of biogas on the greenhouse effect needs to be managed and stored in order to avoid any contact with the atmosphere (Majid *et al.*, 2006).

Studies have also revealed that location of the farms especially of those which breed a large number of animals influences the availability of the animal manure and assessment of its potential for anaerobic digestion (Ivet, 2008). It is considered to be an extra cost transporting biomass within 15-20 kilometers (Deublein, 2008). Manure and all the animal excreta are considered to have great potential for biogas energy production. However, worldwide animal excreta as a result of animal breeding is considered as major anthropogenic source of methane and consequently a contributor to global warming effect (Abbasi, 2012).

Generally the animal dung produces the highest amount of methane compared to the other organic materials like plant residues (Holm-Nielsen *et al.*, 2007). Elsewhere there are many issues experienced for instance in Denmark, several plants had used household waste as a co-substrate but some of them stopped because of problems related to the appropriate separation of the waste which had led to inhibition of the anaerobic digestion process and also the pungent smell (Jørgensen, 2009).

### ***2.7.3 Benefits of Biogas Energy***

Although viewed as a high and capital intensive project, biogas technology has several socio-economic and environmental benefits associated with it. Biogas technology plays an important role in providing a safe, clean energy that is environmental friendly. Integrating biogas technologies among the dairy farmers could help reduce indoor air pollution, thus reduced incidences of respiratory diseases (Katuwal and Bohata, 2009).

This technology also contributes to promote gender equity and empower women (MDG 3) as revealed by studies according to Mwakaje (2008) that use of biogas technology at the household level helps to empower women by reducing and alleviating the drudgery of wood fuel collection. In his study, Mwakaje revealed that in Tanzania, households that are using biogas energy were able to save more time in per day that was used to gather biomass. This time would be spending to perform activities that would generate money hence improving livelihoods of communities. Moreover, the trees that are left standing as a result of reduced reliance on wood fuel in the farms contribute to sustainability and a positive environmental impact. The trees help break wind with positive impacts on the micro-climate, biogas technology and reducing atmospheric pollution (smoke from biomass) and global warming by reducing GHGs (Smith *et al.*, 2012).

In addition, biogas technology may play an important role at the farm level as waste management system (IFAD, 2009) and as such helps eliminates methane emissions that would come from the residues if they were left to decompose in an open field. The animal waste and urine when transformed into energy sources especially among the dairy farmers, the use of bio-slurry is also advantageous for the dairy farmers as it contains a lot of nutrients thus reduce the use of chemical fertilizers (Katuwal and Bohara, 2009). Furthermore, other benefits that are derived from biogas technology include the sale of bio-slurry which provides income for dairy farmers (IFAD, 2009).

It is further indicated that demand for biogas fuel is rising among communities. This is because installation of plant systems is not expensive and can be managed under

low costs. As a result of this, biogas energy can work as an alternative energy for over half the population of a country living in rural areas (Amjid *et al.*, 2011). This provision of green energy can be improved if the local community can learn how to run and manage biogas systems throughout seasons. (Feng *et al.*, 2011). Other studies noted that by products of animals and plants can be utilized so as to generate the green energy (FAO, 2009).

The biogas technology is very important in reducing the cutting down of forest cover (Okello *et al.*, 2013 and scaling down usage of firewood that 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. As a result, vegetation cover also improves hence improved rainfall patterns and livelihoods (Angelidaki *et al.*, 2003).

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 (Pathak *et al.*, 2009). 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 (Drabez *et al.*, 2009). The application of biogas technology has economic, environmental; health and a social benefit which contributes towards sustainable development (Azhar and Baig, 2012; Seadi *et al.*, 2008) and also a source of nutrient rich organic fertilizer from effluent slurry which can be helpful for algae growth, fish production and seed germination.

Studies according to Kim *et al.*, (2006) noted that the benefits of the processes for production of gas through biogas digester compared with conventional were more. This includes the low cost to acquire raw materials, operation cost, cost for de-slugging slurry. The implementation of this technology does require trained manpower to operate (Asikainen, 2004) and the gas was useful as a fuel substitute for firewood, dung, agricultural residues, petrol, diesel, and electricity (KENDBIP, 2011). The cost estimate of biogas energy in comparison with other energy sources like firewood, electricity, charcoal and kerosene was observed that biogas

technology is cheapest technology having no cost of procuring of organic substrates or manures (Felix *et al.*, 2010).

Table 2. 3 Equivalent energy and cost for 1 m<sup>3</sup> of biogas energy

<b>Biogas Energy</b>	<b>Equivalent Energy</b>	<b>Estimated Cost(ZMK)</b>
(1 m <sup>3</sup> ) is equivalent to pressure of 101398 Pa	3.47 Kg Firewood	3,500
	0.52 L diesel	2,600
	4.70 kWh electricity	4,700
	0.80 L petrol	4,570
	1.40 kg charcoal	5,000
	0.62 L kerosene	3,100

Source: Adopted from Felix (2010)

A“floating drum” storage offers a good, simple way of measuring gas production. Therefore, the pressure of the biogas produced can be determined by considering the change in height of the drum and volume of gas (Harris, 2010). Normal pressure of the gas is usually measured using an equivalent height of water, say 10mm or 20mm. In addition atmospheric pressure is acting and this must be added. Therefore, for 1m<sup>3</sup>

of biogas and height 1.2m, the equivalent pressure is:

$$\text{Pressure} = 10 \times 9.8 + 101300 = 101398 \text{ Pascal}$$

And since product of initial pressure and initial volume must be equivalent to product of final pressure and final volume, then pressure can be obtained for any condition (Harris, 2010).

Further studies according to Okello *et al.*, (2013) and Smith *et al.*, (2012) indicates that the upfront cost of a biogas system as well as a cultural bias against biogas as a fuel for cooking are two main barriers to biogas uptake. The anaerobic digestive process also provides the additional benefit of reducing harmful pathogens in waste (Holm-Nielsen *et al.*, 2009).

Other studies (Weiland, 2010) indicate that the by-products of anaerobic digestion of organic matter (substrate left after digestion) produced is a valuable fertilizer due to its nitrogen content and fertilization effects of its flow properties). This anaerobic digestion is also able to inactivate weed seeds, bacteria, viruses and other possible pathogens.

Biogas energy is also converted into usable energy products experienced in some utilizations such as electric and heat energies upgraded and utilization as vehicle fuel; production of chemicals; upgrading and injection in the natural gas grids and fuel for fuel cells (Holm-Nielsen *et al.*, 2009).

Biogas systems also provided a residue organic waste which has superior nutrient qualities over the usual organic fertilizer (Muller, 2009; Pandey *et al.*, 2007) which can help reverse current trends of decreasing productivity due to soil nutrient depletion and increase food security hence improving the nutritional status of a household . It also produces clean energy from residues (Frederickson *et al.*, 2006). Biogas energy productions from animal waste were economically feasible and ease to operate (Zeng and Ma, 2007).

Table 2. 4 Some Biogas Fuel Equivalents

<b>Application</b>	<b>1 Cubic meter biogas equivalent</b>
Lighting	60-100 watt bulb for 6 hours
Cooking	3 meals for a family of 5 – 6
Fuel replacement	0.7 kg of petrol
Shaft power	one horse power motor for 2 hours
Electricity generator	1.25 Kilowatt hours of electricity.

**Source:** Adopted from Kristofferson (n. d. 1991)

Lighting is a major social asset and already there are estimated 10 million households with lighting from biogas (Martinet, 2003). The solid waste that is obtained in the process contains rich nutrients (Mwakaje, 2008). The biogas plant system for production of methane reduces the nitrogen to carbon ratio and instead ammonium nitrate which is a better fertilizer is formed (Haque *et al.*, 2006).

## 2.8 Improvement of Environmental Quality

To achieve a sustainable development, role of energy must be focused. This will help in identifying a type of energy that when utilized enhance positive development in a country's economy. Biogas energy being a clean, safe and renewable energy becomes the most suitable in enhancing development. One such option is biogas, an energy technology that has the potential to counteract many adverse health and environmental impacts connected with over reliance of biomass that has adverse effects on the environment and human health (KENDIP, 2011).

According to WHO (2006) report, most local communities consume biomass fuels everyday through heating and lighting. Due to this heavy consumption, a lot of smoke is emitted every day which is not friendly to environment and health of animals and people. The use of biogas fuel helps mitigate greenhouse gas emissions (WHO, 2006).

In China, an IFAD-supported biogas project has helped about 30,000 poor households by providing nearly 23,000 biogas tanks. As a result, through the use of biogas energy, people's living conditions and the environment have improved, forests are now protected and the labour force has more time for agricultural production (IFAD, 2009). For Kenya to attain the stated United Nations Millennium Development Goals, access to green energy such as biogas energy need to be integrated among the rural and urban dwellers in the country.

Studies according to Okello *et al.*, (2013) and Pandey *et al.*, (2007), inefficient use of wood is associated with pollution, deforestation and related issues such as undesirable change in biodiversity, wood scarcity, and degradation of land and water resources. According to Abbasi (2012), worldwide animal excreta as a result of animal breeding is considered as major anthropogenic source of methane and consequently a contributor to global warming effect. As a result of these challenges, the use of biogas fuel mitigates a wide spectrum of environmental undesirables: it improves sanitation, it reduces greenhouse gas emissions, it reduces demand for wood and charcoal for cooking, and therefore helps preserve forested areas (Drabez *et al.*, 2009).

When the potential environmental impacts are taken into consideration, there will be mitigation of unfriendly gases to the environment such as sulphur dioxide (SO<sub>2</sub>), nitrogen dioxide (NO<sub>2</sub>), carbon monoxide (CO), total suspended particles (TSPs), and poly-aromatic hydrocarbons (PAHs) are possible with the large scale introduction of biogas technology also taken into account, significant reductions in emissions associated with the combustion of biofuels such as (IPCC, 2012).

In South Africa, it was estimated that about 45% of schools had no electricity, 66% had poor sanitation facilities, 27% had no clean water and 12% had no sanitation at all and therefore, installations of biogas plants could help mitigate all of these problems (Abbasi, 2012). According to Fullertone *et al.*, (2008), biogas fuel as a clean and friendly source of energy when used lowered chances for chronic diseases that were associated with smoke inhaled when biomass-based fuels were partially burnt. Such chronic diseases included respiratory infections, ailments of the lungs, bronchitis, asthma, lung cancer and increased severity of coronary artery disease (Susanne, 2011). Biogas technology provides multiple benefits at household, local, national and global levels with major impacts on gender, poverty, health, employment and environment. Communities that adopt biogas systems quickly realize the social, economic, development and environmental benefits for their households.

## **2.9 Health Benefits of Biogas Fuel**

Studies indicate, however, that 400,000 people in Sub Saharan Africa die each year from the health impacts of smoke inhalation because a house with an open fire can have up to 75 times the maximum advised level of air pollution (Okello *et al.*, 2013). The indoor air pollution from open stoves is a major contributor to respiratory illnesses such as pneumonia in children under 5 years and chronic lung disease and lung cancer in adults over 30 years has been attributed to the use of biomass (UNDP, 2009). Moreover, the World Health Organization (2009) estimates that 50 percent of the 2.1 million deaths of children under five annually from respiratory infections are attributable to indoor air pollution, lack of adequate heating, and other precarious conditions.

A field-study from Western Kenya showed that women often spend two to five hours each day on collecting firewood and termed it as the most time-consuming tasks in their day to day household chores. They associated this task to frequent backaches and headaches as a result of carrying heavy loads of firewood (IFAD, 2009). Studies elsewhere have revealed that use of firewood, dung cakes and agricultural residues for heating produce smoke which is environmental pollutant and has been rated as unfriendly to human health (Ezzati, 2005). It has been noted that it is among the main contributors for acute respiratory infections among women, infants and children (Katuwal and Bohara, 2009). The use of biogas energy significantly improves the indoor air quality (Susanne, 2011).

Studies according to Emmelin and Wall (2007) show that some of the effects associated with lack of clean energy include health problems due to indoor air pollution and high opportunity costs related to time spend gathering wood fuel. Smoke exposure in wood fuel in cooking leads to respiratory and eye infections (Fullerton *et al.*, 2008) which mainly affect women and female children since they are the ones predominantly involved in cooking. Fullerton *et al.*, (2008) further indicated that, since the combustion of biogas fuel is relatively clean, it reduces eye ailments associated with smoke from ordinary wood fuel stoves. In addition, dung management and sanitary toilets attached to biogas digesters lead to better hygienic conditions (Azhar and Baig, 2012). It helps keep the areas surrounding households clean and reduces the chances for the spread of infectious and other diseases. Susanne (2011) observed that indoor air pollution contributes to 1.9 million deaths/year and 1.5 billion people in developing nations that have no access to electricity.

In rural Kenya, women regularly cook using locally gathered wood as fuel. Consequently, women and young children in their care are often exposed to high levels of indoor air pollution, especially wood smoke (Mugo and Gatheha, 2010). Studies have revealed that the exposure to residential indoor air pollution in low income countries has been identified as a major source of concern worldwide with significant negative effects on the health of women and children (Emmelin and Wall, 2007; ERC, 2010), who typically spend more time indoors (Susanne, 2011).

The exposure to high levels of indoor air pollution associated with biomass burning ; wood, crop residue and animal dung has been associated with respiratory health outcomes such as chronic obstructive pulmonary disease (COPD), respiratory infections, asthma, pneumonia, and tuberculosis (Fullerton *et al.*, 2008; Naeher *et al.*, 2007; Smith *et al.*, 2012).

A recent meta-analysis of the effects of biomass smoke on COPD found that biomass smoke exposure was significantly associated with the risk of COPD compared to those not exposed to biomass smoke (Hu *et al.*, 2010). A report by the US Department of Energy on biomass cook stoves suggests that a 50% reduction in fuel use and a 90% reduction in emissions, relative to baseline technology, are important targets in global improvements to cook stoves in these environments (U.S. Department of Energy, 2011). In relation to this challenge, biogas digesters represent an important and accessible technology that produces biogas energy, an alternative fuel source consisting primarily of methane, which has the potential to reduce reliance on wood fuel use in cook house operations (U.S. Energy Information Administration, 2010).

The biogas digesters are installed outside the cookhouse and function to anaerobically decompose organic material, such as livestock waste, to generate the gas which is then piped into the house and used for cooking hence reduce risks associated with smoke from traditional biomass. Further studies revealed that, in certain situations where animal manure and water are in sufficient quantity, biogas digesters can reduce reliance on wood fuel, leading to reduced exposure to wood smoke, and potentially to a reduction in negative respiratory outcomes related to wood smoke exposure (Zhang and Smith, 2008).

Studies according to Holm-Nielsen *et al.*, (2009) and Weiland (2010) indicated that adoption of Biogas Technology has positive environmental impacts for instance it reduces environmental pollution which is caused by incomplete burning of kerosene oil, cattle cake, agricultural residues and firewood. It further noted that use of biogas fuel partly contributes to saving forest resources from deforestation, reducing greenhouse gas emissions for instance carbon dioxide, methane and nitrogen monoxide thus mitigating global warming.

The adoption of anaerobic technology has led to achieving digestate that can be used on-site for crop production at an appropriate type without further treatment. The digestate could substitute chemical fertilizer due to the availability of nitrogen to crops. The reuse of digestate represents a sustainable way to control nutrients. Biogas fuel is used for cooking, lighting, heating in small- scale industrial operations and if upgraded can be used as vehicle fuel.

## CHAPTER THREE: METHODOLOGY

### 3.1 Study Area

This study was carried out in Nandi County. Nandi County was formerly a part of Rift Valley Province in Kenya. It has a total area of 2,884.5 km<sup>2</sup> (1,113.7m<sup>2</sup>) with coordinates: 0°20'N 35°10'E / 0.333°N 35.167°E and a total population of 752,965 (2009 Census). Its capital town is Kapsabet and is located 40 Kilometres South-West of Eldoret on the way to Chavakali. The county borders other counties: Kericho to the East, Kakamega to the West, Uasin Gishu to the North, and Kisumu to the South. Nandi County.

Kapsabet municipality has a total population of 86,803 according to 2009 census and is an agricultural town. Within its environs are large tea and maize farms as well as a number of horticulture and dairy concerns. The town has a milk depot operated by New Kenya Cooperative Creameries (New KCC) and the KTDA Chebut Tea Factory.

It is a connection town for Kisumu, Kakamega, Kericho, Eldoret and Nakuru Municipalities. The study was carried out in the Christian Intermediate Technology Centre (CITC) and St. Paul's Theological College (SPTC), both in Kapsabet Town, Nandi County, where there were installations of Biogas (Plate 3.1).

The training institutions are Christian based and located in the same geographical and agricultural area. The study area was selected because it has agricultural potential and functional biogas digester (Plate 3.1 -3.2).The study was conducted at the Christian Intermediate Technology Centre where biogas technology is practiced and St. Paul's Theological College where biogas fuel has not been adopted. The two training institutions are located in Kapsabet town in Nandi County and were purposely selected in order to establish, compare and determine attitudes that influence adoption of biogas fuel as alternative source of energy.



Plate 3. 1 Part of Biogas Plant at CITC Photo 15/01/2014



Plate 3. 2 Biogas Plant at CITC, Kapsabet: Taken Photo 15/01/2014

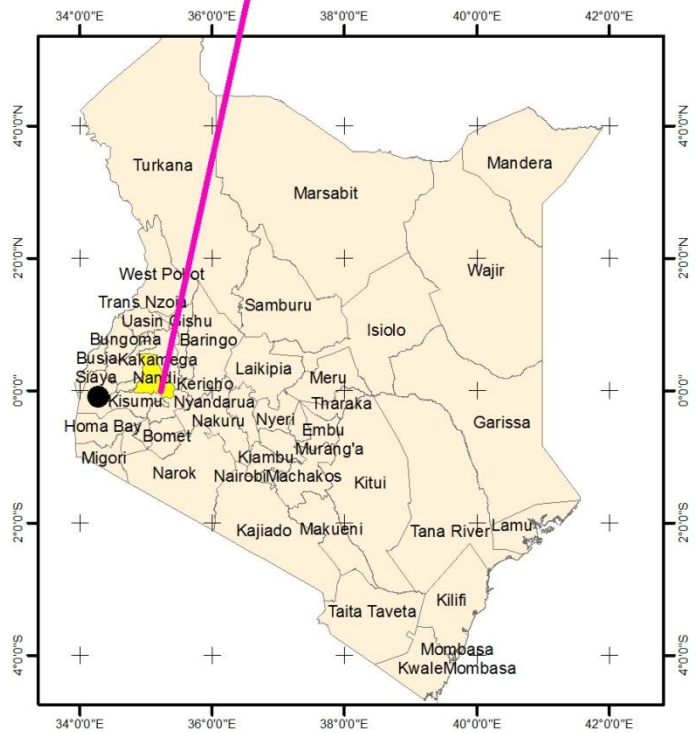
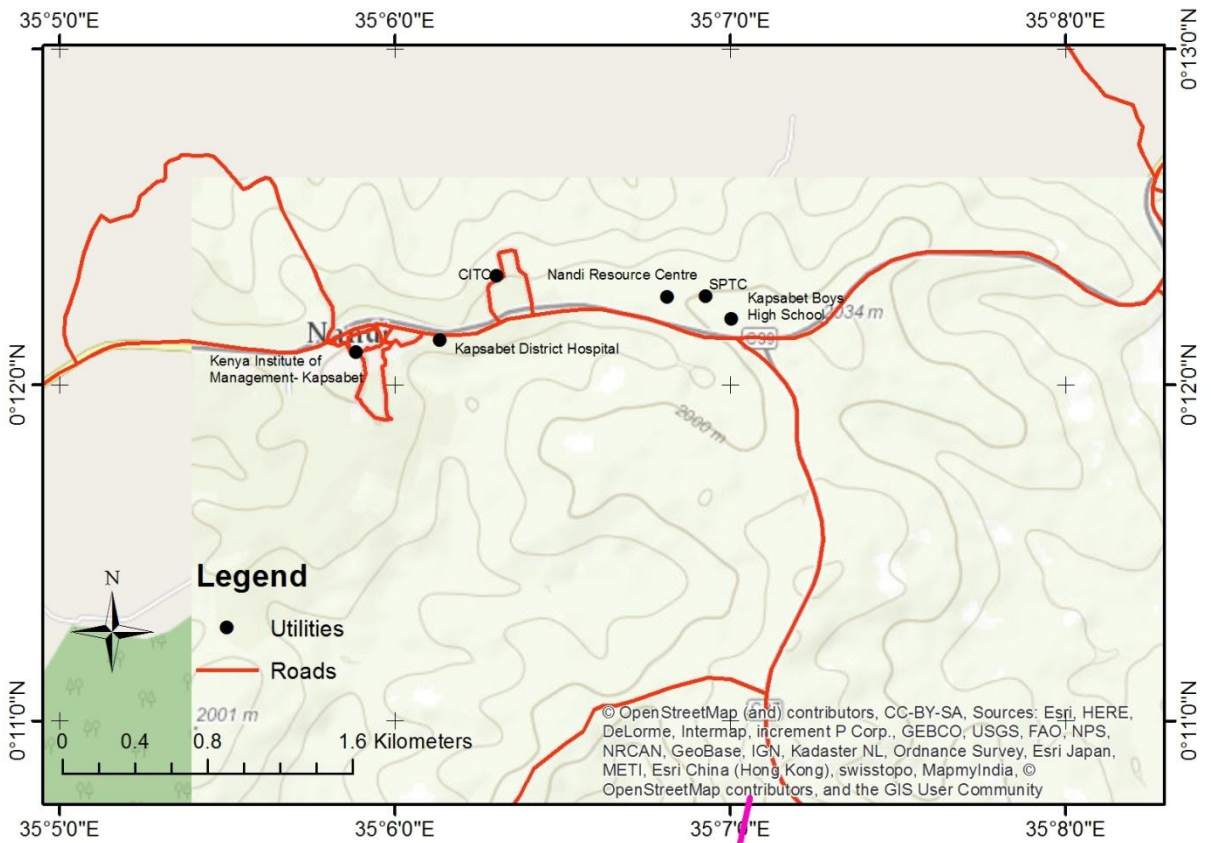


Plate 3. 2 Map of Kapsabet Municipality

### 3.2 Research Design

The study adopted descriptive case study research design. The researcher used quantitative and qualitative research approaches in order to maximize the strengths and minimize the limitations of each. A descriptive case study design was adopted in which all middle level tertiary training institutions in Nandi County were targeted as population and a sample of two institutions was considered. The sample comprised 318 respondents both male and female from the two training institutions. All the 318 respondents involved in the research study were students, non teaching staff, tutors and head teachers of SPTC and CITC. Documentary records, interview schedules and questionnaires were used to collect data.

### 3.3 Target Population and Sample Size

The target population for the research study was all middle level tertiary training institutions in Nandi County. The sample for the study comprised all workers and learners from SPTC and CITC training institutions, that is, 318 respondents including 260 students, 33 teaching staff, 23 cooks and 2 principals. The two institutions were chosen because the sampling method was purposive and also were located under one geographical and agricultural area. The institutions are also Christian based and the respondents were believed to be residents of Nandi County.

Table 3. 1 Distribution of respondents in CITC and SPTC by role and gender

Institution of Respondents	CITC		SPTC	
	Males	Females	Males	Females
Enrolment				
Students	120	60	60	20
Cooks	8	4	7	4
Tutors	12	8	8	5
Principals	1	0	1	0
<b>Total</b>	<b>141</b>	<b>72</b>	<b>76</b>	<b>29</b>

### 3.4 Sampling Procedure

A case of the CITC and SPTC in Kapsabet Town of Nandi County was used for the study because of the availability of the biogas technology at CITC. The biogas technology was used for comparison with other types of fuels in use in the two training institutions. The population was made up of twelve tertiary learning institutions of middle college. The sample comprised all workers and learners of the two training institutions both located at Kapsabet town. Purposive sample selection (Census sampling) was done where 318 respondents were involved in the study (Table 3.2). This was because the researcher considered them to have sufficient information needed for the study. The letters indicating the interview were then circulated among the respondents prior to the interview date.

Table 3. 2 Summary of the History of the Study Area

<b>Institution</b>	<b>CITC</b>	<b>SPTC</b>
Nature of Institution	Technology Centre	Christian College
Establishment	Christian based	Christian based
Gender of Learners	Male and Female	Male and Female
Students	Majority youth	Majority adults
Population	213	105

The respondents from the two training institutions involved both males and females. CITC is a technology centre whereas SPTC is a theological college. Both institutions are Christian based. The highest number of students (respondents) in CITC and SPTC were males.

### 3.5 Data Collection Instruments

This study employed existing documentary records; interview schedules and questionnaires as data collection instruments. The documentary records were obtained from CITC and SPTC showing records of fuel commonly used by the learning institutions.

### ***3.5.1 Documentary Records***

The researcher used existing documentary records in the learning institutions to provide a list of all documents consulted, with copies of (or extract from) documents not widely available attached. It also provided field notes on all interviews in relation to questionnaire provided: in English or language of interview, and in electronic form.

### ***3.5.2 Questionnaires***

Questionnaires had simple and precise questions in relation to availability and use of biogas fuel and other fuels in use in the two training institutions. This research instrument was administered to all respondents who were able to read and write. Semi-structured questionnaire with open-ended items were used to obtain more data from respondents (Appendices IV-VII). The open-ended items were used to give the respondents an opportunity to discuss freely and exhaustively the issues that were raised. The questionnaire assisted the researcher in getting in-depth data that was not possible to get when using existing documentary records from the training institutions. The questionnaire verified current understandings and concepts about adoption and use of biogas fuel. It also helped to gather and help develop new understandings and concepts about biogas fuel adoption and non-adoption.

### ***3.5.3 Interview Schedules***

The interview schedules contained questions designed to obtain information from the heads of institutions and cooks in relation to availability and use of biogas fuel and other existing fuels in the two training institutions. This is because the researcher believed that the heads of institutions would provide some administrative information which would not have been obtained from the students cooks and tutors while for cooks some of them were not literate enough to read the questionnaires and provide adequate information as required by the researcher. Furthermore, the interview schedules were also designed for cooks who were not able to read and write.

### **3.6 Validation of Research Instruments**

Validity refers to the extent to which results from the analysis of data actually represent the phenomenon under research study. The validity of the research study instruments was established with consultation of the experts in the department of Environmental Education of Kenyatta University. Their comments were incorporated so as to improve the validity of the instruments.

Reconnaissance survey was carried out a month prior to the day of data collection in Chepterit Home craft and Christ the King School where twenty (20) pilot questionnaires were administered to respondents. Data was statistically analyzed using SPSS and the Cronbach's coefficient alpha of 0.741 obtained, hence reliable (at least 0.70 or higher). This helped the researcher to design efficient research instruments that were used to collect required data and also get familiarized with the instruments. The research instruments involved were existing documentary records obtained from CITC and SPTC, interview schedules, and questionnaires.

### **3.7 Reliability of Research Instruments**

A measurement is said to be reliable if it reflects mostly true score, relative to the error. A research tool that is reliable measures what is it intended to measure. The research instrument should yield results that can be trusted (that is likely to be true while consistency is the quality with which the results from analysis behave in the same way. The instruments established and used in the research provided reliable data which was subjected to scientific analysis. The result was used to answer the research questions. The questionnaire was tested for reliability by conducting reliability analysis in SPSS using data collected using 20 pilot questionnaires administered to respondents, prior to the actual research. Cronbach's coefficient alpha of 0.716 obtained to determine the internal consistency of the items (Appendix VIII). This is a method of estimating reliability of test scores by the use of a single administration of a test (Mugenda and Mugenda, 2003). Cronbach's Alpha is the most common form of evaluating internal consistency reliability coefficient, and a value of at least 0.70 or higher to retain an item.

The items used to determine reliability were items that concern biogas energy which included; whether biogas is a good fuel to use, biogas fuel is relatively cheaper than other sources; raw materials for biogas fuel production are readily (see Appendix VI).

### **3.8 Data Collection Procedure**

#### ***3.8.1 Research Instrument***

Semi-structured questionnaire consisting of both open-ended and closed-ended questions was used to collect data for this study. The data collected from heads of institutions, tutors, cooks and students included knowledge, perception and opinion on adoption and use of biogas energy in training institutions. The questionnaires consisted of demographic questions, awareness questions to establish respondents' basic knowledge of biogas energy, Likert statements to further assess the respondents' knowledge and perception of biogas energy including factors affecting its adoption, policy questions to assess respondents' opinion on adoption and use of biogas fuel in training institutions. A five-point Likert scale ranging from strongly disagree to strongly agree was used to rate the state of mind of respondents towards various Likert items.

#### ***3.8.2 Administration of Research Instruments***

A pilot study was carried out to test the research instruments. A total of 318 questionnaires were distributed to the respondents in the CITC and SPTC. The target sample was 318 respondents from the two training institutions which included 260 students, 33 tutors, 23 cooks and 2 principals. The questionnaires were self-administered by 295 respondents out of the total 318 since they were literate. The remaining 23 respondents who were cooks were taken through face to face interviews because the researcher felt that they were not literate enough to read the questionnaire on their own and provide accurate information. The researcher was always available to make clarification where it was required.

### **3.9 Data Analysis**

Aided statistical computer components were used to analyze data collected using questionnaires, interview schedules and existing documentary records. This was

done using descriptive statistics. Statistical Packaging for Social Sciences (SPSS) and Microsoft excel were used for data analysis. Completed questionnaires were first examined for consistency purposes followed by numerical coding of the qualitative responses. This was done for better storage and analysis.

The responses were then entered into both MS word Excel and SPSS version 20 creating data sets of factors influencing adoption of biogas fuel and finally data analysis commands were put in place. The hypotheses were tested at a statistical confidence level of 95%. The data analyzed was presented in tables, charts and graphs which made it easier to summarize data while the percentage distribution technique was used to show the particular frequency of respondents preferring a particular alternative and gave face values of factors affecting adoption of biogas fuel in training institutions. Interviews with respondents were analyzed qualitatively to support or dispute the findings from the questionnaire.

A Likert scale was used in this study to evaluate the significance of factors influencing adoption and use of biogas fuel. Statements were designed and response weighed on scale of 1-5 where 1 = Strongly Disagree and 5 = Strongly Agree for positive statements and the reverse scale for negative statements. These statements were designed to measure factors influencing adoption and utilization of biogas fuel in the learning institutions.

## **CHAPTER FOUR: RESULTS AND DISCUSSION**

### **4.0 Preview**

The aim of this study was to focus on attitudes influencing adoption and use of biogas fuel to enhance environmental quality and health in training institutions in Nandi County. The attitudes influencing adoption and use of biogas energy were assessed in terms of respondents' knowledge on awareness about biogas energy as well as their individual opinion on adoption and use of biogas energy in training institutions in Nandi County. The respondents' opinion and perception on adoption of biogas energy was assessed in terms of the extent to which they consider the adoption and use of biogas energy as main contributor to conservation of natural forest cover hence mitigating deforestation, soil erosion, air pollution and global warming. The respondents' opinion on adoption and utilization of biogas energy in learning institutions in Nandi County was assessed in terms of the extent to which they feel the need to adopt and use biogas fuel in training institutions.

### **4.1 Background Information of the Respondent**

#### ***4.1.1 General Characteristics of the Population Sampled***

In this study, the two training institutions were sampled from twelve training institutions in the County with same level of education. The respondents comprised students, tutors, head teachers and non-teaching staff of the two colleges, SPTC and CITC. Overall there were more respondents (52%) from CITC than SPTC (48%), since the former was a larger college than the later.

#### ***4.1.2 Respondents' Distribution by Gender***

Analysis was done based on respondent category, college where the respondent hails from and participation by gender. The study findings indicated a higher participation of the respondents in each category by CITC compared with SPTC. The students who participated in the study comprised of more males than females. The male respondents from CITC comprised 78.1% while the females were 21.9%. On the other hand, there was a participation rate of 69.4% and 30.6% of the males and female respondents from SPTC respectively. The Table 4.1 gives a summary of the distribution of gender by age and respondent category and college. The two head teachers of the colleges were both males.

Table 4. 1 Respondent distribution by category, college and gender

Respondent Category	College		Gender (%)	
			n	
Student	CITC	Male	118	78.1
		Female	33	21.9
	SPTC	Male	75	69.4
		Female	33	30.6
Tutors	CITC	Male	9	33.3
		Female	18	66.7
	SPTC	Male	2	33.3
		Female	4	66.7
Non-teaching Staff	CITC	Male	6	50.0
		Female	6	50.0
	SPTC	Male	5	45.5
		Female	6	54.5

Similar trends, in terms of proportion in participation of the college tutors were noted. However, the participation of the non-teaching staff was almost similar for the two colleges. The results of the study indicated that the proportion of the male tutors comprised 33.3% while the females comprised 66.7% in CITC, while there were 33.3% males and 66.7% females in SPTC. On the other hand, the teaching staff comprised 50.0% participation in each gender and 45.5% and 54.5% participation in male and female respectively in SPTC. Despite an almost equal participation in numbers on the part of the teaching staff, there was clear difference on the part of the other respondents. This was because of the fact that CITC was larger in terms of numbers of respondents than the SPTC and hence there was more sampling in CITC to get the representative sample.

An inquiry into when the institutions were established, it was found that CITC is older than SPTC and hence it is more established in terms of enrollment of students and hence more teaching staff (tutors) and non-teaching staff are required to offer

service to the students during study sessions. (Table 4.1) A Chi-square test of independence indicated that there was no significant relationship between gender and age of the students in CITC ( $\chi^2 = 5.671$ ,  $df = 3$ ,  $p = 0.129$ ), while there was a significant relationship between the two variables in SPTC ( $\chi^2 = 29.647$ ,  $df = 3$ ,  $p = 0.001$ ). The significance of the association was significant to comprehend how variables work. It follows therefore, that, there was significant gender difference in enrolment with most students were males (Tables 4.1 and 4.2).

Table 4. 2 Association between age and gender

College		Value	df	P-value
CITC	Pearson Chi-Square	5.671 <sup>a</sup>	3	.129
	Likelihood Ratio	6.133	3	.105
	Linear-by-Linear Association	.024	1	.877
	n of Valid Cases	149		
SPTC	Pearson Chi-Square	29.647 <sup>b</sup>	3	.000

#### *4.1.3 Age and Level of Education for the Students*

The students at the college were pursuing courses ranging from certificates diploma and degree courses. The findings indicated that the students who were pursuing certificate courses comprise 66.9% aged between 18-25 years, while those between 26- 33 years were 17% while those pursuing diploma courses aged between 18-25 years were 85.8% and ages 26- 33 were 14.3%. Students who were pursuing certificates and diploma courses were the majority (76.4%). The students were of different ages and a cross tabulation indicated that in the two training institutions there was a significant relationship between the level of study and age ( $\chi^2 = 18.864$ ,  $df = 9$ ,  $p = .026$ ), Table 4.2 and Table 4.3.

The level of education was important due to the popular belief that persons with education might have the understanding and can easily adopt biogas fuel given the adequate awareness.

Table 4. 3 Association between students' level of study and age

College			Age Category				Total
			18-21	22-25	26-29	30-33	
CITC	Secondary	n	0	6	3	0	9
	Certificate	n	6	6	6	0	18
	Diploma	n	36	66	14	3	119
	Degree	n	3	0	0	0	3
	<b>Total</b>	<b>n</b>	<b>45</b>	<b>78</b>	<b>23</b>	<b>3</b>	<b>149</b>
SPTC	Secondary	n	3	0	0	0	3
	Certificate	n	3	6	0	9	18
	Diploma	n	12	9	15	21	57
	<b>Total</b>	<b>n</b>	<b>18</b>	<b>15</b>	<b>15</b>	<b>30</b>	<b>78</b>

The association between age and level of study of the students implies that the students have the right age at their level of education to give information required in relation to the study. They are pursuing their courses at the appropriate age or within the age required by the curriculum at their level. In addition and most important, the students ages imply that they are adults and is the most important section of the population that policy makers on green energy can rely on. In other words, this section of the population is a target in terms of changing their attitude and creating

awareness for future adoption of green energy that is biogas fuel, and consequently conserving the environment.

Table 4. 4 Association between level of study and age of respondents

<b>College</b>		<b>Value</b>	<b>df</b>	<b>p-value</b>
CITC	Pearson Chi-Square	18.864	9	.026
	Likelihood Ratio	21.200	9	.012
	Linear-by-Linear Association	5.986	1	.014
	n of Valid Cases	149		
SPTC	Pearson Chi-Square	18.246	6	.006
	Likelihood Ratio	20.019	6	.003
	Linear-by-Linear Association	2.229	1	.135
	n of Valid Cases	78		

Preliminary investigations revealed that there was a low turnover of tutors in the institution. Therefore, the study, a probe with the non-teaching staff gave indications of a relatively long stay in the training institution. A Chi-square test of independence found that there was no statistical relationship between age and length of stay for the non-teaching staff in CITC College. ( $\chi^2 = 2.917$ ,  $df = 3$ ,  $n = 23$ ,  $p = 0.405$ ).

Table 4. 5 Association between age (yrs) and length of stay in the institution (yrs)

	<b>Age Category (yrs)</b>	<b>Length of stay in Institution</b>		<b>Total</b>
		0-9 yrs	10-19 yrs	
<b>CITC</b>	18-21	2	0	2
	22-25	2	0	2
	26-29	1	1	2
	30-33	1	0	1
	Total	6	1	7
<b>SPTC</b>	26-29	1	0	1
	30-33	1	0	1
	Total	6	1	7

The relationship between the two variables for SPTC was indeterminate because the non-teaching staff was of the same age category (constant). ( $\chi^2 = 2.917$ ,  $df = 3$ ,  $n = 23$ ,  $p = 0.405$ )

#### **4.1.4 Institution's Main Fuel**

The study findings sought to find out the type of fuel commonly used by the training institutions. To do this, the respondents were asked about the type of fuel commonly used in the training institutions. The study findings indicated that the most and widely used fuel in the training institutions is wood. The research findings show that 80.8% of the students, 87.0% of the non-teaching staff and 63.6% of the tutors indicated that the common type of fuel used in the institution is wood fuel. This was followed closely by the electricity (24.2%) and finally biogas fuel (12.1%) as indicated by the tutors. The table 4.6 gives a summary of these research findings.

Table 4. 6 The institution's main type of fuels

<b>Fuel</b>	<b>Students</b>		<b>Non-teaching staff</b>		<b>Tutors</b>	
	<b>n</b>	<b>%</b>	<b>n</b>	<b>%</b>	<b>n</b>	<b>%</b>
Wood	210	80.8	20	87.0	21	63.6
Biogas gas	8	3.1	1	4.3	4	12.1
Electricity	42	16.2	2	8.7	8	24.2
<b>Total</b>	<b>260</b>	<b>100.0</b>	<b>23</b>	<b>100.0</b>	<b>33</b>	<b>100.0</b>

From the result in the table above it is an indication that biogas fuel is not widely used in the training institutions. Actually, the institutions largely use wood as fuel which is sourced from the neighboring forest and locally owned fallen trees. In CITC biogas fuel has been adopted as alternative source of energy while in SPTC and the surrounding community the commonly used type of fuel is wood fuel. (Plates 4.1-4.3). The respondents from CITC noted that they obtain consultations in

relation to use of biogas fuel from local experts such as Green Energy Africa (GEA) which operates around North Rift region.

#### 4.2 Attitude of Adopters and Non Adopters of Biogas Fuel

The respondents were asked if they had ever used biogas fuel in their homes. The studies revealed that 90.9% of the tutors and 79.3% of the non-teaching staff have not used biogas fuel in their homes before. On the other hand, a higher proportion (81.6%) of the students indicated that they have not used biogas energy at home (table 4.7).

Table 4. 7 Use of biogas fuel in training institutions

Respondent Category		Frequency	%
Tutors	Adopted	3	9.1
	Not Adopted	30	90.9
<b>Total</b>	-	<b>33</b>	<b>100.0</b>
Non-teaching	Adopted	6	26.1
	Not Adopted	17	73.9
<b>Total</b>	-	<b>23</b>	<b>100.0</b>
Students	Adopted	48	18.5
	Not Adopted	212	81.6
<b>Total</b>	-	<b>260</b>	<b>100.0</b>

A Univariate Chi-square analysis indicated that a significant proportion of the tutors ( $\chi^2 = 22.091$ ,  $df=1$ ,  $n=33$ ,  $p\text{-value}=0.000$ ), non-teaching staff ( $\chi^2 = 5.261$ ,  $df=1$ ,  $n=23$ ,  $p\text{-value}=0.022$ ) and students ( $\chi^2 = 100.8$ ,  $df=1$ ,  $n=260$ ,  $p\text{-value}=0.000$ ) have not used or adopted the use of biogas fuel. The study results together with the type of fuel used confirms and the negative attitude of the respondents explains that use of biogas energy is uncommon in the area and may take a while to be adopted. The availability of trees for firewood seems to be standing in the way of biogas adoption.



Plate 4. 1 A Photo of biogas plant at CITC taken on 1/15/2014. (Authorised by CITC



Plate 4. 2 A cook at CITC attempting to light biogas burner. Photo taken on 1/15/2014 at CITC. (Authorised by CITC



Plate 4. 3 Part of Biogas plant at CTIC. Photo of the researcher taken on 1/15/2014 at CITC

The study findings indicated 100% of the tutors who have adopted biogas fuel strongly believe that biogas fuel is relatively cheap compared to other sources of fuel. It was observed that, a significant proportion (83.3%) of those who have not adopted biogas fuel also believe strongly that the biogas fuel is cheaper compared to other types of fuels. On the other hand 100% of those who have adopted use of biogas fuel agree that the materials are readily available. In addition, the study findings also show that 40% of those who have adopted use of biogas fuel do agree that installation of biogas plant do not require much space whereas 60% of the non-adopters strongly agreed that the biogas materials are readily available. The study also found all (100%) of those who have adopted use of biogas fuel strongly agreed that biogas fuel when used produce clean energy which is friendly to human health.

Table 4. 8 Factors for adoption of biogas fuel

Adoption	Response	Relatively Cheaper		Availability of materials		Adequate Space	
		F	%	F	%	F	%
Adopted	Strongly agree	3	100.0	3	100.0	3	100.0
Not Adopted	Agree	5	16.7	12	40.0	3	10.0
	Strongly agree	25	83.3	18	60.0	9	30.0
	<b>Total</b>	<b>30</b>	<b>100.0</b>	30	100.0	18	60.0

A univariate analysis of the three factors indicate that there was significant agreement on the fact that biogas is relatively cheaper than other sources of fuel ( $\chi^2=16.030$ ,  $df=1$ ,  $p=0.000$ ). Similar results were yielded for biogas installation requiring less space ( $\chi^2= 10.364$ ,  $df=2$ ,  $p=0.006$ ). However for readily availability of raw materials, the agreement was not significant ( $\chi^2= 2.455$ ,  $df=1$ ,  $p=0.117$ ). (Table 4.9).

Table 4. 9 Univariate Chi square Statistics on Factors

Statistics	Relatively Cheaper	Raw materials readily available	Installation require less space
Chi-Square	16.030	2.455	10.364
df	1	1	2
p-value	.000	.117	.006

The study also compared the attitude of respondents who have adopted biogas fuel against those who have not. First, the study findings revealed that all the tutors in SPTC have not adopted biogas as a fuel, while in CITC, a significant number of respondents have not adopted biogas energy ( $\chi^2=16.333$ ,  $df=1$ ,  $p=0.000$ ). To compare the attitude of the adopters and non-adopters, the study grouped the respondents into those who have adopted and those who have not adopted the biogas fuel and compared their attitude on a 5-point Likert scale. The tutors were asked a set of statements that constituted the measure of attitude. The responses on the set of statements were scored on a five point scale with the lowest score being 1 and the highest score being 5. The average score was calculated and categorized as positive or negative for the respective respondent.

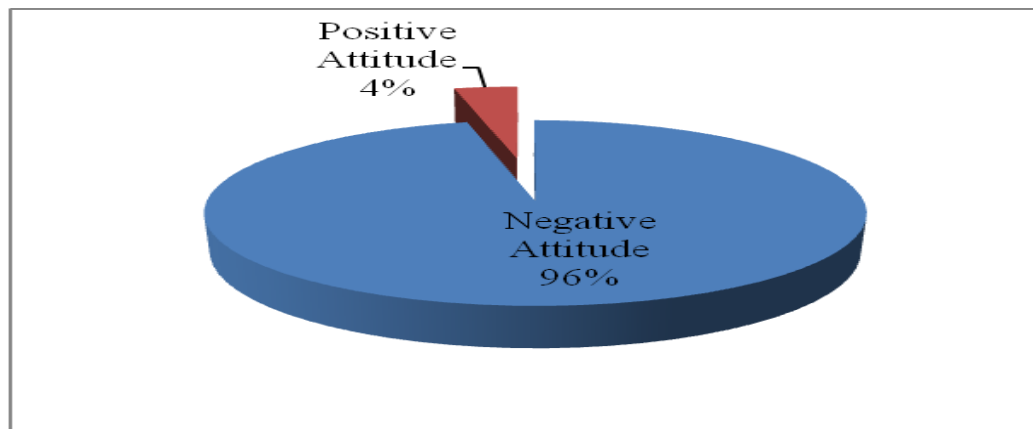


Figure 4. 1 Attitude of the tutors towards biogas adoption

A Univariate Chi-square analysis found a statistically significant difference in respondents' attitude towards biogas adoption ( $\chi^2 = 10.667$ ,  $df = 1$ ,  $p = 0.001$ ). This implies that the attitude of the respondents is a crucial factor as far as adoption of biogas is concerned.

Table 4. 10 Contingency table of biogas use and attitude

Adoption	Attitude Score			Total
	Disagree	Agree	Strongly Agree	
Adopted	3	0	0	3
Not Adopted	0	18	12	30
<b>Total</b>	<b>3</b>	<b>18</b>	<b>12</b>	<b>33</b>

#### 4.3 Factors Influencing Adoption and Use of Biogas Fuel

The study sought to analyze the factors influencing adoption and use of biogas fuel in learning institutions. The questionnaire items asked the three categories of respondents on the factors that make institutions adopt biogas as fuel. This was particularly directed to those individuals who have adopted biogas energy. The study results revealed several factors that influence adoption and use of biogas energy. First, the respondents who have not adopted biogas fuel had the perception that biogas fuel is a dirty thing whereas those who have adopted the fuel noted that biogas energy leads to conservation of the environment. Biogas technology use animal waste (dung), human waste, kitchen waste which decomposes to give out the biogas used as fuel. As a result, wastes which would have been dumped at secluded dumping sites get used up and the bioslurry may be used as fertilizer. The study results reported a 22.5% strong agreement that use of biogas fuel enhances conservation of environment.

The other factor is the fact that biogas is a clean energy. Thirty-two percent (32.8%) of the respondents strongly agreed that use of biogas fuel produce clean energy which does not compromise human health.

An additional 20.0% of all the respondents indicated that it is indeed a clean energy and does not require a lot of space for installation. Twenty-eight (28.2%) of all the three categories of the respondents confirmed that the installation of biogas plant does not require much space. This implies that it can be installed even on a small area of land set aside for it. The other important factor that the respondents cited was the availability of the raw materials to be used for the production of biogas energy. Over 80% of the respondents are in agreement that the raw materials for the production of biogas fuel are readily available. This is because they use cow dung and other domestic refuse (Table 4.11).

Table 4. 11 Factors influencing adoption and use of biogas fuel in learning institutions

Statement	Strongly agree		Agree		Disagree		Strongly Disagree	
	n	%	n	%	n	%	n	%
Raw materials for biogas fuel production are readily available	47	39.2	17	43.5	2	33.3	0	0
Use of biogas fuel leads to conservation of environment	27	22.5%	6	15.4	4	66.7	0	0
Installation of biogas plant does not require a lot of space	22	18.3	11	28.2	0	0	0	0
Biogas fuel produce clean energy which does not compromise human health	24	20.0	5	12.8	0	0	0	0

The study showed other factors that influenced the uptake in the training institution and its environs. They include the installation being expensive because of high installation costs (over 70%), which concur with van der Werf (2010), who indicated

that installing too large biogas plants incur high cost. Results also indicated that social-cultural factors (26%) are hindrance towards adoption of biogas technology which agree with Smith *et al.*, (2012) who observed that cultural beliefs against biogas as a fuel for cooking is the main barrier to biogas uptake. Other obstacles from the results include negative attitude towards use of biogas energy (96%), lack of interest, (10%), inadequate skilled technicians (26%) and lack of credit facilities (70%) (Figure 4.2). Majority of the respondents (over 70%) were in the view that the high upfront cost of installing biogas units was one of the major barriers that have hindered adoption among potential biogas users in the study area.

According to Quadir *et al.*, (2010), high investment costs in installing biogas units have been blamed for the low adoption rates in many developing countries (Figure 4.2).

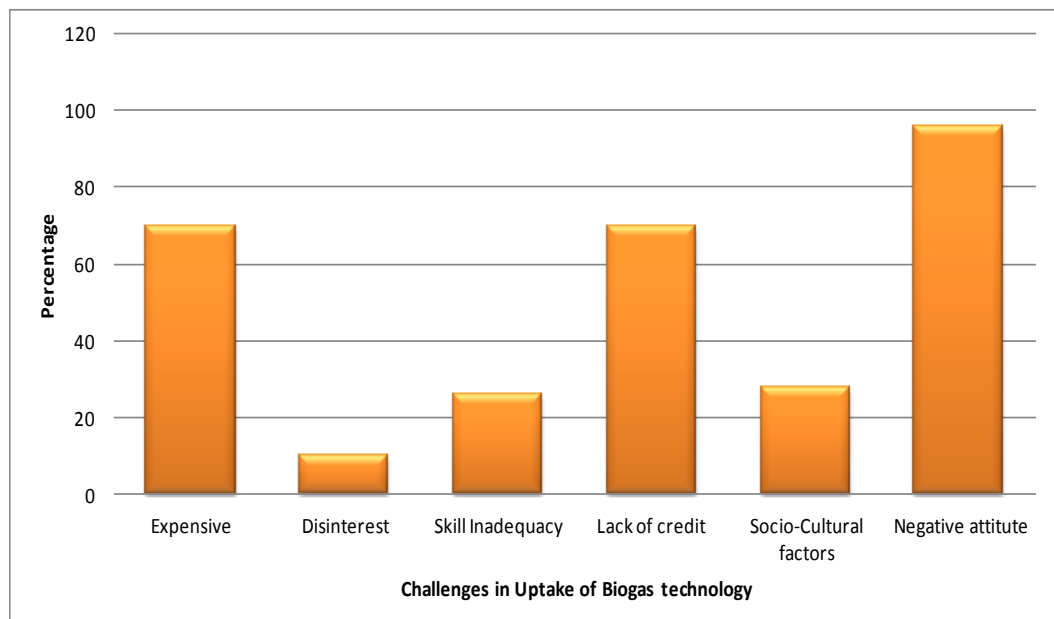


Figure 4. 2 Challenges faced in the uptake of biogas technology in the study area

In a study of the potential of biogas energy in Kenya, Jonusauskait (2010) found that the high upfront investment costs coupled with duty of 25% and a 16% VAT of all imported biogas appliances with the exception for the small biogas generators renders the prices of biogas appliances uncompetitive and discourages their use. Biogas users are left with the option of using inefficient LPG appliances which are unprofessionally modified by the various biogas systems builders to certify the need

of their customers (Bond and Templeton, 2011). Some of the respondents felt that some social-cultural factors (26%) hindered the uptake of the biogas technology in the study area, particularly in the surrounding environment, at least from information of the staff of CITC and SPTC colleges. For instance, according to the tutors, the prevailing social structures on land tenure system in the study area had prevented some of the women who were willing to adopt biogas technology not if their husbands were not willing or far away, as family land and resources belong to the man. In Sudan, socio-cultural beliefs influenced the acceptability of biogas technology in some of the rural communities (Omer and Fadalla, 2009). This shows that cultural factors do hinder the uptake of biogas technology.

The other factor that hindered the uptake of the technology was negative attitude (96%) and the notion that biogas energy was dirty technology as it used animal waste to cook. In Tanzania, a study by Mwakaje (2008) revealed that people, who have not adopted biogas technology (95.0%), had the perception that biogas energy is a dirty thing; however, on seeing physically the functioning of bio-latrines, many households were motivated to adopt the technology. The potential biogas fuel users need biogas oriented training through demonstrations and dissemination of information on how biogas digesters work; the importance and viability of biogas energy in improving livelihoods and environmental management.

The limited availability of well trained and skilled biogas technicians was another barrier attributed to the low adoption status in the study area. According to the tutors, the highly skilled biogas technicians were based either in Nanyuki or Embu and this increased the cost of installing biogas to cover their transport costs. This trend tallies with Amigun *et al.*, (2008) views that biogas technology adoption in many African countries has remained low due to lack of locally trained biogas technicians.

According to Mugo and Gatheha, (2010) for increased adoption of biogas technology to occur, there is need to have sufficient number of trained artisans at the local level who can construct effective biogas units and provide quality services for any interested clients at a reasonable cost. This shows that if local people are trained in

biogas installation, operation and maintenance skills then the adoption rates would increase in the study area. Thus, the draft National Energy policy should be implemented and initiate capacity building programmes in institutions such as village polytechnics on biogas plant installation, operation and maintenance skills to provide quality service to potential clients at the local level.

The other major factor is the lack of credit facilities (70%). According to the respondents, the high initial cost and lack of credit financing arrangements have hampered the uptake of the technology among the potential clients. This clearly indicates that some of the potential biogas users may not have the cash to pay for biogas plants upfront, thus they cannot benefit from biogas. In Tanzania, 95 % of the dairy farmers reported that lack of credit facilities was one of the major factors for the low adoption status of biogas technology among potential users (Mwakaje, 2008). These results agree with the findings of this study. A large percentage (70.0%) of the respondents was in the view that many of the micro- finance institutions in the study area lacked loan products for the installation of biogas plants. This may suggest that if the local micro-finance institutions provided low interest loans for biogas procurement, many households in the study area could adopt the technology.

The study further attempted to explore the availability of the commonest material for use of biogas production. These materials included animal, human and kitchen waste. The study indicated a rate of 21.7% agreement by all the respondents on the availability of the raw materials used in the production of biogas fuel. Summing over for total for all the materials, 60.0% of respondents indicated that the raw materials for biogas production are readily available (Figure 4.3). A Univariate Chi-square analysis indicated a significant proportion of the respondents attesting to the availability of the raw materials ( $\chi^2=5.671$ ,  $df=1$ ,  $p=0.000$ ).

The study revealed that raw materials for production of biogas fuel were readily available (Figure 4.3).

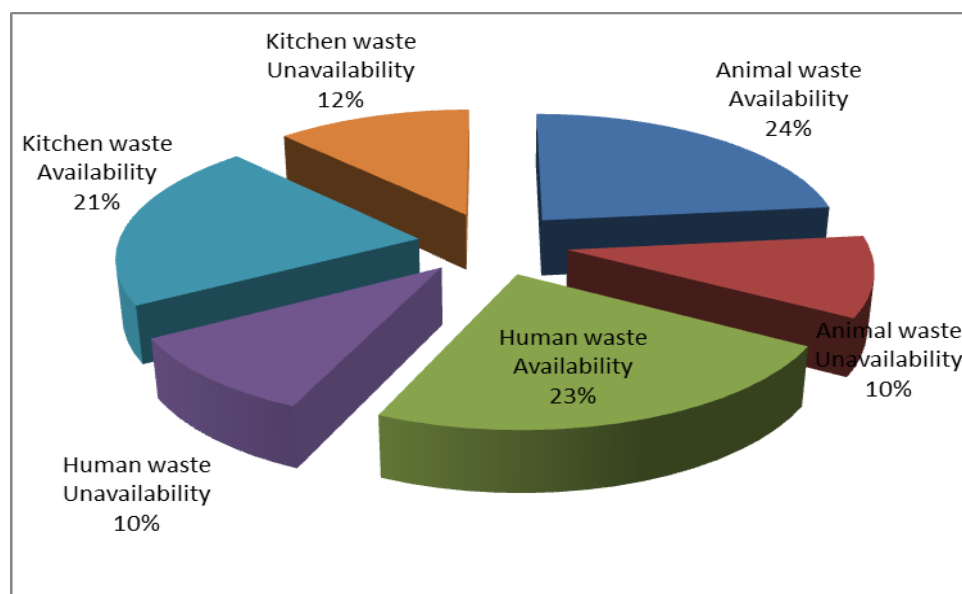


Figure 4. 3 Availability of raw materials for production of biogas fuel

The institutional and individual decision to adopt biogas fuel was because of a number of reasons. These included; its low cost, appropriateness and ease of getting raw materials for production of biogas fuel. From the results, 85.4% of the students indicated that production of biogas fuel is cheaper and affordable as compared to other sources of energy. This was followed by the ease to get it at 7.7% (Figure 4.4).

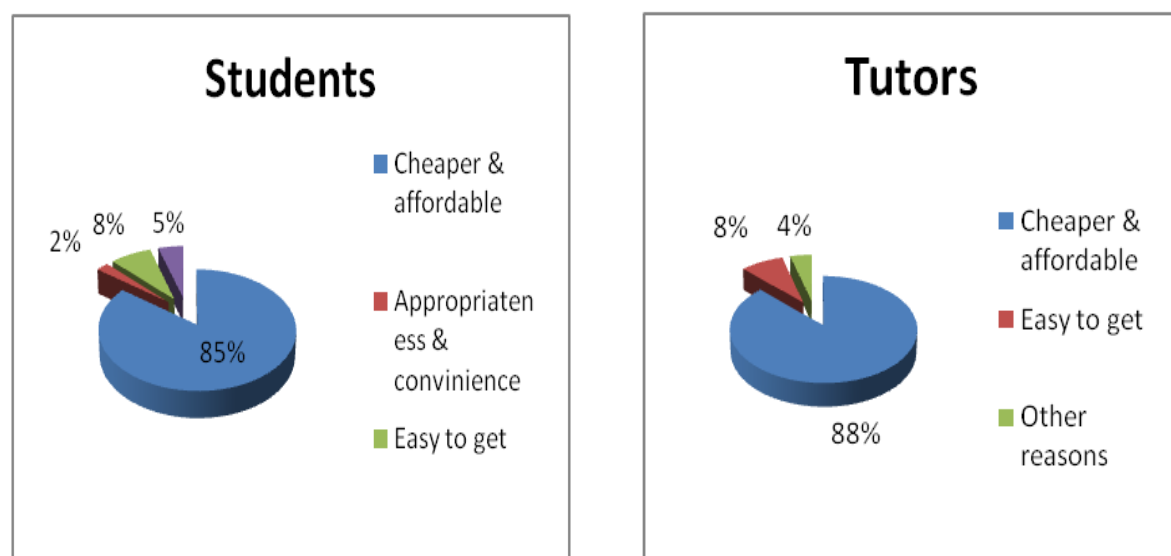


Figure 4. 4 Institutional and individual decision to adopt biogas fuel

In the tutor category, 87.5% indicated that biogas fuel is cheap and affordable, 8.3% said it is easy to get while 4.2% gave other reasons like not having an alternative source of energy. Largely because of the low cost of biogas fuel, most of the respondents are of the view that biogas fuel should be wholly adopted in the training institutions.

Further challenges indicated that the study relied on the case of CITC to establish the main challenges that stand in the way of using biogas energy. According to staff of CITC, the staff cited the challenges that they encounter when using biogas fuel. The staff in CITC cited low gas production (48.5%), vandalism of plastic sheet (7.6%) by people, gas leakage (28.5%) and blockage of inlet pipe (15.4%). The college was using plastic tubular digesters that failed to meet their energy demands as a result of low gas production which was brought about by gas leakages, blockage and vandalism of plastic sheet. This forced the training institutions to use their previous conventional fuel sources. The study according to Yadvila *et al.*, (2008), concurs with the results of the study from CITC that there was low gas production due to the above mentioned challenges (Figure 4.5).

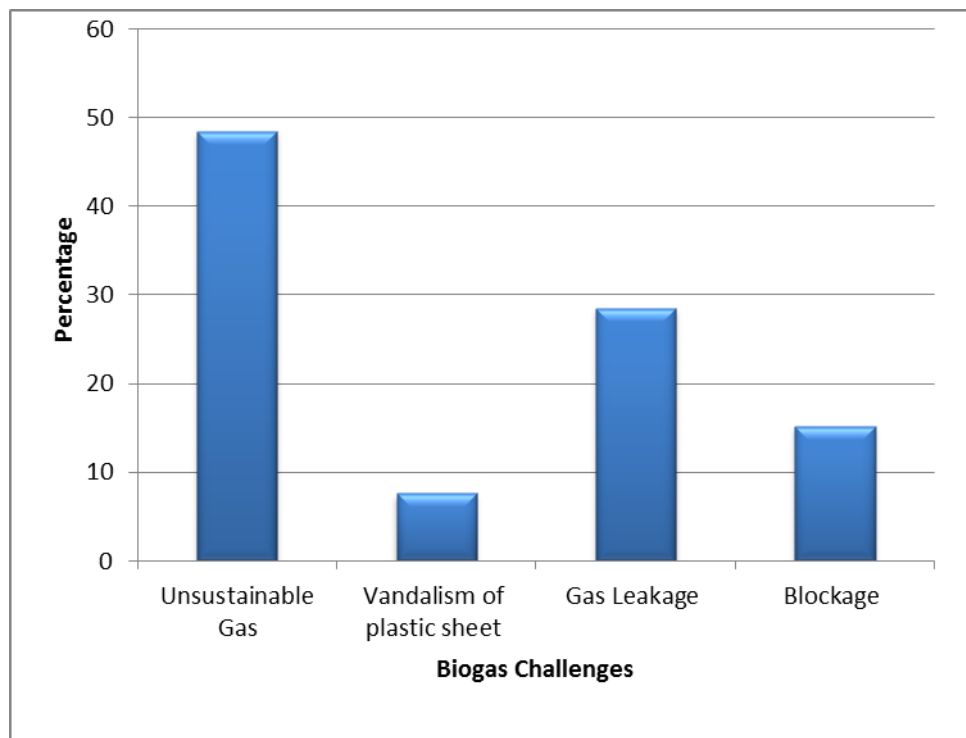


Figure 4. 5 Challenges of Using Biogas Technology at CITC

The other challenge mentioned by the staff at CITC was vandalism of plastic sheet (7.7%). In most cases, the plastic tubular digesters are exposed to the sun to enhance anaerobic breakdown of organic materials, and this exposes the sheet to the risk of being pierced by people with sharp objects, especially naughty students. The college had learnt to overcome the challenge of vandalism by fencing up the area covered by digesters and growing cover crops such as pumpkins to provide shade and camouflage the plastic sheet.

The other major challenge that the college experienced was gas leakage. According to Bond and Templeton (2011) gas leakage is a common problem regardless of the biogas digester design. Any loss through leakages minimizes the chances for customer satisfaction. It was common to see leaking pipes strapped with rubber tube straps to prevent gas leakage. This result shows that technical problems with the plastic tubular digesters were resolved more easily with users doing repairs on their own digesters without the help of a biogas technician.

Blockage of biogas digesters outlet pipe was another challenge mentioned by the staff of CITC. A blockage in the digester occurs when the digested manure attaches itself to the pipe which should transport the bio-slurry outside (Bond and Templeton, 2011). In many developing countries inadequate expertise for construction and maintenance of biogas plants is often cited as one of the major constraints hindering dissemination of biogas technology (Mwakaje, 2008). As such, the recent formation of the Association of Biogas Contractors in Kenya should put in place a legal, regulatory framework and establish quality control standards to guide the entire process of building a biogas unit including informing the potential client on what to expect of biogas technology. Overall, the benefits accrued from the use of biogas clearly outweigh the challenges faced by the users.

#### **4.4 Awareness and Utilities of Biogas Energy**

The study sought to establish the awareness of the respondents on biogas energy. In particular, the respondents were asked if they have heard about biogas fuel with the aim of ascertaining their knowledge on it.

The study results gave a significant awareness of biogas energy with 97.7 % of the respondents having had knowledge about biogas fuel (Table 4.12). Some of the respondents learned about biogas fuel through the media while others learned through the Christian community services around their training institution. The majority of the students' respondents (97.7%) had an idea about biogas fuel.

Table 4. 12 Awareness about biogas fuel

<b>Response</b>	<b>Frequency</b>	<b>Percent</b>
Yes	254	97.7
No	6	2.3
<b>Total</b>	<b>260</b>	<b>100.0</b>

The result above implies that adoption and utilization of biogas fuel is largely dependent on the awareness of the populace. According to Mwakaje (2008) revealed that people who have not adopted biogas technology had the perception that biogas energy is a dirty thing; however, on seeing physically the functioning of bio-latrines, many households were motivated to adopt the technology. The potential biogas fuel users need biogas oriented training through demonstrations and dissemination of information on how biogas digesters work; the importance and viability of biogas energy in improving livelihoods and environmental management.

This concurs with the results of the study that the respondents who have adopted biogas technology have a positive attitude as compared to those who have not adopted. Other than the continuous use of biogas fuel, how the consumer learned to adopt and use it gives the overall picture of the extent of its utilization. For those who understood the details of biogas fuel they reiterated the effectiveness of the fuel.

The utilities of biogas energy were rated on as good, very good or excellent.

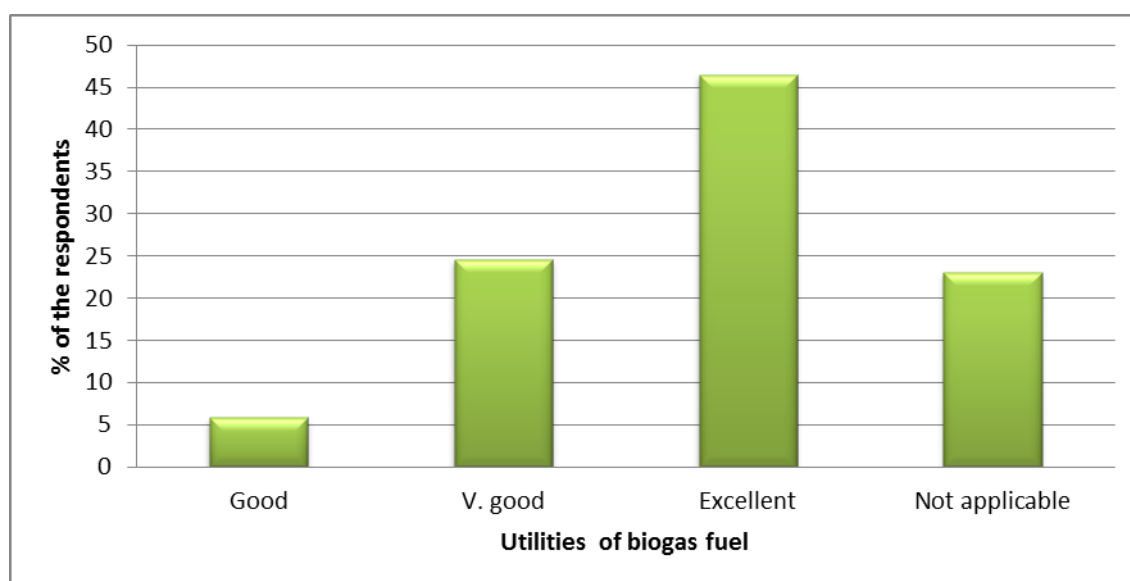


Figure 4. 6 Utilities of biogas fuel compared to other sources of energy

The proportions of the respondents who indicated that the biogas energy was excellently effective comprised 46.5%. This was followed by those who rated it as a very good fuel at 24.6%. Majority (79.1%) respondents indicated that use of biogas fuel is very effective as compared to other sources of fuel (Figure 4.6).

#### 4.5 Hypothesis Testing

The study postulated two hypotheses; one, use of biogas fuel affects human health negatively and two, use of biogas fuel harms the environment. To test these hypotheses, Chi-square test of independence was used. In the test, two categories were noted in each case. Therefore, the cross tabulation for the variable involved in the hypotheses was generated and p-value noted and interpretation made.

In the table 4.13 below, the number of those who responded that use of biogas fuel affects the environment negatively was four (4). The Chi-square test was carried out and the p-value noted. It indicated that there is a significant difference between the variables compared and since those who responded no were more (n=29), the hypothesis that “biogas fuel affect the environment negatively” is rejected at

significance level 95% and conclude that use of biogas fuel does not affect the environment negatively.

A similar test was carried for the other hypothesis “biogas fuel affects human health negatively” and the Chi-square test made. The observed n who responded that use of biogas fuel does not compromise human health was significant (n=248) while those who indicated that use of biogas fuel affects human health negatively were 12. The p-value of 0.000 meant that we reject the hypotheses and conclude that use of biogas fuel does not affect human health negatively.

Table 4. 13 Chi-square tests of hypothesis - Effect of biogas fuel on health

<b>Statement</b>	<b>Response</b>	<b>Observed n</b>	<b>Expected n</b>	<b>Residual</b>		
Environmental Harm	Yes	4	16.5	-12.5	$\chi^2$	18.94
	No	29	16.5	12.5	df	1
	Total	33			p-value	.000
Effect on Health	Yes	12	130.0	-115.0	$\chi^2$	203.46
	No	248	130.0	115.0	df	1
<b>Total</b>		<b>260</b>			<b>p-value</b>	<b>.000</b>

The majority of the observed n responded that use of biogas fuel does not harm the environment. ( $\chi^2=18.94$ , df=1, p-value=0.000).

## **CHAPTER FIVE: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS**

### **5.1 Summary of Findings**

This study focused on attitudes influencing adoption of biogas fuel in selected Christian based training institutions in Nandi County, Kenya. This was as a result of uncontrolled harvesting of trees and shrubs for wood fuel that has led to environmental drawbacks (deforestation and pollution). Due to these challenges, there need to have alternative source of fuel that is sustainable and environmentally friendly. The study was carried out in CITC and SPTC training institutions both located at Kapsabet town, Nandi County. The research instruments involved were existing documentary records obtained from the two training institutions, interview schedules, and questionnaires. The data collected were analyzed using descriptive statistics and results presented in tables, frequencies and percentages.

From the study findings, the attitude of adopters and non-adopters was not significantly different and hence the use of biogas fuel as a source of energy in training institutions was varied. The institutions have not adopted biogas fuel as alternative source of energy and neither have individuals in the institutions used biogas fuel in their homes. Most of the institutions and majority of the individual respondents use wood as the main source of fuel since its readily available and cheap.

However, despite the fact that majority of the respondent have not adopted use of biogas energy, they agree that it is an excellent and convenient source of energy. The study results concur with Jury *et al.*, (2010), that the biogas technology was considered to be an excellent tool for improving life, and livelihoods in the developing world. It also agrees with Raskovic *et al.*, (2009), that biogas technology is a very good solution to local energy needs, and provides significant benefits to human and ecosystem health. A significant majority of the non-adopters of biogas energy had negative attitude and consequently they have not adopted biogas as a source of energy in training institutions as well as home.

The adopters of biogas energy view it as a fuel that is relatively cheaper than other sources and its use leads to good conservation of the environment. This resonates well with Drabez *et al.*, (2009) that use of biogas fuel leads to conservation of environment. In addition Drabez *et al.*, (2009) adds that raw materials for biogas fuel production are readily available and installation of biogas plant does not require a lot of space. Further it indicated that biogas fuel produce clean energy which does not compromise human health. The factors that influence adoption and use of biogas fuel were varied during the research study.

The respondents identified the following factors as influencing adoption and use of biogas energy. They include conservation of the environment, biogas fuel production materials are readily available and it is a clean energy which does not compromise human health. In addition, there was no much expertise in its installation, maintenance and use. Also the availability of skilled manpower and space for installation of biogas plant enhances its adoption and use of the fuel in training institutions and homes. These were attributed to the raw materials for biogas fuel production being readily available which reconciles with figure 4.6 and installation of biogas plant does not require a lot of space which concurs with Zeng, and Ma, (2007).

The availability of raw materials such as animal waste, human waste and kitchen waste was found to favor the adoption and use of biogas fuel in training institutions. The cost of production of biogas fuel also influences its adoption since it was found that it is relatively cheaper than other sources. Biogas fuel produces clean energy which does not compromise human health and its use leads to conservation of environment.

## **5.2 Conclusions**

In the study, there are a number of facts that became clear, for instance, there was poor awareness among the populace and the adoption of biogas energy as alternative source of energy would lead to conservation of the environment. However, there are factors that need to be addressed if biogas energy is to be widely adopted. Therefore, the study made the following conclusions.

1. Biogas fuel perceptions among potential customers were poor unless they are exposed to local promotion activities. Even though potential customers are moderately positive about the biogas technology, the demand is low and households perceive too many barriers. However, there was a misconception between the actual costs of applying biogas technology and the costs potential clients perceive.
2. Potential households are poorly informed about the costs of applying biogas technology, the facilitation of loans for construction and the financial benefits of applying biogas technology. The local promotion activities are most effective and mass communication exposures are highly inefficient. Attitude can be changed if people perceive benefits despite the cultural and religious taboos relating to night soil from toilets. Educating the farmers on the direct (less fuel wood, labor or smoke) and indirect benefits (better health, education, food production) of biogas systems is an important factor in motivating them to adopt biogas systems. This also applied to Government officials, who responded by including biogas development in the overall national development.
3. Biogas fuel was adopted and utilized as an alternative source of energy that could lead to the improvement of environmental quality in learning institutions compared to other sources of energy. From the study the adoption and utilization of biogas fuel as an alternative source of energy has led to the improvement of environmental quality in training institutions and also produce clean energy which does not compromise human health. The availability of animal waste and human waste as raw materials significantly affect the production of biogas fuel. The use of biogas fuel mitigates a wide spectrum of environmental undesirables as it improves sanitation, reduces greenhouse gas emissions, demand for wood and charcoal for cooking and therefore helps preserve forested areas. The study concludes that use of biogas fuel is a very good solution to local energy needs, and provides significant benefits to human and ecosystem health. The fact that biogas conserves the environment is a very important aspect of its use. The use of biogas fuel conserves the environment and is therefore clean since it uses wastes that would otherwise be pollutants. Such wastes decompose and

eventually become harmless. Their use as fertilizer can bring some economic dimensions on the part of the adopters or biogas users

4. The awareness of biogas technology is critical to the adoption of biogas fuel. Public and private agencies comprising of government and NGOs need to step up campaign on the use of biogas energy, particularly for the rural populace. This ought to be done through all means possible to reach as much audience as possible.

More and more people need to be employed to act as community mobilizers who can turn around factors that hinder adoption and utilization of biogas energy.

### **5.3 Recommendation**

From the study the following recommendations were made;

1. The trainings on installing other energy systems as well or cluster themselves with other specialists. This way they can offer a range of energy solutions to rural households and are not limited to a single product.
2. The use of biogas fuel is not without challenges during its use. Institutions and members of the public need to be given support when using biogas energy. Issues of maintenance need be given as an impendent service since this will ensure continued use of the technology and not revert to conventional fuel sources.
3. National Energy Policy draft should be brought into force and zero rate VAT and reduce customs duty on biogas plants and equipment to promote adoption of biogas units especially among potential users.
4. There is need to reach a high penetration degree in the localities where the adoption of biogas technology is currently active, focus should be based on individuals with a high status in the community (the early adaptors) to create a spin-off of the technology (through social peer pressure).
5. The government should provide the community with appropriate tools and skills to effectively sell biodigesters.
6. There should be capacity building to create awareness to people about the benefits of biogas fuel at a young age. Institutions should provide materials

about the importance of the environment and the benefits of biogas fuel. This will enable them to make sensible choices when they grow older.

7. The public and private biogas actors should carry out massive community/public awareness on the benefits and potential of biogas technology by show casing the benefits to each gender.

### **5.5 Areas for further research**

From the study the following areas for further research were made;

1. Other studies should be carried out on safe storage of biogas energy that is produced locally in institutions and community.
2. Pertaining to biogas energy, an evaluation and the role of public and private agents need to be carried to ascertain their impacts in the wake of the negative attitude and socio-cultural factors.

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## APPENDICES

## APPENDIX I: LETTER OF INTRODUCTION FROM UNIVERSITY



KENYATTA UNIVERSITY  
GRADUATE SCHOOL

E-mail: [kubps@yahoo.com](mailto:kubps@yahoo.com)  
[dean-graduate@ku.ac.ke](mailto:dean-graduate@ku.ac.ke)  
Website: [www.ku.ac.ke](http://www.ku.ac.ke)

P.O. Box 43844, 00100  
NAIROBI, KENYA  
Tel. 8710901 Ext. 57530

Our Ref: N50/CE/14480/09

Date: 4<sup>th</sup> March, 2012

The Permanent Secretary,  
Ministry of Higher Education, Science & Technology,  
P.O. Box 30040,  
NAIROBI

Dear Sir/Madam,

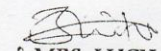
**RE: RESEARCH AUTHORIZATION FOR RISPER CHELAGAT TARUS REG.NO  
N50/CE/14480/09**

I write to introduce Risper Chelagat Tarus who is a Postgraduate Student of this University. She is registered for a M.Envi degree programme in the Department of Environmental Education in the School of Environmental Studies.

Ms. Tarus intends to conduct research for a Thesis Proposal entitled, "Factors Influencing Adoption of Biogas Technology in Learning Institutions in Nandi County, Kenya".

Any assistance given will be highly appreciated.

Yours faithfully,

  
f MRS. LUCY N. MBAABU  
FOR: DEAN, GRADUATE SCHOOL

LNM/rwm

**APPENDIX II: LETTER TO THE PRINCIPALS OF THE INSTITUTIONS**

Risper C. Tarus,  
Kenyatta University  
P.O. Box 43844-00100,  
Department of Environmental  
Education  
**Nairobi.**

The Principal,  
CITC,  
P.O. Box  
**Kapsabet.**

Dear Sir/ Madam,

Re: Questionnaire

I am a master's student carrying out a research study on *ATTITUDES INFLUENCING ADOPTION OF BIOGAS FUEL AMONG WORKERS AND LEARNERS IN SELECTED CHRISTIAN BASED TRAINING INSTITUTIONS IN NANDI COUNTY*. By agreeing to participate in the study you signal your informed consent for your voluntary participation. This questionnaire will not take more than 20 minutes to complete and I'm seeking for your honest opinion. Please feel free to respond to the item responses in their raw form. The information given will be treated confidential. In case of any difficulty please do not hesitate to call me on 0726 268 124. I will be forever grateful for your kind assistance.

Thanks in advance.

Yours faithfully,

Tarus C. Risper

Risper C. Tarus  
Kenyatta University  
P.O. Box 43844-00100,  
Department of Environmental Education  
**Nairobi.**

The Principal,  
St. Paul's Theological College,  
P.O. Box  
**Kapsabet.**

Dear Sir/ Madam,

Re: Questionnaire

I am a master's student carrying out a research study on *ATTITUDES INFLUENCING ADOPTION OF BIOGAS FUEL AMONG WORKERS AND LEARNERS IN SELECTED CHRISTIAN BASED TRAINING INSTITUTIONS IN NANDI COUNTY*. By agreeing to participate in the study you signal your informed consent for your voluntary participation. This questionnaire will not take more than 20 minutes to complete and I'm seeking for your honest opinion. Please feel free to respond to the item responses in their raw form. The information given will be treated confidential. In case of any difficulty please do not hesitate to call me on 0726 268 124. I will be forever grateful for your kind assistance.

Thanks in advance.

Yours faithfully,

Tarus C. Risper

**APPENDIX III SELF-INTRODUCTION TO RESPONDENTS**

KENYATTA UNIVERSITY

P.O. Box 43844-00100,

NAIROBI.

Date: 9<sup>th</sup> December, 2012.

Dear Sir/Madam

I am a student at Kenyatta University, School of Environmental Studies, Department of Environmental Education, pursuing a Master of Science in Environmental Education. Currently, I am conducting a research study entitled.

***“ATTITUDES INFLUENCING ADOPTION OF BIOGAS FUEL AMONG WORKERS AND LEARNERS IN SELECTED CHRISTIAN BASED TRAINING INSTITUTIONS IN NANDI COUNTY, KENYA”***

The findings of this study will contribute to knowledge that will greatly assist the training institutions in making decisions regarding adoption of biogas fuel in Nandi County. You have been identified as one of the respondents in this study because, you are considered to be well qualified, experienced and possess the attributes and characteristics sought in this study. The purpose of this letter is to request for your participation by responding to the question items regarding the study and returning it on the date specified. There will be no direct benefits, no risks, no hazards or discomforts associated with this study procedures. Identity is concealed and therefore, you are requested not to reveal your name and information provided will be highly confidential and will be used only for the purpose of this study.

Participation is voluntary and that you may, at any time during the course of this study be free to withdraw without any penalty, injury or loss of benefits if any.

Kindly return this questionnaire/instrument by January 1<sup>st</sup> 2013.

Thanks in advance

Yours faithfully

Risper Chelagat Tarus - Researcher

Cell Phone No 0726 268 124

#### APPENDIX IV: QUESTIONNAIRE FOR PRINCIPAL

*This Questionnaire is for collecting data on FACTORS INFLUENCING ADOPTION OF BIOGAS FUEL AMONG WORKERS AND LEARNERS IN SELECTED CHRISTIAN BASED TRAINING INSTITUTIONS IN NANDI COUNTY. All the information given shall be treated as confidential. To enhance confidentiality, do not enter your name or that of your school in the Questionnaire.*

Please read the following statements and then respond by placing a check mark in the box or space that best represents your opinion on the issue addressed in the statement.

##### **Section I: Background Information**

1. What is your gender?
  
2. What is your age?
  
3. How long have you been in the training institution?
  
4. What is your highest academic qualification?
  
5. What professional courses have you attended in the last five years?

##### **Section II: General Information about the Training Institution**

1. Which is the training institution's operation status (**Tick as appropriate?**)

Boarding ( )    Day ( )    Boarding and Day ( )

2. When was the training institution started?
3. Show the training institution's yearly enrolment

YEAR	TOTAL ENROLMENT
2008	
2009	
2010	
2011	

5. What is the size of your training institution's land in terms of acreage?
6. How do you utilize the training institution's land?
7. Does the training institution keep cattle?
8. How does the institution utilize the waste products from cattle?
9. What does your institution use for fuel? (Tick as appropriate)  
Wood fuel ( )      Gas fuel ( )      Electricity ( )
10. What are the reasons why you opted for the fuel in 9 above?
11. What is the approximate monthly cost of the fuel used?
12. Have you heard of biogas fuel?    YES ( )      NO ( )
13. Have you used biogas fuel?      YES ( )      NO ( )
14. How did you learn about biogas fuel?
15. Do you have a family?
16. (i) Do your family use biogas fuel?  
  
(ii). If yes, how do you compare the cost of biogas fuel and that of firewood?  
  
(iii). Does the use of firewood harm the environment?

Tick the appropriate in the following table.

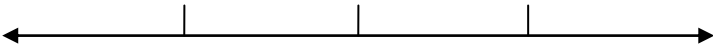
	<b>Statement</b>	<b>Strongly Agree</b>	<b>Agree</b>	<b>Disagree</b>	<b>Strongly Disagree</b>
1	Biogas fuel use in the training institutions is a cheap source				
2	Use of biogas energy in training institutions conserves environment				
3	Use of biogas fuel in training institutions require high skilled labour				
4	Use of biogas fuel in training institutions enhance good health among its users				
5	Use of biogas fuel in training institutions saves more time used to fetch biomass fuel				

**Thank you very much for taking your precious time to fill this questionnaire.**

## APPENDIX V: QUESTIONNAIRE FOR THE TUTORS

*Please read the following statements and then respond by placing a check mark in the box or space that best represents your opinion on the issue addressed in the statement*

1. What is your gender?
  
2. What is your age?
  
3. Which is the training institution's common type of fuel? (**Tick as appropriate**)  
 Wood fuel ( ) Gas fuel ( ) Electricity ( )
  
4. What are the reasons why the training institution opted for the fuel in 3 above?
  
5. Have you heard about biogas fuel use? A. [YES] B. [NO]
  
6. How did you learn about biogas fuel?
  
7. (i). Do you have a family?  
  
 (ii). If yes, how do you support it in terms of energy fuel?
  
8. (i). Do you use biogas fuel at home? A. [YES] B. [NO]  
  
 (ii). If yes, how do you compare it with other type of fuels in terms of cost?  
 Low High
  



  
9. In relation to vision 2030 of the United Nations, how would you sensitize people on the importance of biogas fuel as a clean and renewable energy?
  
10. What were some of the strengths in the use of biogas fuel?

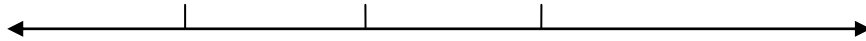
11. What were some of the challenges in the use of biogas fuel?

12. (i) Does biogas fuel use affect the environment negatively? [YES] B. [NO]

(ii). If yes, what is the level of the effect on the environment?

Low

High



13. Is the cost incurred in biogas fuel production affordable to middle level earners?

A. [YES] B. [NO]

14. Does the biogas fuel use affect the human being's health?

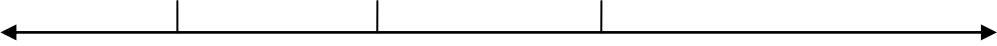
A. [YES] B. [NO]

15. What is your view about its use in learning institutions?

**Thank you very much for taking your precious time to fill this questionnaire.**

## APPENDIX VI: QUESTIONNAIRE FOR THE STUDENTS

*Please read the following statements and then respond by placing a check mark in the box or space that best represents your opinion on the issue addressed in the statement*

1. What is your gender?
  2. What is your age?
  3. What is your level of study?
  4. Which is the training institution's common type of fuel? (**Tick as appropriate**)  
Wood fuel ( ) Gas fuel ( ) Electricity ( )
  5. What could be the reasons why the training institution opted for the fuel in 4 above?
  6. Have you heard about biogas fuel? A. [YES] B. [NO]
  7. (i). Have you ever used biogas energy at your home? A. [YES] B. [NO]
  - (ii) If yes, how can you rate its effectiveness compared to other sources of energy?  
Poor Excellent
- 
8. Briefly state some of its strengths in the use?
  9. Briefly state some of its challenges in the use?
  11. Does the use of biogas fuel harm the environment?  
A. [YES] B. [NO]

12. Does the biogas fuel use affect human's health?

A. [YES] B. [NO]

13. What is your view about its use in training institutions?

14. What is your opinion on the role of biogas technology in improving environmental quality in the training institution?

15 How would you advice training institutions on the use of biogas fuel?

16. What is your future plan concerning biogas fuel use as a clean energy?

**Thank you very much for taking your precious time to fill this questionnaire.**

**APPENDIX VII: QUESTIONNAIRE FOR THE NON TEACHING STAFF**

*Please read the following statements and then respond by placing a check mark in the box or space that best represents your opinion on the issue addressed in the statement*

1. What is your gender?

2. What is your age?

3. How long have you been in the training institution?

4. Which is the training institution's common type of fuel? (**Tick as appropriate**)

Wood fuel ( ) Gas fuel ( ) Electricity ( )

5. What could be the reasons why the training institution opted for the fuel in 4 above?

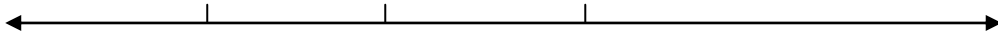
6. Have you heard of biogas fuel? A. [YES] B. [NO]

7. (i). Have you used biogas fuel at home? A. [YES] B. [NO]

(ii). If yes, how can you rate its effectiveness compared to other sources of energy?

Poor

Excellent

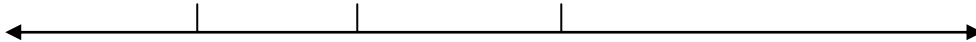


8. (i) Does biogas use harm the environment? A. [YES] B. [NO]

(ii) What is the level of the effect on the environment?

Low

High



10. Compare the cost of biogas fuel production and other fuels used at the institution

11. Does the biogas use affect the human health? A. [YES] B. [NO]

12. What is your view about biogas fuel use in training institutions?

13. How would you advise the training institution on the use of biogas fuel?

### APPENDIX VIII: RELIABILITY ANALYSIS

#### Reliability Statistics

Cronbach's Alpha	n of Items
.716	6

#### Item Statistics

	Mean	Std. Deviation	N
Biogas is a good fuel to use	2.24	.902	33
Biogas fuel is relatively cheaper than other sources	1.82	.584	33
Raw materials for biogas fuel production are readily available	3.67	.890	33
Installation of biogas plant do not require a lot of space	3.55	.833	33
Biogas fuel produce clean energy which do not compromise human health	4.24	.614	33
No impact benefit	1.82	.683	33