ASSESSING THE CHALLENGES OF ADOPTING BIOGAS TECHNOLOGY IN ENERGY PROVISION AMONG DAIRY FARMERS IN NYERI COUNTY, KENYA.

RUTH WANJIRU WACHERA (B. Env. S (CD)

N50/12315/2009

A Thesis submitted in Partial Fulfilment of the Requirements for the Award of the Degree of Master of Environmental Studies (Community Development) in the School of Environmental Studies of Kenyatta University

October 2014

DECLARATION

This thesis is my original work and has not been presented for any degree or any other award in any other University

Signature…………………………….......Date ……………………………………

Ruth Wanjiru Wachera (B.Env. S (CD))

Department of Environmental Studies and Community Development

Supervisors:

We hereby confirm that this thesis was examined by us as principal University Supervisors.

Dr. Fuchaka Waswa

Department of Agricultural Resources Management

Kenyatta University

Signature……………………………............. Date ……………………………………

Prof. Thomas Thoruwa

Department of Mathematics and Physical Sciences

Pwani University, Kilifi

Signature……………………………........... Date ……………………………………

DEDICATION

To God Almighty for his sufficient grace, to my mother, my son Donnel, Bramuel, family members and friends for their patience and immeasurable assistance offered while battling to finish this work.

ACKNOWLEDGEMENTS

The author wishes to acknowledge Dr. Fuchaka Waswa and Prof. Thomas F.N. Thoruwa for their valuable guidance and encouragement as supervisors in the course of this study. Kenyatta University course lecturers who through many efforts prepared me to carry out this research work. Course mates and work mates for their keen interest, support and encouragement. Special thanks are also extended to my family members and friends; for their material, moral support, love, prayers and encouragement.

Profound appreciation also goes to the Ministry of Agriculture and Livestock Extension Officers (Mukurwe-ini Office), Wakulima Dairy Limited (Mukurwe-ini), Mukurwe-ini Development Initiative and various Subject Matter Specialist (SMS), other key informants and the study area dairy farmers' community for the pertinent information they provided.

Last but not least, the author is indebted to the Horn of Africa Environmental Regional Network (HOAREN) Ethiopia for funding my research. Most sincere thanks are also extended to all farmers of Mukurwe-ini Agro-System, Nyeri County, without whose cooperation, the data would have not been collected.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

ABBREVIATIONS AND ACRONYMS

ADC	Agricultural Development Cooperation
CAP	Community Action Plan
CBO	Community Based Organization
CBS	Central Bureau of Statistics
CSD8	8^{th} Commission for Sustainable Development
DAO	District Agriculture officer
DFID	Department for International Development
FAO	Food and Agriculture Organization of United Nations
FGD	Focus Group Discussion
GEF	Global Environmental Fund
GHG	Green House Gases
GTZ	German Development Organization
HH	Household
IEA	International Energy Agency
IGAD	Inter Governmental Authority on Development
IFAD	International Fund for Agricultural Development
KARI	Kenya Agricultural Research Institute
KENDBIP	Kenya National Domestic Biogas Programme
KNBS	Kenya National Bureau of Statistics
LPG	Liquefied Petroleum Gas
MDGs	Millennium Development Goals

MoE	Ministry of Energy
NAEP	National Agricultural Extension Policy
NALEP	National Agriculture and Livestock Extension Programme
NEMA	National Environment Management Authority
NGO	Non-Government Organisations
PRA	Participatory Rural Appraisal
PTD	Plastic Tubular Digester
RETs	Renewable Energy Technologies
SACCOs	Savings and Credit Cooperative Society
SEP	Special Energy Programme
SMEs	Small and Medium Enterprises
SNV	Netherlands Development Program.
SOE	State of Environment Report
SPSS	Scientific Programme for Social Scientists
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UN Energy	United Nations Energy Programme
UNFCC	United Nations Fund on Climate Change
WCED	World Commission on Environment and Development
WHO	World Health Organization

ABSTRACT

About 90% of Kenya's rural population relies on wood fuel to meet their daily cooking energy needs. The consequences of over reliance on biomass energy are far reaching with adverse effects on the economic, social and environmental spheres of sustainability. Animals are an important source of food and income for many rural people, but their manure is a source of one of the world's most potent greenhouse gases. Turning manure into biogas, as an alternative source of energy has not being fully exploited in Kenya. The study aimed at assessing the challenges of adopting biogas technology in energy provision among dairy farmers. This study employed a descriptive research design: to determine the relative importance of cooking energy sources, to evaluate the impacts of biogas technology on households and assess the challenges facing households in the uptake of biogas technology. It also sought to establish the opportunities available in disseminating biogas technology. To achieve the above objectives, the study sampled 120 households and 7 key informants. Primary data were derived from field surveys using questionnaires, key informant interviews and focus group discussions. Qualitative and quantitative data was descriptively analysed through descriptive statistic like frequencies, correlation coefficients, percentages and measures of central tendency such as means and mode were used to summarize and interpret the research findings. The results of the study show that primary cooking fuels were firewood (76.7%) and charcoal (6.7%). The results also revealed that only about 35.8% of the farmers are using biogas technology. On the impacts of biogas technology, about 88.4 % of the biogas users confirmed reduced household energy costs, over 83.7 % of the users noted reduced work load hence more free time, about 93% of the users indicated that cooking was more convenient while 9.3 % of the farmers confirmed increased income (mean of KES. 3500) from the sale of bio-slurry. In addition, majority of the biogas users made use of bio slurry as an organic fertiliser to maintain soil fertility. As the study indicates, dairy farmers faced challenges in the uptake of biogas technology. These challenges include high installation costs coupled with lack of credit facilities as well as absence of locally trained technicians. On the opportunities towards increasing the uptake of biogas technology among households, the study found that both public and private extensions agents were active involved in promoting biogas technology. However, they are faced with a myriad of setbacks such as poor promotional strategies and limited support by the government; inadequate funds, gender issues, ignorance and low level of awareness about biogas technology. The study concludes that the potential of biogas technology in energy provision is huge but it is poorly tapped. In order to unlock the huge potential of biogas technology, financial credit facilities should be made more accessible especially for the low income farmers, sustained and comprehensive educational and awareness creation on the use of biogas technologies should be enhanced and more efforts ought to be done in training biogas technicians at the local level. This calls for good partnership between public, private sector and civil society.

CHAPTER 1: INTRODUCTION

1.1 Background

In people's daily lives, energy provides essential services for cooking and heating, lighting, food production and storage, education and health services, industrial production, and transportation. However, there is a real energy gap between industrialized areas and poorer, mainly rural and peri-urban communities where obtaining energy for basic human needs is a daily challenge (FAO, 2006). An estimated 2.5 billion people in developing countries rely heavily on biomass, such as fuel wood, charcoal, agricultural waste and animal dung, to meet their energy needs for cooking. In Sub-Sahara Africa and in Asia excluding China and India, 93% of the rural population depend on such resources. It is expected that one third of the world's population will still rely on these fuels until 2030 (IGAD, 2007). Continued over dependence on unsustainable wood fuel and other forms of biomass as primary sources of energy to meet household energy needs has contributed to negative impacts on the environment. In addition, continued use of traditional biomass fuels contributes to poor health among users due to incomplete combustion and smoke emissions in poorly ventilated houses common in rural areas (Biogas for Better Life, An Africa Initiative, 2007).

In Africa, access to energy is a major challenge; the rural poor are seriously affected by the depletion of their energy resources, especially firewood. This has put pressure on women and children and further heightens their vulnerability to falls and attacks during firewood collection.

As distances become longer due to deforestation, wood fuel collection has become a time and energy consuming activity for the average rural woman. Chris (1998) observed that besides the economic hardship associated with gathering and cooking with biomass, the indoor air pollution created by such fuels is a health hazard, particularly to women and children. This is reflected by emissions of smoke during combustion of solid particulate matter that regularly exceed the safe levels as cited by the World Health organization guidelines by several orders of magnitude (World Health Organization, 2009).

Recent report on World Energy Outlook by the International Energy Agency (IEA) clearly stated that "current global trends in energy supply and consumption are *patently unsustainable*" (IEA, 2008). To overcome the situation, it has identified two major energy challenges that the world has to overcome: 1) "securing the supply of reliable and affordable energy" and 2) "effecting a rapid transformation to a low-carbon, efficient and environmentally benign system of energy". To meet these challenges, reducing dependence on oil and biomass has become one of the priority issues for most countries around the world. So far, biofuels such as biogas are the most rapidly expanding and widely used types of renewable household fuel, although they still accounted for only 1.5% of total global household fuel demand in 2006 (IEA, 2008).

In Kenya, wood fuel accounts for 68% of the total primary energy consumption and is much higher in the rural areas where it is estimated to be 80% (UNEP, 2006). This scenario explains the reason behind Kenya's low forest cover of 1.7% (Masinde and

Karanja, 2011) against the World's recommendation of 10% (Government of Kenya, 2011). The demand for energy is expected to grow commensurate with population growth, thereby exerting more pressure on already endangered forest cover (Kulundu, 2003). In addition, the livelihood of people in the Kenya will continue to be significantly impaired by energy poverty thus affecting the social, economic and environmental spheres of the people.

Biogas is an energy technology that has the potential to counteract many adverse social, economic, health and environmental impacts connected with traditional biomass energy use in Kenya. The use of biogas as energy source has proven itself to be an important strategy in solving the problems of energy usage in rural areas of developing countries (Biogas for better life, An Africa Initiative, 2007). By using existing substrates like dung and other waste products to produce biogas, single households and communities can become more or less self-sufficient in terms of energy and in the long run promote sustainable livelihoods among the rural communities (NEMA, 2007).

According to the Ministry of Energy (MoE, 2002), the technical potential for biogas in Kenya is high especially in the high population density areas where zero grazing is practiced. The current market is immature and slow with Non-Governmental Organizations (NGO's) and private sector led sales, led by a small number of pioneers (KENDBIP, 2009). The important role played by biogas technology cannot be over looked. According to Tafdrup (1995), biogas systems can yield a whole range of benefits to the users including production of heat, light and electricity, transformation of organic waste into high quality fertilizer, improvement of hygienic condition and environmental advantages through protection of soil, water and woodlots. Biogas as renewable energy can improve livelihoods of people in a sustainable way. As such, there is need to enhance the use of biogas energy to improving the lives of people especially in the rural setting.

1.2 Problem Statement and Justification

Biomass fuels are the main source of energy in Mukurwe-ini, Nyeri County. However, problems relating to environmental degradation, deforestation, land clearance, population increase and drought are placing more and more pressure on dwindling forest and woodland resources. The resultant energy poverty has continued to have considerable negative social, economic and environmental effects in the study area. Heavy Dependence on biomass fuel has led to wood fuel scarcity and increased opportunity costs due to the additional time spent collecting fuel wood (Mugo and Gathea, 2010).

Several mitigation strategies have been used in the past to avert the situation such as on-farm agro-forestry to provide wood fuel. However, this has not been successful given the number of years trees take to mature before they could be used as wood fuel. Nonetheless, Mukurwe-ini is a high potential area for dairy cattle production with the small holder farms keeping between 2 and 6 dairy cows under zero-grazing units. It was envisaged that these households are all potential adopters of biogas plants. However, observations at the farm level indicate that very few farmers have adopted biogas technology. This research sought to assess the challenges of adopting biogas technology in energy provision among the dairy farmers.Investing in biogas technology at farm level will reduce dependence on trees and thus help in forest conservation, mitigation of the effects of climate change, alleviate poverty and thus contributing to community well-being. These benefits are all envisaged in Kenya's Vision 2030, 2010 Kenya National Constitution, Agenda 21 and in the Millennium Development Goals.

1.3 Objectives

The overall objective of this study was to assess the challenges of adopting biogas technology despite its potential to enhance energy provision among small-holder dairy farmers. The specific objectives were to:

i. Determine the relative importance of energy sources among the smallholder dairy farmers;
ii. Assess the challenges affecting farmers in adopting biogas technology in the study area
iii. Assess the opportunities available for increasing adoption of biogas technology within individual households in the study area.

1.4 Research Questions

This study was guided by the following key questions:

i. What is the relative importance of energy sources at the household level?
ii. What challenges do smallholder dairy farmers face in the adoption of biogas technology?

iii. What challenges do biogas technology promoters/agents face in advocating and promoting the technology?

iv. How can biogas energy be promoted as an alternative source of the energy in this area?

1.5 Assumption

In this study, the apparent low adoption of biogas technology among Mukurwe-ini Dairy farmers was premised on lack of adequate knowledge of its potential as an alternative energy source.

1.6 Conceptual Framework

In Kenya, wood fuel accounts for 68% of the total primary energy consumption and it is much higher in the rural area where it accounts for 90% of the households that use wood fuel as their main cooking energy (Government of Kenya, 2011). From the conceptual framework (Figure 1.1), the continued use and reliance on wood fuel has led to depletion of biomass leading to woodland degradation. The resulting changes lead to increased expenditure on wood fuel due to high demand and scarcity. In addition, a series of serious eco-environment problems such as loss of carbon sinks through deforestation, soil erosion and indoor air pollution occur. Further, the reliance of wood fuel heightens vulnerability and drudgery for women and children in wood fuel collection and cooking. This could have negative implications on human well-being (Figure 1.1).

The dotted arrow in the figure (1.1) indicates the intervention path with biogas technology which provides the dairy farmers with biogas energy and bio-slurry. By switching to biogas, households will gain an access to improved energy service which will improve human well-being through reduced expenses on energy sources for cooking and reduced wood fuel consumption hence more sustainable use of natural resource base. Further, availability of biogas fuel reduces the pressure on forests. In addition, the installation of a biogas plant will reduce indoor smoke thus better health for the individuals, household and community as a result of employing biogas stoves instead of burning fuel wood.

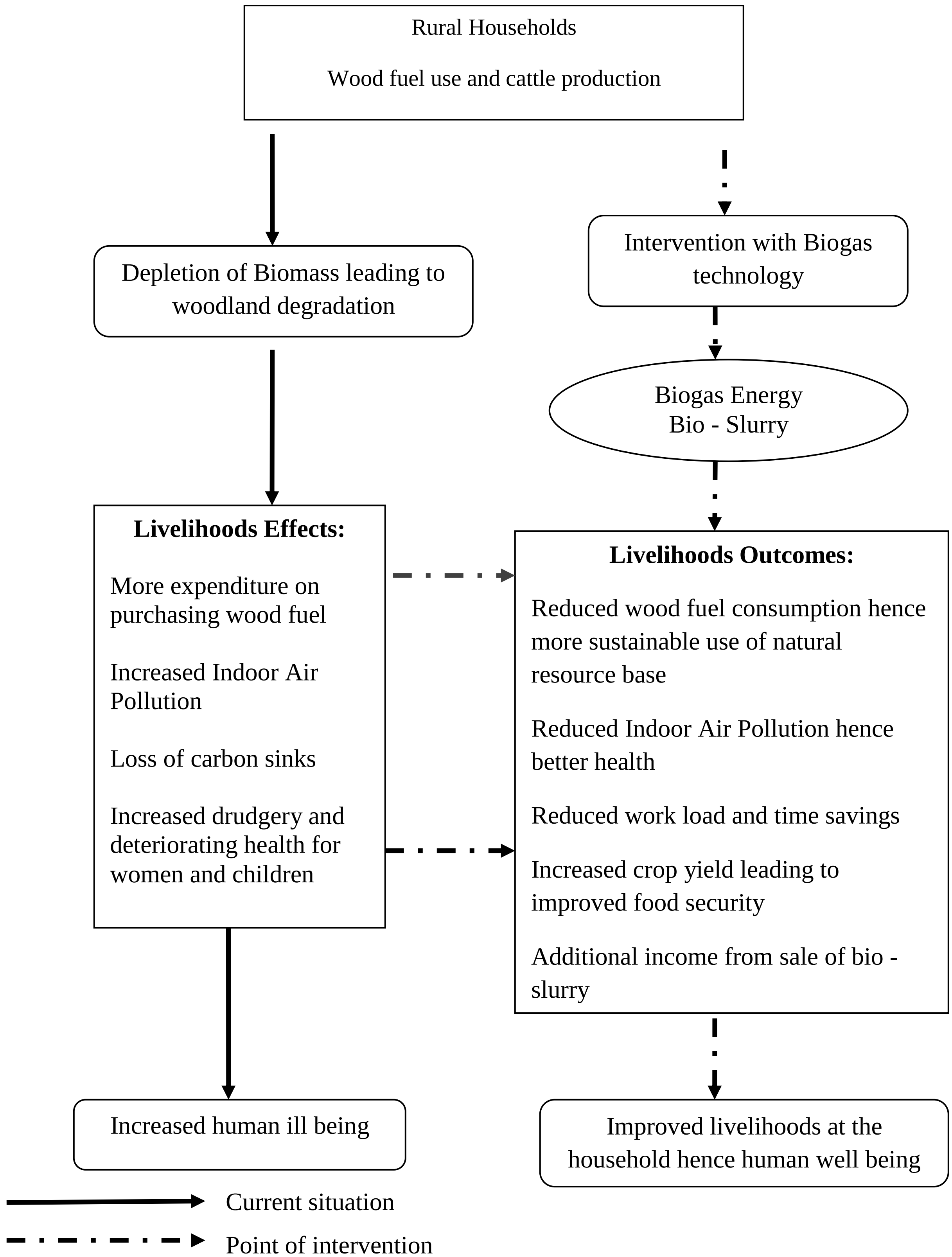


Figure 1.1: Wood fuel – livelihoods conceptual framework (Source: Author)

The presence and the use of biogas among households, will mean significant time savings and reduced workload as biogas will relieve women and female children from the burden of travelling long distances in search of wood fuel, time for preparation of fire and constant fire monitoring. The time spent on fetching firewood could be spent on other more productive activities such as farming, childcare, business ventures, improvement of the home and other community activities.

On the other hand, the bio-slurry coming out of the biogas plants would provide excellent organic manure in which all the useful nutrients remains preserved. This will enable the dairy farmers to save money, which is otherwise, spent for the purchase of costly inorganic fertilizers. The use of bio-slurry on the land will lead to improvement in crop yield thus improve food security at the household level. In addition, the use of bio-slurry will also help in improving micro-flora of the soil and building the soil structure and texture. The bio-slurry may provide income generation opportunities, as some of farmers may try to gain additional income by selling surplus bio-slurry. These would all finally lead to well-being of the dairy farmers. This study sought to explores these linkages with the aim of portraying the potential of biogas technology for improved and sustainable livelihoods among small holder dairy farmers. The results of this study will be geared towards revealing the potential of biogas technology in improving the livelihoods of dairy farmers.

1.7 Definition of Terms

A driver: any natural or human induced factors that directly causes a change in the eco-system

Agriculture Technologies: knowledge and information that farmers access and use.

Biogas: Biogas is a form of renewable energy just as solar, wind, hydrogen and biomass. It is gas that is produced when organic material of animal or plant origin ferments in an oxygen- free/anaerobe environment that utilizes organic waste sources to produce a flammable methane gas suitable for cooking and lighting purposes.

Extension agent: is any person who delivers extension information or messages to farmers or who manages other extension agents in an organization providing extension service whether public or private.

Extension services: it is the process in which knowledge, technology, information, advice and other non-material support are provide to farmers. It is aimed at improve knowledge, change attitude/behaviour, lead to adoption of new technologies thus improving farmers livelihoods.

Gender: can be defined as the socio-cultural construction of roles and relationships between women and men

Human ill-being: a state of poverty which is lack or shortage of capital. It is deprivation of wellbeing lacking material of a good life, physical weakness, vulnerable, isolated and powerless (WHO, 2005)

Human well-being: a state of comprising of basic material for a good life and choice, good health, good social relation and security (WHO, 2005)

Kenya National Domestic Biogas Programme (KENDBIP): it is an umbrella framework for implementing domestic biogas projects in Kenya to improve livelihoods of rural farmers through benefits of domestic biogas and develop of a commercially viable, market oriented biogas sector (KENDIP, 2011)

Land tenure: refers to the terms and conditions under which rights to the land and land based resources are acquired, held, transferred or transmitted

Stakeholders: a person, group or organization or system which affects or can be affected by an organization action

CHAPTER 2: LITERATURE REVIEW

2.1: Introduction

The chapter reviews various studies conducted in the area of biogas technology and sustainable livelihoods from a global to local scenario. It highlights the achievements in the area and explores what challenges remain. The section starts with an overview of global energy consumption and sources of energy, sources of energy and consumption in Kenya, sources of energy and sustainable livelihoods agriculture and energy development, social, economic and ecological benefits of biogas technology and energy and gender perspective. The last section is on the evolution of biogas technology at the household level in Kenya, constraints to adopting the technology and the adequacy of the Kenya's energy policy in promoting biogas energy at the farm level.

2.2: Overview of Global Energy Consumption and Sources of Energy

A major challenge in 21st Century will be that of implementing sustainable development and meeting the energy needs of the ever increasing world's population. According to the International Energy Agency (IEA, 2008), about 2.4 billion people, (that is around a quarter of the world's population) have no access to electricity and rely heavily on unsustainable biomass energy to meet their energy needs (IEA, 2008). Moreover, under today's energy policies and investment trends in energy infrastructure, projections show that as many as 1.4 billion people will still rely on biomass in 2030 (IGAD, 2007).

This scenario is not different in Africa, where figures for Eastern and Southern African countries indicate that a high proportion of total national energy supply is derived from the diminishing biomass energy (Karekezi, 2002). Biomass energy, which refers to a wide range of natural organic fuels such as wood, charcoal, agricultural residues and animal waste, is often used in its traditional and unprocessed form. According to the IEA (2008), even oil rich African countries like Nigeria continue to rely on 97 percent biomass energy to meet their bulk household energy requirements.

The processes of energy production, distribution and consumption have many adverse effects on the local, regional and global environment including indoor, local, regional and global air pollution. It contributes to particulate matter in the air, land degradation, acidification of land and water, and climate change (UN-Energy, 2005). Global consequences of unsustainable use of biomass as source of energy are well documented. Globally, 55% of the wood extracted from forests is for fuel, and fuel wood is responsible for 5% of global deforestation (UNFCC, 2010). Statistics suggest that some 1.86 billion m^3 of wood is extracted from forests for fuel wood and conversion to charcoal. Of this total, roughly one-half comes from Asia, 28% from Africa, 10% from South America, 8% from North and Central America and 4% from Europe.

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. Some 44 percent of these deaths are in children; and among adult deaths. Moreover, burning of biomass discharges carbon dioxide, methane and other greenhouse gases leading to global warming hence climate change (WHO, 2009).As a result, the energy sector has a significant part to play in reducing the environmental damage and harmful effects by introducing renewable and green energy sources to supply modern cooking fuels.

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 effects and to contribute to environmental sustainability (NEMA, 2009).

Kenya is currently in an energy deficit position both for commercial and non-commercial energy. At national level, biomass mostly wood fuel accounts for about 68 percent of the total primary energy consumption, followed by petroleum at 22 percent, electricity at 9 percent and others at about less than 1 percent. In rural areas, the reliance on biomass is over 80 percent (*Session Paper No. 4 of 2004 on Energy*, 2004). Only approximately 15 percent of Kenyans have access to grid electricity. Access to affordable modern energy services is constrained by a combination of low consumer incomes and high installation costs. In the rural areas, where only about 4 percent of the population has access to electricity; the scattered nature of human settlements further escalates distribution costs and reduces accessibility.

According to the Poverty Reduction Strategy Paper for Kenya for the period 2001- 2004, demand for wood fuel outstripped supply, and the country was likely to be faced with a wood fuel deficit of 4.1 million tons in the future. 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. However, the potential of livestock waste has not been effectively utilized in the provision of modern energy for a variety of reasons. One is the failure to exploit the opportunities for transforming wastes from livestock keeping, agricultural production and processing into locally produced modern energy. High incidence of poverty is another constraint to shifting from traditional to modern renewable energy utilization (Biogas for a Better Life an African initiative, 2007). The challenge at hand is how to reduce over-reliance on wood-fuel among the rural poor who have limited access to alternative 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 Energy and Environmental Degradation.

Agenda 21 and the UNFCCC have highlighted the adverse local and global impacts of energy supply and end-use on the environment. Continued over-dependence on unsustainable wood fuel and other forms of biomass as the primary sources of energy to meet household energy needs has contributed to serious environmental drawbacks. These drawbacks include deforestation, soil erosion, air pollution and global warming resulting to climate change (IGAD, 2007).

Moreover, in Africa, the consumption of firewood and charcoal continues to increase, with fuel wood consumption predicted to increase by 2030 to over 137% of the 1970 base rate, while charcoal consumption is expected to increase to over 5 times the 1970 base rate (IGAD, 2007). This is presents a crisis, as the process of charcoal production means that more wood needs to be used in providing energy from charcoal than would be needed for firewood. Furthermore, environmental degradation due to collection of firewood, fodder and shelter materials has resulted to increased soil erosion, surface water pollution, flash- flooding, and loss of natural habitats, which limits livelihoods opportunities. It is predicted that by 2030 the number of people in Africa relying on biomass for cooking and heating is expected to increase to over 140% of the 2000 rate (I.E.A, 2008).

In Kenya, over-reliance on primary biomass energy has led to the widespread exploitation of forest resources with adverse environmental impacts. The forest cover in the country has diminished to 1.7 percent (Masinde and Karanja, 2011); which is substantially below the world's minimum recommended coverage of 10 percent. As a result, there has been a reduction in water levels in rivers and dams leading to inconsistent power supply and frequent power outages. The use of petroleum for power generation does not offer a lasting solution due to fluctuations in global market prices of crude oil, and the climate impacts of increased GHG emissions. Transportation of petroleum over long distances is also risky and contributes to increase in GHG emissions (I.E.A., 2008)

Environmental degradation is further exacerbated by climate variability and unpredictability of rainfall patterns. In addition, continued consumption of traditional biomass fuels contributes to poor health among users due to smoke emissions in the poorly ventilated cook houses common in rural areas. Converting from today's use of biomass into cleaner and green technologies would increase the standard of living, health and local environment and at the same time help reduce climate change. Furthermore it would give an improved chance of economic development. Biogas technology has the potential to counter many adverse changes associated with traditional biomass use. A study in India revealed that an estimated 6 million tons of firewood were replaced by the use of biogas in 1996 (Gautam *et al.*, 2009).

2.4 Sources of Energy and Sustainable Livelihoods

The current patterns of energy production and use, which have shaped the development process in the past, are unsustainable. The challenge currently faced by many countries around the world is providing energy services that allow all people to achieve a decent standard of living, consistent with sustainable human development. This link between energy and development remains a key factor in development policy (IFAD/FAO, 2003).

Energy scarcity, both in terms of availability and suffiency is considered to be the single biggest factor affecting communities' well-being and livelihoods. Worldwide, 2.4 billion people rely on traditional biomass fuel for cooking because they do not have access to modern and renewable fuels (IEA, 2008). Hundreds of millions of people, mainly women and children spend several hours daily gathering firewood, often from considerable distances, for household needs. As result, this demands more of their time and energy thus denying them opportunities in empowerment such as economic, income generating activities and school attendance respectively (Smith *et al.,* 2005).

Welfare research has highlighted that, many developing-countries households use wood fuel stoves that lack working chimneys or hoods for venting the smoke outdoors. Although there have been no large-scale statistically representative surveys, hundreds of small studies around the world in typical local situations have shown that such stoves produce substantial indoor concentrations of small particles typically 10 to 100 times much more than the World Health Organization global air quality guidelines (WHO, 2002).

The indoor air pollution from these 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/WHO, 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 carried out by IFAD and FAO (2003) 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.

An emerging theme in development policy is that of "sustainable livelihoods". FAO recognizes the concept of promoting sustainable livelihoods as a means to combat food insecurity, energy poverty and environmental degradation. The livelihoods concept denotes the means, activities, entitlements and assets by which people make a living (DFID, 1998). For poor rural people to escape from poverty, they must be able to improve their livelihoods in ways that they can cope with, and recover from stresses and shocks, while maintaining and enhancing their material, social assets and opportunities, both now and in the future, and while not undermining the natural resource base.

The need for a focused examination of the role of energy in achieving sustainable socio-economic development has identified a series of actions required to increase the adoption of sustainable renewable energy options. 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, 2.4 billion people burn biomass fuels on a daily basis to boil water and to cook food. As a result 2 million tonnes of biomass are going up in smoke every day. However, to deliver the same amount of energy, dung used in a biogas digester produces only 1% of the greenhouse gas emissions of those produced by dung burnt in a traditional stove. 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, 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 Millennium Development Goals (MDGs), access to modern energy such as biogas need to be integrated among the potential dairy farmers in the country. It is well documented that Biogas Energy if well adopted by rural and urban households in Kenya will go a long way to contribute to the achievement of MDGs 1, 3, 4, 7 & 8.

2.5 Agriculture and Energy Development

The links between energy and agriculture have already been established in the international arena. Agenda 21 and the 8th Commission for Sustainable Development (CSD8) highlights, the dual role of agriculture as an energy user and as an energy producer. This dual function implies greater agricultural productivity on the one hand, and higher levels of energy sustainability through the production of CO^2-neutral bio energy on the other (Denton, 2005). Agenda 21 recognizes the need for sustainable agriculture as being essential to energy provision and advocates for rural energy transition to help reverse the current trend of energy crisis in rural areas. Wastes from agricultural production such as manure from livestock keeping, are a source of one of the world's most potent greenhouse gases. For example, one sow and her piglets will produce about 9 tons of carbon-dioxide through the methane generated by their droppings (IFAD, 2003). According WHO (2006), dung used in a biogas digester produces only 1% of the greenhouse gas emissions of those produced by dung burnt in a traditional stove.

However, turning manure into biogas energy is a triple-win situation: as it will improve the lives of poor rural people by giving them an affordable source of energy for cooking and lighting, replacing the time spent for wood fuel collection with money-making activities, and reducing the release of Greenhouse Gases that cause global warming. Many countries have successfully utilized agricultural wastes like manure to provide energy at the household energy. For example, in China and India, rural programmes have promoted biogas plants as ideal candidates for village use due to their advantages in energy and fertilizer production as well as the improved health benefits by substituting for inefficient wood fuel use (Gautam *et al.*, 2009).

Biogas technology has advantages over other renewable energy technologies because it has the added benefit of producing a soil amendment that can boost agriculture productivity. In terms of boosting agricultural productivity, biogas technology through the use of the waste (Bio- slurry) can have positive effects on Agriculture by improving soil fertility and food productivity due to the fact that slurry from the biogas systems is used as fertiliser for crop farming According to Myles (2004), the digested liquid manure coming out of the biogas plants provides an excellent organic manure in which all the useful nutrients remains preserved (due to decomposition in the enclosed digester of the biogas plant) for promoting environmentally sound eco-farming.

2.6 Energy and Gender perspective

Women play a crucial role in the provision and use of household energy either for cooking or heating. Even in male headed households, women are still wholly responsible for the provision of all energy resources at the household level, Denton (2005) observes that women are condemned to an unenviable future of endless searching for fuel and often left juggling multiple roles most of which are contingent on the provision of energy. As such, energy poverty tends to affect women and men differently. As women energy concerns are in tune with the quest for systems that would relieve them of multifarious repetitive tasks (Denton 2005). However, women often face difficulties accessing land, labour, water, capital technologies and other services. Women's roles as agents of social and economic development have often being devalued. As a result, women are prevented by customs, legal and attitudes from owning and controlling assets and worse still in decision-making.

According to Mugo and Gathea (2010), energy poverty continues to place a disproportionate burden on women and children (especially girls). As wood fuel and biomass becomes scarcer and charcoal less affordable, women are forced to spend considerable amounts of time collecting wood fuel. In addition, 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). Women bear the invisible burden of the human energy crisis; as such they need modern and more efficient energy sources to improve their work and quality of life both within and outside the home (Muchiri, 2008). Biogas technology is a renewable source of energy that may contribute immensely to household energy needs especially for women.

2.7 Social - Economic and Ecological benefits of Biogas Technology

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 clean source of energy that is free from smoke and soot.

The use of raw biomass and dung as fuel is common phenomena in the lives of the rural community especially the poor. According to WHO (2002), indoor air pollution is responsible of an estimated 1.5 million women and children in the developing world each year. Integrating biogas technologies among the dairy farmers could help reduce indoor air pollution, thus reduced incidences of respiratory diseases. A quantitative study carried out in Nepal revealed that households that used biogas energy for their cooking had their respiratory diseases, eye infection and headaches decreased by approximately 40% for women and 20% for male respondents (Katuwal and Bohata, 2009).

It also contributes to promote gender equity and empower women (MDG 3). The use of biogas technology at the household level helps to empower women by reducing and alleviating the drudgery of wood fuel collection. A study by Mwakaje (2008) in Tanzania revealed that households with biogas were saving 3-4 hours per day that was previously used in wood fuel collection. Biogas technology also helps in soil fertility improvement. The waste (bio-slurry) from the digester is good source of organic manure at the farm level (Myles, 2004). 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 also has other potentials such as having a positive effect on reducing atmospheric pollution (smoke from biomass) and global warming (by reducing GHGs).

In addition, biogas technology may play an important role at the farm level as waste management system (IFAD, 2009). As it 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. In addition, other benefits that are derived from biogas technology include the sale of bio-slurry which provides income for dairy farmers.

2.8 Energy Governance in Kenya

Up until the 7th of October 2004; when the *Sessional Paper No. 4 on Energy*, was passed in parliament. Kenya operated without a comprehensive energy policy. The broad objective of the Energy Policy was and is to ensure the provision of adequate, quality, cost-effective, affordable supply of energy while ascertaining environmental conservation (GTZ, 2009). Currently, Kenya's energy sector is governed primarily by the Energy Act 2006, whose broad objective is to ensure adequate, quality, cost effective and affordable supply of energy to meet development needs, while protecting and conserving the environment. The 2006 Energy Act is a great improvement over the previous one which had little to say about renewable energy or energy efficiency (Government of Kenya, 2006).

The Act empowers the Energy Minister to "promote the development and use of renewable energy technologies, including but not limited to biomass, biodiesel, bioethanol, charcoal, fuel wood, solar, wind, tidal waves, hydropower, biogas and municipal waste“(Government of Kenya, 2006). However, the Act does not define specific policies for the promotion of renewable energy policies but sets the policy framework for the energy sector i.e. petroleum and electricity and consolidates regulations of the Electric Power Act from 1997 and the Petroleum Act from 2000 (GTZ, 2009). Nonetheless, the necessary legal and regulatory framework for renewable energy such as biogas technology still needs to be put in place. Moreover, the Act is faced with a number of challenges that include; rural energy suffers low priority and status in planning and development, resource allocation, upgrading and expanding the current energy infrastructure.

2.9 Evolution of Domestic Biogas at the Household level in Kenya

Developments in Kenya’s biogas industry is usually grouped into three main periods: pre- colonial and colonial era, post- independence and the present state

Pre - Colonial and Colonial Era

Biogas technology was introduced in Kenya in the mid of 1957 by white settler farmers. The farmers used the biogas digesters to provide gas and bio- slurry in their farms. The bio- slurry or sludge was used as an excellent fertilizer and that its application to coffee trees in the farms greatly improved productivity (GTZ, 2009). Around the same period, Koru Coffee Research sub-Centre in Western Kenya developed an elaborate biogas plant that supplied the offices and staff houses with energy for lighting and cooking. By 1958 a private company, Tunnel Technology limited, was constructing biogas plants in different parts of the country. The company made biogas digesters commercially, marketing the effluent as the main product with biogas as a useful by-product. Between 1960 and 1986, company sold more than 130 small biogas units and 30 larger units all over the country. Tunnel Technology biogas digesters, some are still working after fifty years can be found in various parts of Kenya, although mainly in the so-called high productive areas of Central and Western Kenya(GTZ, 1987; GTZ, 2009) .

Post Independence Era

After independence, Kenya was faced with adverse effects of oil importation on the domestic economy and balance of payments as result of the global oil crisis of the early 1970’s. However, it is until 1980 when the main interest in biogas technology was aroused by the International-UN renewable energy conference held in Nairobi (GTZ, 2009). This gave birth to the Special Energy Programme, collaboration between the then Ministry of Energy and Regional Development and German Technical Cooperation organization (GTZ) in 1981. The period witnessed state-funded, community-type biogas projects in several livestock keeping communities in Kenya.

The main objective of the programme was to promote biogas in Kenya, by launching a training programme for technicians. The Special Energy Programme (SEP) opted for the floating drum type based on the designs’ merits and supported by the established steel manufacturing capacity in Kenya (GTZ, 1987). The programme focused on the medium scale farmer who owned three to five cows in a zero grazing units. For these farmers only the $10m^3$floating drum digester was built. Since the early biogas activities of GTZ-SEP were concentrated in the Meru District, the floating biogas digester was referred as the “Meru Biogas Plant”. By the early 1990, approximately 800 biogas units were built under direct and indirect influence of Special Energy Programme. Indirect influence was through the several trainees who begun to build “Meru biogas digesters” under commercial arrangements (GTZ, 2009).

At about the same period in 1981; another official biogas project albeit smaller scale, was introduced through the cooperation between Kenya and the Chinese government. The Chinese introduced the fixed dome digesters by then commonly referred to as Chinese design. This program was wound up in 1986; nonetheless, this program did not have a positive impact as that of the Special Energy Programme. As a result, there was no sustained dissemination of the fixed dome biogas digesters in the country (GTZ, 1987)

Current state of Biogas Technology in Kenya

Presently the technology has evolved and gained a lot of interest among rural households due to increased fuel costs on wood fuel and charcoal. The increased demand has aroused the interest of local Small and Medium Enterprises (SME) some of which are working in close linkages with local and foreign experts, Government Organizations (GOs) and Non-Government Organizations (NGOs) (GTZ, 2009). The models available range from portable digesters as small as $6M^3$ to large turn key projects. Materials in use include plastic, steel, rubber, concrete and masonry. The latest entry is the Africa Biogas Partnership Programme targeting small-scale dairy farmers and planning to assist in the construction of several thousands of biogas digesters in the next five years (2009-2013) including Kenya (KENDIP, 2009).

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 (KENDIP, 2009).The overall goal of the Programme is to improve livelihoods of rural farmers through benefits of domestic biogas and develop of a commercially viable, market oriented biogas sector.

The programme envisages to positively contribute to the Government's goal of enhancing equity and wealth creation opportunities for the poor; energy; Science, Technology and Innovation (STI) as stipulated in the Kenya's current development blueprint, the "Kenya Vision 2030; a globally competitive and prosperous Kenya" 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, 2011).

2.10 Barriers to the Adoption of Domestic Biogas Energy

Biogas technology has not yet been successfully adopted as either an energy or economic strategy in Africa (Biogas for better life an African initiative, 2008). In Africa compared to Asia, biogas technology dissemination has been relatively unsuccessful. Njoroge (2002) attributes the non-progressiveness of most biogas programmes in Africa are due to the following factors: a) failure of African governments to support biogas technology through a focused energy policy, b) poor design and construction of digesters, c) wrong operation and lack of maintenance by users, d) poor dissemination strategies, e) lack of project monitoring and follow-ups by promoters, and f) poor ownership responsibility by users.

In Kenya, a study commissioned by Shell Foundation in 2007 identified, the high costs of installing the biogas systems as the major bottleneck in adopting the technology. No doubt, it is a capital intensive undertaking for most potential users. Although, the construction of biogas plants is costly and is far above the means of most rural households, the presence of biogas facilities would make a big difference in their way of living, via the provision of a sustainable source of clean energy for cooking and rich organic fertilizer for agricultural activities (KENDIP, 2011). In the awake of deteriorating weather patterns as a result of global warming and climate change, this has reduced agricultural and livestock productivity in the rural areas. It is obvious that biogas technology will not thrive in rural agricultural communities in Kenya without government support in the form of subsidies and flexible payment arrangements (GTZ, 2009).

Reviews by Gitonga (1997), indicates that lack of credit schemes to help farmers to acquire biogas plants, is another barrier that hinders the adoption of this technology especially among the potential users. Many of the banking institutions have unfavourable requirements for renewable energy technologies financing such as biogas technology. In cases where financing mechanisms are provided for end users, these are often not within the reach of the majority of the population. For example, a UNDP/GEF biogas project in Zimbabwe benefited mainly affluent rural households, since over 80 percent of rural population could not afford the smallest biogas system even at the cheapest rates. Moreover, stringent requirements for loan applications excluded majority of the rural population from qualifying, deterring the potential users (Mapako, 2000).

Another factor that hinders biogas adoption is the minimal disposable income among farmers and competing needs for the limited available financial resources (GTZ, 2009). Due to current poor economic performance, there is an increasing level of household poverty, which affects the purchasing power of the rural households. As result, many households' have very little savings to invest in non-polluting energy technologies such as biogas.

2.11 Challenges facing Biogas Promoters in disseminating Biogas Technology

Negative images caused by failed biogas plants in regards to non-functioning and/or poorly functioning biogas digesters, has heavily damaged the reputation of biogas technology. In Kenya, the Ministry of Energy Survey (2002) revealed that over 1100 biogas systems were available in the country, but about 30% of them were reported not to be in good working condition. This scenario has put off potential biogas users. Similar observations were made by GTZ (2009), during it survey on the market potential of domestic biogas in rural Kenya. The survey pointed out that, some of the biogas systems were not functioning at all while others operated below the required capacity.

A study by Shell Foundation in 2007 revealed that in Africa, low awareness on the value of biogas technology has been another factor inhibiting its uptake. Inadequate or lack of biogas technology awareness has proven to be an up task for the technology promoters. As many of the potential users of the technology are not aware of the technology, many have not even seen it, or those who have are ignorant about how it operates or works, its benefits and personal relevance to them (Biogas for a better life initiative, 2007).

Mwirigi *et al.*, (2009), observes that social- cultural factors have hindered the promotion and dissemination of biogas technology. In many areas of Sub-Saharan Africa, biogas is considered to be a dirty technology and social stigma exists against its use because of social beliefs. Many people consider the taste of the food cooked by biogas to be inferior to that cooked on a wood or charcoal stove. A survey carried out by Heifer International in Central Uganda revealed that most of the communities use slow cooking methods like steaming of green bananas that require a lot of time and energy (SNV, 2011). As a result, the traditional stoves are the preferred option for most community members as they think that biogas stoves generate a lot of energy that is mostly used while boiling food rather than steaming food. As such, these types of cultural perceptions have greatly impaired the adoption rates of energy saving technologies that are meant to conserve energy and provide a superior energy source in Africa.

Contrary to Asia, biogas technology has not been very successfully promoted in Africa, and this is due to poor dissemination and marketing approaches by national governments and the nongovernmental organizations in African countries to promote the technology. The present trend in many African countries is that the private sectors, mainly the Non-Governmental Organizations and Faith Based Organizations are the real drivers of the biogas technology (GTZ, 2009). In Kenya, the approach by the Ministry of Energy in propagation of the technology in rural areas has to a large extent remained the same since mid-1980s. The Energy Centres provide basic information and technical advice on biogas and materials needed and also conduct demonstrations.

They can also refer potential customers to credible local technicians. It is estimated that through the ministry's biogas promotion programme about 1300 biogas plants have been established, but there are no records available to verify this estimate. However, the Energy Centres are characterized with limited human and financial resources and have remained the focal points for dissemination of information on biogas.

2.12 Policy Trends in Energy Services Delivery in Kenya

Before the Sessional Paper No. 4 of 2004 on Energy, Kenya did not have a comprehensive energy policy. Previously, the Sessional Paper No. 10 of 1965 that dwelt on the Electric Power Act (Cap 314) was used to regulate the energy sector. In 1984, there was the National Energy Policy and Investment Plan, which focused on the importance of energy availability, effective use of energy, generation of the resource, potential of domestic energy sources and increasing capacity of electricity generation.

The plan also had guidelines on the wood fuel sector, encouraging domestic substitution and promotion of alternative sources of energy, manpower development, effective co-ordination, and energy distribution network. However, these guidelines were silent on environmental aspects of energy-related activities and deficient on consumer interest and involvement in energy activities (Government of Kenya, 1986).

In the 1984/88 Development Plan, the focus remained on the supply of petroleum, electricity and wood fuel. The Plan was silent on other sources of energy such as biogas, coal, solar, wind, ethanol and other biomass resources. This was followed by *Sessional Paper No. 1 of 1986 on Economic Management for Renewed Growth*, which did not focus much on the power sector; instead it called for the establishment of the Department of Price and Monopoly Control within the Ministry of Finance to monitor action in restraint of trade and to enforce pricing in various sectors, including petroleum (Government of Kenya, 1986).

In the 1989/93-plan period, the government aimed to direct efforts towards development and exploration of renewable energy resources such as solar, wind, biogas and wood fuel and towards the use of efficient kilns and cook stoves. In the 1994/99 Development Plan, the concern for sustainable use of energy resources was raised. The next significant legislative development came in 1997 in the form of the Electric Power Act, which was enacted to replace Cap314 in order to take in new developments on board; and to make it more responsive to private sector participation in the provision of electricity. The Act also provided for rural electrification based on supply for a limited scale using renewable energy technologies (Government of Kenya, 1986).

However, the Sessional Paper No.4 of 2004 on Energy recognizes the contribution of biogas technology to rural energy supply, and hence the need to improve system management and the level of awareness so as to enhance wider acceptance and adoption of the technology. Currently, the national energy policy has a number of broad objectives, including ensuring adequate, quality, cost effective and affordable supply of energy to meet development needs, while protecting and conserving the environment. These are contained in the Economic Recovery Strategy for Wealth and Employment Creation and in Sessional Paper No. 4 of 2004 on Energy. Further to this, As indicated in Part V of the Energy Act section 103, the Energy Act provides for promotion of the development and use of renewable energy technologies which include biomass, biodiesel, bio ethanol, charcoal, fuel wood, biogas and municipal waste. This is to be done by the parent Ministry of Energy (Government of Kenya, 2006).

CHAPTER 3: METHODOLOGY

3.1 Introduction

In this chapter, the procedures used in conducting the study are presented. They include the study area characteristics, research design, target population, sample and sampling procedures, research instruments, validity and reliability of instruments, data collection and data analysis procedures.

3.2 Study Area Characteristics

3.2.1 Location

This study was done in Muhito area, Mukurwe – ini Central Ward in the current Mukurwe ini District, Nyeri County (Figure 3.1). The study area lies within latitude 36 ^{0} 34'' E and longitude 0^{o} 42'S.

3.2.2 Climate

Mukurwe – ini is a humid zone with an average annual rainfall of 1250-2500mm (Jaetzold and Schmidt, 2007). The rainfall pattern which is bio modal, determines seasonality. The long rains begin in March and end in May while short rains start in October and end in December. The annual average temperature ranges from below freezing point on top of Mount Kenya to over 34 degrees in the lower areas. The mean annual temperatures are 25 Degrees. These climatic regimes give rise to a warm tropical climate ideal for intensive dairy farming.

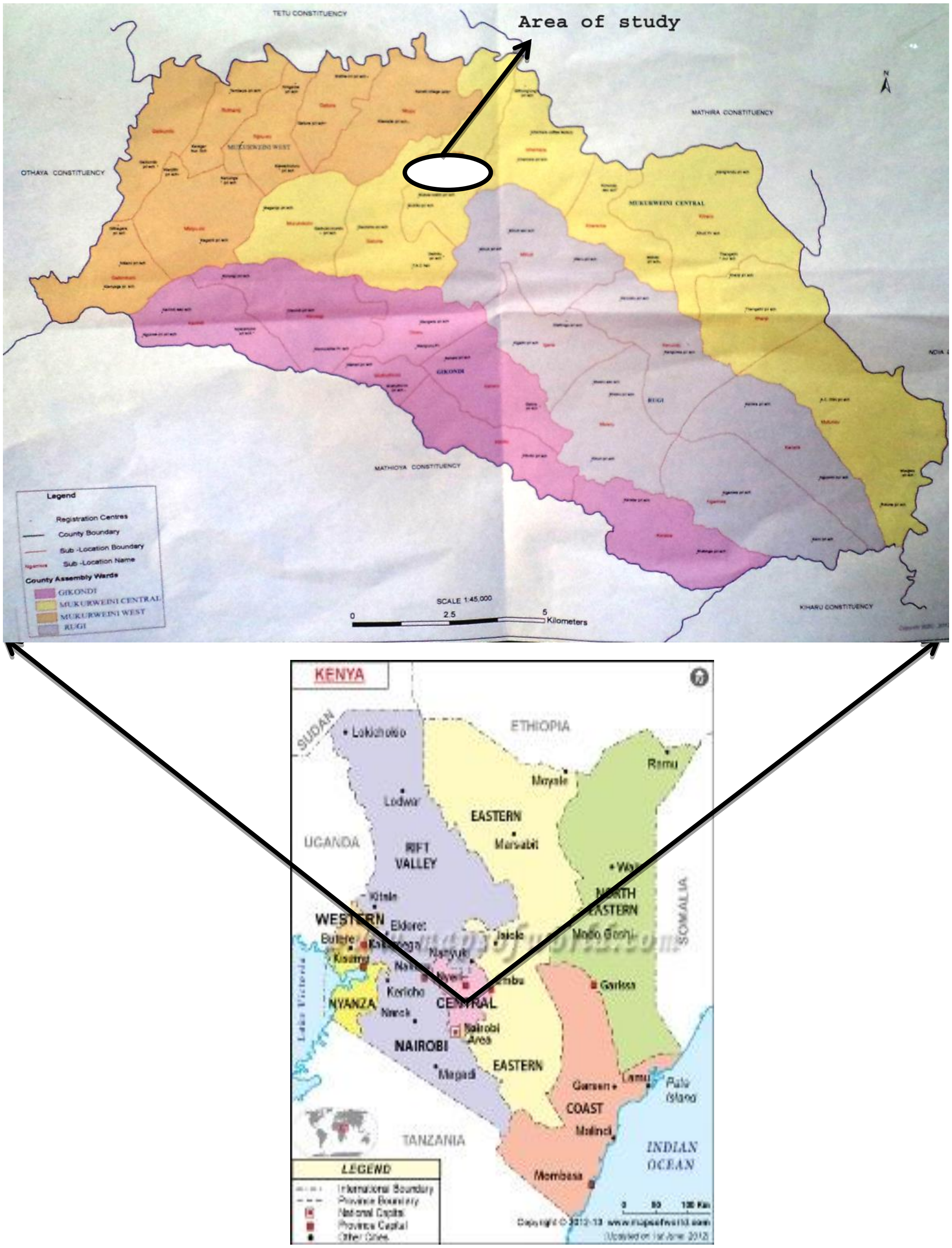


Figure 3.1: Map of Mukurwe-ini District showing the study area

3.2.3 Soil and Topography

The study area has deep red soils with fertility (nit sols, andosols, andic and chromoluric phaeoszxems and nitrochromic) (Jaetzold and Schmidt, 2007). In addition, the topography is hilly with deep water valleys. A favourable geographical characteristic for biogas technology is a slightly hilly terrain (Marchaim, 1992); this makes the distribution of the bio-slurry from plant to flow with ease. This condition is present in Mukurwe-ini as observed during the field visits.

3.2.4 Population

According to the 2009 national census, the population of Mukurwe-ini was 83932 persons (KNBS, 2010).The average population density is 470 persons per km^2. According to KNBS (2010), the population is increasing at a rate of 2.6 %/year. Wood fuel is the most important energy source for cooking and kerosene for lighting purposes. Charcoal burning is also an important economic activity. Given the high population density coupled with high dependence on wood fuel as the major energy source, deforestation and other forms of environmental degradation are an eminent threat (Mukurwe-ini Constituency Strategic Plan, 2012-2017). With intensive dairy farming in confined animal feeding (zero- grazing) units, only a few of the dairy farmers are turning to biogas technology as an alternative source of energy. There is need therefore to assess the potential of biogas technology towards sustainable dairy production, positive societal transformation, economic development and environmental sustainability.

3.3 Research Design and Plan

This study was in nature descriptive and adopted descriptive methods of research as explained by Hendrick *et al,* (1993). According to Best and Kahn (1993), descriptive research is concerned with relationships or conditions that exist, attitudes held by people and practices that prevail. Bell (1993) notes that descriptive surveys aim to obtain information for a representative sample of the population; from which the researcher is able to generalize the findings of a large population. The study was aimed at assessing the challenges of adopting biogas technology in energy provision among dairy farmers.

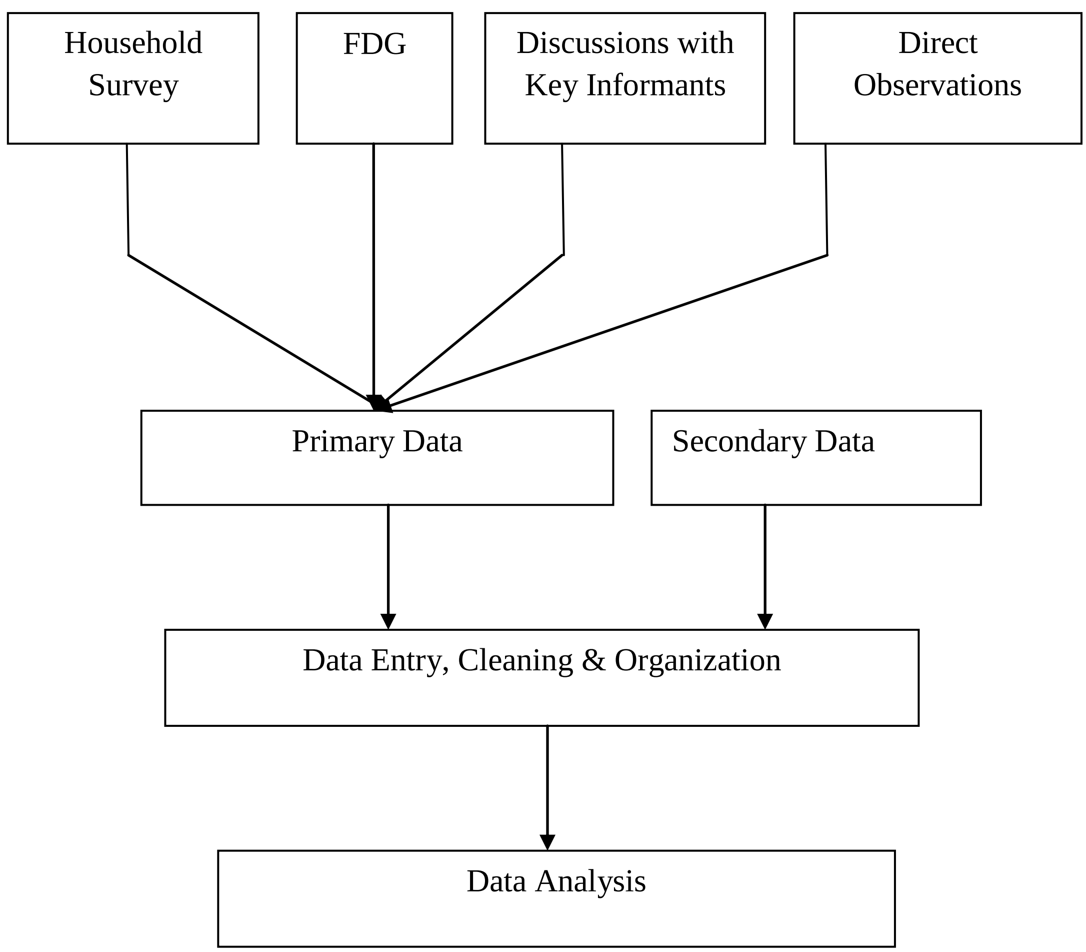


Figure 3.2: Research Plan

The study also made use of both qualitative and quantitative methods of data collection so that both methods would complement each other. According to Bryman (2008), the strength of one method helps to overcome the weaknesses of another thereby achieving a cost benefit analysis balance. Qualitative and quantitative data were gathered from the primary and secondary data sources (Figure 3.2). The instruments used were researcher's own questionnaire, focused group discussion, key informant interviews and observations. The questionnaires were administered to all 120 subjects in the study area with the aim of gathering information on the potential of biogas technology on improving livelihoods. A focused group discussion was also conducted to clarify and cross- check issues that were not adequately addressed by the respondents since the FGD members had in-depth knowledge of biogas technology in the study area. The key informants were interviewed on area and matters pertinent to biogas technology.

3.4 Target Population and Sampling Procedure

In this study**,** the target population comprised of dairy farmers and biogas extension agents. The sample size comprised 120 respondents randomly selected from a list of 1204 dairy farmers provided by Wakulima Dairy Limited (2011). Purposive sampling was used to identify key informants from the relevant community based organization, contact farmers, line ministries and farmers' self-help groups (Table 3.1). Gay and Airasian (2003) define purposive sampling as one which involves selecting a sample based on experiences or knowledge of the group to be sampled.

Table 3.1 FGD members and Key Informants Sampled.

Type of Organization		Name
1.	Non-Governmental Organizations (NGO's)	Wakulima Dairy Limited Mukurwe ini Development Initiative
2.	Agricultural and Livestock Extension Officers	Ministry of Agriculture Ministry of Livestock and Development
3.	Dairy Farmers Self Help Groups	Gakindu Dairy Farmers Self- help Group Wendani Dairy Farmers
4.	Local Community leaders	Directors of Dairy farmers in the milking collecting zones
5.	Biogas Technicians	Pioneer Farm Technologies

Source: Author

3.5 Validity and Reliability of Research Instruments

Validity is defined as the accuracy and meaningfulness of inferences, which are based on the research result (Mugenda and Mugenda, 1999). In this study, piloting of the instruments in ten dairy farmers that were not in the study was used to validate them and to determine their accuracy, clarity and suitability. The aim of the prestesting was gauge the clarity and relevance of the instruments. The procedure helped in modifying and removing a few ambiguous responses or weakness and hence produced revised instruments used in the actual study.

3.6 Data Collection Methods

Data collection was done using different methods depending on the specific objectives. In determining the current relative importance of energy sources, this research relied on both primary and secondary sources of data. The primary data was derived from field surveys using questionnaires and key informant interview (Appendix 7.3). The advantages of using questionnaires are: the person administering the instrument has an opportunity to establish rapport, explain the purpose of the study and explain the meaning of items that may not be clear. The questionnaires were self constructed based on the study objectives and the questions. The interview schedules were administered to respondents with the aim of bringing to light the relative importance of energy sources among small-holder dairy farmers. Secondary data was also synthesized from reports, periodicals, journals, newsletters and electronic media.

To evaluate the impacts of biogas plants on users, the research relied on the self administered questionnaires and interview schedule with respective biogas plant users. The interview schedules were administered to the plant users with the aim of bringing to light the impacts of biogas technology.Additional investigation tools included observations, especially on the use of biogas and bio-slurry at the farm level. Furthermore, different literature books on biogas technology and other information from electronic media on the impacts of biogas technology on livelihoods were also reviewed.

To assess the challenges faced in adopting biogas technology, the research survey relied on both primary and secondary data. Primary, data was derived from field surveys using questionnaires, focus group discussions (FGD's) and key informant interviews (Appendix 7.3). The interview schedules were administered to respondents with the aim of pointing out challenges faced in adopting biogas plants. The focus group discussions were carried out to cross check and clarify issues that were not adequately addressed by the respondents. The FGD members had in-depth knowledge of the status of biogas technology in the study area and the discussion was conducted mainly to explain, reinforce and enrich the survey results. Supplementary data (mainly secondary) were obtained from other key informants and stakeholders in the biogas industry in the study area; mainly the NGO's, biogas technicians and community based organizations engaged in the promotion of biogas technology.

On the opportunities for increasing adoption of biogas technology within individual households, the research survey relied on both primary and secondary data. Primary data was gathered from key informants, interviews, field surveys using questionnaires. The key informants are believed to have in-depth knowledge on some issues were interviewed through tailor-made interview schedule to give information specific areas of interests. In addition, secondary data was also obtained from text books, periodicals, journals, newsletters, electronic media as well as other related articles.

3.7 Data Analysis Methods

After the data had been collected it was cross- examined to ascertain their accuracy, competences and identify those items wrongly responded to, spelling mistakes and blank spaces. Quantative data was subjected to the computer for analysis using Statistical

Package for Social Sciences SPSS Version 11.5 computer package. In order to determine the current relative importance of energy sources, data was collected from the sample population using researcher's questionnaires that were analyzed using SPSS computer package. The research findings were presented in graphs, tables and figures as appropriate. In addition, descriptive statistics such as the frequency distribution namely percentage, frequencies and the measures of central tendency such as means and mode were derived from the respondents. These were used to summarize and interpret the research findings. Pearson's product- moment correlation coefficient was also used to analyze the different variables to establish whether there was any kind of relationship.

On the impacts of biogas technology on users, field data collected was analyzed using SPSS (version 11.5) computer package. The research findings were presented in graphs, tables and figures as appropriate. In addition, key informants from various community based organizations, dairy self-help groups and biogas technicians were interviewed using tailor-made interview schedule to give information on specific areas of interest. Qualitative data obtained through field observations and key informant interviews were analyzed either in text, diagrams or photographs to explain the potential and impacts of biogas technology in the study area.

On the challenges faced in adopting biogas technology, field data collected from the sample population using researcher questionnaires and key informant interviews were analyzed. The research findings were presented in graphs and tables. In addition, several policy documents with implication on biogas technology and energy were reviewed, analyzed and gaps identified.

On the opportunities for increasing adoption of biogas technology within individual households, data collected from the Non-Governmental Organization (NGO's), biogas technicians, community based organizations were analyzed to identify the opportunities and major constraints in promoting biogas technology in the study area. In addition, key informants from the departments of Ministry of Agriculture and Ministry of Livestock and Development were interviewed using tailor-made interview schedule to give information on specific areas of interest. Descriptive statistics such as frequency distributions namely percentages were used to summarize and interpret the research findings.

CHAPTER 4: RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter is a presentation of the results of the study as per each objective. It starts with the social-demographic, education levels and occupation information of the sampled population. It then shows the sources of energy and relative importance, the impacts of biogas technology among dairy farmers and the challenges faced by farmers in the uptake of biogas technology. Discussions based on the information contained in the results were also made, conveying the meaning of the findings by linking it to all the sections of the study from the background, objective and literature reviewed. Where applicable results supported by or contradicting with other studies carried out were also pointed out.

4.2 Socio-Economic Information of Respondents in Mukurwe-ini

4.2.1 Socio-Economic Sphere

The average population density in the study area was 470 persons per km^2 (KNBS, 2010) and is expected to increase over the years. Increase in population means the demand for wood fuel in the area will grow amidst the existing scarcity. Food and Agriculture Organization (FAO, 2009) estimates that in the coming decades the total wood fuel consumption in Eastern Africa will continue to grow as result of increase in population. Moreover, widespread poverty in many rural areas of developing countries is a critical factor in continued dependency on biomass energy sources and persistent traditional and inefficient means of using them.

Frequent subdivision of land parcels had leads to uneconomical units that would ultimately undermine tree woodlots, food security and community livelihoods. The study established that only 29 % of sampled 120 households were female headed while 71% were male headed (Table 4.1). The study being gender neutral, the respondents were randomly selected and the low number of female headed households may be attributed to the scenario in Kenya, where the society is highly patriarchal and gender roles; dictate that men as household heads, and hence decision makers over family resources including energy provision and land.

Table 4.1 Social demographic data of the sampled population

Characteristic		Frequency	Percentage (%)
Gender	Female	35	29
	Male	85	71
Total		120	100
Age brackets			
18-25 Years		4	3.3
26-40 Years		39	32.5
Over 40 Years		77	64.2
Total		120	100

Further, society has assigned roles, access and ownership of resources along gender lines. Within households, the gendered division of labour generally allocates to women the responsibility for household energy provision. It was noted that, even though 71 % of sampled population was male headed, the main collectors, producers and users of household energy were women who could not make any decisions independently on issues related to energy at the household level. This was also noted in female headed households as decision making was restricted and had to consult their sons or a male member of the family on any major issues related to energy such as procuring of a biogas plant, tree planting, felling of trees or even sale of trees. As such, the concept of gender neutrality has been applied to energy service planning, assuming that women and men have the same needs for energy services (Muchiri, 2008). However, such gender blind planning is now becoming exposed as unsustainable as women bear the invisible burden of human energy crisis more than men (Denton, 2005). This is because women and men have different roles in the energy system.

The study found there was a negative correlation between gender and ownership of a biogas system (Table 4.2). The Pearson Correlation (r) being - 0.186 and the p-value being at 0.05. This suggests the probability of male headed households adopting biogas technology was higher than that of their female headed household counterparts in the study area.

The negative correlation of gender of household head with the adoption of biogas technology is crucial regarding the categories of households to be targeted in biogas promotion in the study area. Organizations involved in the promotion of biogas technology should note that women headed households are central in the biogas technology transfer process. Women headed households should also be brought on board in the biogas energy planning and development process in order to achieve a greater dissemination coverage and impact of the technology. This could be achieved through promotion of biogas energy use in women self- help groups and organisations.

Table 4.2: Correlation matrix between Gender and Biogas Ownership in Mukurwe-ini Area

		Gender	Biogas
Gender	Pearson Correlation	1	-.186*
	Sig. (2-tailed)		.042
	N	120	120
Biogas	Pearson Correlation	-.186*	1
	Sig. (2-tailed)	.042	
	N	120	120

*Correlation is significant at the 0.05 level (2-tailed).

The household survey analysis revealed that out of the 120 households interviewed, majority of the respondent were over 40 years at 64.2%. The other age bracket 26-40 represented 32.5% while the remaining 3.3 % represented the age brackets between 18-25 years. It was also noted that in the sampled population there were no farmers under the age of 18 years. This is because most young people migrated to towns in search of paid jobs leaving the older people behind to practice dairy farming and crop production. The study found that the age of the household head was uncorrelated with the decision to adopt a biogas system (Table 4.3). This means that households in the study area adopted biogas technology irrespective of being young or old. However, the results of this study contradict the study findings of Walekhwa *et al.*, (2009) in Uganda, where the probability of younger household heads adopting biogas technology was higher than that of their older counterparts.

Education has been significantly linked to technology adoption, this is through the proven ability to understand and embrace new innovations and exposure to development dynamics. The study found there was no correlation between level of education and biogas technology adoption (Table 4.3). This implies that biogas technology has been embraced irrespective of the farmer's level of education. A similar finding was reported by Mendola (2007), where educational level of the household head was uncorrelated with the decision to adopt an assortment of selected technologies in Bangladesh. These results are contrary to some other adoption studies (Mwirigi *et al.*, 2009 and Mwakaje, 2008) where the likelihood of adoption of biogas energy increased with more years of formal education of the household head.

Table 4.3: Correlation matrix between Biogas and Age of the respondents

		Biogas	Age	Education Level
Biogas	Pearson Correlation	1	.062	-.076
	Sig. (2-tailed)		.503	.410
	N	120	120	120
Age	Pearson Correlation	.062	1	.239**
	Sig. (2-tailed)	.503		.009
	N	120	120	120
Education Level	Pearson Correlation	-.076	.239**	1
	Sig. (2-tailed)	.410	.009	
	N	120	120	120

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

About 33.3 % of the respondents had attained post-secondary education implying considerably high levels of exposure to modern technology. Those with secondary education and primary education were 38.3% and 21.7% respectively, while those with pre-primary were 6.7% (Figure 4.1). The study further found and observed that some farmers with pre-primary (3.3%) and primary (21.7 %) education had embraced biogas digesters in their households. In a study carried out by Mwakaje (2008) in Tanzania, the likelihood of adoption of biogas energy increased with more years of formal education of the household head. This does not concur with the results of this study.

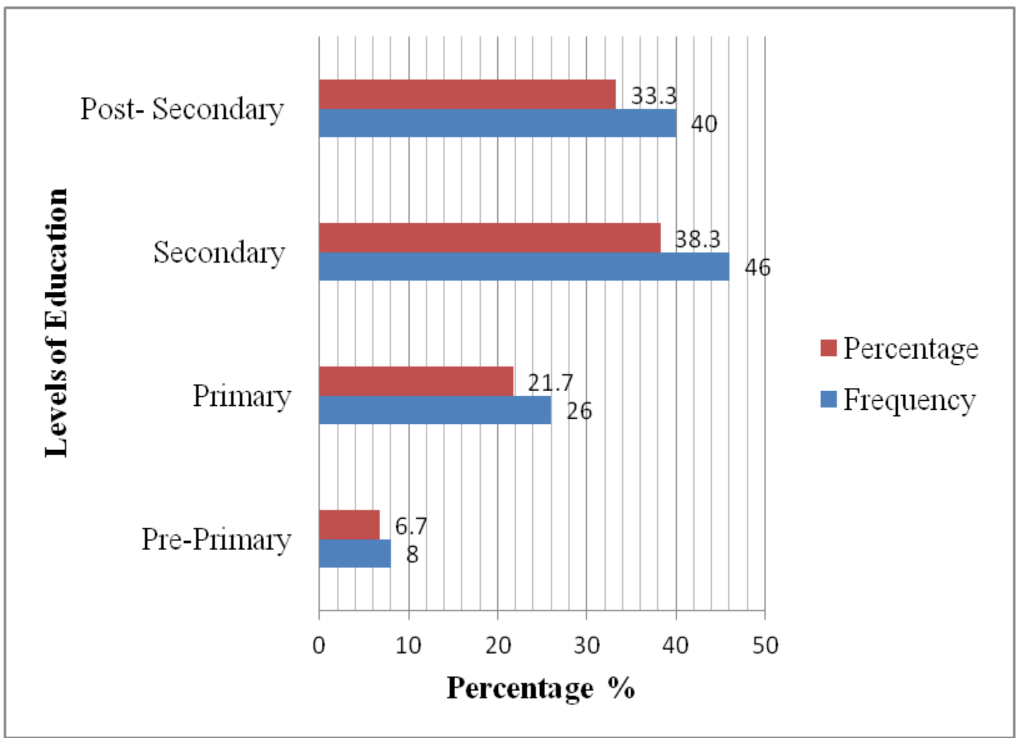


Figure 4.1: Education levels of the Respondents in Mukurwe – ini Area

4.2.2 Occupation of Respondents in Mukurwe-ini

From the study, it was established that 75% of the respondents practiced dairy farming, 12.5% and 2.1 % were on salaried and casual employment respectively, while 4.1% practiced business and trading activities (Figure 4.1). Muriuki *et al.*, (2001), observes that in Kenya dairy farming is a very significant source of income and food for an estimated 625,000 smallholder producer households. This concurs with results from this study that dairy farming is the economic main stay of most of the dairy farmers in Mukurwe-ini. According to Walekhwa *et al.*, (2009), empirical evidence suggest that probability of a household adopting biogas technology was directly proportional to a household income, the number of cattle owned, a household size and the ever increasing cost of traditional fuels. Thus, from the above findings, dairy farming provides manure for biogas generation and hence most of the households are potential owners of biogas plants.

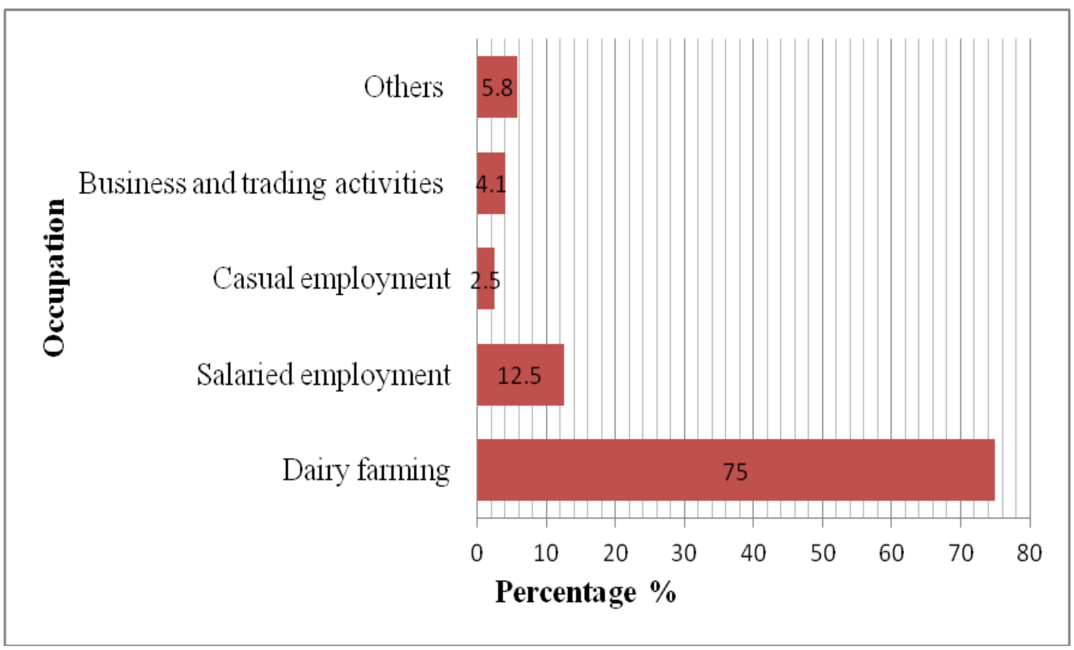


Figure 4.2: Occupation of Respondents in Mukurwe-ini

4.2.3 Household Livestock Enterprises

Livestock production is an important income generating activity for Kenya's rural smallholders' farmers. According to Mwakaje (2008), dairy farming plays a key role in the lives of poor, rural people in developing countries, providing a major proportion of their cash income, capital assets, draught power, fuel and fertilizer. On the other hand, dairy manure has the potential for biogas generation. As such, the study results indicate that the mean number of zero grazed cows per household was 3 dairy cows and 1 calf (Table 4.4). Schwengels (2009) observes that two or more zero grazed cows and other livestock including pigs can be appropriate to meet family's cooking needs using biogas technology. This supports the study results and means that all the households under the study have the potential to meet the required dung for biogas production as the cows are all zero-grazed.

Table 4.4: Household Dairy Cows Population

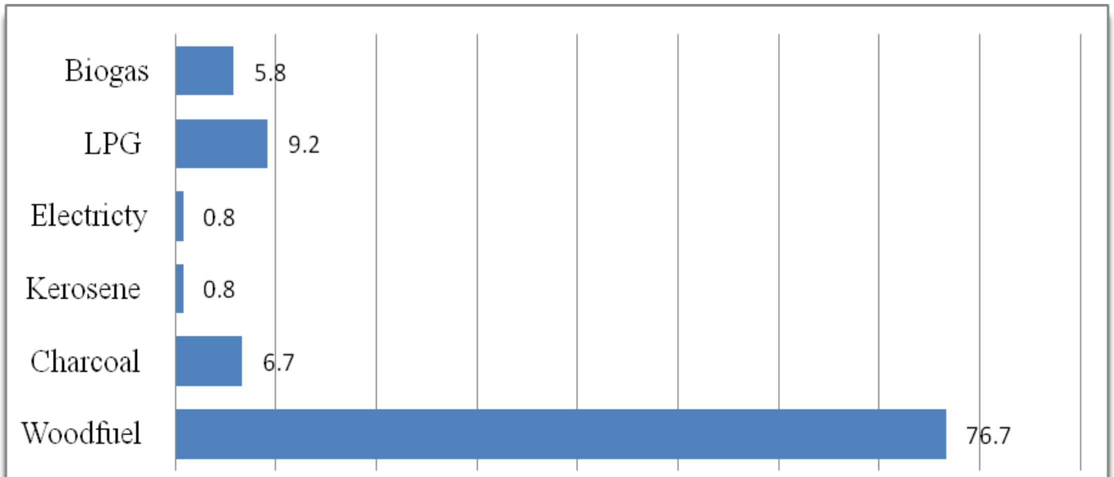
	N	Minimum	Maximum	Sum	Mean	Std. Deviation
No. of Cows	120	1	9	421	3.51	1.506
No. of Calves	118	0	4	169	1.43	1.008

4.3 Household Energy Sources and Relative Importance

4.3.1 Cooking Energy Sources at the Household level

The study revealed that 76 % of households use wood fuel as their main source of energy for cooking (Figure 4.3) These results are further backed by the findings of a recent KHIBS study that revealed that wood fuel remained the predominant fuel for cooking with 80% of household in rural areas and 10% in the urban centres (KIHBS, 2007). During transect walks; observations revealed that the area is energy stressed as young trees were pruned to provide twigs as wood fuel.

The impacts of this reliance are vast and while some effects are immediate, the full strength of many may not be felt until far into the future. This implies that there should be concern on the environment, as more trees have to be felled to provide wood fuel and charcoal for the growing population and societal transformation. The consequences of the country's reliance on biomass fuels are far reaching, while the environmental impacts are most notably discussed. Effects of deforestation such as soil erosion and decreasing water tables have lasting impacts, while consequences of climate change are predicted to exacerbate poverty and strongly affect those who are most vulnerable (FAO, 2009).



	Woodfuel	Charcoal	Kerosene	Electricty	LPG	Biogas
Percentage	76.7	6.7	0.8	0.8	9.2	5.8

Figure 4.3: Sources of Cooking Energy at the Household Level

The use of wood fuel for cooking is a major cause of health problems in developing countries due to indoor air pollution. These biomass fuels are burnt using smoky and inefficient traditional stoves with very poor combustion in unventilated kitchens producing a high concentration of dangerous pollutants: primarily carbon monoxide and particulate matter, and also nitrogen oxides and polyaromatic hydrocarbons (Muchiri, 2008). In Rural Kenya, many women and girls cook and spend time near the fire in poorly ventilated kitchens. They are typically exposed to very high levels of indoor air pollution, many even for three to seven hours a day over many years. This heightens their vulnerability to increased respiratory infections, cancers, and eye diseases. Availability of a continuous, clean and smokeless source of energy such as biogas would reduce a substantial amount of smoke and in-door air pollution compared to a traditional wood fire. Thus, by providing clean energy for cooking, biogas reduces the disproportionate health burden at the household. For instance, reduction of smoke in the kitchen prevents especially women from getting smoke related diseases or health problems.

The respondents who used charcoal as their main source of energy were 6.7%. According to Kantai (2002), charcoal use is higher in cities than in rural areas, being the primary cooking fuel for most urban households. Kantai's observation may explain the low percentage of households that use charcoal as their main source of cooking energy given that the study area (Mukurwe-ini) is a rural area. Many people are unaware of the health and ecological consequences of using charcoal. Exposure to indoor air pollution especially the particulate matter, from the combustion of charcoal has been implicated as a causal agent of respiratory diseases in Kenya (Muchiri, 2008). Other diseases associated with IAP include chronic obstructive pulmonary disease (COPD), asthma, cancer of the nasopharynx and larynx, tuberculosis, prenatal conditions, low birth weight, and diseases of the eye such as cataract and blindness (Muchiri, 2008). On ecological consequences, charcoal is made by using a method called carbonization. In carbonization, wood fuel is heated in a kiln where the air is limited. In Kenya, the majority of charcoal is produced in earth mound kilns, where wood and twigs are piled and covered with layers of dirt and left to burn for 5 to 10 days. Due to the low efficiency of the kilns, the production of 1 kg of charcoal requires up to 10 kg of wood (Kituyi, 2004). This means more trees need to be felled to produce charcoal leading to loss of trees hence accelerating further woodland degradation.

Only about 0.8% of the respondents used kerosene and electricity as their main source of cooking energy. This may due to the fact that kerosene is mostly used as common source of light for many rural households and only about 4% of rural population has been connected to the national electricity grid (Rural Electrification Authority, 2009). In addition, the other reason for the rare use of electricity is that it is very expensive. The study further showed that 9.2% of the households used LPG as their main source of cooking energy while 5.8 % used biogas (Figure 4.3). A comparison of households with and without biogas facility, showed wood fuel is still the main source of energy for both. However, among the respondents with biogas digesters, reliance on wood fuel is on the decline where (53.5%) of the respondents with biogas still use wood fuel as their main source of energy for cooking compared to (76.6%) of those without biogas. A study conducted by Dahoo (2011) in Kenya produced similar findings regarding biogas energy use and the reduced reliance and use of wood fuel. The amount of wood consumed per day was lower by 40% for the group of women using biogas digesters (average consumption of 14 lbs/day) compared to the referent group (25 lbs/day). This shows that there might be a drastic reduction on the use of wood fuel if biogas technology is embraced at the household level (Table 4.5). From an environmental point of view, the use of biogas at the household level reduces utilization of wood fuel as an energy source therefore contributes to reducing woodland degradation and deforestation. Thus, the use of biogas as a renewable energy can make an important contribution to the protection and improvement of natural resources and the environment. In addition, instances where wood fuel is purchased reduced reliance on wood fuel means that money is saved thus, strengthening the families' economy.

Table 4.5: Comparison of household cooking energy sources between households with biogas digesters and those without the digesters

Characteristic	Description	With biogas N=43		Without biogas N=77	
		Frequency	%	Frequency	%
Main Household Cooking Energy source	Wood	23	53.5	59	76.6
	Charcoal	2	4.7	6	7.9
	Electricity	-	-	1	1.3
	Kerosene	-	-	1	1.3
	LPG	4	9.3	10	13
	Biogas	14	32.5	-	-

The use of charcoal was also on the decline with only 4.7 % of the respondents with biogas energy using it as their main source of cooking energy compared to 7.9% of those respondents without biogas facilities. The above results suggest that the presence of biogas facilities reduces the demand for wood fuel, electricity and kerosene as sources of energy for cooking within households. The money saved from reduced demand would improve the economic status of households hence improving their livelihoods and reducing their vulnerability.

4.3.2 Challenges of Accessing Energy among the Respondents

The study showed that respondents faced various challenges when accessing their sources of cooking energy. The main challenges were high cost (58%), inaccessibility of cooking energy at 25%, transportation costs and unreliable supply at 15% (Figure 4.4). The respondents complained that they incurred high costs in procuring cooking energy such as wood fuel, LPG and charcoal. This may be attributed to increasing demand for these commodities. A 13 kg cylinder of gas varied between 2600 Kshs and 3000 Kshs depending on the brand and lasted between 2 to 3 months. Further, the respondents who used LPG gas felt that the commodity was more expensive in the study area given that it is a rural setting.

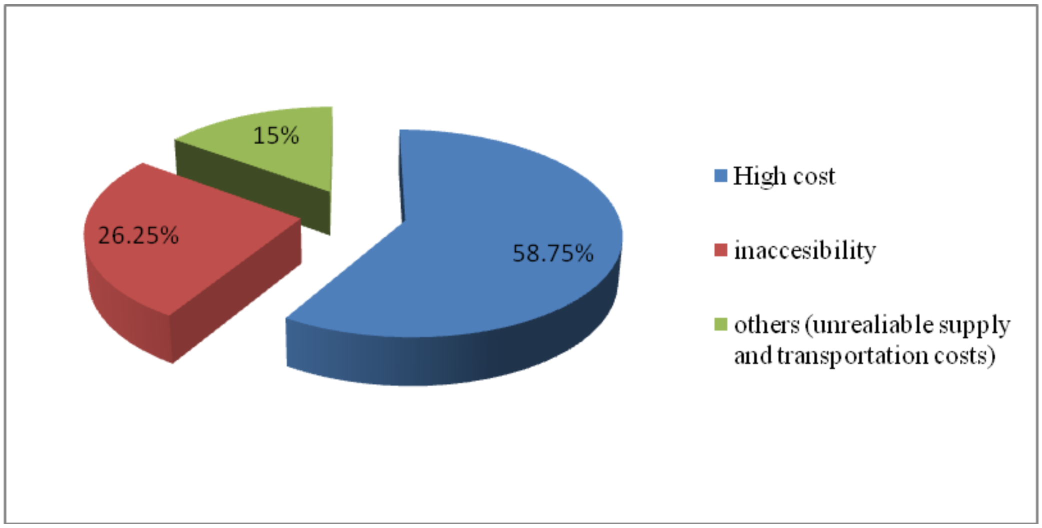


Figure 4.4 Challenges of Accessing Cooking Energy at the Household Level

Declining of wood areas and increased population density in the study area has forced people to cover their energy need by buying wood. The price of a foot of wood fuel varied between Kshs 400 and Kshs 600 depending on the size of the wood and would only last for two weeks at the household level. The purchasing of wood fuel or other energy sources weakens a family economy to the extent that the money spent on energy is taken away from other basic supplies like food or school fees increasing their vulnerability and lessens their opportunities to plan their future or make other investments. According to FAO (2009), the demand of wood fuel in Kenya is increasing, while at the same time the scarcity of firewood is a growing problem and degradation is making the fulfilling of the wood fuel need even more difficult.

As such, it is advisable that the National Energy Policy encourages the use of other renewable energy sources such as biogas and solar energy by putting in place tangible and smart incentives especially among the rural community. The price of a bag of charcoal varied between Kshs 950 and Kshs 1000 and is bought in bag that weighs around 40 to 50 kilogram's. Households that cooked more with a charcoal stove used the bag for only one month. In Taita, Kenya, 30% of the households who used charcoal as their main cooking energy used a bag of 50 kilos for less than one month (Zschauer, 2010). This concurs with the results of this study.

The other major challenge is inaccessibility. In the past, wood fuel used to be a free or low cost energy source that was easily on-hand in the study area. According to focus group discussions and key informant interviews; wood fuel is no longer as accessible since all the natural forests have been encroached on, so people no longer have anywhere to go fetching wood fuel or even burning charcoal, the few forests that exist are owned privately. The use of wood fuel increases households' vulnerability by raising the work-load of women in particular and putting a strain on a household fuel budgets.

Furthermore, wood fuel collection needs to be carried out in the daylight, which thus diminishes chances of acquiring additional incomes or social interactions. One of the women respondent said "*In the past l never bought wood fuel as l would collect in the neighbourhood, but now l have to buy and ferry it on back to my homestead*". This shows that wood fuel is no longer easily accessible and community members have to spend more time, money and physical energy in search of wood fuel. There is merit in Muchiri's observation that as wood fuel becomes scarce as a result of over harvesting. Drudgery increases on the part of women who are forced to travel longer distances and spend more time, money and physical energy in search of wood fuel (Muchiri, 2008).

However, Gurung (1997) asserts that widespread adoption of bio-gas plants has the potential of substantially reducing the drudgery of women and children by 2 hours per day. As such, there is need to intensify and enhance women's ability to afford and to utilise cleaner forms of energy such as biogas by undertaking public education and awareness creation on the potential and benefits of biogas energy in reducing drudgery for women.

4.3.3 Household's Satisfaction of Energy Supply

Majority of the households (85%) were dissatisfied with their cooking energy sources. 57.5% of the respondents were dissatisfied with wood fuel, 21.7% were dissatisfied with charcoal, 13.3% with Liquefied Petroleum Gas, 2.5% with electricity and 4.2% of those who used kerosene (Table 4.6).

Table 4.6: Dissatisfaction with Energy Source in Mukurwe-ini Area

Source of Cooking Energy	Percentage of Respondents who are Dissatisfied
Wood fuel	57.5
Charcoal	21.7
Liquefied Petroleum Gas (LPG)	13.3
Electricity	2.5
Kerosene	4.2
Total	100

This means that majority of the households are dissatisfied with their sources of energy and any effort to upgrade to a superior energy source would be considered important. The majority of the respondents who expressed dissatisfaction with wood fuel mentioned that it is expensive (21.1 %), 36.8% mentioned that wood fuel supply was unreliable, 35.5% felt that wood fuel was inefficient whereas 6.6% (Table 4.6) were dissatisfied with wood fuel as it produced smoke during combustion pre-disposing the respondents to health risks such as respiratory diseases, coughs, risk of burns especially to children and sore eyes

Table 4.7: Reasons for Dissatisfaction with Energy Source in Mukurwe-ini

Reasons for Dissatisfaction in %	**Unreliable supply**	**Inefficient**	**Expensive**	**Smoky**	**Total**
Fire wood	36.8	35.5	21.1	6.6	100
Charcoal	13.8	14.9	64.9	6.4	100
Liquefied Petroleum Gas (LPG)	0	0	100	0	100
Electricity	4.7	0	95.3	0	100
Kerosene	2.9	5.8	82	4.3	100

Baseline monitoring of pollution in kitchens in Kajiado and West Kenya by Intermediate Technology Development Group (ITDG) showed that smoke levels from wood fuel were unacceptably high: in Kajiado, the 24 hr average of respirable particulates was 5526$\mu g/m^3$. In West Kenya, the levels were 1713$\mu g/m^3$compared to the acceptable EPA standards for acceptable annual rates of respirable particulates 150$\mu g/m^3$ (Muchiri, 2008). However, a study conducted by Dahoo in Kenya, the research findings suggests that using biogas in cookhouses improves respiratory symptoms of the users (Dahoo, 2011). This is because biogas is smokeless and environmentally friendly energy technology hence minimizes diseases caused by smoke such as coughs and other respiratory diseases. Thus, there is need sensitize and carry out education campaigns on the health benefits of acquiring a biogas plant at the household level.

The respondents dissatisfied with charcoal mentioned it was expensive 64.9%, about 13.8% felt the supply of charcoal was unreliable, 14.9% were in the view that charcoal was inefficient while 6.4% cited it was smoky hence posing health risks. The most significant health concern using charcoal is the smoke, especially, when the burning happens indoors without proper ventilation or chimneys. Smoke from firewood, charcoal and kerosene contain carcinogens and small particles, which damage the lungs and respiratory organs (WHO, 2009). In addition, the use of charcoal pre-disposes the users to carbon monoxide poisoning. On electricity, 2.7% of the respondents said that its supply is unreliable while 95.3% mentioned it was too expensive to use as a source of cooking energy and only use it for lighting purposes. According to Pandey *et al.,* (2007), in many developing countries electricity network suffers from frequent blackouts and it is too expensive to use it as a source of energy to cook meals. This concurs with my results.

The respondents who used kerosene, about 2.9 % complained the supply was unreliable, 82% were dissatisfied that it was expensive, 5.8% felt that kerosene was inefficient while 4.3 % complained it was smoky and produced a foul smell (Table 4.7). According to UNEP (2006) kerosene is mainly used light many rural homes in Kenya as it is too expensive to use as cooking fuel.

4.4 Impacts and Uses of Biogas Technology

4.4.1 Types of Biogas Digesters Adopted

The study results showed that only 35.8 % of the dairy farmers had adopted a biogas plant at the household level. According to GTZ (2009), there are many designs or models of biogas plants such the floating drum, the fixed dome and the plastic tubular digester. However, the study revealed that the types of biogas digesters in use in the study were fixed dome (28%) and the plastic tubular digester (PTD) (72%) bio digesters (Figure 4.5).

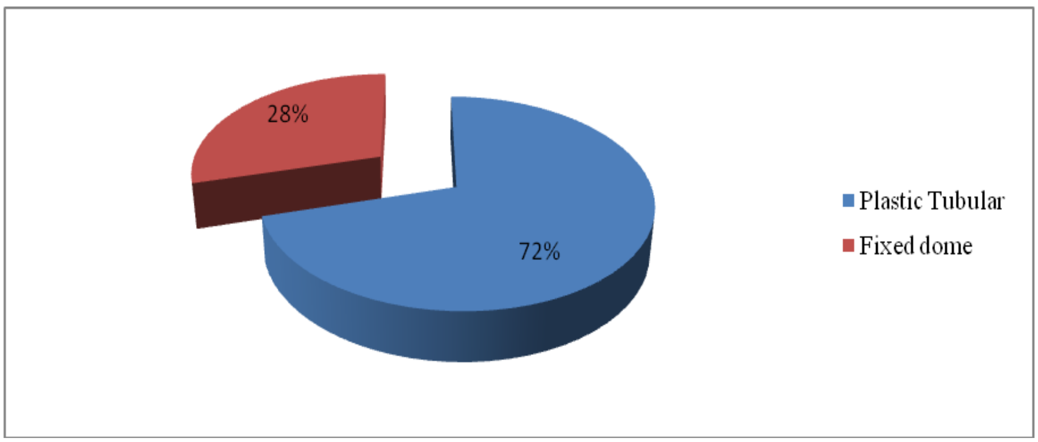


Figure 4.5: Types of Biogas Digesters in the Study Area.

According to McCulloch *et al.*, (1998), the technologies that people embrace and use play a fundamental role in shaping the efficiency, equity and environmental sustainability of natural resource management. These technologies are of little value unless they are judged to be appropriate by farmers and subsequently adopted. The plastic tubular digester was the most popular where out of 43 households with biogas digesters 72 % had adopted this type of biogas design (Figure 4.6 & Plate 4.1). According to Kassenga (1997), the type of plastic materials needed for this digester can be obtained locally, and construction requires relatively simple skills, thereby significantly lowering costs. According to Karanja and Kiruiro (2004), the plastic-tube digesters were introduced in Kenya in early – mid 1990s as a low-cost option to the conventional digesters and the adoption of the technology had increased over the years in different parts of the country.

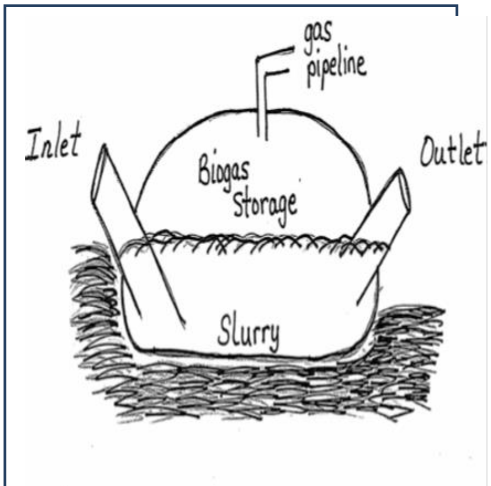


Figure 4.6: Schematic diagram of a Plastic tubular digester (Source: GTZ, 2009)

Plate 4.1 A plastic tubular digester in Mukurwe-ini area

This type of digester is popular in Vietnam because the materials used in construction are cheap and are locally available (Zhu, 2006). This concurs with the results of this study. The popularity of the Plastic Tubular Digester (PTD) may be attributed to the lower costs incurred in installation and unlike the masonry types such as floating drum and fixed dome that are capital intensive. This means that if the cost of installing the floating drum and fixed dome digesters is lowered or subsidized then more potential non biogas users may take up the technology. As such, the Scaling-Up Renewable Energy

Program (SREP) should consider incorporating a biogas digester subsidy strategy especially among the low income dairy farmers to facilitate the acquisition and installation of biogas digesters.

The study results further showed that about 28% of the households with bio digesters had adopted the fixed dome biogas design (Figure 4.7 & Plate 4.2). In Uganda, the fixed dome and floating drums were the most preferred types of biogas digesters due to their longer life spans when compared to the plastic tubular design (Walekhwa *et al*., 2009).

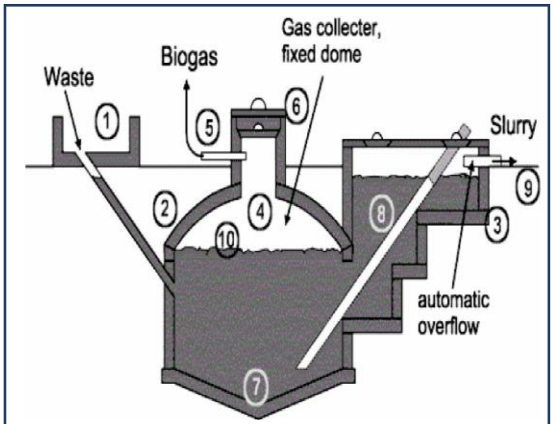


Figure 4.7: Schematic representation a fixed dome biogas digester (GTZ, 2009)

Plate 4.2: A fixed dome biogas digester in Mukurwe-ini

This contradicts the results of this study as the plastic tubular digester design was the most popular design in the study area. The high upfront costs of installing the fixed dome digester design may explain why most households in the study area prefer the PTD.

4.4.2 Effects of Biogas Digesters on Dairy Farmers Livelihoods

The use of biogas technology contributed to the livelihoods of the dairy farmers in several ways. These were economic, social as well as ecological benefits. About 88.4 % of the biogas users said it reduced family expenditure on energy, 83.7% said it saved time in preparation and cooking of food, 100% of the biogas users said it provided the much needed organic bio- slurry, 81.4 % said it reduced smoke in the kitchen, 93% said it provided readily available fuel, 93% said it made cooking more convenient and only 9.3% said it generated income from the sale of bio-slurry (Figure 4.8).

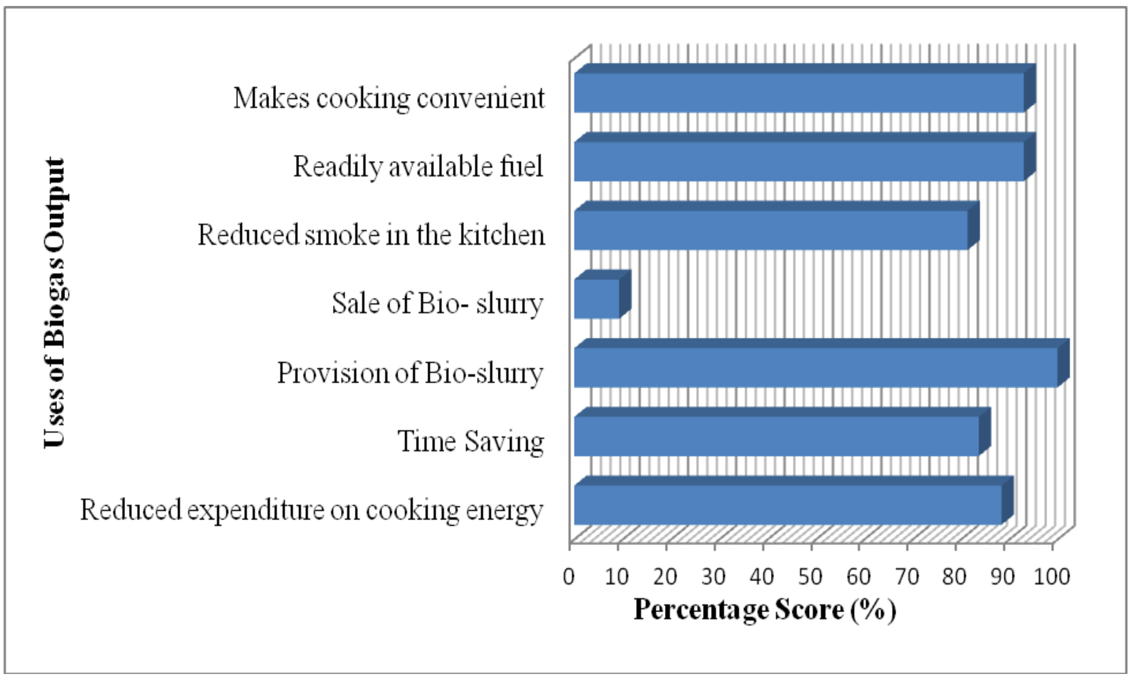


Figure 4.8: Benefits of using Biogas Technology among Respondents

Reduced family expenditure on energy was one of the main benefits of using biogas energy at the household level among the respondents. According to Lekule (1996); consumption of wood fuel could be reduced by up to 60% if biogas energy is used at the household level. Majority of the respondents who used biogas energy noted reduced expenditure on conventional fuel consumption at the household level. For example, one of the respondents who previously used liquid petroleum gas (LPG) before switching to biogas observed that the LPG cylinder now goes for a year unlike before when it only lasted 4 -5 months. Another respondent, who supplemented biogas energy with wood fuel, noted that wood fuel previously used for one month prior to installing a biogas unit now goes for three months or more.

Plate 4.3: A household cooking with biogas stove (Notice there is no soot on the cooking pot)

Plate 4.4: Bio-slurry being applied to banana plantations

A study by Hamlin (2012), in rural Kenya showed that a woman whose main source of cooking energy was firewood reported that her supply of firewood would last about three to four months before installing a biogas unit could now be used for well over one year. This agrees with the results of this study that biogas use at the household level helps to reduce expenditure on energy. The reduced expenditure on energy helps to strengthen the family's economy thus providing more money for essentials such as food, school fees, clothing and other income generating activities. This forms an important reality that can be used in the promotion of biogas technology, through show-casing in the impact of the technology in reducing household expenditure on energy.

On time saving, most of the respondents mentioned that biogas energy helped to reduce the amount of time spent in cooking, fetching of wood fuel and cleaning of utensils as pots and other kitchen accessories do not get stained with soot so much, and time is therefore saved on their cleaning (Plate 4.3). The results of this study agrees with the research findings of Karanja and Kiruiro (2004), where 100% of the respondents in Central Kenya Highlands reported reduced work load after installing a biogas digester at the household level. The saved time can be used for acquiring additional incomes leading to livelihood diversification at the household level.

The provision of bio-slurry, a by-product of biogas production was another benefit experienced by 100% of the respondents in the study area (Plate 4.4). The majority of farmers seemed to understand the importance of using bio-slurry to improve agricultural productivity. The humus contained in bio-slurry improves soil nutrients and structure; the bio-slurry nutrients increase crop yields and save on inorganic fertilizer costs (Myles, 2004). The application of bio-slurry could result into higher crops yields thus improve the food security of the dairy farmers. Moreover, higher crop yields would indirectly provide income from the sale of surplus harvest.

From the study about 81.4 % of the respondents experienced reduced smoke in the kitchen as result of installing a biogas digester at the household. The use of biogas energy positively affected the well-being of households by reducing indoor air pollution. According to Tereza (2011), one of the main health benefits of biogas are mainly related to a substantial reduction of smoke and in-door air pollution compared to a traditional wood fuel. This concurs with the results of this study.

Reduced smoke in the kitchen has direct effects on wellbeing in that its disproportionate reduces health burden of smoke related diseases or health problems especially for women who are often responsible for obtaining energy source and cooking. Close to 93% of biogas users, indicated that biogas provided a readily available fuel which made cooking more convenient. Some of the women respondents confirmed that they no longer woke up early to light wood fuel fire to assist their children to prepare for school and to warm water for milking cows. According to the women, the presence of biogas energy creates positive social impact on the lives, contributing to their empowerment.

Other benefits derived from using biogas at the household level include; the sale of bio-slurry, although only 9.3 % of the respondents sold the bio-slurry at an average of Kshs 3500 to earn an income. According to Tereza (2011), some of the biogas users try to gain additional income by selling surplus bio-slurry. A study by Hamlin (2012) in rural Kenya revealed that farmers with biogas units were selling bio slurry between Kshs 2,000 to 5,000 per truckload. This agrees with results of this study that bio slurry could provide farmers with the much needed income, thus improving the family's livelihoods. Additional income at the household can improve the standard of living and contribute to the economic and social development of the dairy farmers.

4.4.3 Challenges Faced by Households when using Biogas Energy

The study showed that some of the dairy farmers faced various challenges when using biogas energy. The main challenges were low gas production (38.5 %), vandalism of plastic sheet (7.7%) by people, gas leakage (38.5%) and blockage of inlet pipe (15.5%) (Figure 4.9). Most of the biogas users with the plastic tubular digesters felt that their installed digesters failed to meet their energy demands as a result low gas production especially during wet and cold months of April, May, June and July. This forced the families to use their previous conventional fuel sources. According to Yadvila *et al* (2004), fluctuation in temperature throughout the year, decreases biogas production especially during the winter months. This concurs with the results of the study.

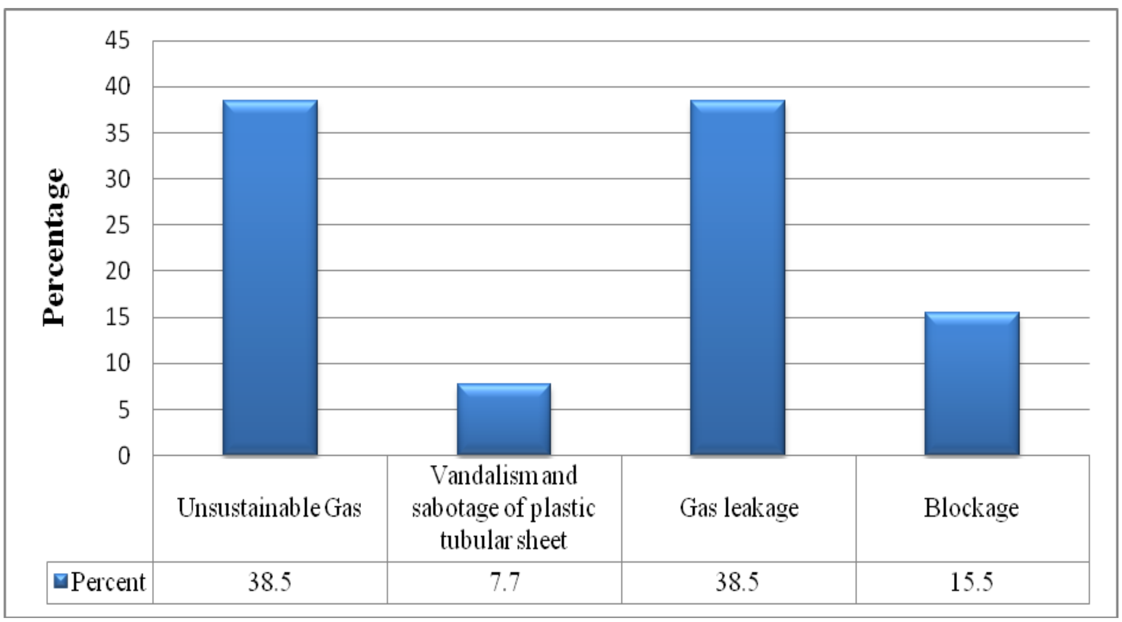


Figure 4.9: Challenges of Using Biogas Technology in the Study Area

The other challenge mentioned by the biogas users 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, this exposes the sheet to the risk of being pierced by people with sharp objects. Some of the biogas users 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 was gas leakage. According to GTZ (2009) 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 biogas users. A blockage in the digester occurs when the digested manure attaches itself to the pipe which should transport the bio-slurry outside (GTZ, 2009). 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.

4.5 Obstacles to Biogas Technology Uptake in the Study Area

The study showed that several factors were responsible for the low adoption status of biogas technology in the area. The main factors were high installation costs (70%), social-cultural factors (46%), negative attitude towards biogas energy (17%), lack of interest, (10%), inadequate skilled technicians (26%) and lack of credit facilities (70%) (Figure 4.10). Majority of the farmers (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*., (1995), high investment costs in installing biogas units have be blamed for the low adoption rates in many developing countries.

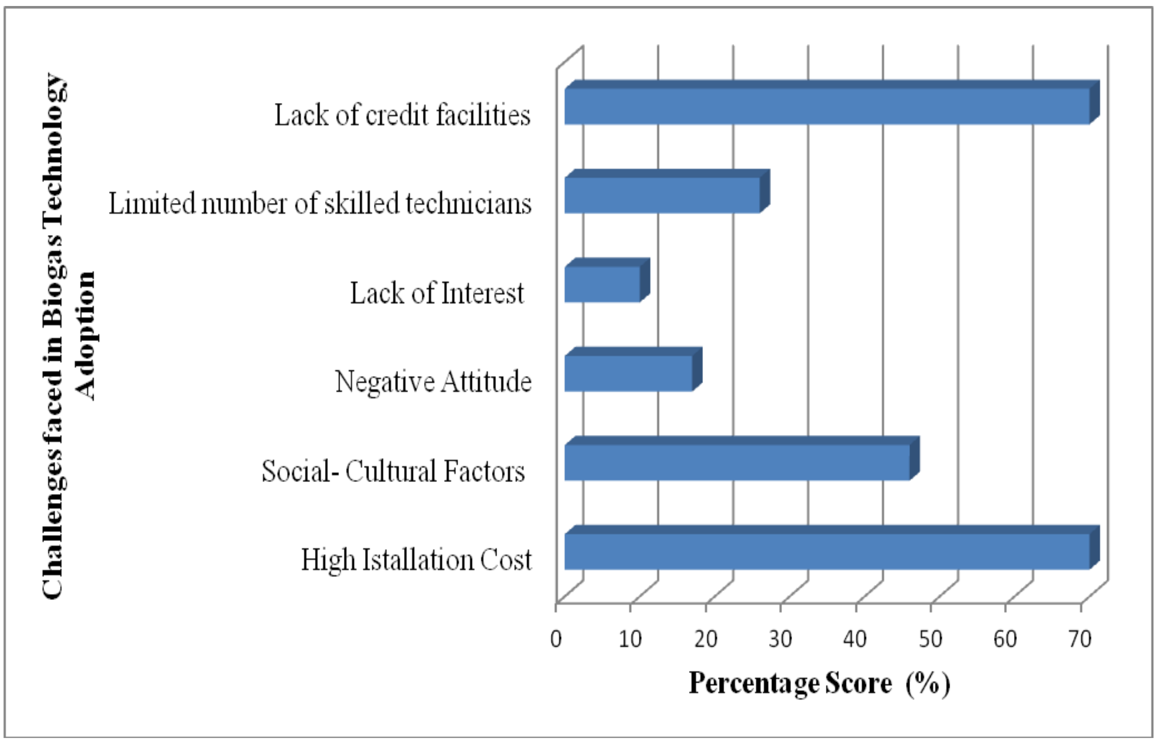


Figure 4.10: Challenges faced by farmers in the uptake of biogas technology in the study area

In a study of the potential of biogas energy in Kenya, Jonušauskait (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, lenders 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 (GTZ, 2009). As such, the draft National Energy Policy 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.

Some of the respondents felt that some social-cultural factors (46%) hindered the uptake of the biogas technology in the study area. For instance, according to the FGD, 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, 2003). This shows that cultural factors do hinder the uptake of biogas technology. 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.

The other factor that hindered the uptake of the technology was negative attitude (17%) and the notion that biogas was dirty technology as it used animal waste to cook. In Tanzania, a study by Mwakaje (2005) revealed that a number of people who have not accessed biogas technology had the perception that biogas is a dirty thing; however, on seeing physically the functioning of bio latrine, many households were motivated to adopt the technology. The potential biogas 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 FDG, 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 *et al*., (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 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 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 of the respondents were 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.

4.6 Opportunities for increasing Biogas Technology uptake in Mukurwe-ini

4.6.1 Types of Biogas Extension Agents

The biogas extension agents in the study area were drawn from both private and public sector. The public actors were those from the core government ministries that is the: Ministry of Agriculture, Ministry of Livestock and Development and Ministry of Energy while the private actors included local self-help groups, non-governmental organizations (NGO's) and individual farm owners.

The extension officers from the Ministry of Agriculture provided extension services on biogas technology through the Home Economics Extension wing and sensitized the farmers about biogas under the auspices of the National Agriculture and Livestock Extension Programme (NALEP). On the other hand, the extension officers from the Ministry of Livestock and Development promoted biogas technology through the provision of extension services on good management of livestock waste through conversion to biogas to foster recovering of energy and improving waste management at the farm level. The private actors in the study promoted biogas technology by establishing demonstration farms, sourcing for funds from development partners and provision of subsidies and incentives to attract potential dairy farmers to install biogas plants in their farms.

4.6.2 Constraints facing Public Extension Agents in Biogas Promotion

Some of the challenges that faced extension agents from the public sector in promoting biogas technology in the study area were few extension agents (20%), delayed disbursement of funds at (38%), poor promotion strategies at (15%,) lack of demonstration space at (10%), high installation costs at (40%), lack of credit facilities at (16%) and low interest at (10%.) (Figure 4.11).

The public extension workers complained of a large farmer to extension agent ratio as they are understaffed. This prevents them from giving individual attention to farmers often preferring to meet farmers in groups during farmers' field days. In addition, delayed disbursement of funds has also hampered the promotion of biogas technology in the study area.

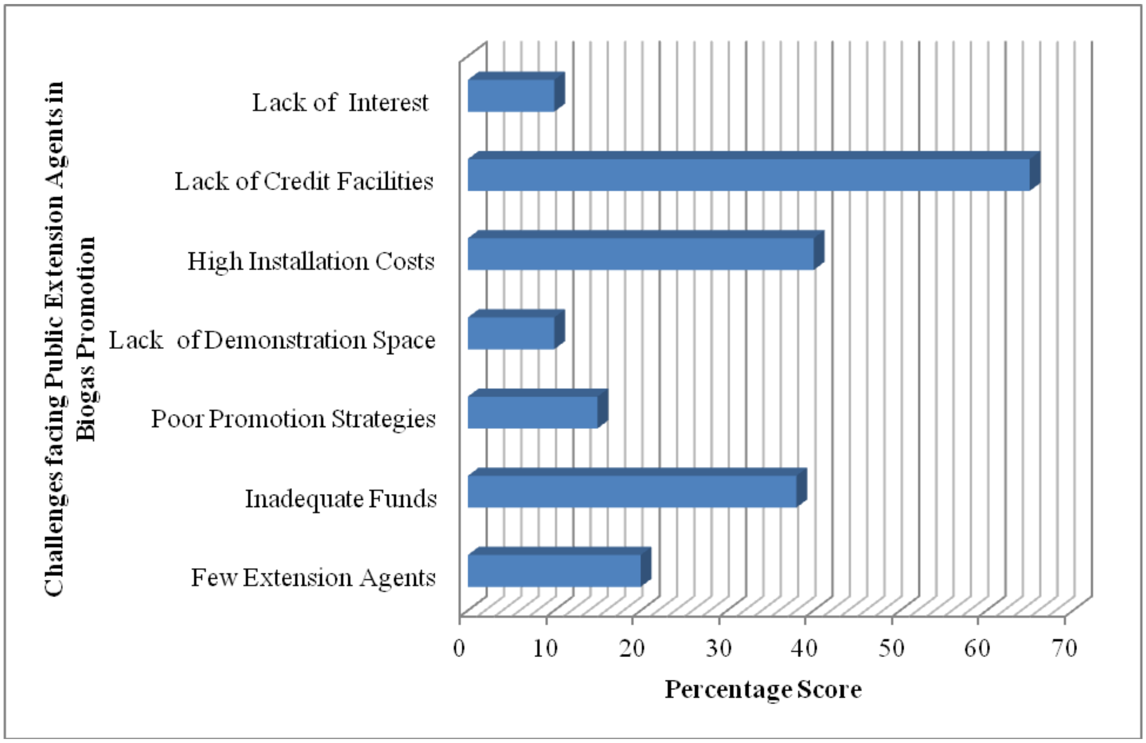


Figure 4.11: Constraints facing Public Extension Agents in Biogas Promotion in the Study Area

According to the government biogas extension agents, the promotion of biogas energy was treated as a cross-cutting issue during their service delivery and visits to the farms. The extension agents said that the scenario was this way because of budgeting constraints and the funds allocated do not factor in biogas technology promotion on its own. This shows that there is managerial flaw by the government in the promotion of biogas technology. As such, there is need for the draft National Energy Policy to view biogas technology as a viable option for applying rural energy by putting in place the necessary financial support to extension agents so as to promote the technology in areas with high potential.

The other major challenge that faced public extension agents in the promotion of biogas technology was poor promotion strategies by the government. The extension agents felt that government has not adequately promoted biogas technology through electronic and print media instead the government issues supportive statements of biogas technology to farmers in public gatherings, farmers' field day, agricultural shows and workshops. A survey conducted by GTZ (2009) revealed that biogas promotion in Kenya was largely done by private enterprises or non-governmental organizations (NGO's) through electronic and print media. This concurs with the result of this study. As such, the Ministry of Energy should collaborate with the private sector to launch a media campaign on biogas technology to arouse interest among potential users, such marketing strategies would provide the required impetus to boost and promote increase use of biogas.

Lack of demonstration farms on biogas technology, the extension workers cited that they don't have biogas demonstration farms in the study area. The one available was at Wambugu farm which was about thirty (30) kilometres away. This scenario forced the extension workers to issue supportive statements to farmers during farmer's field days, farmer's workshops and meetings on the potential of biogas technology in energy provision and waste management. With very little practice to show case to their potential biogas users, this shows that the institutional framework for popularization of biogas technology at the grass root level needs to be strengthened. According to Zhu (2006), the establishment of biogas demonstration farms in Vietnam has been one of the key success factors in the promotion of the technology in the country. The draft National Energy Policy needs to enhance awareness of biogas as an alternative household source of energy by establishing public biogas digesters at each county assembly ward to bring the visibility of the technology at the grass root level.

High installation costs have always hampered the biogas extension in the study area. The extension agents cited that the high initial costs, coupled with inadequate financial credit facilities are some of the barriers to effective biogas technology adoption. Evidence from many African countries indicates that the investment cost of even the smallest biogas unit is prohibitive for most poor African rural households (Karekezi, 2002). In Uganda, a study conducted by Pandey *et al.,* (2007), revealed that the most important constraint hindering the dissemination of biogas technology has been the high initial cost of installation. This concurs with the results of this study.

Lack of awareness and limited information on the benefits and potential of biogas technology was another major hurdle faced by the extension agents in their biogas extension services. According to Bhat *et al.,* (2001), lack of awareness of the value of biogas has been attributed as inhibiting factor in the uptake of this technology in India. This supports the findings of this study. As such, there is need for the key stakeholders in biogas technology to sensitize the public on the potential of biogas energy in improving their livelihoods.

4.6.3 Challenges facing the Private Biogas Actors in Disseminating Biogas Technology

The constraints faced by the agents in the private sector in promoting biogas technology in the study area were; negative publicity at 15%, limited government support at 20%, gender issues at 28%, and lack of trained installers at 30%, high installation cost at 68% and finally ignorance at 15% (Figure 4.12).

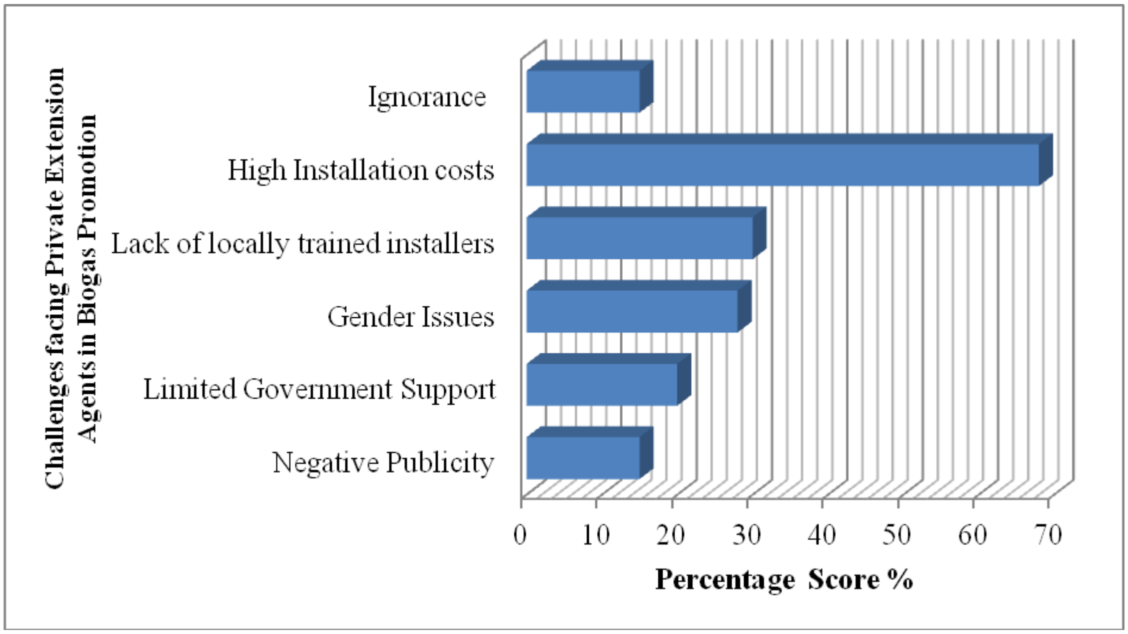


Figure 4.12: Challenges facing Private Biogas Actors in Disseminating Biogas Technology

Negative publicity of biogas technology as a result of poorly functioning biogas digesters was a major hurdle faced by the private biogas technology extension agents in the study area. According to the extension agents, some of the dairy farmers did not feed the digesters as advised by the technicians resulting to low gas production hence creating a negative image on the technology. According to Marchaim (1992), one key failure factor in the development and dissemination of biogas technology in many developing countries is wrong operation and poor maintenance by the users creating a bad image of the technology to non-users.

The other constraint faced by the private extension agents in the promoting biogas technology is limited government support. The private extension agents were in the view that government support on biogas energy was minimal and lacked proper and appropriate institutional structures. For instance, one of the extension agent respondents said *"there is no duty on generators whereas all imported biogas appliances are charged a duty of 25% and a VAT 16%"*. This shows that some of the government policies do not promote the use of biogas energy technology and need to be revised. The National Energy Policy needs to enforce rebates, waivers and promote local manufacture of biogas plants and equipment's in the country.

The private biogas promoters felt that the high installation costs incurred while putting up a biogas plant especially the masonry types such as the fixed dome and floating drum was one of the primary constraints in biogas plant installation. This problem has further being aggregated by lack of credit facilities on biogas installation from the local banks, SACCOs and other micro-finance institutions in the study area. According to GTZ (2009), the absence of funding mechanisms is probably the main hindrance in biogas plant installation in Kenya. This concurs with the results of this study.

Gender issues were also pointed out as another constraint faced by the private biogas technology extension agents. According to extension agents, the prevailing social structures on land tenure systems in Kenya where land belongs to the man have inhibited the adoption and installation of biogas plants by willing women. Although, the Sessional paper on Energy notes the existing cultural structures that inhibit access to modern energy technologies, very little action has been taken to address the social-cultural hurdles. It therefore, calls for a deliberate policy to mainstream gender issues in policy formation, energy planning, energy production and use (Government of Kenya, 2004). In addition, a review of cultural barriers that hinder access to energy and other economic opportunities by women should be taken and the necessary measures undertaken.

Lack of trained biogas installers in the study area posed a major constraint in the dissemination of biogas technology. The private biogas extension agents complained that they were forced to source for qualified biogas installers as far as Embu and Nanyuki as they were no other trained biogas installers locally. This scenario increases the cost of biogas installation which is normally passed to the consumers.

4.6.4 Measures to increase the uptake of Biogas Technology

In order to increase the uptake of biogas technology in Mukurwe-ini, the dairy farmers and biogas actors (Public and Private) mentioned the following ideas and measures. The main measures were provision of credit facilities (80%), increased government support (60%), training biogas technicians (28%), increase awareness on biogas (20%) and establishing of biogas farms (21%) (Figure 4.13).

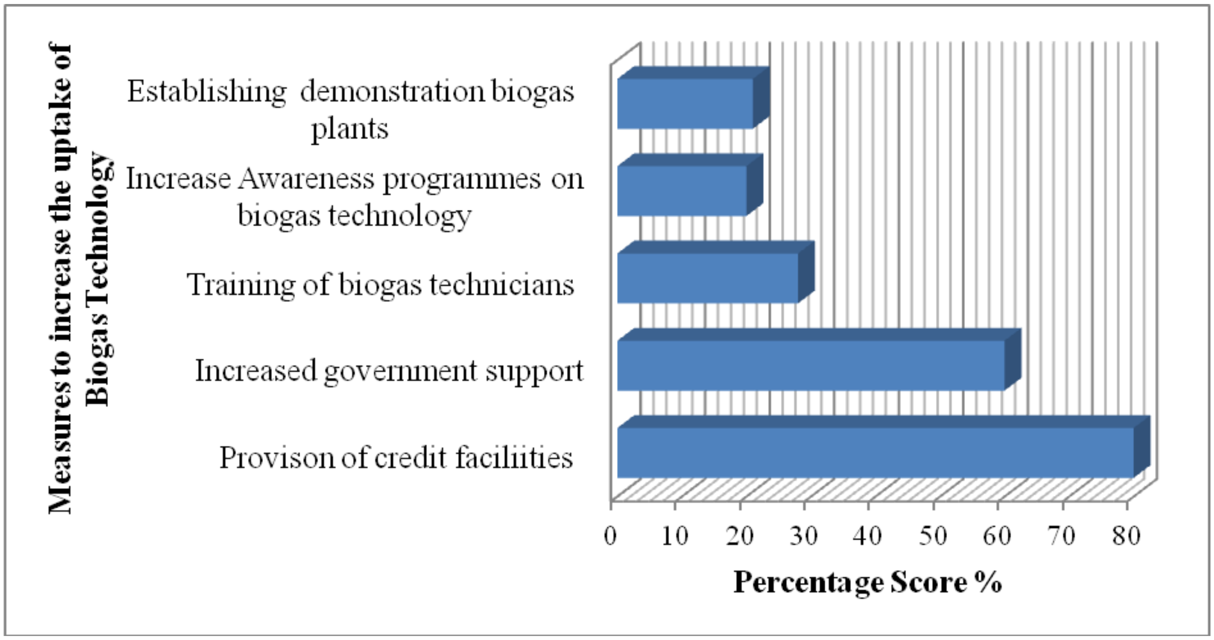


Figure 4.13: Possible Measures to increase the uptake of Biogas Technology in the Study Area.

The provision of micro-finance services is viewed by 80% of the respondents as one the measures to increase adoption and up take of biogas technology among non-biogas users in the study area. These views tallied with those of biogas disseminators in the study area, they cited that lack of biogas credit financing services posed a barrier among prospective users. According to Mugo and Gathea (2010), the uptake of biogas technology in Kenya has remained very low due to high installation costs. This concurs with the results of this study. Further to this, Mugo and Gathea (2010) advices that, an introduction of a financial credit system for interested consumers, especially in the dairy farming areas; could see many households adopting the technology. Mugo's advice tallies with the views of the biogas actors in the study area

About 60% of the respondents called for increased government support in promoting biogas technology as it has done with electricity through the Rural Electrification Programme. Although, the government in its Sessional Paper No.4 of 2004 on Energy recognizes the contribution of biogas technology to rural energy supply (Government of Kenya, 2004). There is no specific government policy statement to explain and strategies in place for the promotion of biogas technology in rural Kenya. Instead, the government has established energy centres to serve as biogas demonstration centres; this approach has not been effective (GTZ, 2009). Sustained support and promotion by the Government through the Ministry of Energy followed by sustained collaboration with the private sector would provide the required platform for biogas technology promotion. In addition, the biogas disseminators called for the government to review the taxation on imported biogas appliances. They cited that the 25% duty on imported biogas appliances increases addition cost on the already capital intensive project. They were in the view that a tax waiver duty on biogas appliances would promote the uptake of the technology in Mukurwe-ini given it is a high potential area.

About 28% of the respondents felt that there should be increased training programmes for biogas artisans, technicians, and all professionals involved in biogas dissemination. During the focused group discussion, one of the respondents lamented that his biogas digester was not working to it full capacity due negligence of the biogas technician. This shows that in the study area, some of them of the biogas technicians are not well trained. According to Mugo *et al.*, (2010), for increased adoption of the biogas technology to occur, there is need to have sufficient numbers of trained artisans who can construct and provide quality services for any interested clients. The National Energy Policy should be enforced and capacity building of biogas technicians at the village polytechnics be rolled out. This will create a pool of trained biogas technicians at the local level.

Increased awareness creation and community training on the benefits of biogas was another measure that was viewed appropriate (20% of the respondents). For potential biogas users to appreciate and embrace the technology there is need for them to understand the benefits accrued. As such, there is need for community sensitisation on the social, economic and environmental gains that would arise if they adopted biogas plants at the household level. The draft National Energy Policy should be enforced and mechanisms put in place to sensitise people on the potential of biogas energy as an alternative source of energy especially in the high potential areas.

Another measure highlighted by the study was establishment of biogas units at the local level especially in the village polytechnics. The biogas actors were in the view that awareness on biogas technology was very low hence the need to practically show case its potential at the local level. According to Ahlborg and Hammar (2010), for biogas adoption rates to improve in high potential areas in developing countries there is need in educating the communities on the benefits and importance of the technology at the local level. As such, there is need for all stakeholders in the biogas industry to create a platform for promotion of the biogas technology. An increased awareness about the technology could create a demand for the technology among potential and interested clients.

CHAPTER 5: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary of Findings

The aim of this study was to assess the challenges of adopting biogas technology in energy provision among dairy farmers in Mukurwe-ini, Nyeri County, Kenya. The findings showed that the main sources of cooking energy at the household level were wood fuel at 76.7% and charcoal at 6.7 %. According to the study, the main challenges of accessing energy at the household were high costs incurred in purchasing fuel, inaccessibility and unreliable supply especially of wood fuel. About 57.5% of the households were dissatisfied with wood fuel, 21.7% with charcoal, 13.3% with LPG, 2.5% with electricity and 4.2% with kerosene as their sources of energy.

Further only about 35.8% of the sample population farmers had adopted biogas technology despite the study area being of high potential given the number of farmers having intensive dairy production systems. Further, the results showed that biogas plants were installed by dairy farmers irrespective of their education level, occupation and age. The most popular type of biogas plant was the plastic tubular digester at 72% because of the low cost incurred during installation. Respondents indicated that the use of biogas technology reduced energy expenditure, enhanced income generation, use of bio-slurry reduced reliance on the use of chemical fertilizers, made cooking more convenient, reduced smoked in the kitchen, and also saved time in meal preparation and cleaning of utensils.

The study also showed that biogas technology users faced some challenges such as low gas production (38.5%) during the cold months, vandalism of plastic sheet (7.7%), gas leakages (38.5%) and blockage of the inlet pipe (13.5%). In terms of challenges affecting farmers in adopting biogas technology, results showed that the uptake of the technology is mainly constrained by high installation costs coupled with lack of credit facilities (70%), absence of skilled biogas installers (26%), social-cultural barriers (46%), negative attitude towards biogas energy and lack of interest (17%).

In terms of opportunities available towards increasing the uptake of biogas technology among households, results showed that both public and private extensions agents were disseminating the technology in the study area. However, they are faced with different setbacks in disseminating the technology. The major constraints were few extension agents (20%), delayed disbursement of funds (38%), poor promotion strategies by the government (15%), lack of demonstration space (10%), high installation costs (40%), lack of credit facilities (16%) from financial institutions, gender issues (15%), lack of trained installers (30%) and ignorance (15%) among potential users.

5.2 Conclusions

The study showed that firewood and charcoal are still the main source of cooking energy in the study area despite the enormous potential for the development of biogas through the use of cattle dung. The use of biogas technology has had significant impacts; it has provided households with cooking energy, bio-slurry for soil application, saved time spent in cooking and cleaning utensils. It has also been used an income generating activity through the sale of bio-slurry by some of the farmers. The study also found that farmers faced a myriad of challenges in the uptake of biogas technology. Some of the challenges were high installation costs, lack of credit facilities from local financial institutions, and inadequate skilled technicians. Currently, public and private extension agents have played an active role in promoting biogas technology in the study area. However, their promotional activities are hindered by limited support from the government, high installation costs, and negative image of the technology and absence of skilled biogas technicians.

5.3 Recommendations

In order to unlock the huge potential of Biogas Technology in Mukurwe-ini in Nyeri, there is need for policy and institutional framework reforms by biogas promoters in government and private sector to develop sustainable strategies to improve the use of biogas among potential users.

The following issues need to be addressed:

- Access to biogas procurement credit facilities – means should be found to make the technology more accessible, as the results show that only a limited share of the rural communities can afford a biogas plant. Lack of access to credit facilities is a major bottleneck to adoption of biogas plants among potential users. It is envisaged that the provision of credit facilities with low interest rates will encourage the dairy farmers to invest in biogas plants especially among the all potential clients, with particular emphasis on the poor, women and other disadvantaged groups. Local farmers associations and savings groups could play a vital role in providing affordable low interest loans for interested farmers.

- More attention should be directed to sensitise households on the benefits of biogas technology. There is still a limited awareness about the economic, social and environmental benefits of biogas, hence there is need for educational and awareness campaigns on biogas benefits and successes at the local level. This can be done through the combined efforts of the government through the line ministry, extension service, private sector and civil society organisations.
- There is need to train at local level, biogas technicians on the different biogas designs, maintenance and repairs of biogas plants to create a pool of qualified technicians at the local level. The presence of trained biogas technicians would lessen construction costs, mistakes and improper feeding of digesters among the users.
- On the issue of Gender and Social-Cultural issues: there is need to undertake public education and awareness creation on the social- cultural structures, norms and practices hindering the uptake of biogas technology especially by women. This should be achieved through improved networking and collaboration with stakeholders promoting biogas technology on the benefits of the technology on each gender.
- Further research needs to be conducted in the study area on the indoor air quality impacts of biogas plants after installation and other health benefits of using biogas to the users. To date, economic and environmental benefits have been the

driving factor of biogas promotion, while important health benefits have been underemphasized

- Further research is needed to identify locally available and appropriate materials that can used to bring down the costs of investing in biogas technology

6. REFERENCES

Ahlborg, H. and Hammar, L., (2010). Drivers and barriers to rural electrification in Tanzania and Mozambique – grid extension, off – grid and renewable

Amigun *et al.* (2008). Commercialisation of biofuel industry in Africa: A review. *Renew. Sustain. Energy Rev.*

Bell, J. (1993). *Doing your Research Project*. Buckingham: Oxford University Press.

Best, J.W. and Kahn, J.V. (1993). Research in Education (7th Edition). Boston Allan and Bacon Press.

Bhat, P.R., Chanakya, H.N., and Ravindranath, N.H. (2001). Biogas plant dissemination: Success story of Sirsi, India. Energy for Sustainable Development.5 (1):39-46.

Biogas for better life, An Africa Initiative, (2007). A Feasibility Study by Shell Foundation, Nairobi, Kenya.

Brylinsky, T. (1997). Review of 'Structural Adjustment, the Environment and Sustainable Development.

Bryman, A. (2008). *Social research methods*. 3 ed. Oxford: Oxford University Press.

Cecelscki, E. (2001). Gender and Energy Conservation in Namibia: A case study with special references to GTZ/ProBEC Interventions. Nambia.

Chandran, E. (2004). *Research methods: A quantitative approach*. Nairobi: Daystar University

Chris, D. (1998). Rural Development in the Third World. Routledge Publishers. London.

Clancy, J. (2002). Household Energy and Gender: an Introduction. University of Twente, Technology and Development Group. The Netherlands.

Dahoo, C. (2011). MSc. Thesis: The Impacts of Bio-digesters on Kenyan farm women. Dalhousie University, Canada.

Denton, F. (2005). Communities on the Margins of Development.UNDP West Africa.

Department of International lnternational Development (DFID), (1998). "Sustainable rural livelihoods", UK Department for International Development, London. Energy technologies for cooking. *Energy Conversion and Management,* Vol. 36, No. 12, pp. 1129-1132.

Food and Agricultural Organization (FAO), (2009). Enabling agriculture to contribute to climate change mitigation. FAO, Rome.

Food and Agricultural Organization (FAO),(2006). Global Forest Resources Assessment.2005.FAO Forestry Paper 147. FAO. Rome. Italy.

Food and Agricultural Organization and World Energy Council (FAO/WEC), (1999). "The challenge of rural energy poverty in developing countries", World Energy Council, FAO, London.

Gautam, R. and Ghimire, S. (2009). Biogas as a sustainable energy source in Nepal: Present status and future challenges; Renewable and Sustainable Energy Reviews 13 248–252. Nepal.

Gay, L. R and Airasian, P. (2000). *Education Research: Competencies for Analysis and Application* .6th edition. New Jersey: Prentice Hall.

Gitonga, S. (1997). Biogas Promotion in Kenya: A review of experiences, Practical Action, Warwickshire, UK.

Government of Kenya. (2011). *Scaling Up Renewable Energy Program (SREP). Investment Plan for Kenya*. (May). The Government Printers. Nairobi, Kenya.

Government of Kenya, (2009). Kenya Facts and Figures 2009. Kenya National Bureau of Statistics. The Government Printers. Nairobi, Kenya.

Government of Kenya, (2007). Kenya Vision 2030. The Government Printer, Nairobi. Kenya.

Government of Kenya, (2006). *Energy Act*. The Government Printer, Nairobi, Kenya

Government of Kenya, (2004). *Sessional Paper No of 2004 on Energy*. The Government Printer, Nairobi, Kenya.

.GTZ, (2009). Agro-industrial biogas in Kenya Potentials, Estimates for Tariffs, Policy and Business Recommendations. Herausgegeben von Ministry of Energy, Kenya.

GTZ-SEP, (1987). Dissemination of Biogas in Rural Areas of Kenya. Nairobi, Kenya.

Günter *et al*., (2010). Promotion of Private Sector Development in Agriculture. Nairobi. Kenya

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

Hendrick, E.T., Bickman, L. and Rog, L.D, (1993). Applied Research Design. A practical Guide, Sage Publications, New Delhi.

International Energy Agency (IEA), (2008). *Key World Energy Statistics 2008*: OECD/IEA, Paris, France.

International Fund for Agricultural Development (IFAD), (2009). Rota, A., Liversage, H. and Calvosa, C. "Livestock and Land: tools for design" in Livestock Thematic Papers: Tools for project design. International Fund for Agricultural Development (IFAD), Rome.

International Fund for Agricultural Development (IFAD), (2009). (Draft). *Comprehensive Report on IFAD's Response to Climate Change through Support to Adaptation and Related Actions.*

International Fund for Agricultural Developmentand Food and Agricultural Organisation (IFAD/FAO), (2003). *Labour Saving Technologies and Practices for Farming and Household Activities in Eastern and Southern Africa, Labour Constraints and the Impact of HIV/AIDS on Rural Livelihoods in Bondo and Busia Districts, Western Kenya*, Nairobi. Kenya.

Inter- Government Authority on Development(IGAD), (2007). Annual Report. Nairobi, Kenya.

Jaetzold, R. and Schmidt, H. (2007). Farm Management Handbook of Kenya, Natural Conditions and Farm Information. Vol.11B Central Kenya, Ministry of Agriculture, Nairobi, Kenya.

Jonušauskait, G. (2010). Perceived benefits & challenges of biogas adoption among households in Kenya. *IVM Institute for Environmental* Studies, pp. 1-59.

Kamfor, (2002), "*Study on Kenya's energy demand, supply and policy strategy for households, small scale industries, and service establishments*. Final Report." Nairobi: Ministry of Energy.

Kantai, P. (2002). Hot and Dirty: Inside Kenya's 23 billion Shilling Charcoal Industry. *Eco Forum; Environmental Liaison Centre International*. Nairobi, 2002, 16-22.

Karanja, G.M. and Kiruiro E.M. (2004). Low-cost On-farm Biogas Production. KARI Technical Publication Note No. 25 KARI, Nairobi.

Karekezi, S. (2002).Renewables in Africa - meeting the energy needs of the poor. *Energy Policy 30, 1059-1069.*

Kassenga, G. R. (1997). Promotion of renewable energy technologies in Tanzania. *Resources, Conservation and Recycling 19, 257-263*.

Katuwal, H. and Bohara, A. K. (2009). Biogas: A promising renewable technology and its impact on households in Nepal. *Renewable and Sustainable Energy Reviews. 13*, 2668-2674.

Kenya National Bureau of Statistics (KNBS) (2010). The 2009 Kenya Population and Housing Census, Government of Kenya August 2010 Vol. 1A.

Kenya National Domestic Biogas Program (KENDBIP). (2012). Annual Report. Nairobi, Kenya.

Kenya National Domestic Biogas Program (KENDBIP). (2009). Annual Report. Nairobi, Kenya.

Kenya Population and Housing Census Highlights. (2009). Kenya National Bureau of Statistics, The Government Printer, Nairobi, Kenya.

KIPPRA. (2007) *Strategies for Securing Energy Supply in Kenya*. Discussion Paper No. 74. Kenya Institute of Public Policy Research and Analysis. Nairobi, Kenya.

Kituyi, E. (2004). Towards sustainable production and use of charcoal in Kenya: exploring the potential in life cycle management approach. *Journal of Cleaner Production* 12, 1047–1057.

Kulundu, N. (2003). *The Role of Energy in Job Creation*. Paper presented at the energy conference, Grand Regency Hotel, Nairobi, Kenya. March 18th 2003.

Lekule, F.P. (1996). *Technologies for improving the wellbeing of rural women in Tanzania.* Final report submitted to FAO/SIDA Farming Systems Programme.

Madan, B. B., Amrit, B., Karki. Jagan, N. S. and Sundar, B. (2004). Biogas as Renewable Source of Energy in Nepal Theory and development BSP – Nepal.

Mapako, M. (2000). Renewable and Energy for Rural Development Theme Group: Data and Statistics Compilation - Zimbabwe. African Energy Policy Research Network (AFREPREN/FWD), Nairobi.

Marchaim, U. (1992). *Biogas processes for sustainable development. FAO Agricultural services* Bulletin 95. Rome, Italy

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

Mbuthi, P. Odongo, F., Machera, M. and Imitira, J. K. (2007). *Gender Audit of Energy Policy and Programmes in Kenya*, ENERGIA reports.

McCulloch, A.K, *et al.*, (1998). Property Rights, Collective Action and Technologies for Natural Resourcebnmnbnn Management: A Conceptual Framework FRAME WORK. Washington D.C., IFPRI.

Ministry of Energy, Government of Kenya, (2002). *Study on Kenya's energy supply and policy strategy for households, small-scale industries and services establishments*. Final report. The Government Printer, Nairobi. Kenya.

Muchiri, L. (2008). Gender and Equity in Bio Energy Access and Delivery in Kenya. Practical Action Eastern Africa.

Mugenda,M.O. and Mugenda, A.G. (2003). Research Methods Qualitative and Quantative Approaches. African Centre for Technology Studies (ACTS), Nairobi, Kenya.

Mugo, F. and Gathea, T. (2010). *Biomass energy use in Kenya*. A background paper prepared for the International Institute for Environment and Development (IIED) for an international ESPA workshop on biomass energy, 19-21 October 2010, Parliament House Hotel, Edinburgh. Practical Action, Nairobi, Kenya.

Mukurwe-ini Constituency Strategic Plan. (2012). Mukurwe-ini Constituency Office.

Muriuki H.G., Mwangi, D.M. and Thorpe, W. (2001). How smallholder dairy systems in Kenya contribute to food security and poverty alleviation: results of recent collaborative studies. URI: http://hdl.handle.net/10568/1725. Accessed on 31/01/2012.

Mwakaje, A.G. (2008). Dairy farming and biogas use in Rungwe district, south-west Tanzania: a study of opportunities and constraints. Renewable and Sustainable Energy Reviews, 12, 2240–2252.

Mwirigi, J.W., Makenzia, P.M. and Ochola, W.O. (2009). "Socio-economic constraints to adoption and sustainability of biogas technology by farmers in Nakuru Districts, Kenya" Energy for Sustainable Development Vol. 13(2): pp. 106 – 115.

Myles, R. (2004). Environmental, Social and other Positive Impacts of Building Household Biogas Plants in Rural India. A paper prepared for (World-Council-for-Renewable-Energy) and EUROSOLAR sponsored Second World Renewable

Energy Forum: Renewing Civilization by Renewable Energy, from May, 29 - 31, 2004, Bonn, Germany.

National Environment Management Authority (NEMA). (2007). *Effects of Climate Change and Coping Mechanism in Kenya*. Kenya; NEMA/ UNDP, Nairobi, Kenya

National Environment Management Authority (NEMA). (2005). *State of Environment Report 2004*. NEMA Secretariat, Nairobi, Kenya.

Netherlands Development Program (SNV) (2011). Brief report 2010 and plan 2011 of the Working Group on Domestic Biogas under the Energy for All Partnership. Accessed from http://www.snvworld.org/en/Pages/Publications-item.aspx?publication=596 on November 12th 2012.

Njoroge, D.K. (2002). Evolution of biogas technology in South Sudan: current and future challenges. Proceedings from biodigester workshop. Available at http://www.mekarn.org/Procbiod/kuria.htm. (Access date: 09/07/2012)

Omer, A. M. and Fadalla, Y. (2003). Biogas energy technology in Sudan. *Renewable Energy 28, 499-507.*

Pandey, B., Subedi, P., Sengendo, M. and Monroe, I. (2007) Report on the Feasibility of a National Household Biogas Commercialization Program in Uganda. Winrock International.Retrievedfrom:http://www.snvworld.org/en/Documents/Biogas_for_better_life_an_African_initiative_Feasibility_study_Uganda_2007.pdf (14-11-2012).

Quadir, S.A., Mathur, S.S. and Kandpal, T.C. (1995). Barriers to dissemination of renewable Report of the Millennium Assessment WHO, Geneva.

Rural Electrification Authority (REA) (2009). Kenyan Electricity Expansion Project (EASP) Rural Electrification Authority (REA), *Resettlement Policy Framework 2*.

Schwengels, P. (2009). Dairy Manure Biogas Opportunities in Manica Province, Mozambique. A Preliminary Assessment. Prepared for Land O' Lakes International Development Smallholder Dairy Development Program in Manica Province, Mozambique.

Smith, K.R. and Webb S.E. (2005). Household fuels and ill-health in developing countries: what improvements can be brought by LP gas (LPG) Paris, France.

Spagnoletta, S.A. (2007). Viability study for the application of small size biodigesters in the Andean rural zone of Cajamarca. Loughborough University.

Standing, H. (2002). Understanding the links between energy, poverty and gender. Boiling Point No. 48. IT Publications. Systems Analysis, Chalmers University of Technology, Göteborg, Sweden.

Tadesse, L., (2011). Study on Current Status of Institutional Biogas Plants in Ethiopia's. Master's Thesis. Addis Ababa University, Ethiopia.

Tafdrup, S. (1995).Viable Energy Production and Waste Recycling from Anaerobic Digestion of Manure and Other Biomass Materials. Biomass and Bio Energy, 9 (1-5): 303-14.

Tereza, Z. (2011).Improving sustainability of rural livelihoods in Son La province, Northwest Vietnam: Potential of use of biogas digesters.

United Nations and Development Programme and World Health Organisation (UNDP/WHO). (2009). *The Energy Access Situation in Developing Countries, a*

Review paper focusing on the Least Developed Countries and Sub-Saharan Africa, Nairobi, Kenya.

United Nation Energy.(UN Energy) (2006). *Assessing Policy Options for Increasing the Use of Renewable Energy for Sustainable Development: Modelling Energy Scenarios for Ghana*, UN-Energy, UN Division of Sustainable Development, New York.

United Nations Energy. (UN Energy) (2005). "*The Energy Challenge for Achieving the MDGs"*, web: http/www: esa.un.org/un-energy accessed on 29/07/2010.

United Nations Environment Programme (UNEP). (2006). *Kenya: Integrated assessment of the Energy Policy*. *With focus on the transport and Household energy sectors*. 83 p.

United Nations Funds on Climate Change (UNFCC).(2010).Small-Scale Biogas digester for Sustainable Energy production in Sub-Saharan Africa.

Wakulima Dairy Limited. (2011). *Annual Report.* Mukurwe-ini. Kenya.

Walekhwa, P.N., Mugisha, J., and Drake, L., (2009). Biogas energy from family-sized digesters in Uganda: Critical factors and policy implications. *Energy Policy*. Volume 37, No 7, July 2009, 2754-2762

World Bank, (2008). *World Development Report 2008: Agriculture for Development*, World Bank, Washington, D.C.

World Bank, (2007). *Climate change adaptation in Africa: a microeconomic analysis of livestock choice*. World Bank Policy Research Working Paper No. 4277, July 2007.

World Bank, (1999)."*Fuel for thought - environmental strategy for the energy sector"*, World Bank, Washington, DC.

World Health Organization (WHO), (2009). The Energy Access Situation in Developing Countries: A Review Focusing on the Least Developed Countries and Sub-Saharan Africa, New York.

World Health Organization (WHO). *(*2006). *Fuel for Life: Household Energy and Health.* Geneva.

World Health Organization (WHO). (2005). Ecosystems and Human Wellbeing; Health Synthesis

World Health Organization (WHO). (2002). *World Health Report: Reducing risks, promoting healthy life.* Geneva, World Health Organization.

Yadvika, S., Sreekrishnan, T.R., Kohli, S. and Rana, V. (2004). Enhancement of biogas production from solid substrates using different techniques—A review. *Bioresour. Technol. 95*, 1–10.

Zhu, T. (2006). Assessment of Small-Scale Biogas Systems and Their Widespread Dissemination in Can Tho City, Viet Nam[http://digitalcollections.sit.edu/isp_collection/303/ Accessed 28th May 2012.

Zschauer, K. (2010). Land use and agriculture in the Taita Hills – a case study of Ngangao. In Johansson, T., Pellikka, P. & Sorvali, J. (edit.). Safari Njema- an interdisciplinary field expedition to South-East Kenya. *Expedition Reports of Department of Geography*, University of Helsinki 46. 125 p.

7. APPENDICES

7.1: Farmers Questionnaires

Section One: Socio-Economic Information

1 a) General information

Date: ____________________ Location:______________________

Sub-Location: ___________________________Village: ______________________

Gender	Male [ ]	Female [ ]		
Age	18 -25 [ ]	26-40 [ ]	Over 40 [ ]	
Education Level	Primary [ ]	Secondary [ ]	Post-secondary[ ]	None [ ]
Means of livelihood	Farmer [ ]	Casual labourers[ ]	Business [ ]	Employed [ ]
Farming activities	Cash crops [ ]	Food crops [ ]	Dairy Livestock [ ]	

b) If you choose Dairy in above

c) State how many? Cows …………………. Calves …………………

2: What value do you attach to dairy cattle? *Tick (√) appropriately*

Value	Very Important	Moderately Important	Less important	Not Important
Main source of income				
Biogas production				
Security/collateral for funds				
Cultural fulfilment				
Any other specify ………				

Section Two: Sources of Energy

3 What are the sources of energy that you use?

Source of energy	Frequently Used	Moderately Used	Less Used	Never Used
Wood fuel				
Charcoal				
Liquid petroleum Gas				
Biogas				
Electricity				
Kerosene				
Any other specify				

(b) Briefly explain why it is your main source of energy?

…………………………………………………………………………………………

3 What are the major challenges of accessing energy in your household?

Costs	[ ]
Accessibility	[ ]
Others (specify)	…………………………………………

4 a) How much money per week, on average do you spend on the above source of energy?

Kshs ……………………………..

b) How much time per week, on average, do you spend collecting wood for cooking?

Minutes …………………………..

c) If you have a biogas digester how much time per week did you spend collecting Wood, on average, for cooking prior to getting your biogas digester? Minutes …………………………..

d) How much money per week, on average, do you spend on wood for cooking? Kshs ……………………………..

e) If you have a biogas digester how much money per week did you spend on wood, on average, for cooking prior to getting your biogas digester? Kshs ………………………

f) How much money per week, on average, do you spend on other fuels for cooking? Kshs ……………………….

g) If you have a biogas digester how much money per week did you spend on other fuels, on average, for cooking prior to getting your biogas digester? Kshs ………………….

h) Do you get wood that has been dried for 6 months or more? Yes [ ] No [ ]

i) When you get wood for cooking, how often do you cut down a whole tree?

i. Every week [ ]
ii. Every month [ ]
iii. A few times during the year [ ]
iv. Once during the year [ ]
v. Never [ ]

J) When you get wood for cooking, how often do you cut limbs off of a tree?

i. Every week [ ]
ii. Every month [ ]
iii. A few times during the year [ ]
iv. Once during the year [ ]
v. Never [ ]

5: Are you satisfied with the energy supply used in the household at present? *Indicate the number in the space provided*

Energy Source	Satisfaction Yes No	Reason for dissatisfaction 1. Unreliable 3. Too expensive 2. Inefficient 4. Others (specify)
Wood		
Charcoal		
Electricity		
Paraffin/ Kerosene		
LPG		
Biogas		
Solar		
Others Specify		

Section Three: Information about Biogas Energy among the Smallholder Dairy Farmers.

6: Does your household have a biogas system? Yes [ ] No [ ]

If 'yes', which type of Biogas system? ___________________________________

If 'No', are you aware of Biogas as a source of energy? Yes [ ] No [ ]

7: In your opinion, briefly explain the associated benefits of using biogas energy

Social

…………………………………………………………………………………………………

Economic

…………………………………………………………………………………………………

Environmental

…………………………………………………………………………………………

8 (a) What do you consider to be the main challenges of adopting biogas energy in your opinion?

Limitations	Very Important	Moderately Important	Less important	Not Important
Lack of adequate funds				
Poor infrastructure (lack of zero grazing unit)				
Inadequate skilled disseminators				
Poverty				
Community's negative attitude towards biogas energy				
High installation cost				
Lack of interest				
Any others Specify ……………………………………				

b) Briefly explain your ratings above......................................………………………

9: In your opinion what are some of the measures that would improve in the replicating the biogas technology among small-holder dairy farmers?

Possible Measures	Very Important	Moderately Important	Less important	Not Important
Provision of Micro-finance				
Increased government will and support				
Increased training programmes for disseminators				
Community leadership program in renewable energy				

Establish demonstration centres				
Any other specify………………………………				

7.2: Focal Group Discussion themes

i. Status of biogas technology adoption in the study area
ii. Challenges faced by dairy farmers in adopting biogas plants
iii. Impacts of biogas technology on farmers' livelihoods
iv. Constraints facing biogas actors in promoting biogas technology
v. How to increase the uptake of biogas technology in the study area

7.3: Key Informant Interview

Biogas Promoters/ Actors Questionnaires

Section one: General Information

Date…..Area:…………………………………….

Questionnaire no...

Type of actor Public ( ) Private ( )

2. How long have you worked in this area (in years)

0-5 ( ) 5-10 ( ) 10-15 ( ) over 15( )

3. How long have you been promoting biogas?

4. How would you rate the use of biogas technology in this area?

Rating	Please tick where applicable
Very good	
Good	
Fair	
Satisfactory	
Unsatisfactory	

Section Two: Challenges facing biogas promoters in promoting biogas technology at the farm level

5(a) Please tick in order of importance (from 1= most important). What do you consider to be the main causes of low adoption of biogas technology in this area?

Limitation	Tick as applicable	Rate in order of importance 1 as the highest
High installation costs		
Phobia of biogas energy		
Poor infrastructure		
Any other specify		

(b)Briefly explain your rating……………………………………………………………..

6 (a) In your opinion what are some of the measures that would improve the adoption of biogas technology in the area. Please tick and rate in order of importance and rate in order of perceived priority.

Possible measures	Tick as applicable
Provision of micro finance	
Community training on renewable energy technologies	
Establishing demonstrations centres	
Increased government support	
Any other specify	

(b) Briefly explain your rating ……………………………………………………………

7(a)In your opinion do you think the government has done enough to promote biogas technology in the area?

If yes, how? ……………………………………………………………………………..

If no, what needs to be done? Briefly explain