

**ADOPTION OF BIOGAS TECHNOLOGY AS AN ALTERNATIVE ENERGY SOURCE
IN GAKAWA LOCATION, NYERI COUNTY, KENYA**

SAMUEL NDUNG'U IKONYA

N/50/CE/22651/10

**A Masters Project Submitted in Partial Fulfilment for the Degree of Master of
Environmental Studies and Community Development of Kenyatta University**

February 2018

DECLARATION

“This project is my original work and has not been presented for a degree in any other University”.

SAMUEL NDUNGU IKONYA

N/50/CE/22651/10

Signed-----

Date-----

“We as University supervisors confirm that the work reported in this project was carried out by the candidate under our supervision”.

Dr Felix L. Mingate

Department of Environmental Studies and Community Development

Kenyatta University

Signed-----

Date-----

Dr Joseph K. Muriithi

Department of Environmental Studies and Community Development

Kenyatta University

Signed-----

Date-----

DEDICATION

I would like to dedicate this project to my loving wife, Emily, and my children, Collins and Annette, whose unconditional love and support went beyond any expectations. My son, at such young age, accompanied me most of the time during the field. He taught me important life lessons that success consists of hard work, resiliency and leaving a positive impact in the life of those we meet. I dedicate it too; to my parents who implored on me to trust the Almighty God in all my endeavours, to never give up, and required that we give the best of ourselves in the family.

ACKNOWLEDGMENT

I thank the Almighty God for walking with me and giving me company when I felt lost and alone through this long journey of this academic endeavour.

Throughout the development of this research I had the support of several people and institutions, without which I would probably be unable to undertake this journey. To all of them I would like to express my deepest gratitude.

Sincere thanks go to the farmers who volunteered to be interviewed. Without sacrificing their valuable time to answer the survey questions, this study would not have been possible. I particularly single out Mr. Nyamu the Biogas programme coordinator at Kenya National Biogas Programme (KENBP), whose guidance and assistance was a great input. Mr. Lawrence Alaro assistance with data analysis is greatly appreciated.

I cannot say exactly how grateful I am to Dr. Felix Mingate and Dr. Joseph Muriithi. Their guidance in this study was beyond measure.

I would also like to extend my sincere thanks to my colleagues, Mr. Mutuota Chege, Mr. Chris Njuguna, and Mr. Zablon Chege, for reading through the various drafts, and giving me insightful comments.

I would like to express my deepest gratitude to my brother John Njoroge who sponsored my tuition for this course and the entire Ikonya family for providing the emotional and moral support.

To all these people and more I thank you for your contributions and generous support which will always be engrained in my mind.

ABSTRACT

This study aimed at evaluating the factors influencing the adoption of biogas as an alternative energy source in Gakawa location, Nyeri County. The study delved into the socio cultural factors which influence the adoption potential of biogas technology; the attitude towards adoption of biogas technology among the small scale farmers and the role of formal and informal institutions in the use of biogas as an alternative energy source. Using multi stage sampling a sample of 351 households was sampled to capture the experiences of biogas adopters and other potential adopters. Primary data was collected through a questionnaire consisting of both open ended and close ended questions. Secondary data was accessed from key informants such as agricultural extension officers, heads of local cooperative dairy society, and Non-Government Organization coordinators, involved in the energy-environment landscape. Data was analysed using Statistical Package for Social Sciences and results presented in frequency tables. The study reveals that the household characteristics contributed to the attitude towards adoption. The result showed that, Biogas Technology adoption was significantly affected by the age, gender and educational level of the farmer ($R^2 = 0.045, 0.077$ and 0.094 respectively), $P < 0.05$. The study revealed that 66.7 % of the respondents have poor understanding of biogas technology. The results indicated the ineffectiveness of community development officers (46.2 %), and extension officers' failure to spend time with the farmers (48.4 %), as the main reasons that hinder adoption. The study thus revealed great gaps in the extension services envisaged to provide the requisite information $r=0.228, P=0.0001$. The study recommends a participatory approach with all stakeholders towards improving rural incomes and access to affordable credit facilities. The study recommends the revitalization of the extension services in the concerned department and the strengthening of community resource groups that sensitize the local community to engage in other livelihood strategies that do not destroy the environment. This is with the aim of making adoption of biogas as an alternative energy source.

TABLE OF CONTENTS

DECLARATION	ii
DEDICATION.....	iii
ACKNOWLEDGMENT	iv
ABSTRACT	v
TABLE OF CONTENTS	vi
LIST OF TABLES	xi
LIST OF FIGURES	xiii
ACRONYMS AND ABBREVIATIONS	xiv
INTRODUCTION	1
1.1 Background to the study	1
1.2. Statement of the problem and justification	4
1.3 Objectives of the study	5
1.4 Research questions	6
1.5 Research hypothesis	6
1.6 Significance of the study.....	6
1.7 Conceptual framework.....	7
1.8 Definitions of terms	10
CHAPTER TWO	12
LITERATURE REVIEW	12
2.1 Introduction.....	12
2.1.1 What is Biogas?.....	12
2.1.2 Global Energy Outlook.....	14
2.1.3 Renewable energy and sustainable development,	17
2.1.4 Livestock as a potential renewable energy source.....	18

2.1.5 A Global perspective of Bio-Gas Technology (BGT).....	19
2.1.6 Biogas status in Africa	21
2.1.7 The status of biogas adoption in Kenya	23
2.1.8 Kenya National Domestic Biogas Programme (KENDBIP)	24
2.1.9 Kenya’s Energy Policy guidelines and energy situation.....	27
2.2 The Impact of Decision Making on Adoption of Agricultural Technology	28
2.2.1 Decision making models.....	30
2.2.2 Technology adoption and acceptance-paradigms.....	35
2.3 Social- Cultural Factors, their Influence on Decision Making and Adoption of Technology.....	36
2.3.1 The Social Factor.....	37
2.3.2 Culture, energy and adoption of technology	39
2.3.3 Culture and energy household preferences	40
2.3.4 Value of in-kind household contributions towards adoption.....	41
2.3.5. Influence of Gender relations in household decision making	42
2.3.6 Gender segregated extension services	43
2.4 Attitude towards use of Biogas as an alternative energy source.....	45
2.5 Role of the Change Agent- Formal, Informal Institutions and Extension Services.....	47
2.5.1 Promotion and Marketing policies	48
2.5.2 Operation and maintenance	49
2.5.3 Training.....	50
2.5.4 Access to credit.....	51
2.5.5 Community involvement and implementation	52
2.6 Summary and identification of research gap.....	53
CHAPTER THREE:.....	54
METHODOLOGY	54

Introduction	54
3.1 Study area.....	54
3.1.1 Population, location and size.....	54
3.1.2 Climatic and Agro-ecological characteristics	56
3.1.3 Agro practices.....	56
3.1.4 Socio-economic characteristics	58
3.2 Research design.....	59
3.3. Study population.....	59
3.4 Sampling procedure and Sample size	59
3.4.1 Sampling procedure	59
3.4.2 Sample size.....	60
3.5 Data Collection.....	61
3.6 Data analysis	62
CHAPTER FOUR.....	64
RESULT AND DISCUSSION	64
4.0 Introduction.....	64
4.1 Demographic information of the respondents.....	64
4.1.1 Locality of Persons who responded to the questionnaire in the households	64
4.2. Socio cultural factors affecting adoption of BGT	65
4.2.1 Gender of the respondents.....	66
4.2.2 Age of the respondents.....	67
4.2.3 Period of residency of the farmers	69
4.2.4 Education levels of the respondents	70
4.2.5 Marital Status and occupation of the respondents	72

4.2.6 Relationship between farmer characteristics variables and adoption of biogas technology.....	73
4.2.7 Cooking energy Source, Availability and consistency of the fuel wood resources	75
4.2.8 Availability and consistency of fuel wood by Non BGT adopters.....	80
4.2.9 Money spent by the non-BGT adopters on fuel	81
4.2.10 Energy saving technology practiced by some non-BGT adopter farmers	82
4.2.11 Source of lighting available among the respondents	84
4.2.12 Land utilization by the farmers.....	86
4.2.13 Land tenure.....	87
4.2.14 Decision making on energy options used by the family	89
4.3 Attitudes and adoption of Biogas technology	90
4.3.1 Attitude towards social cultural factors affecting adoption of BGT	91
4.3.2 Farmers views on ways to improve acceptance of biogas technology	98
4.3.3 Mode of stock keeping.....	99
4.3.4 Benefits from adoption of biogas technology	104
4.4 Institutional arrangements and BGT adoption	107
4.4.1 Farmer’s response towards Extension services in the area	108
4.4.2 Institutional Challenges faced by the respondents in Biogas Technology adoption ..	113
CHAPTER FIVE	117
5.1. SUMMARY OF THE FINDINGS, CONCLUSIONS AND RECOMMENDATIONS	117
5.2.1 Social cultural factors influence the level of adoption of biogas as alternative energy source.....	119
5.2.2 The attitude of farmers towards the use of biogas technology as an alternative energy source.....	120
5.2.3 Institutional arrangements influence on the level and rates of adoption of biogas as alternative energy source.	122

5.3. Recommendations	124
5.4 CONCLUSIONS	125
5.5 AREAS FOR FURTHER RESEARCH	126
REFERENCES	128
APPENDICES	144

LIST OF TABLES

<i>Table.2.1 People Relying on Traditional Biomass (million)</i>	16
<i>Table 2.2 Domestic biogas plants in rural areas in Kenya</i>	25
<i>Table 2.3 2014 (KENDBIP) Production table</i>	27
<i>Table 3.1: Population size: Kieni East-Gakawa location</i>	56
<i>Table 4.1: Locality of the sampled farmers (Non -BGT adopters)</i>	64
<i>Table 4.2: Gender information of the farmers</i>	66
<i>Table 4.3 Age of the respondents</i>	67
<i>Table 4.4: Period of residency of the farmers</i>	70
<i>Table4.5 Education levels of the respondents</i>	71
<i>Table 4.6 Marital Status</i>	72
<i>Table 4.7 Correlation on the age of household and adoption</i>	74
<i>Table 4.8 Regression results showing the relationship between age gender and education with adoption</i>	75
<i>Table 4.9: Energy saving technologies adopted by the Non -BGT adopter</i>	82
<i>Table 4.10: Lighting sources used by the farmers</i>	84
<i>Table 4.11: Sizes of the Farms owned by farmers</i>	86
<i>Table 4.12 Method of land acquisition</i>	88
<i>Table 4.13 Decision making Trends</i>	89
<i>Table 4.14: Socio cultural challenges to biogas adoption in the area noted by the BGT adopter</i>	93
<i>Table 4.15: Social cultural challenges affecting adoption of BGT noted by Non-adopters</i>	94
<i>Table 4.16: Non-BGT adopters Farmers views on ways to improve acceptance of biogas technology</i>	99
<i>Table 4.17: BGT Adopters' suggestions towards increased adoption potential of biogas technology</i>	104

<i>Table 4.18: Most important benefits in adoption of biogas technology (non-adopters).....</i>	<i>105</i>
<i>Table 4.19: Main benefits to biogas adoption in the area noted by the BGT adopters.....</i>	<i>106</i>
<i>Table 4.20: Farmers taking up the recommendation of the advice from the visits.....</i>	<i>111</i>
<i>Table 4.21: Awareness of the extension officers in the location.....</i>	<i>113</i>
<i>Table 4.22: Challenges faced in BGT adoption.....</i>	<i>114</i>

LIST OF FIGURES

Figure 1: Conceptual framework showing the representation of the factors that may influence a farmer’s decision to accept and adopt biogas technology.....	9
Figure 2.1: Biogas Schematic	13
Figure 2.2: Phases of decision making process	31
Figure 2.3: The Stages of Innovation Diffusion	33
Figure 3: Map of Nyeri county-inset Gakawa location.....	56
Figure 4.1: Occupation of the farmers	73
Figure 4.2: Cooking energy source for the BGT adopter farmers.....	77
Figure 4.3: Cooking energy source for non BGT adopter farmers.....	78
Figure 4.4: Non BGT Adopter Farmers’ source of firewood.....	79
Figure: 4.5: Availability and consistency of fuel wood	80
Figure 4.6: Amount of money spent by the farmers on wood fuel per load.....	81
Figure 4.7: Cross Tabulation of Possession of Title Deed *state of adoption.....	88
Figure 4.8: Non BGT adopters system of stock keeping.....	101
Figure 4.9: Farmers who were aware about extension officers and received advice given regarding biogas	108
Figure 4.10: Frequency of inspection of the farms by CDOs.....	109

ACRONYMS AND ABBREVIATIONS

ABPP	: Africa Biogas Partnership Programme
AD	: Adopter
BGT	: Biogas technology
BSP	: Biogas Support Programme
COMPACT	: Community Management for Protected Areas Conservation
EAC	: East African Community
GoK	: Government of Kenya
GR	: Guara region
GT	: Gathiuru
GVEP	: Global village Energy Partnership
GY	: Gatuanyaga
Hivos	: Humanist Institute for Cooperation with Developing Countries
HMIS	: Division of Health Management Information Systems
IEA	: International Energy Agency.
IPCC	: Inter-governmental Panel on Climate Change.
KA	: Kahurura

KB	: Kiboya
KDF	: Kenya Defence Forces
KENAFF	: Kenyan National Farmers Federation
KENDBIP	: Kenya National Domestic Biogas Programme
KFWG	: Kenya Forestry Working Group
KG	: Kaga region
KIHBS	: Kenya Integrated Household Baseline Survey
KWAP	: Kenya Wood fuel and Agro forestry Project
MDG	: Millennium Development Goals,
NAD	: Non Adopter
NBMMP	: National Biogas and Manure Management Programme
OECD	: Organisation for Economic Co-operation and Development
SE4ALL	: Decade of Sustainable Energy for All
SNV	: Netherlands Development Organization
UNDP	: United Nations Development Program

INTRODUCTION

1.1 Background to the study

Energy is a vital ingredient in meeting human needs such as food, running water, heat, light and transport. Thus to realise meaningful development, the availability of sustainable, clean and reliable sources of energy is indispensable (Chel 2011). Everyday humankind hustles to make ends meet which includes access to energy, its reliability and ultimately cost. The *Global Tracking Framework 2015* indicates that progress in improving access to clean cooking facilities has been relatively slow, and more than 40% of the world's population still relies on solid fuels for cooking, keeping the goal of universal access to modern cooking by 2030 at a far distance. According to the report primary energy intensity (the global proxy for energy efficiency) fell by more than 1.7% a year over the tracking period, still nearly a full percentage point slower than the Decade of Sustainable Energy for All (SE4ALL) objective. Most African countries are struggling to meet present energy demands (Amigun *et al.*, 2008). Thus, in recognition of the importance of energy access for sustainable economic development and supporting achievement of the Millennium Development Goals, the United Nations (UN) General Assembly designated 2012 as the International Year of Sustainable Energy for All (Kin, 2011). Further the United Nations General Assembly (2014) unanimously declared the decade 2014-2024 as the Decade of Sustainable Energy for All.

According to Kariuki (2013) the lack of access to modern energy services hinders the ability of the population of developing countries like Kenya to benefit from opportunities for economic development and increased living standards. The most common types of fuel in Kenya used for preparing food are firewood, charcoal, cow dung and farm

residues like maize, sorghum stalks and maize cobs (Gathui and Ngugi, 2010). It's clear that, the lack of access to clean and sustainable energy by most people in Kenya does not only hamper economic growth in the country but also denies many of the poor in the country the chance opportunity to seek their personal development (Kariuki 2013). According to Gathui, *et al.*, (2011), Charcoal is used by over 82% of the urban population and 34% of the rural households with demand likely to rise with population growth, increased urbanization, and the development of cottage industries. Goldemberg, (2000) affirms that only renewable energy resources can solve the problem of sustainable development. The transition from traditional uses of biomass for energy to more efficient and higher quality bioenergy often referred to as '*modern*' bioenergy, points at biogas as a viable alternative to biomass. Generated primarily from animal and kitchen wastes, it can be used directly in conventional low-pressure gas burners. Methane capture from animal manure to burn and create energy makes biogas production eligible for carbon credits that can pay for the operation costs of the biogas plant (GACC, 2014). Biogas provides essential energy services that do not disrupt the climate system, degrade the environment, or create conflict over resources.

The 2010 Global Burden of Disease Report places household air pollution, the third most deadly global risk factor annually (mainly due to cardiovascular and respiratory illnesses), accounting for about 3.5 million deaths (Hazra *et al.*, 2014). Further Martin *et al.*, (2012) reports burning solid fuels in primitive cook stoves as the primary environmental cause of death. A year-long observational study in Kenya found lower, but not statistically significant, changes in percentage of children with observed cough and severe pneumonia in households using improved stoves (Foote *et al.*, 2013).

While researching in rural communities among women groups in Rajasthan India, Frangos *et al.*, (2012) reported that the burden of collecting fuel wood was the primary incentive that women had to begin using biogas. Khoiyangbam (2008) argues that BGT has the potential to address the pressing, social, environmental and economic problems in rural areas. Mwirigi *et al.*, (2009), have also indicated that replacing firewood with biogas makes cooking, cheaper, easier, cleaner and safer. They observed that biogas meets half of *energy cost* for the plant owners (Mwirigi *et al.*, 2009). Renwick (2007) also effectively argues that since it does not require overtly sophisticated capacity to construct and manage; many people can produce their own, on farms with their animal wastes. It's been proved as the most compatible solution to the dairy farmer.

Majority of Kenyan farmers rely on wood as their main source of energy for both cooking and lighting (KENDIP 2015). This results in heavy depletion of the country's forest reserves and thus serious environmental degradation (Hofstad *et al.* 2009; Kohlin *et al.*, 2011). Even though clean and renewable energy technologies such as solar, wind and biogas have been around for decades, the adoption of Biogas technology for Gakawa community has been painstakingly slow. Deforestation in Gakawa location has increased considerably over the years threatening the local biodiversity (GoK, 2009). Furthermore, the feeling that firewood is 'free' sometimes exacerbates the problem where women have to gather it free from close-by shrubs and trees. The introduction of the improved cooking stove (ICS) that was meant to diminish the demands and consumption rates did not achieve the expected results. The war against environmental degradation needs a change of tactics. Gakawa location boasts of the expansive Mt Kenya watershed which is the main source of water of many rivers that support diverse biological resources of global,

regional and national importance (Kenya Forestry Working Group (KFWG), 2005, GoK, 2009). Though there have been government and private sector involvement in the sensitization of environmental degradation and embracing alternative energy sources, the low adoption of Biogas technology (BGT) in the region continues to baffle many. Figures from Community Management for Protected Areas Conservation (COMPACT), reveals that there are about 70 farmers in Kieni East who are beneficiaries of a United Nations Development Programme- Global Environmental Facility (UNDP-GEF) support Kenya region (IFAD 2010). Even though energy future is unpredictable, one thing that appears almost certain is that, Gakawa's energy future landscape will be different from today (IFAD 2010, GoK. 2009).

1.2. Statement of the study problem

It is Kenya's vision to provide its citizens with a clean, secure and sustainable environment by the year 2030. To achieve this; the country has to promote sustainable and renewable energy as envisaged in the Climate Bill of 2013 through various activities (GoK, 2016). Agriculture has a dual role not only as an energy consumer but also has the potential to generate and supply energy in the form of bio energy (FAO, 2000). Most of the residents are small scale farmers who are heavy consumers of firewood. The scarcity results in the unsustainable, illegal harvesting of trees from the neighbouring Mount Kenya forest in Gakawa. In several locations in the study area such as Gathima, and places such as Kiboya, Mureru, and Burguret, areas ranging from 10 per cent to 100 per cent of forest land has been converted into open grasslands/rangeland (IFAD 2010). This poses an environmental threat not only to the local biodiversity, but also to the Mt Kenya water tower. The subdivision of large ranches and wheat farms in Gathiuru/Burguret

(previously owned by descendants of white settlers) saw an influx of new tenants which led to further demand for fuel wood (GoK, 2009). This translated into inadequate supply and increased wood fuel prices. The decreasing farm sizes due to new tenants in the location have also forced the farmers, to cut down on the sizes and mode of stock keeping of their livestock. The potential of livestock waste in the provision of biogas technology in the region is not only viable, but is also compatible with sustainable development in all its dimensions (UNDP 2015). Ngugi *et al.*, (2007) advances that most households that have 2 or more cattle under zero grazing or 4 or more under semi zero grazing are technically eligible to benefit from biogas technology. Gakawa provides an ideal setting for substituting biogas for wood fuel. This study therefore seeks to provide to a better understanding of the factors contributing to a relatively low adoption and use of biogas among the farmers despite this worrying environmental scenario.

1.3 Objectives of the study

The general objective of this study was to evaluate adoption of biogas technology as an alternative energy source in Gakawa Location, Nyeri County, Kenya. It sought information on the reasons for adoption or non-adoption of BGT by examining the rural farmer demographic characteristics, decision making roles and their attitudes towards alternative energy source. It also focused on their social cultural attributes, the role of the change agents; the formal and informal institutions; and how these factors influenced the adoption of BGT.

The specific objectives of this research were:

- i. To examine the extent to which social cultural factors influence the level of adoption of biogas as an alternative energy source.

- ii. To examine the attitude of farmers towards the use of biogas as an alternative energy source.
- iii. To assess the extent to which institutional arrangements influence the level and rates of adoption of biogas as an alternative energy source.

1.4 Research questions

- i. To which extent do social cultural factors influence the adoption potential of biogas technology?
- ii. What is the attitude towards adoption of biogas technology among the small-scale farmers?
- iii. What is the role of formal and informal institutions in the use of biogas as an alternative energy source?

1.5 Research hypothesis

H₀₁: Social cultural factors do not significantly affect the adoption potential of biogas technology.

H₀₂:- The farmer's attitudes do not influence their decision to accept and adopt the biogas technology as an alternative energy source.

H₀₃- Formal and informal institutions do not significantly affect the adoption potential of biogas technology.

1.6 Significance of the study

The study contributes to a better understanding of the factors driving adoption and use of biogas by a typical family in rural Kenya. It further gives indicators that will allow further elaboration and test the applicability of the theories and models that have been used to explain the root causes of household fuel choice and technology adoption.

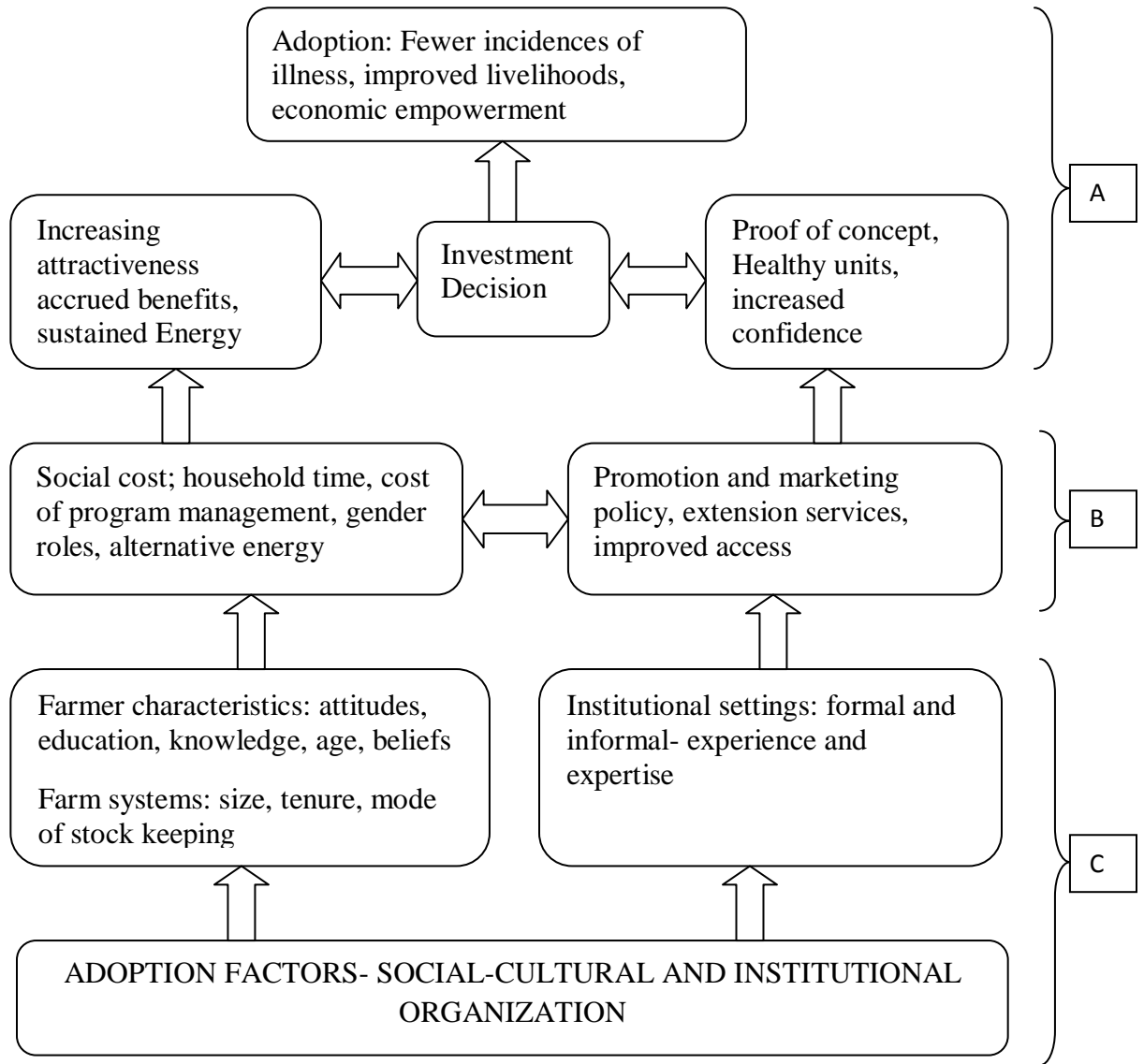
1.7 Conceptual framework

In a farm setting, farmers are faced with a myriad of interplay of different factors which influence their reasoning or decision making in acceptance, adoption or rejection of a new technology. Figure 1.1 below presents the main building blocks of the conceptual framework that guided the study.

It illustrates that small-scale farmers make investment decisions in acceptance and adoption of BGT technology as a result of the interaction of several different variables. Biogas production is rather congruent with the core capabilities of farmers, like growing, harvesting and processing agricultural products. However, due to its focus on energy instead of food production, adoption of biogas technology might also require a number of potentially disruptive changes. In particular, its strong integration into the daily routines of farming requires a careful and active process of embedding (Wirth *et al.*, 2013). Thus the rate of adoption does not only depend on the decision making process but also on the human, social cultural and institutional organization that play a key role in influencing the decision making process that enable the farmer achieve an inside view of BGT technology.

Social cultural factors play a key role in determining whether a person would agree to use biogas as alternative energy source. Primarily, these inspirations are derived from the traditions, customs, beliefs, and perceptions of an individual's culture. As such the independent variables that relate to farmer's characteristics such as age, beliefs, and education and previous experience, have a significant influence on the attitudes (personality), knowledge, value orientation, as they determine their reasoning in acceptance of the technology. Also most often ignored, are value of household time to

operate the plant, and the value of “in-kind” contributions of household for the biogas plants (Renwick, *et al.*, 2007).



A-Dependent Variable, B-intervening variable C-Independent Variable

Figure 1: Conceptual framework showing the representation of the factors that may influence a farmer’s decision to accept and adopt biogas technology.

Source: Researcher 2015

The institutional arrangements shall provide settings related to the policy and organisation of the BGT system, general infrastructure, marketing infrastructure, proximity to BGT services, information sources and extension services. Where there are facilitating factors, formal and informal institutions with experience and expertise shall provide, not only the requisite awareness but also post installation support through sustained promotional and incentives programs. Further too, the farm system; land tenure, farm size, and farm type, including the availability of alternative or competing energy sources that may be construed to be “convenient or free”, have direct influence on the availability of direct capital to be injected. These dependent variables ultimately determine the capacity of the farmer to accept the technology (Mwirigi *et al.*, 2009).

These institutions ultimately and deliberately influence the selection of specific types of biogas plants and how they are financed and operated (Wirth *et al.*, 2013). Because the technology is now largely commercially driven, the profit motive is a necessary ingredient for wider involvement of the private sector (Ngugi *et al.*, 2007).

Where farmers have access to healthy units and witness successful biogas use, this will invariably increase proof of concept, which is important because of the scarcity of fuel wood. They will adopt it because it puts less pressure on the constant need to replenish fuel wood. This will reinforce preference over biomass and other competing alternative energy sources. The outcome of the uptake includes quantifiable health benefits such as getting rid of indoor pollution, improved soil fertility from use of the slurry, accrued societal and private benefits, and cumulative benefits of sustained energy and reduced loss of forests. This shall results in new opportunities for social and economic empowerment of the community.

1.8 Definitions of terms

The following definitions are used in this study.

Adoption potential: This is the likelihood of uptake of a new technology or practise when required information or materials are made available to the farmer. Assessing the adoption potential of a practise involves determining its bio-physical performance, profitability and acceptability to the farmers.

Alternative energy source: Energy derived from sources that do not use up natural resources or harm the environment.

Biogas energy: A renewable gaseous fuel derived from biological materials that can be used as an energy source instead of fossil fuels, typically to replace conventional natural gas, propane, heating fuel oil, diesel fuel, or gasoline.

Biogas extension: Activities and procedures for motivating people to adopt biogas technology.

Global Environment Facility (GEF): the international financing mechanism providing incremental funding for projects with global environmental benefits, jointly implemented by UNDP, UNEP and the World Bank.

Greenhouse gases (GHG): These are gases covered by the Kyoto Protocol which are carbon dioxide, methane, nitrous oxide, hydro fluorocarbons, per fluorocarbons and sulphur hexafluoride.

Ideologies: These are belief systems; a set of ideas that constitutes one's goals, expectations, and actions; how one looks at things.

Institutional arrangements: Are the policies, systems, and processes that organizations use to legislate, plan and manage their activities efficiently and to effectively coordinate with others in order to fulfil their mandate.

Kyoto Protocol: The international agreement to address the threat posed by the steady accumulation of heat-trapping greenhouse gases in the earth's atmosphere-2013 to 2020. (The United Nations Climate Change Conference in Doha, Qatar 2013).

Poverty line: An arbitrary international real income measure usually expressed in constant dollars (e.g. \$ 1.75), used as a basis for estimating the proportion of the world's population that exists at bare levels of subsistence.

Small scale/small holder farmer: is a farmer whose access to agricultural land ranges between 0.2 and 12 hectares as defined by the Central Bureau of Statistics and the two definitions are assumed to have the same meaning in this study.

Technology Transfer: this is the process of converting the concept of the technology into a sustainable framework that is understandable to the local people.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter reviews the literature relating to energy scenarios at global and Kenyan perspectives which necessitate the need for alternative energy sources such as biogas. It provides a review of alternative energy source perspective in relation to sustainability, renewable energy and development. The chapter further examines adoption theories, the roles of extension agents, social and cultural factors involved in decision making processes, and farmer's attitude towards biogas technology. The account and experiences of biogas technology in other countries as well as in Kenya are also reviewed for comparison purposes. Planning and policy regulations in regard to the energy sector in Kenya are given an overview in this chapter.

2.1.1 What is Biogas?

Biogas plants capture gas (methane and carbon dioxide) released from animal manure for use as a household fuel for cooking and lighting (Hazra, *et al.*, 2014). The majority of existing biogas is produced using anaerobic digesters, gas-tight high-moisture enclosures that provide a stable environment for methane-producing bacteria to flourish. In the biogas, dung is inserted through an inlet into a sealed mixing pit, where biogas is generated through anaerobic digestion (Hazra, *et al.*, 2014). The raw biogas is collected from the digester and then flared or processed and used in energy applications as a replacement for electricity, natural gas, propane, diesel fuel, or gasoline (Teodorita *et al.*, 2008). After digestion the slurry released from the plant is often used as an agricultural fertilizer.

Biogas can be compressed, much like natural gas, and used to power motor vehicles. Biogas can also be cleaned and upgraded to natural gas standards when it becomes biomethane (Biogas World 2016).

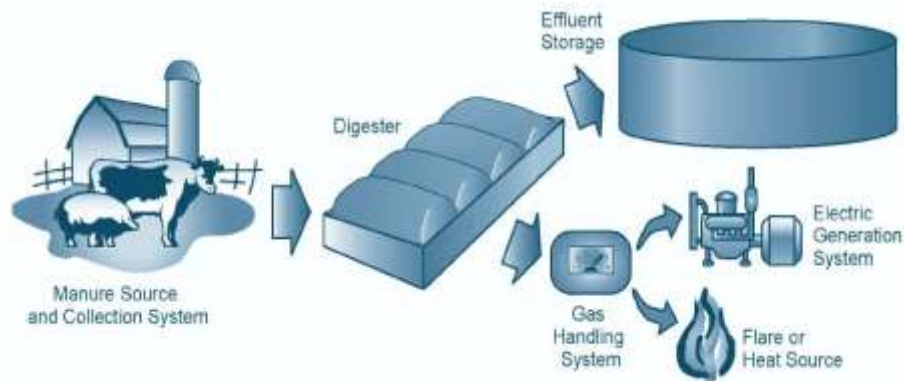


Figure 2.1: Biogas Schematic

Source: U.S. Environmental Protection Agency, EPA, (2014)

What is technology?

The *Merriam-Webster* dictionary defines technology as “*the practical application of knowledge especially in a particular area*” or “*a manner of accomplishing a task especially using technical processes, methods, or knowledge*” The same dictionary defines innovation as “*the introduction of something new*” or “*a new idea, method, or device*” (www.merriam-webster.com/dictionary).

Technology is not only the equipment, but also the knowledge required to fund, manufacture, operate and maintain the equipment. Egbue and Long (2012) have pointed out that adoption of new technology is considered a motivating impetus for economic growth and sustainable development. There is need to demand from policy makers the need to harness other alternative sources of energy that can grow at the same pace with changes in technology.

A technology is not successful if its user does not accept it and in case of BGT, it is astoundingly true. It has become therefore important to explore the factors that envisage user's acceptance and practice of new technologies (Mpele, 2013).

2.1.2 Global Energy Outlook

In this section an overview of the world's energy situation is recapped highlighting global status and projections on adoption and scenario analysis on biomass use.

Agriculture has a dual role as an energy user and as energy supplier in the form of bio energy (FAO, 2000). In most developing countries, energy for cooking consumes more energy than any other single activity (Practical Action 2012). According to IEA (2011), over 90% of household energy needs in many developing countries, especially in rural areas, are met by biomass, such as fuelwood, charcoal, agricultural waste and animal dung, supporting over 2.5 billion people. What is more worrying, is that the absolute number of persons particularly in Africa and Asia using solid fuels, is increasing even though figures reveal that the proportion of households relying mainly on solid fuels for cooking has decreased world-wide, from 62% in 1980 to 41% in 2010 (Bonjour *et al.*, 2013).

A report on World Energy Outlook by the International Energy Agency (IEA 2011) clearly stated that the world today faces a significant energy divide; between rich and poor countries. It further indicated that more than 95% of the world's population without access to electricity and clean cooking facilities live in sub-Saharan Africa and developing Asia. It is against such backdrop that Organisation for Economic Co-operation and Development (OECD) and IEA (2006) reports indicated that in the absence

of new policies, the number of people relying on biomass would increase to over 2.6 billion by 2015, and to 2.7 billion by 2030 because of population growth.

Table.2.1 People Relying on Traditional Biomass (million)

<i>Region</i>	2004	2015	2030
TOTAL (In millions)	2527	2640	2727
Sub-Saharan Africa	22.75%	23.75%)	26.41%
North Africa	0.16%	0.19%	0.18%
India	29.28%	29.43%	28.68%
China	19%	17.16%	14.45%
Indonesia	6.17%	6.48%	6.60%
Rest of Asia	19.35%	19.73%	20.57%
Brazil	0.91%	0.98%	0.99%
Rest of Latin America	2.37%	2.28%	2.13%

Source: OECD and IEA (2006)

In the reference scenario, as presented in the table 2.1, where no new policies are introduced, the number of people relying on traditional Biomass rises from 2.5 billion in 2004 to 2.6 billion in 2015 and to 2.7 billion in 2030. The UN projections (recommendation of the United Nations Millennium) targeted 1.3 billion people switching to other sources of fuel by 2015 (UN 2013).

However meeting such targets poses a considerable challenge given the current trends in traditional biomass use in developing countries. On a typical three stone wood-fired stove, about 18 percent of the energy goes into the pot, 8 percent into the smoke and 74 percent is waste heat. But it is the pollutants that are of more concern (WHO, 2007).

Therefore all efforts should be geared towards making the acceptance and adoption of BGT a reality at the moment rather than in future.

UN-Energy and the Decade

According to UN (2014), energy is the golden thread that connects economic growth, increased social equity, and an environment that allows the world to thrive. At a time when 1.2 billion people worldwide lack access to electricity, when 2.8 billion people do not have clean and safe cooking facilities, and when a shift to sustainable energy use is imperative to protect the Earth's climate, no less than a worldwide effort is required to achieve sustainable energy for all (Ki Moon, 2011). Properly designed biogas digesters are capable of improving sanitation, reducing greenhouse gas emissions, decreasing demand for wood and charcoal for cooking and hence help to preserve forested areas and natural vegetation.

In his address, Ban Ki-moon, the Secretary-General of the United Nations, (*A vision statement on sustainable energy for all* (Ki Moon, 2011)) lamented the continued emissions of carbon dioxide and other greenhouse gases from fossil fuels that contribute to changes in the Earth's climate. The UN with its many organizations, *Global Tracking Framework*, United Nations Development Program (*UNDP*); *The United Nations Industrial Development Organization (UNIDO)* *The United Nations Educational, Scientific and Cultural Organization (UNESCO)* that are member organizations of UN-Energy undertake several initiatives involved in efforts that support the decade 2014-2024 as the Decade of Sustainable Energy for All.

These include among others; *Clean Start-a* programme that supports access for low-income households and micro-entrepreneurs to modern energy through microfinance - designed to support at least 2.5 million people by 2017.

Poverty and energy

Currently the issue of energy poverty is one of the most important concerns in the international agenda, together with climate change and environmental sustainability. Poverty affects people's access to energy due to the involved costs. There exists a strong link between poverty and development (Karekezi *et al.*, 2014). Improving rural livelihoods which include access to clean and efficient energy provides the best way out for poor rural people to escape from poverty.

Energy poverty leads to drudgery, greater health risks and lack of time to focus on income-generation, educational or other self-nurturing activities. Leisure, for example adversely affects their efforts to liberate themselves from poverty. It is rather ironical that, poor families allocate a significant percentage of their income to energy services (7-12 %) according to Bacon *et al.*, 2010, and up to 19 % according to Winkler *et al.*, (2011) but still cannot afford modern energy services. Ghulam *et al.*, (2009) thus observe that properly designed renewable energy supply and technologies, including BGT, can benefit communities in many ways.

2.1.3 Renewable energy and sustainable development,

By using renewable resources and non-polluting technology, biogas generation serves a triple function: waste removal, environmental management and energy production (IFAD 2012). Renewable Energy (RE) sources have low environmental impact, widely available

and are naturally replenished. BGT can insulate countries from fuel price volatility; and improve those countries' balance of payments (UN, SE4ALL 2012). Further Langeni *et al.*, (2010), suggests that each household can realise up to US\$ 724 by replacing wood use with biogas, apart from other positive impacts to the environment. It also includes carbon (credit) finance that could therefore be used to cover part or all of the costs. According to Bajgain & Shakya (2005), in Nepal, it is estimated that each installation avoids 4.6Mt CO₂ e/year-(the amount in Metric tonnes, of carbon dioxide (CO₂) emitted per year). Average per capita emissions in developed regions are significantly higher than in developing regions. In developed regions, average emissions are about 11 metric tons of CO₂ per person per year, compared to about 3 metric tons in developing regions (UN, 2013). Containing the growth in global emissions demands bold, coordinated, national and international action. The United Nations Climate Change Conference in Doha, Qatar, prompted significant steps in the right direction by forging a consensus on a second commitment period under the Kyoto Protocol—from 2013 to 2020 (UN, 2013).

2.1.4 Livestock as a potential renewable energy source

The United Nations (UN), Food and Agriculture Organization (FAO) estimates that current emissions of methane and nitrous oxide from manure of domesticated animals are responsible for about 6% of man-made greenhouse gas emissions (FAO, 2006). Many researchers attest that collecting and controlling animal manure reposes a great potential for reduction of greenhouse gas emissions (O'Mara 2004, and Steinfeld *et al.*, 2006). The greatest potential for using livestock as a renewable energy source lies in small-scale mixed farm systems where farmers can create synergies, for example by feeding animals

crop residues and using animal manure to fertilize crops (IFAD, 2012). Manure-based biogas digester systems are considered ecologically friendly since the technology captures and utilizes methane directly, thereby limiting total greenhouse gas emissions from livestock (IFAD, 2012).

Additionally, the by-products of the ‘digesters’ provide organic waste (biogas slurry), of superior quality than conventional fertilizer, which can lead to increased yields in the farms (IFAD, 2012, Hazra *et al.*, (2014). This is a great incentive to farmers who have been faced with dwindling farm produce harvests which are associated with poor farming practices among them the application of conventional fertilizers.

2.1.5 A Global perspective of Bio-Gas Technology (BGT)

This section outlines some highlights of adoption and use of biogas from the global, African and Kenyan perspective and their factors underlying.

The mere ownership of at least two cows can warrant biogas installation as the dung from the two cows typically suffices to meet the cooking requirements of a household. According to UN (2010), this has made the technology relevant in some rural and peri-urban settings but more particularly in south Asia and Africa where animals roam freely. Biogas use in non-OECD Asia, produced from the anaerobic digestion of manure, is mainly concentrated in rural areas (World Bank, 2015). Over the past decade (1994-2011), biogas consumption in this region grew by an unprecedented 35% per year. As the fuel is produced on site, there are limited distribution challenges or costs beyond the delivery of the equipment (UNIDO, 2010).

Globally, the European Union has invested a heavy chunk of its research funds in developing new biogas technologies. It has put in place environmental legislation to encourage the technology of Anaerobic Digestion (AD) (Cassie *et al.*, 2010). Germany leads in this field with the largest installations, numerous laws, policies and incentives propping up its status. In the US, the AgSTAR program run by the Environmental Protection Agency (EPA) U.S. Department of Agriculture (USDA) and the U.S. Department of Energy (DOE) aims at making reduction in methane emissions from livestock waste management operations through the use of biogas recovery systems Camillo, and Nicole (2011). Sweden, Germany and Switzerland are far ahead and have been using biogas to run cars, trains and buses since 2005 (Cassie *et al.*, 2010). Today, Germany converts half of their biogas generated from sewage sludge digestion to fuel cars (Cassie *et al.*, 2010). However, the most common use for anaerobic digestion is on farms and in waste water treatment plants.

BGT can also improve on lighting at night. Interestingly though lighting is a basic need, in many villages around the world, it is regarded as a status symbol. With biogas technology children now study after dark, do their home-work using the BGT lamps just like the solar lamp (Uppuluri *et al.*, 2008). A good biogas lamp can illuminate a room far better than wick kerosene. With this they improve on their educational skills allowing children useable hours of the day for the whole community (Blunck *et al.*, 2007).

One primary reason for lack of widespread use of biogas around the world is the high initial investment for putting in a biogas facility and a steady supply of animal manure. The other reason is the low investment for despite year-over-year growth in global clean energy capacity, global investment in clean energy in 2016 declined by 18% from 2015

to \$288 billion (down from \$349 billion in 2015). Worldwide, wind and solar continued to experience the highest levels of new investment of all renewable technologies in 2016 (91% of all asset classes). Even so, there are many biogas plants in use around the world; 42.8 million in China and 4.4 million in India alone (GACC, 2014). Hivos (2013) attributes the successful Biogas Programme (BPiI) in Vietnam and the Biogas Support Programme (BSP) in Nepal to the ‘multi-stakeholders sector development approach’. However, much more is required to achieve the Sustainable Energy for All initiative goals by the year 2030 (IEA/ World Outlook 2015).

2.1.6 Biogas status in Africa

In Africa, the biogas technology has been stirred by the publicity efforts of various international organizations and external agencies through their publications, meetings and visits (Parawira, 2009). However attitude and level of awareness is not commensurate with the rates of adoption. Various researchers such as Josue (2005) UN Director, Food Security and Sustainable Division, contend that Africa is endowed with rich and diverse renewable and non-renewable natural resources. However, its people remain among the poorest in the world. Thus improving the welfare of people in Africa requires sustainable development. Nevertheless according to the head of the U.N. Environment Program (UNEP, 2011), Africa is leading in the push for clean energy policy-making as climate change turns millions of its people into "food refugees". Over the years several biogas programmes have been initiated in Africa, among them “The Foundation Biogas for Better Life” (Renwick, *et al.*, 2007).

Biogas technology utilizing animal waste was introduced in Tanzania as early as the 1950s by private stakeholders. Between 1975 and 1982, the government through the

Small Industries Development Organisation (SIDO), Netherlands Development Organization (SNV), Tanzania and the Parastatal Organization, Centre for Agricultural Mechanization and Rural Technology (CAMARTEC) increased the dissemination of this technology in the northern regions (Mwakaje, 2012). Between the years 1984 and 1985, CAMARTEC was involved in building capacity by training technicians in biogas plant construction. As Mwakaje (2008) noted, that despite all the efforts, the biogas technology was not widely adopted by the rural poor communities. She attributes this to poor diffusion of the biogas technology including high installation and maintenance costs and inadequate awareness about the technology. To reduce production and construction cost 2000 polythene tubular digesters using locally manufactured plastic were promoted that simplified installation and operation costs (Mwakaje, 2012). Between year 2009 and 2013, the sum of 3716 Biogas plants were built. The targeted biogas units were 3258 and actual constructed biogas plants were 3819; this was 117% increase of biogas plants in 2013 alone. This gives evidence clearly that adoption of biogas technology in Tanzania is increasing (Wilson *et al.*, (2015).

SNV Uganda (2010) indicates that biogas has been in Uganda since 1950 and that its dissemination and adaptation have met limited success owing to the higher installation costs and low technical human resource potential. The number of bio-digesters installed in Uganda grew from an estimated 100 in 1990 to 700 digesters by 2008. The Uganda Domestic Biogas Programme built 583 plants in 2010 and 1,354 in 2011. The programme target was to build over 20,000 biogas plants by 2013. The Ministry of Energy and Development set a goal in 2007 to increase biogas units to 100,000 by 2017 (Bernhard, 2013). The government of Uganda has identified biogas technology not only as means for

replacing a sub-optimal fuel supply but also for its ability to address the problems of the lack of basic sanitation and access to agricultural fertilizers (Okello *et al.*, 2013; Smith 2012; Yu *et al.*, 2008).

In Rwanda few households and large communities use BGT for cooking across the country. In 2006, the Government of Rwanda incensed by the continued reliance on firewood as a domestic energy source launched a National Domestic Biogas Programme NDBP (Arjun *et al.*, 2014). Dr. Rose Mukankomeje, REMA, (2012) reported that the Rwandese government vision was to replace firewood, which provides 85 per cent of its energy needs with biogas for cooking at all its prison kitchens by 2013. With technical support from SNV Netherlands Development Organization, the programme targeted the installation of 15,000 family sized (between 4 and 10m³), high-quality biogas plants by the year 2011. However, according to Arjun *et al.*, (2014) a mid-term review conducted in late 2009 led to a rescaling of the target to 5,000 digesters and in 2010 a new target of 3,000 digesters was proposed. It was reported that in the period from 2007 to 2010, the National Domestic Biogas Programme (NDBP) had built about 682 family-sized biogas plants and about 2237 domestic digesters had been installed by September 2012.

2.1.7 The status of biogas adoption in Kenya

The uptake of BGT had remained bumpy since it was the introduced into Kenya in the mid-1950s. It was not until the Kenya National Domestic Biogas Programme (KENDBIP) set up by the Kenya National Federation of Agriculture Producers (KENFAP), currently Kenya National Farmers Federation (KENAFF), rolled out a biogas programme in 2010 that Biogas gained some impetus (Ngugi *et al.*, 2007). Later industry players include, the planning and construction agency, AKUT *Umweltschutz* in Berlin which carried out some feasibility and concept studies for specific biogas plant projects

in the agricultural sector of Kenya. It was involved in the construction of nearly 150 farm-scales. The Association of Biogas Contractors of Kenya (ABC-K), with about 30 Biogas Construction Enterprises (BCEs) also offers assistance to biogas masons willing to register companies.

2.1.8 Kenya National Domestic Biogas Programme (KENDBIP)

This programme is part of the Africa Biogas Partnership Program (ABPP) a Public-Private-Partnership (PPP) initiative funded by Directorate General for International Cooperation (DGIS) and implemented by Hivos and SNV in Burkina Faso, Ethiopia, Kenya, Senegal, Tanzania and Uganda. The main objective of the National Biogas Programme is to support the development of biogas sector and coordination of all relevant stakeholders. KENDBIP has been the main actor in developing a robust BGT sector and dissemination of domestic biogas plants in rural areas in Kenya. Examined below are the major highlights of the Programme undertakings in promoting BGT in Kenya.

Between the years 2009 to the end of 2013 in a programme called Phase 1 phase (2009-2013) they targeted dissemination of 8,000 domestic biogas plants. Due to renewed interest in the adoption of BGT and other alternative forms of energy among rural households in Kenya, a total of 11,579 biogas plants were installed in the country against a target of 11,690 plants. This target was revised upwards after the first 2 successful years of implementation, representing 99% target achievement. It also saw an entry of other competing designs, specifically tubular digesters e.g. Q-Energy, Flexi-biogas, Pioneer technologies etc. This period saw many new entrants in the sector with Entrepreneurs,

private and public institutions and rural development agencies all getting involved in complementing the effort in the promotion and uptake.

Table 2.2 Domestic biogas plants in rural areas in Kenya

Year	Targets	Achieved	Percentage
2009-2013	11,690	11,579	99%
2014	4004,(revised 3000)	2533	63%

Source: KENDIP 2014

Another milestone in the BGT industry has been the introduction of plastic digesters. This has provided the market with alternative digester design options which significantly improve the biogas credit landscape. It is explicable that potential biogas credit providers prefer financing of plastic bio-digesters which are movable, as opposed to the masonry fixed dome plants due to the fact that these plants serve as security to the loan. As a result in 2014, the plastic digesters accounted for 466 plants out of 2533 installed during the year representing 18% market share in their first year in the market (KENDIP 2014).

Each of the manufacturers of these designs have active partnerships with several leading financial and MFIs including K-rep bank, Equity Bank, Dairy Sacco's etcetera (KENDIP 2014). Thus they are able to access loans for purchase of their other products, and which have been expanded to include these plants at negotiated terms and conditions. The major plastic manufacturers working with the Programme are SIMGAS and KENTAINERS

(KENDIP 2014). Other Industry players include, Ecofinder Kenya, Biogas Africa, Kentainers Limited, Aquinas Tec Group; which has championed a new technology known as *Blue-flame BiosluriGaz*, and *Taka Moto Biogas*, which in March 2013 introduced the ‘Pay-as-you-go’ (PAYG) Biogas pilot project. The sector has continued to attract more entrepreneurs with Uganda based Q-Energy and Kenya’s Flexi-biogas rolling out their tubular digesters in the market. Roto Moulders also designed and introduced a proto-type of their Roto bio-digester. Rehau Homegas from Germany and Huawei International Green Energy Holding from Hong Kong are also venturing into the market.

KENDBIP contribution towards new plant installations has been captured in Table 2.3 below.

Table 2.3 2014 (KENDBIP) Production table

SOURCE	J	F	M	A	M	J	J	A	S	O	N	D	Totals
KENDBIP	173	85	75	119	159	87	167	204	219	189	180	126	1783
VEP	28	23	15	0	25	16	10	10	21	10	9	5	172
SCODE	15	10	10	5	5	6	7	6	5	5	6	6	86
CREPP	1	10	7	0	0	3	4	1	0	0	0	0	26
KENTAINERS	0	55	40	20	0	84	5	0	2	0	0	3	209
SIMGAS	0	19	85	51	13	14	23	19	16	4	13	0	257
TOTALS	217	202	232	195	202	210	216	240	263	208	208	140	2533

Source: KENDIP (2014)

2.1.9 Kenya's Energy Policy guidelines and energy situation

The Kenya Vision 2030 identified energy as one of the infrastructure enablers of its social economic pillar. Sustainable, affordable and reliable energy for all citizens is a key factor in realization of the Vision. The new constitution further provides governance of the energy sector in line with the devolved government system. Thus Kimuyu, *et al.*, (2011) observes that Kenya has more robust laws and institutions supporting the energy sector than many other countries in sub-Saharan Africa. The National Energy Policy (GoK 2012), developed with the aim of providing affordable quality energy for all Kenyans recognizes the importance of the level and the intensity of energy use in a country, as a key indicator of economic growth and development.

Kenya is well endowed with renewable energy resources. However their use in provision of alternative energy has been limited. There are about 31 million Kenyans without access to electricity and using biomass for cooking. (Kimuyu *et al.*, 2012) estimated that 1,170,000 people (3 %) use Solar, 78,000 (0.2%) use biogas, whilst 39,000 people (0.1%) utilize wind. In view of this, The Kenya Institute for Public Policy Research and Analysis (KIPPRA, 2010) advanced that there is technical potential for domestic biogas in Kenya. 200,000 biogas plants would deliver clean and safe renewable energy to a country with more than 1.5 million small holder dairy farmers. With these startling facts, it's apparent that the benefits of biogas are becoming more apparent to eligible households faced with wood fuel scarcity and increasing energy costs.

However, it is only geothermal, wind and co-generation (generation from bagasse) which have been seriously exploited and connected to the national electricity grid. Kenya generates most of its energy from hydroelectric dams but water levels have fallen due to

recurring drought. It is now investing heavily in geothermal and wind power. In an effort to reduce dependency on fossil fuels the African Development Bank (ADB) financed Africa's biggest wind farm on the shores of Lake Turkana. The \$819-million project is set to produce 300 megawatts (MW) of electricity per year, boosting Kenya's energy supply by 30 percent (UNEP 2011). Further Toyota and Hyundai targeted to build a fourth geothermal power station in Naivasha, 100 km (60 miles) northwest of Nairobi, which would increase geothermal capacity from 115 MW to 395 MW by 2014. However looking at it from different angle, according to UN SE4ALL (2012), it may take almost another decade to reduce our dependency to a considerable extent. The reality is that the components and raw materials used in these projects are designed and manufactured in fossil fuelled factories and finished products are then transported to the power station by means of road or rail network.

2.2 The Impact of Decision Making on Adoption of Agricultural Technology

Unlike other non-farming businesses, agriculture entails a peculiar environment for decision makers such as farms, and farming, have unique characteristics. Daydé et al., (2014) argues that this means that for each farm, farmers may need to make decisions under quite different contexts. Kadlec (1985) illustrates this idea by asserting that an important attribute of a successful manager is the ability to make decisions that will enable the business to attain its goals.

Farmers around the world constantly face farming decisions involving personal aspirations and experience, socio-cultural backgrounds, resources availability and constraints. Costa & Rehman, (2005) have pointed out in their studies that farmers' various objectives, which are often conflicting, impact the decision making process. They

report that objectives often change in the context of the farmers' life cycle stage, personality, experiences and farm characteristics. In terms of decisions, this means that priorities change over time and so does the process of decision making. Further the inadequacy of the available information limits choices for the right fuel for household decision makers. Nuthall (2010) relates intelligence to farmers' decisions, as follows; a) Memory; b), Ability to improve constructs; c) Creativity; and d) Visual-spatial ability. Further Marra, & Ghadim, (2003), reveal that a relevant part of farming intelligence is farmers' learning processes, which allow for the improvement of their managerial abilities. Specifically, learning is important because it allows for skill improvements, uncertainty reduction (as one's proficiency increases) and better decision making. However according to Nuthall, (2010) the learning process varies among farmers, with some learning by seeing (visual), hearing (auditory), doing (kinaesthetic) or reading and writing (text processing). The extent to which these preferences combine altogether defines farmers' overall learning style. Wake *et al.*, (1988,) describes them as informational, observational, and experiential; the observational learning, in turn, involves primarily learning by observing (visual). For example, this may involve assessing the paddock or the unit design and estimate the amount of dung that can be collected. Finally, farmers who prefer to learn from their own experience have a predominant experiential learning style (kinaesthetic and, possibly, visual). These farmers are likely to run small tests with technology (i.e. divisible technology) before wide implementation. These three learning styles are most usefully seen as complementary.

While studying farmers' conservation practices within an agricultural context, Greiner, Patterson and Miller, (2009) investigated farmers' intrinsic and extrinsic motivations.

They found out that farmers pursuing lifestyle and conservation objectives were intrinsically motivated to adopt conservation practices because this enabled them to fulfil their value system. On the other hand farmers primarily focusing on financial and economic or social objectives seemed to be mainly driven by extrinsic motivations, such as government incentives or society recognition. Indeed ‘What will people think about me?’ is a scenario often reflected by early adopters and laggards respectively (Carey & Elton 2010, Pereira 2011).

However it is not without challenges that decisions are made. Nonetheless understanding individual’s perception of, and attitude, to risk seems, therefore, is a necessary condition for the understanding of how farmers make decisions, including adoption decisions.

2.2.1 Decision making models

Decision Making theories, models illustrate the risk and uncertainty involved in decision making within a farm context. Traditionally, the Decision Making process has been described as a series of phases (and steps) that farmers should go through.

A summary of the phases involved in decision making, with their respective steps, is presented in Figure 2.2 below. This linear model of Decision Making has come under much criticism. However, Ohlmer, (1998) and (Nuthall, 2010; Olson, 2003), argue, that farmers do not follow linear steps when making decisions. In her comparative analysis (Pereira , 2011) showed that both linear and dynamic models pay little attention to the *mental processes* of decision making; these mental processes provide information on ‘how’ and ‘why’ decisions are made. Instead, both linear and dynamic models essentially focus on the *functional processes* of decision making that is, from a managerial perspective.

Phase 1	Phase 2	Phase 3	Phase 4
(Assessment)	(Making sense)	(Action)	(Analysis)
<i>Steps:</i>	<i>Steps:</i>	<i>Steps:</i>	<i>Steps:</i>
Identify problem or opportunity	Collect data about each alternative.	Make the decision.	Evaluate outcome.
Identify alternatives	Analyse alternatives thoroughly.	Implement the decision	Bear responsibility.

Figure 2.2 Phases of the decision making process

Sources: Kadlec (1985) and Kay et al., (2008)

According to Nuthall (2010), farmers’ managerial ability relates to many attributes including taking and accepting responsibility for decisions made to achieve farming objectives. These attributes involve farmers’ personality; - personality traits are best represented by the five factor model (FFM).

Ohlmer *et al.*, (1998), Olson (2003), and Nuthall, (2010) have proposed, therefore, a matrix model to better represent the dynamics of the decision making process instead of the linear step-by step model. In their revised conceptual model, the decision process encompasses four phases and four sub-processes (Ohlmer *et al.*, 1998). This conceptual dynamic model represented advancement in knowledge regarding the process of decision making and, as highlighted by Nuthall (2010), seems to be the “*logical way to operate*”. The key individual influences causing behaviour are motivations, abilities and understanding, aptitude and knowledge style. Further Chiavenato (1983) has formulated

the so-called *motivational cycle* that illustrates how motivation triggers the decision making process and influences behaviour, such as technology adoption.

Rogers' diffusion of innovation model

According to Rogers (1995) successful diffusion of an innovation occurs in five stages (Figure 2.3 below). First, potential recipients must have *knowledge* of the innovation. They must then be, *persuaded* to form a positive or negative view of the innovation. Potential adopters then make a *decision* to adopt or reject the innovation. They *implement* their decision and go through the final stage of *confirmation* in which they seek information to affirm their decision. This process is also influenced by cultural differences. After the initial stage of awareness and knowledge the potential adopters are still faced with the decision whether or not to adopt a technology. More emphatically, Halwagi *et al.*, (1986) argues that one other sensitive dynamic in the demonstration and diffusion process is the "one-strike principle." He uses the analogy of the rules of baseball, in which a batter is allowed three strikes before being, called out. In his comparative analysis Halwagi *et al.*, (1986) points out that in diffusion dynamics, particularly with an open public demonstration like a biogas unit, the technology promoter or development worker will customarily only have "one strike," or one attempt to achieve success or failure. He positions that a public demonstration is very different from a laboratory experimental process, in which a failure can be counted as success since it discloses what will not work and the laboratory technician can try it repetitively until success is achieved.

Stage	Description	Action Item
Knowledge	Potential adopter becomes aware of an innovation, understands how to use it, or the underlying principles that drive its function.	Introduce technology, process, or other innovation in relation to existing systems. Emphasize functionality.
Persuasion	Potential adopter actively seeks information about the innovation and uses previously acquired knowledge of the innovation to evaluate its potential effect on him or her. He/she also seeks social feedback on his or her attitude toward the innovation.	Create emotional, financial, or other connection beyond function.
Decision	Emphasize benefits across stakeholder groups Potential adopter chooses to adopt or reject innovation by testing its personal utility (e.g. extended test drives of a new car).	Maximize rewards and social benefit/confirmation.
Implementation	Transition from mental to physical action or behavioural adjustment.	Provide infrastructure to support behavioural change.
Confirmation	Adopter seeks social reinforcement of his or her decision. Seeks to avoid dissatisfactions or disappointment – will reverse decision if disappointed.	Critical mass and support of referent others (prominent early adopters).

Figure 2.3: The Stages of Innovation Diffusion

The public demonstration has all eyes fixed upon it. If it works, it is declared a success, but if it flops it is considered a failure and public sentiment does not allow a clean slate for successive experimentation (Halwagi *et al.*, 1986). Thus it should not be overlooked that the interest of later target groups will be affected by the pilot model.

The view of a profit ‘maximizer farmer’, which postulate that people make decisions in order to maximise ‘utility’ (or well-being) has been criticized by Gladwin, (1989) who are concerned with real-world decisions. They propound that people are unlikely to have the single objective of maximizing profit (that is, economic objective) but a mix of economic and non-economic objectives. However, Daydé, *et al* (2014) in their concept called *operational decision-making*, advance that Operational decisions depend on tactical and strategic commitments. They argue that decisions are made independently of each other. This is without regard for anything that has gone before and ignoring that they are made in compliance with the overall production logic expressed by the on-going plan. In addition to the plan, past experience and knowledge, perception of the current state and belief of what might result from particular actions, goals and preferences, affect decision-making. They note too that these may vary among individuals.

According to Kay *et al.*, (2008), these decisions are either at strategic or tactical levels. At a strategic level, decisions have major impacts on the farm business as a whole since they focus on the long-term horizon. In contrast, decisions at tactical levels concentrate on medium to short term impacts and therefore are more limited in scope. The extent to which a decision impacts on the attainment of farming goals ultimately determines the relative importance of this decision. In general, strategic decisions are more important than other decisions (Pereira 2011). In this regard, Biogas systems have been able to meet

both the practical and strategic gender needs for family members who are responsible for preparing and processing food and working in the kitchen. Further, Pereira (2011) argues for a more holistic approach to human nature. She argues that the theories are overlooking relevant aspects of decision making. She postulates that within this holistic view, a farmer, or any person, is not seen solely as an individual economic agent, who acts exclusively to maximise his/her economic goals. Rather, he/she is part of a social system, influencing and being influenced by this system. However, according to Triandis (2002), empirical studies have shown that farmers' behaviours often do not conform to the models.

2.2.2 Technology adoption and acceptance-paradigms

Porter and Donthu (2006), advance two research paradigms that have emerged to explain technology adoption and acceptance. One paradigm is system specific, focusing on how a technology's attributes affect an individual's perception of a technology. This inadvertently affects the usage of the specific technology. The technology acceptance model (TAM) has come to be one of the most widely used models within this paradigm (King and He, 2006; Porter & Donthu, 2006). According to Flett *et al.*, (2004) adopting a technology is centred on farmers' belief. TAM describes the relationship between internal psychological variables – such as beliefs, attitudes, and behavioural intention – and actual system usage (Davis *et al.*, 1989).

Davis *et al.*, (1989), pointed out in their study that the two primary predictors in TAM that affect technology usage are *perceived usefulness* (PU) and *perceived ease of use* (PEOU). Porter & Donthu, (2006) add their views to this discussion by presenting another paradigm that focuses on latent personality dimensions to explain the use and acceptance of new

technologies. Analysing these beliefs amongst dairy farmers in New Zealand, Flett *et al.*, (2004) found that farmers' beliefs regarding the usefulness and ease of use of technologies discriminated adopters from non-adopters; perceived usefulness being more important than perceived ease of use. According to Beedell and Rehman (2000), beliefs are formed on the basis of the type of information an individual is exposed to, his/her experience and implied knowledge. The perception of fuel-saving, environmental protection and human health protection also influences the decision to adopt biogas.

Parasuraman, (2000) in his research has also identified the technology readiness index (TRI). Technology readiness can be regarded as a gestalt emanating from four personality dimensions: *optimism, innovativeness, discomfort, and insecurity*. According to Parasuraman (2000) these personality dimensions affect people's tendency to embrace and use new technologies. In this respect, optimism and innovativeness function as mental enablers, while discomfort and insecurity function as mental inhibitors to accepting new technologies.

However Lin, *et al.*, (2005) and Lin, *et al.*, (2007) in their research combine the two paradigms by integrating the TRI and TAM into one model looking at it from different angle that includes technology readiness as an antecedent of perceived usefulness and perceived ease of use in TAM.

2.3 Social- Cultural Factors, their Influence on Decision Making and Adoption of Technology

A full understanding of the user' perception of innovations, culture, and form of communication channels used to diffuse understanding of the innovation and in particular leadership dynamics are important in the technology adoption success. Thus the basic

principle of any planning should be to involve those concerned in the planning process as early as possible. Lekhanya, (2013), advance that resistance to new ideas is fuelled by fear, lack of knowledge, religious and cultural beliefs and traditional practices. Respectfully, introducing biogas generation into an optimally run agro ecosystem is complicated by numerous resource, environmental, engineering, and social constraints. Such reduce the practicality and reliability of biogas generation and the prospects for widespread diffusion of this otherwise desirable technology.

2.3.1 The Social Factor

The significance of social factors in deployment of technology has been an area of interest for many researchers. There is enough evidence supporting the view that technology adoption decision is subject to social influence. Eseonu and Egbue (2014) *illustrate* that the rate of technology adoption varies depending on a variety of social factors. These include among others the nature of the technology, societal receptiveness and government policy. Further, Godwin and Guimaraes (1994) advance three factors that are to be considered to see social involvement in technology advances, that is;

1) social need-to feel strong desire of something, 2) social resources-the capital, material, and skilled personnel vital for innovation and adoption of new thing, 3) sympathetic social ethos-an environment in which the dominant groups are prepared to consider innovation seriously and are receptive to new idea.

Godwin and Guimaraes (1994), postulate that the non-consideration of these factors may inevitably lead to poor rates or unsuccessful adoption of a technological innovation. Therefore, it is necessary to consider the social system farmers find themselves in to understand adoption decisions holistically. Wirth *et al.*, (2013) thus advances that diffusion of Biogas technology needs to be integrated into established procedures of

farming. They advocate that the professional culture of farming is key for whether the innovative technology is used and how.

Consequently, despite largely relying on their own resources and experiences, farmers also interact with a large number of people, including both their peers and others in agricultural support organisations. This enables farmers to learn about benefits of new technologies from their peers, imitate their peers' decisions, or respond to their peers' experience. Further Oreszczyn, *et al.*, (2010) advance that, farmers' learning about new technologies happens in a complex social learning system. The importance of the social context in farmers' adoption decisions is twofold: first: farmers may feel the pressure of social actors to behave in particular ways (e.g., cultural settings). Secondly farmers learn about new technologies from interacting with other social actors, the so-called social learning. Thus the composition of farmers' social milieu has been regarded as influential on adoption decisions. Social influences, networks and cultural values were found to influence decisions.

The study of Oreszczyn *et al.*, (2010,) calls this the "*web of influencers*". The specific mechanism in which farmers 'web of influencers' operates and impacts on adoption decisions may be provided by the Theory of Planned Behaviour (TPB), particularly regarding its 'subjective norm' component. According to Mpele (2013) individual persons consider people who are close to him/her, such as family, friends and relatives to him/her, when thinking of using new technology.

Zia *et al.*, (2009), in his report in Afghanistan, eludes that mountain communities are organised around strong traditional institutions such as the Shura (a consultative body). They stress that it is particularly important for development practitioners to understand

the social structure and to identify the marginalised groups they are working amongst. Furthermore working with communities must be based on the principles of participation, inclusion of all members of the community (Zia *et al.*, 2009).

2.3.2 Culture, energy and adoption of technology

Modern societies and cultures depend on intensive energy use from the extraction of natural resources. Energy-consuming practices show the interdependence between our societies and our relation with nature (Horta *et al.*, 2014). Depending on a society's ideology, energy usage is affected. Culture, according to Matsumoto (2007) emerges from the interaction of basic human nature with specific ecological contexts in which groups exist through a process of environmental adaptation. It is important in energy because how one lives is a facet of one's culture. Cultural values and beliefs vary among different cultures which invariably dictate their perspective for technology (Leidner *et al.*, 2008). The consequence is that then technology adoption will be affiliated to these cultural differences. A society's norms, values, beliefs, and attitudes are facets that have been passed on over several generations. Therefore whenever a new technology is to be integrated, its assimilation will fit more easily if its component features fit with the cultural facets of the target community. Thus in his comparative analysis, Adkins *et al.*, (2012) has indicated that the traditional systems of rural agricultural cultures can be expected to provide strong supporting support for individual or communal household biogas development (Adkins *et al.*, 2012). In situations where an innovative intervention restricts the traditional modicum of the cultural system; its acceptance and assimilation will be more problematic. For example, Native Americans frequently object to hydropower projects because they disrupt stream flow, which is of great spiritual

importance to Native American culture (Wilk, 2006). It is widely accepted that local communities due to their indigenous knowledge and traditional practices have a pivotal stake in environmental management and development. Energy consumption inconspicuously bridges nature and culture (Szerszynski 2010). Cultures which value creativity, technological ability and higher education, are more successful at adopting innovations. Thus culture is one of the most critical elements that allow people to develop and launch innovative ideas (Eseonu and Egbue, 2014). Indeed cultural definitions evolve that signify what is proper work for men and women, what odours are considered tolerable, what is defined as being dirty or clean, and in relation to BGT; the appropriateness of handling cow manure with ones hands' and whether it is more appropriate for women rather than men to handle it.

2.3.3 Culture and energy household preferences

Further behavioural and cultural factors also influence energy household preferences. For example homely feelings for individuals of a society influence how buildings are constructed and how energy is used, which is indeed a facet of culture. Certainly in Japan there is still widespread resistance to domestic space heating and cooling. Japanese people heat the space under a sunken dinner table and trapped the heat with a cloth around the edge of the table. They are genuinely comfortable this way (Wilk 2006).

Comparatively developing countries record higher adoption than developing countries. This reluctance may be tied to cultural beliefs related to taste preferences, familiarity of cooking with traditional technologies and ignorance by the populace on the social - economic, environmental, and health benefits of BGT energy.

Attesting to this, Wingenbach and Bielecki (2014), found the use of traditional cooking stoves in Guatemala and rural Mexico, as a heat and a light source as well a meeting point for the families was a hindrance. Even in circumstances where families are able to afford cleaner alternatives, many households stuck to using fuel wood. Likewise in India and several other countries, many wealthy households retain a wood stove for baking traditional breads.

In addition cultural values and norms determine consumers' perception of whether other people believe they should engage in certain behaviour (Mpele, 2013). For example cultural change, (where increasingly) the presence of the man in the kitchen preparing and cooking food over the BGT unit is more visible ostensibly as the kitchen is now smoke free and the BGT unit more user friendly. Kileo and Akyoo (2014), Bajgain and Shakya (2005) both agree presenting that kitchens are increasingly being used as a family rooms because they are now smoke free and better lighted.

2.3.4 Value of in-kind household contributions towards adoption

In most instances where the locals put up a BGT plant on their farms that they have on a sponsored themselves, normally it is the households that have to typically provide contributions of unskilled labour and locally available materials, such as sand and water for construction of the plant. This is done communally and is unpaid for. Construction depends on the availability of qualified operators and local contributions in the form of free labour solicited from within or from other group members. For example in a recent study on Sustainable Livestock Development in the Greater Horn of Africa Regional (GHA) by African Development Bank (2010) there were reported instances of utilization of community labour through such programs as food for work. For example,

smallholder farmers were digging earthen dams manually in Mwingi District (Mati, *et al.*, 2011). This reduces the costs of construction and installation even further.

According to Mulinda *et al.*, (2013) the labour-intensive burden demanded in the livestock farms for preparation of animal fodder, fetching of water for mixing with animal feedstock, and the regular upkeep, is a constant worry to the farmers. For the potential biogas users who may have to hire farmhands, this increases operational costs. Disappointingly too, Lauterbach, and Zuckerman, (2013) asserts that the burden of unpaid workload in developing countries is largely and mostly done by women. Besides, Wawa (2014) reports that it is the women who will shoulder the burden of not only taking care of the cows; they also feed the plant and ultimately use the gas in the kitchen. This work goes unrecognized; the in-kind contributions will depend on availability of local materials and may vary in different locations.

2.3.5. Influence of Gender relations in household decision making

Gender has been singled out in many studies as the key factor in decision making when it comes to adoption of a technology (Doss 2001). Gender relations determine levels of participation in decision making process within the household and in the community. According to the UN (UNDP 2012) Report; women remain marginalized from decision-making processes in relation to energy, and gender-sensitive energy projects and research. Disappointingly the poor women participate in the informal economic sector which relies strongly on biomass as its main energy source, which, in turn, does not feature heavily in national energy policies (UNDP 2012).

In particular, women and girls in the developing world are disproportionately affected in that regard (UNEP 2011). Indeed according to UNDP (2012), women and girls are often

primarily responsible for collecting the climate-induced, scarce natural resources of fuel and water at the community level. Though women are the main interested parties concerning biogas for cooking, they are kept out of many decision-making processes.

In a related study on cook stoves, Miller and Mobarak, (2013) have pointed out that with the balance of power skewed towards the men in rural communities; the decision to purchase a clean stove often resides with the men. Previous results (FAO 2011, Chapter 11), from the developing countries show that men and women do not adopt new technologies at the same rate or benefit equally from their introduction. This is because women have different technological needs because the balance in their productive responsibilities is different from men's (Lauterbach, and Zuckerman (2013). Investment in cooking technologies – that first and foremost benefit women – might not necessarily be first priority for male decision makers. Additionally, given the fact that men spend a limited or no time around a stove, their motivation to invest in a cook stove despite its benefits can be low. Further, once a plant is constructed, its women who are the most affected by the malfunctioning of the plant (Ishara 2011).

Failure to consider gendered interests and the different needs of men and women can limit the effectiveness of energy programmes and policies, as well as other development activities that involve energy use (Sulo *et al.*, 2012).

2.3.6 Gender segregated extension services

Extension provision in developing economies remains low for both women and men, and women tend to make less use than men of extension services. According to a World Bank report, women's access to extension services may be constrained by the fact that most

extension agents are men, as are most contact farmers (Lauterbach, and Zuckerman, (2013).

Social restrictions on interactions between genders may constrain or even prohibit the kind of contact that extension training entails (Kathleen & Gale 2009). Male extension agents are less able to reach female farmers as there are cultural and social restrictions (Kathleen & Gale 2009). This may result in women being left out from extension services and management decision-making. The assumption that women's interests and views are always expressed through their spouses may lead to women being left out in the socio-political decision making organization of the community.

Lauterbach, .and Zuckerman, (2013) further indicate that the extent to which the extension agent's gender mattered differed significantly according to socio-cultural contexts. For example in Afghanistan, as in many communities, gender relations differ greatly from one ethnic group to another. Some social customs deter unrelated men and women working together, to the extent that in some communities women cannot be contacted by men in the absence of their husbands (FAO, 2011). It is thus very difficult to involve women in development interventions, public gatherings, or even meet with them. This blocks women from accessing extension information and new technologies. Among male extension agents, cultural attitudes may also limit the importance they attach to women's training, and they may lack understanding of women's priorities and training needs. On the other hand if extension agents also attach too much attention towards women, for example, providing special credit to women in their policies, this could become a genesis for conflicts between husbands and wives within the households.

2.4 Attitude towards use of Biogas as an alternative energy source

According to Fazio and Carol, (1986), an attitude affects an individual's behaviours by filtering information and shaping the individual's perception of the world. Whereas according to Petty and Krosnick, (1995), the strength in the attitude amplifies or neutralizes the effect of the attitude on behaviours. For example, a user who strongly holds a favourable attitude toward using a certain technology may adopt and continuously use the technology; but a user who weakly holds a favourable attitude toward using a technology may be easily persuaded to change his or her favourable attitude, preventing adoption or continued use of the technology. Myles (2007) thus argues that in BGT, the decision to invest in the building of BGT plants came from men if they could be convinced that biogas digested slurry (manure) was good for their agriculture.

A technology is not successful if its user does not accept it and in case of BGT it is also true. Thus Frangos *et al.*, (2011) and Money and Turner (2005) stress that user's play a major role in accepting or rejecting an innovation. In order to increase technology uptake, it is necessary to understand perceptions working as barriers, promote information dissemination and education, towards allowing farmers change negative beliefs, attitudes and perceptions.

Greiner *et al.*, (2009) reports, farmers' beliefs, attitudes and perceptions are influential aspects in adoption decisions as they inform farmers' intentions towards a particular behaviour. Pereira (2011) also effectively argues that positive beliefs, attitudes and perceptions usually lead to a favourable predisposition for adoption whereas negative feelings reduce the chances of voluntary adoption. An individual's positive attitudes to a

technology can be regarded as an intention to use that technology and actively support its development in the society.

Although accessibility of fuel, functionality and aesthetics are the other primary factors considered by people in the choice of cooking device bought and used (Ngugi *et al.*, 2007), the adoption of new technologies unfortunately is made difficult by uncertainties. These revolve around unexpected consequences of the technology associated with the use of any new technology. The adoption of BGT is faced by among other factors, lack of awareness of biogas characteristics and utilization ways. The relationship between knowledge and attitude is significant. Attitudes are positive or negative, depending on the attributes of the object or behaviour and how these attributes fit in one's belief system. While avoiding fuelwood is the primary reason for farmers to install a biogas unit; other benefits such as witnessing successful biogas use, reinforces their preference for biogas over biomass. This increases confidence in the technology and further encourages non-users to become users.

Given risk is unavoidable (Olson, 2003); it has been considered an important barrier for technology adoption. Risk is inherent to farm decisions as farmers do not have complete control of, or information about, the outcomes and associated probabilities of a decision (Olson, 2003). There is strong evidence showing that risk aversion, reduced technology adoption, particularly in situations where perceptions of relative riskiness and scale of operation were increased. In contrast, risk takers have been found to be more open to technology adoption. Public perceptions of risk depend on various demographic and cultural factors.

In a review of empirical studies on the role of risk in technology adoption, Marra *et al.* (2003) report that attitude to risk, risk preferences and the perception of the relative riskiness of enterprises impact adoption decisions. Xi Yu *et al.*, (2014) further advances that it is likely that the ‘costs’ of perceived uncertainty about the new technology may outweigh the expected potential benefit and hence, discourage the diffusion of technologies. As a result, much empirical evidence suggests that risk-averse individuals are less likely to adopt new technology, despite risk-reducing nature of the technology (Liu, 2013).

2.5 Role of the Change Agent- Formal, Informal Institutions and Extension Services

According to the International Labour Organisation (ILO) it is not possible to clearly distinguish a formal sector and an informal one. There is a constant intermixing of activities classed as formal and informal in all the sectors of the economy. The informal sector is often organized along strong hierarchical family, ethnic and religious relationships. Informal activities are often characterized by low levels of capital, skills, access to organized markets and technology; low and unstable incomes and poor and unpredictable working conditions. Helmek and Levitsky (2004) define their distinction as follows: ‘formal institutions are openly codified, in the sense that they are established and communicated through channels that are widely accepted as official whilst informal institutions are socially shared rules, usually unwritten, that are created, communicated, and enforced outside of officially sanctioned channels’.

According to Wirth *et al.*, (2013), institutions play a crucial role for the development and diffusion of novel technologies. Nowak and Korsching (1983) stress the importance of institutional factors in enhancing farmers' uptake of agro-environmental initiatives.

Contrary to other new energy technologies like solar cells, heat pumps or stationary fuel cells, biogas plants cannot be set up and left alone, but must be filled, monitored and emptied constantly, that is, they have to be integrated into the daily routines of farmers. Thus Wirth *et al.*, (2013) in their study have argued that, it is the interplay of public support schemes for renewable energy technologies and the professional culture of farming which had a decisive influence on which kinds of biogas plants were built and how many. The decision to adopt or reject a new technology by a prospective targeted user rests on several factors. According to Prakash (2007) any factor that affects successful performance of a biogas plant has a bearing on the acceptability of the technology.

2.5.1 Promotion and Marketing policies

The awareness of the entry of a new technology is dependent on the promotion activities. With BGT, it is paramount to sensitize the public or the target residents of the benefits accruing from the uptake/adoption on their health status and their immediate environment. This invariably develops their willingness and eagerness thus improving the adoption potential. Promotion is part of the learning process through which new skills are learnt, managerial abilities are improved, which reduces uncertainties, for better decision making. Farmers who are more exposed to formal extension information have a high propensity towards adoption than those with less exposure.

Institutions increase the predictability of the decision-making situation by setting rules that govern the players, suitable actions and strategies, and accredited results and linkages

among decisions (Heywood, 2000). Biogas technology promoter is the first contact with the potential biogas users. They have the opportunity to guide the potential user objectively without rushing to meet their programs or business targets.

2.5.2 Operation and maintenance

The performance of the biogas plant has a bearing on the acceptability of the technology (Prakash, 2007). The overall performance of the BGT units explicably relies on a proficient team to ensure professionalism to achieve expected results. Standards have to be set and these standards are not limited to the design, construction materials or method, and after-sales service of biogas plants. In addition, the quality of information provided to the potential users prior to their investment decision is important.

The choice of digester type to build often lies with the promoter, whether organization, individual or a small micro enterprise (SME). Moreover the choice of design is more often dictated by the perceived cost of the construction. It is common for the potential user to demand for a design seen previously in another location. The availability of different types and variations of the same design ends up confusing the customer. Some biogas contractors are not capable of presenting the technology to the farmer objectively. They appraise the designs they are familiar with and present all others as potential failures and or expensive. A good understanding has a positive influence on the way the plant is operated and maintained.

The reputation of the technology has been in the past put to task whenever some functional plants operate below optimal capacity and worse still when there is total failure (Ngugi *et al.*, 2007). Many plants ostensibly fail due to poor management and follow up services, thus plants suffer from poor maintenance and repair. This invariably from a project that constructs too many units all at once, this compromises the quality of

standards (KENDIP 2014). Ngugi *et al.*, (2007), argues that witnessing unit breakdowns and identifying the number of failed or unused plants deters households from adopting biogas technology in Kenya. From the demonstration farms around and where there are functional units, increases confidence. This brings other potential farmers into the adoption group (Chen 2014). A well-constructed plant with satisfied user is the only way to ensure proper extension of biogas technology.

Incidentally, Wirth *et al.*, (2013) have highlighted the role of institutions in order to explain why specific socio-technical designs emerge and diffuse or why some regions or sectors fare better than others. According to Alternative Energy Promotion Centre, Nepal, 2000, large majority of the companies engaged in plant construction had a profit motive, thus there was some negligence about the quality control and after-sale-service (AEPC 2000).

2.5.3 Training

The sustainability of renewable energy among target groups is more often than not hampered by absence of capacity development support. Besides ability to pay for constructions and ownership to livestock, the users understanding of the technology has a significant role to play in determining the success or failure of their biogas system. The provision of support from promoting agencies and post installation support comes in handy to determine acceptability and adoption. Once the biogas plants are in operation the private sector investment can support the long-term sustainability. Thus Wirth *et al.*, (2013) stresses the importance of formal institutions not only for providing financial incentives but for other regulatory support.

2.5.4 Access to credit

According to Phiri (2007) the role of credit in the adoption as an institutional factor provides the necessary capital which facilitates the farmer's potential to afford a given technology and maintain its usage.

Affordability is among the primary factors considered by people in the choice of cooking device bought and used (Ngugi *et al.*, 2007). One drawback for the rollout of this technology is relatively high set-up costs, so it only becomes affordable to those on higher incomes. The EUROBSERV'ER, (2012), reported that financial incentive schemes and regulatory support play a key role in the development and diffusion of biogas.

Building and maintaining of a Biogas systems is an investment in itself. In many situations the residents input is limited leaving the local government to support the initiatives. Such government subsidies are not sustainable to promote and ensure the sustainable development of BGT. Many developing countries already suffering from limited resources and expertise are unable to raise the requisite infrastructure. Hence financial support has to be sourced from without (Winkler, 2011; UNFCCC, 2008; Pegels, 2009; UN-Energy/Africa, 2011; UNEP, 2012). These foreign investors as well as development agencies normally have strings attached to this aid exposing countries to macro-economic risks.

Some regions have further multi-sourced subsidies from, central or national government coffers, the local governments and also funds from own savings. Such an approach becomes an enabler for more people to adopt BGT boosting its uptake. For example, USAID's Nepal Biogas Microfinance Capacity Building Program has established

appropriate financial institutions to help continue and sustain the development of the biogas sector in Nepal.

2.5.5 Community involvement and implementation

For a successful roll out and sustainability of renewable energy projects the target community has to be involved for them to own such initiatives. This involves a participatory approach where project experts, as they provide employment, also impart technical and managerial skills to the community members (Dengerink, 2011). Their non-involvement poses among other risks, sabotage, delayed completion and discontinuation (Rambo, 2013). In Uganda, for instance, the non-involvement of communities and civil society groups delayed the completion of the 250 MW Bujagali power- station along River Nile. Wirth *et al .*, (2013) add their views to this discussion by saying that local professional culture has a modulating effect on policies that are set up to foster biogas technology. Based on their observation they projected higher diffusion rates where local culture and public support schemes were well aligned. Further biogas plant construction generates income and business opportunities in rural areas. The Nepalese biogas sector generated, at least 9,000 vacancies in different organisations, especially biogas companies and appliance workshops. The poor, illiterate rural people continuously harness their skills through training to become better mason through such Biogas Support Programs (SNV 2010).

Individual solutions are not adequate to tackle energy poverty and especially in regard to Biogas adoption. This is why it is imperative to involve or integrate the efforts of both the formal and informal institutions in setting a joint agenda for BGT development for resolving the underlying systemic constraints. This calls for a multi-actor approach which

includes the full spectrum of stakeholders - from poor households to national governments, farmers' unions, MFIs, investors, industry associations and influential NGO society organisations. We can therefore expect that, (as earlier mentioned) the cultural and professional embeddedness of farmers – and the informal institutions it consists of – play a crucial role for which kinds of biogas plants are built and by whom they are operated.

2.6 Summary and identification of research gap

From reviewed literature there is evidence that changes in energy acquisition, accessibility and consistency has direct influence on, perceptions, towards the use of biogas as an alternative energy source in promoting environmental sustainability. There is enough evidence supporting the view that, no alternative energy technology, no matter how technologically advanced, will have a significant impact unless it is adopted by a significant percentage of the intended users. Therefore, it is necessary to consider the social system farmers find themselves in to understand adoption decisions holistically. The success of biogas programme depends heavily upon the workable and an effective implementation plan that is based upon the grassroots reality of the sector. The role of farmers' preferences in adoption decisions has received very limited attention in adoption studies conducted by economists. There is still insufficient attention to detail in the concept of actualizing adoption of biogas with a substantial gap on farmer's socio-cultural factors, and role of promotion activities identified in this research study.

CHAPTER THREE: METHODOLOGY

Introduction

This chapter is organized along the following sections: population location and size of study area, climatic and agro-ecological characteristics, socio economic characteristics, research design, study population, sample size and sampling procedure, data collection procedures, and finally data analysis. The aim of this chapter was to provide a justification of the type of data used in the project, methods used in their collection and statistical analytical techniques adopted in the data analysis. The challenges faced by the researcher in applying the various techniques during the field work are discussed as they influenced the result obtained in the analysis.

3.1 Study area

3.1.1 Population, location and size

Gakawa location is registered as County Assembly Ward No 0476. It comprises of Kahurura, Gathiuru and Githima Sub–Locations of Nyeri County with a population of approximate 26,321 persons. Gakawa sub division is located in Kieni East Constituency in Nyeri North Sub County on the western edge of the Mt Kenya Forest ecosystem; one of the largest single forest blocks in Kenya. The location covers an approximate area of 251.50 Square Kilometres. Due to the similar agro-ecological characteristics and activities experienced in the region, three sub locations were purposefully chosen for comparison purposes to authenticate results for the Sub County.

Table 3.1: Population size: Kieni East-Gakawa location

Location	Male	Female	Total	Households	Area(km. ²)	Population Density
Gathiuru	2,886	2,484	5,370	1,609	118.21	145.43
Githima	2,416	2,439	4,855	1,363	39.04	124.36
Kahurura	7,981	8,115	16,096	5,125	94.29	170.71

Source: Population Census Volume 1: Population by Households: Kenya Open Data. (2011).

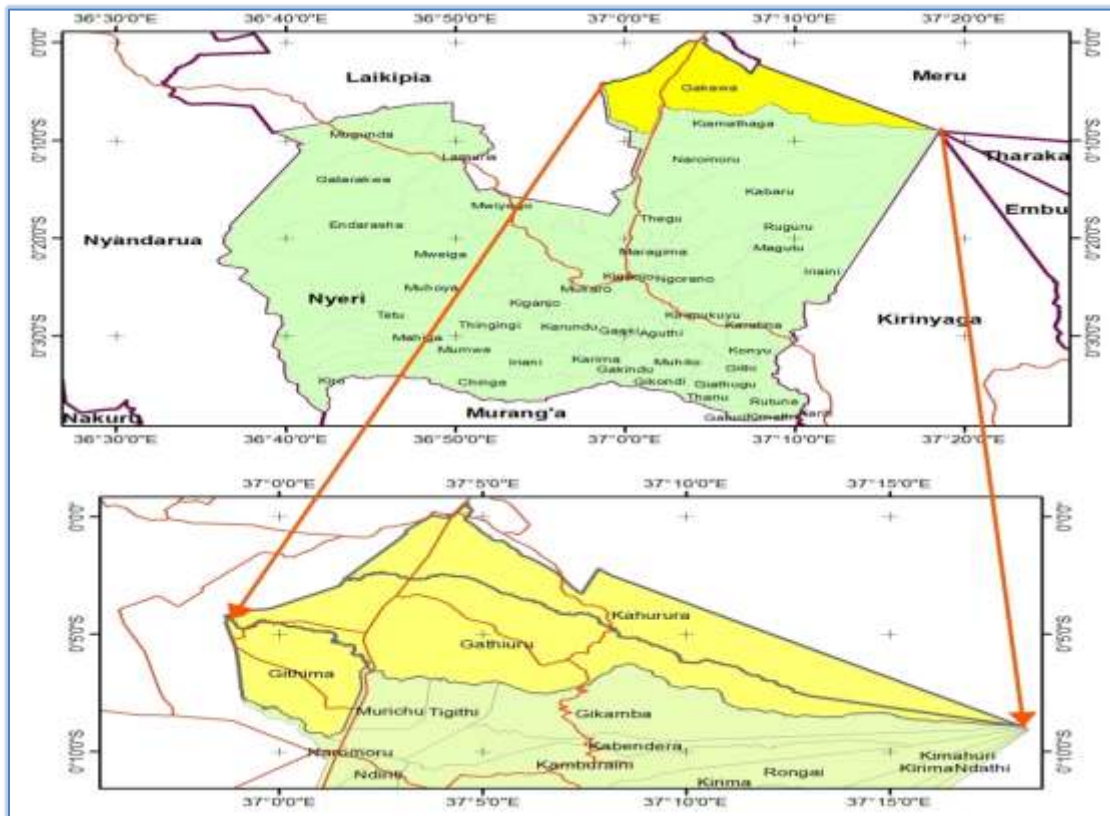


Figure 3: Map of Nyeri county-inset Gakawa location: Source: KUGIS Lab 2014

3.1.2 Climatic and Agro-ecological characteristics

The region falls in the rain shadow of Mt Kenya. Temperatures range between 13–28° C during the hot season between January and March, while the average annual rainfall of 500 mm (GoK, 2009b). The region is characterised by low primary vegetation productivity and high geographical and seasonal availability (both surface and accessible ground water). This also explains the scant vegetation in the region.

Gakawa economic and environmental resources include crops and trees on farms, livestock, and a small amount of water and riverine forest. It also boasts of tourism (it hosts Nanyuki airstrip) and wildlife utilization, wood and non-wood products exploitation. In the past, the region was covered with forests which would have forest products such as timber, wood fuel, fodder, herbal medicine harvested. These forests play vital roles such as maintenance of water cycle, wildlife habitat, taking repository of a wide range of biodiversity. The increasing population pressure is forcing people to encroach on fragile water catchment areas for farming and pasture in Mt. Kenya. This negatively impacts on water availability.

3.1.3 Agro practices

Being part of the Kieni plateau, there are a lot of agro practices that incorporates crop farming, pastoralism, and dairying. Traditional herds are still favoured in goats and sheep that are either tethered or roam freely under close watch of some herds' boys and men. Small scale farmers grow subsistence and drought resistant crops with a mixture of horticulture and wheat farming. There is growing of maize (zea- maize), beans, and with irrigation the growing of horticultural crops, like tomato, butternuts, cabbages, kales,

most which find their way into the local markets whilst others are being taken to far place like Mombasa, Nairobi.

However many agripreneurs in the study area its environs have abandoned farmlands due to constant destruction of crops by elephants. There have been many other external factors affecting agripreneurs in Nyeri County including monkey and baboon invading their farms. According to a report by Kenya Government drought management agency, the worst hit areas include Gathiuru, Kahurura and Burguret villages in Gakawa location. The most recent menace has been the millipede invasion (2014-2016) which has rendered farming almost impossible, as the pests invade crops on the field and in the stores.

None the less, just like the rest of the country and in the county where farmers are having problems with tea and coffee to the extent of uprooting them, there is need to diversify agricultural practices. Towards this, several initiatives have been carried out in the region. For example in 2005 Kenya Organic Agriculture Network (Koan) which has been promoting organic agriculture in the country introduced a tree species- the *Tea tree* (referred to as *Melaleuca alternifolia*). Tea tree farming is becoming popular due to its good returns (requires low labour input, is pests and diseases free and has a ready market). Already a number of farmers have started enjoying the economic benefits of tea tree.

To further improve on nutritional status and incomes of vulnerable members of the community through upgrading of local goats , the ‘NJAA MARUFUKU KENYA (NMK) PROJECT’, the Grassroots Alliance for Community Education (G.R.A.C.E.) implemented over a two year period between June 2013 and June 2015, a project christened ‘*Kieni East Dairy Goat Upgrading Program for Better Nutrition and*

Economic Empowerment'. The purpose was to increase dairy goat milk yields and introduce internal savings and lending schemes in Kieni East district (Nyeri County Government report, State Department of Agriculture 2015).

3.1.4 Socio-economic characteristics

With the instabilities that rocked the country in 1990, 1992, 1997, 2002, 2007, many internally displaced people have relocated to Gakawa Location. These efforts have either been on an individual basis, or land buying schemes and, more recently the government relocation programme (GoK, 2009). Poverty data based on the Kenya Commission on Revenue Allocation shows that Gakawa location has the lowest percentage of individuals below poverty line due to the high population of immigrants and the urban population around Equator which is part of Nanyuki town (GoK, 2009). According to Kenya Open Data, County Fact Sheets, 2011, the percentage of biogas users in Nyeri County, Gakawa included, is negligible. The region faces amongst other weaknesses a weak human capital base due to low investment in education, poor on non-existent physical infrastructure such as roads, irrigation canals, factories, hospitals and telecommunications. It is also faced with a fragile ecosystem that is being pushed to the limit, and marginalisation due to poor past policies from the centre, what with the perception that Kieni is a “high potential” area, thus attracting low interest from private sector investment (RoK. 2013).

Gakawa location is partially served by I C T -Broadband connectivity.; being a beneficiary of the project by Communications Authority of Kenya ‘The TV white space technology’ connectivity initiative (the ‘2013 Trial Authorization’). These projects relied and continue to rely on a combination of wireless technologies designed to operate on a

license-exempt or unlicensed basis, including Wi-Fi and TV White Space base stations and end user devices (C.A.K. 2014).

3.2 Research design

The study adopted a descriptive research design which emphasizes the measurement and analysis of relationships between variables. The selection of these designs was guided by the nature of data that was to be collected, the time available as well as the objectives of the study. Given the dynamic and urgent nature of the solid fuel challenge, the researcher had to collect first-hand information from the field. The researcher was mainly concerned with views, opinions, perceptions, feelings, and attitudes towards the use of biogas as an alternative energy source. This information was collected through the use of questionnaire and interview techniques.

3.3. Study population

This study targeted mainly farmers' households whose energy needs have been mainly wood fuel. It is these households that have had the burden of collecting and utilizing, the ever diminishing wood fuel stocks. Some of the farmers have been involved in community self-help groups that participate in various economic projects creating awareness about alternative energy sources. Consequently collection of data was enhanced since the location was easily accessible.

3.4 Sampling procedure and Sample size

3.4.1 Sampling procedure

The study adopted a non-probabilistic, sampling purposive sampling, in the selection of adopters from the sampled households. Thus the NGOs and Government offices that have a footprint in the environment and energy sector were identified. Snowball sampling was

used for biogas adopters who then identified other farmers who had already embraced biogas technology. 3 local dairy cooperatives from each sub-location were sampled. Random sampling was used to target the non-adopters farmers' households in which the respondents chosen were based on their convenience and availability.

3.4.2 Sample size

For the non-adopters, the researcher adopted Fisher's formula to determine the sample size

$$n = \frac{n'N}{N-1+n'}$$

Where,

n is sample size

$$n' = Z^2 pq D/d^2$$

Z^2 is the confidence level taken as 1.96 at 95%

p is a proportion of the targeted population estimated at 0.5 confidence level at 95%,

q is $1-p$,

D is design effect of 1 and,

d is level of statistical significance taken as 0.05.

$$\text{Hence, } n' = (1.96^2 * 0.5 * 0.5 * 1) / 0.05^2 = 384$$

N = accessible population (in our case, Gakawa division has 8097 households).

Therefore,

$$\text{Sample size, } n = 384 * 8097 / \{8097 - 1 + 384\}$$

$$= 366 \text{ households.}$$

According to KENDIP (2014), the number of adopters stood at 180 in the whole constituency and at 71 in Gakawa location. The population is manageable for a census.

This is in line with Watson (2001) who has spelt out that when the population is small it's preferable to do a census of everyone in the population. Consequently the researcher visited the 71 adopters in the location.

3.5 Data Collection

The study employed both qualitative and quantitative approaches in collecting both primary and secondary data. The qualitative approach allowed the researcher to make an in-depth investigation of variables related to adoption and non-adoption of biogas technology. Through the interactive approach and the use of interviews schedules the researcher was able to elicit from the informants perspectives which enhanced the quality of data collected. Institutions supporting biogas development were consulted for understanding their performance and constraining factors they are facing. This was imperative because of the salient issues in perspective.

Structured questionnaires were used to collect data from adopters and non-adopters. The questionnaires first part sought to collect background data from the farmers. For non-adopters, the second part sought for information on their current energy needs and biogas technology awareness. For adopters, the second part sought information on installations and current status enjoyed from adoption of BGT. The researchers adopted the face-to-face and drop and pick later method to improve on the response rate.

The researcher used observation as a tool to gauge the respondents' attitudes based on their facial expressions, gestures and other hidden or doubtful response behaviours. The researcher further developed an observation schedule to capture the characteristic of farms and farms structures, types of Biogas units. Some of these have been recorded in the farms and photos presented in the report.

The study measured reliability of data based on the set guidelines and ability to meet objectives. To achieve content validity, the study relied on current data from relevant stakeholders.

3.6 Data analysis

Descriptive statistics and analysis were used to analyse quantitative and qualitative data obtained from closed-ended and open-ended questions. The study used means, standard deviation, relative frequencies and percentages to interpret the quantitative data. Qualitative Data obtained was coded and clustered into common themes for subsequent statistical analysis. The Statistical Package for Social Sciences (SPSS) computer software was used for quantitative analysis to generate data array used for subsequent data analysis.

To answer the first objective, data was presented using frequency tables, pie charts, cross-tabulations, and histograms to indicate the distribution of background characteristics of respondents. A stepwise linear regression analysis was carried out on the socio-cultural factors that influence adoption of biogas technology. To test for correlation between social-cultural variables and BGT adoption, a Pearson product Moment Correlation was generated. For the second and third objectives data was analysed using the likert scale and regression analysis. This generated quantitative reports through tabulations, percentages, and measures of central tendency. Responses of ‘undecided’ were also included in the analysis and were considered to indicate the lack of knowledge or disability to evaluate obstacles facing BGT and measures to improve it, hence ignorance which was assumed to contribute to non-adoption of biogas technology. Furthermore some respondents having not being exposed to BGT felt they could not answer or give

their opinion on the benefits of adopting it nor factors that would improve it, thus declined to answer the two sections in the questionnaire. Pearson's product Moment correlation test was used to determine the degree of relationship between lack of education, ineffectiveness of community development officers, extension officers failures, limited land for expansion, poor marketing policies, positive publicity and marketing and adoption of BGT.

CHAPTER FOUR

RESULT AND DISCUSSION

4.0 Introduction

This chapter covers data analysis, presentation and interpretation of findings on the factors influencing the adoption potential of Biogas technology in Gakawa location in Nyeri County. Data was collected from selected households and key informants such as District Agricultural Officer, District livestock Officer, Cooperative society chairpersons and NGOs such as KENAFF/KENDIP.

4.1 Demographic information of the respondents

In this part, general information about the respondents is analysed by the use of frequencies and percentages. The data obtained is presented in the following sections.

4.1.1 Locality of Persons who responded to the questionnaire in the households

The general description of the location of the persons who responded to the questionnaire in the households is presented in table 4.1. Gakawa has 8097 households. Based on the population size per locality, farmers sampled were from Githima (37.5%), Gathiuru and Guara (15.4%) and Kahurura and Kaga (47.1%) regions.

Table 4.1: Locality of the sampled farmers (Non -BGT adopters)

Area /Sub-location	No. of farmers	Percent (%)
Githima	105	37.5
Gathiuru and Guara	43	15.4
Kahurura and Kaga	132	47.1

Source: Field Survey (2015)

Based on the population distribution the respondents were from Kaga village (28.2%), Guara Village (15.4%), Gatuanyaga village (12.9%), Kianda Village (11.4%) and Kiboya village (10.4%).

A major development occurred during the study that significantly affected the research. Since the study targeted farmers' households, the researcher had to revise the data regarding households for the following reasons: 1). the region of Kahurura has been restructured and split into several units namely *Munyaka*, *Kwa -Mwea*, *Ngerima* and *Equator*. The first three comprise of squatters who were chased out of the neighbouring former Kenya Defence Forces (KDF) farms which they had been occupying for several years. The squatters were later apportioned ¼ acre plots. It is this semi-urban population that has been captured as households (GoK 2009). The researcher established that these are squatters but not farmers' households and had presented a high number of populations of households (not necessarily farmers' households). 2) 'Equator' trading centre is the hub that provides residential settlements to a majority of persons. These persons are either working as farm labourers in various farms around or employed to perform various tasks in Nanyuki Township. These are definitely not farm households thus cannot be counted as rural farmers. Secondly the figures supplied by COMPACT of the total numbers of adopters in Kieni East (about 70 beneficiaries of UNDP-GEF) were revised as there had been later initiatives by USAID in Kahurura region in Gakawa and not the whole of Kieni East thus picking 71 adopters (IFAD 2010).

4.2. Socio cultural factors affecting adoption of BGT

The main objective was to investigate how social cultural factors influence adoption decision. The factors are considered a function of level of understanding and awareness

determining adoption potential. The factors considered for this study included age, gender, education level, decision making trends, period of residency, land tenure system, mode of stock keeping, sources and alternative sources of energy, cultural beliefs and perception.

4.2.1 Gender of the respondents

As highlighted in this study gender has an implication on household decision making systems in that the decision on whether the household adopts biogas technology or not, significantly depends on the head of household.

Table 4.2: Gender information of the farmers

Category of respondent	Non BGT Adopters (n=280)		BGT Adopters (n = 71)	
	No. of farmers	%	No. of farmers	%
Male	147	52.4	56	78.9
Female	133	47.5	15	21.1
Total		100		100

Source: Field Survey (2015)

Results in table 4.2 show that most of the non-BGT adopter farmers were male (55.4%) while 44.6% were female. Among the BGT adopter farmers, majority (78.9%) of the farmers were males while 21.9% were females. 39.0% of these farmers were in the ages of above 60 years (Table 4.3). Based on the research findings the majority of the households have elderly parents with 36.6% of farmers of 41 – 50 years of age. During the informal interviews and filling in of questionnaire, the researcher noted that in

instances where both the husband and wife were physically present, occasionally the wife would have the husband answer. However, during the informal interview the women would seem to have more input and interjections than the men. Men were more reserved in their responses regarding domestic cooking practices. Women were more inquisitive on the biogas application whereas the men were mostly concerned about the cost implications.

4.2.2 Age of the respondents

Table 4.3 Age of the respondents

	Non –BGT Adopters (n=280)		BGT Adopters (n = 71)	
Age (Years)	No. of farmers	%	No. of farmers	%
Less than 20	34	12.1	3	4.2
21 - 30	32	11.4	0	0
31 - 40	41	14.6	7	9.9
41 - 50	79	28.2	26	36.6
51 - 60	38	13.6	7	9.9
Above 60	56	20.0	28	39.4
TOTAL		100		100

Source: Field Survey (2015)

The Table 4.3 indicates that, 28.2% of non-BGT adopters, interviewed were in the age bracket of 41 – 50 years whereas 20.0% of these farmers were above 60 years of age. Amongst the adopters 33.6%, are above 51 yrs. of age. This has implications on adoption as it represents an ageing population that has adopted the technology. The findings agree with Wawa (2014) who reports that older people are more established and have a fixed

abode compared to younger people. Such are able to invest in expensive and permanent non-transferable projects.

Further, the research having been carried out between November and March, when schools are on recess saw 4.2% of BGT adopters' respondents and 12.1% of non-BGT respondents adopters being interviewed are under the age of 20 years (Table 4.3). They were in charge of the households then as their parents were out eking a living. They would occasionally engage the researcher and their parents in a heated discussion on the state of energy needs from their perspective suggesting that they would prefer electricity as it would enable them enjoy more services. This improved on the response rate and discussion.

Further culturally the issue of handling cow dung has had reservations among the young people. From the interviews the elderly people have no reservations about getting their hands dirty handling cow dung. According to Adkins (2012) the close man-animal-land relationships include a reliance on the use of animal dung for fuel and fertilizer and its paste qualities in certain buildings. This becomes an easy entry point for adoption of BGT for the rural farmers who already acknowledge some benefits accruing from livestock rearing (Adkins 2012). This was confirmed by GAD 11, an elderly lady, who had this to say during the interview;

“Say what!! We have no qualms handling cow dung, I mean, haven't we always been using it to plaster and smoothen our mud huts on the floors and walls? What is the fuss all about, just pick mix, with ash, and using our hands, get on!”

She was bewildered with the allegation that the youth were not ready to handle cow dung. Also GAD 3 acknowledged collecting of the cattle dung for the first time was

difficult. This was shared by other BGT adopters who thought the idea of collecting cow dung was cumbersome, too tiring, and embarrassing.

'I cannot fathom myself collecting mounds of cow dung, certainly not me; I can't 'do it!'

They would not imagine themselves going around with buckets picking the “mounds”.



PLATE 1; Interview sessions: *A key informant assists in translating the questions to the respondents who could only communicate in the local dialect (Kimeru).*

Source: Field Survey (2015)

4.2.3 Period of residency of the farmers

The households were also asked to state the number of years they had stayed on their farms. Data represented on Table 4.4 indicated that, 1.1% of non BGT adopters had only been in the area of residence for less than 2 years whilst 50.7% of BGT adopters had been residing in the area, for more than 20 years as compared to 36.4% of BGT non-adopters. This represents an ageing population. With age taking up the toil, they no longer are able to walk long distances as they did earlier on to search for firewood. From the field interviews, it is this group that has seen the transformation of the landscape right before their eyes as forests disappear and now experience scarce and dwindling firewood stocks.

They appreciate the desire to seek alternative solution acknowledging the existence of inadequacy of wood fuel. For a few elderly farmers they acknowledged their children honour them with Meko (LPG) gas cookers, an observation captured during the field study.

Table 4.4: Period of residency of the farmers

Period (years)	Non BGT adopters (n=280)		BGT Adopters (n=71)	
	No. of farmers	%	No. of farmers	%
Less than 2	3	1.1	0	0
3 - 5	21	7.5	2	2.8
6 - 10	55	19.6	13	18.3
11 - 15	48	17.1	9	12.7
16 - 20	51	18.2	11	15.5
More than 20 years	102	36.4	36	50.7
TOTAL		100		100

Source: Field Survey (2015)

4.2.4 Education levels of the respondents

The respondents were asked to provide details on highest levels of education attained.

Data presented on Table 4.5 show that 42.3% among adopter farmers had tertiary education as compared to 9.3% amongst the non-adopters. Those who attained secondary education among the BGT adopters were 23.9% as compared to 57.9% of non-adopters. Among the adopters 26.8% had primary education whilst 27.9% were non adopters. 66.2% of BGT adopters as compared to 67.2% had education levels beyond primary school. Kariuki (2009) in an analysis of nationally representative data from Kenya relates

a higher level of education with adoption of biogas technology. This study indicated that low levels of education in adoption of Biogas technology was not a limiting factor as captured in the high number of non-BGT adopters who have secondary education.

Table 4.5 Education levels of the respondents

Educational level	Non-BGT Adopters (n=280)		BGT Adopters (n = 71)	
	Number	%	Number	%
No formal education	11	3.9	5	7.0
Primary	78	27.9	19	26.8
Secondary	162	57.9	17	23.9
Tertiary	26	9.3	30	42.3
Informal	3	1.1		
TOTAL		100		100

Source: Field Survey (2015)

Mattis *et al.*, (2010), reports that education enables people to have the ability to understand and embrace new innovations. This study established that a majority of the initial adopters were retirees', including civil servants, teachers, police officers, and agricultural officers now living on their farms. It is this group; having retired to their farms was more likely to have invested in permanent and non-transferable enterprise like livestock farming. Some BGT adopters alluded to, that due to their nature of work they had become exposed to BGT and some had actually visited Nyeri Farmers Training Centre (Wambugu Farm) where they had been introduced to biogas technology.

4.2.5 Marital Status and occupation of the respondents

The data recorded on Table 4.6, shows that 91.5% of adopters and 71.4 % of non-BGT adopters were married. This has implication on BGT as it directly relates to decision making trends in the households.

Table 4.6: Marital Status

Marital status	Non BGT Adopters (n=280)		BGT Adopters (n = 71)	
	No. of farmers	%	No. of farmers	%
Single	62	22.1	6	8.5
Married	200	71.4	65	91.5
Separated/divorced	6	2.1		-
Widowed	12	4.3		-
TOTAL		100		100

Source: Field Survey (2015)

Information gathered from field informal interviews revealed that those either divorced or widowed, having challenges as all household chores, decision making and financial burden was left to the sole individual. For instance a widower during filling of questionnaire KA'NAD 134 lamented:

'After the death of my wife I had no one to take care of my animals, and one by one they all died leaving me with just this empty house.'

Data on primary occupation of farmers presented on Figure 4.1 reveal that 69.3% of the non-BGT adopters were farmers as compared to 25.4 % of adopters who were in informal employment. Whilst 15.7% were in formal employment among non-adopters 38.9% of adopters in this category, 9.3% of the respondents were still in schools.

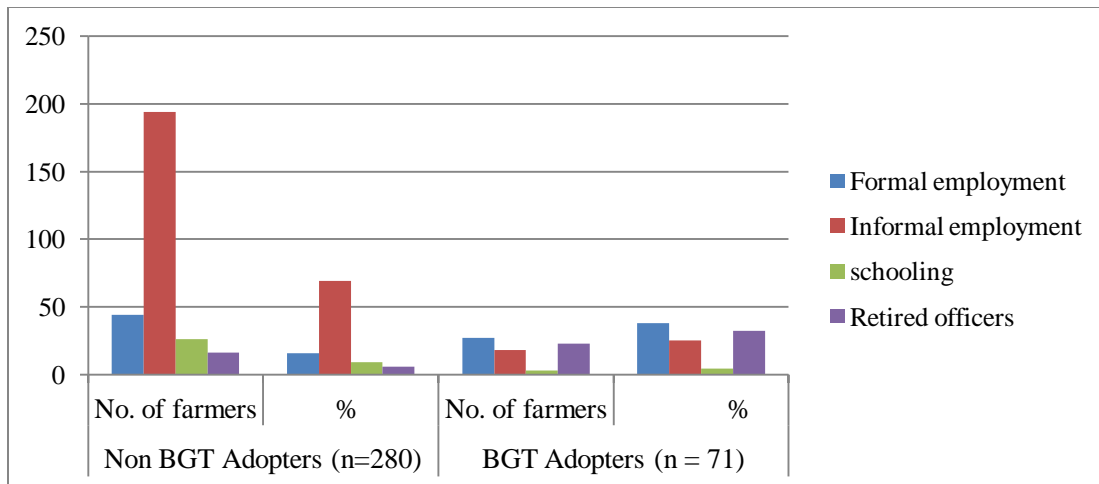


Figure 4.1: Occupation of the farmers Source: Field Survey (2015)

Among the non-adopters 5.7% were retired officers as compared to 32.4 % among adopters. The major economic activity in the study area is crop cultivation and livestock keeping with 65.7% of the farmers earning their living through this. This implied that such farmers relied entirely on their farms output to meet their basic needs. Those who have secondary occupation have the extra income to supplement what is realised from the farm. This data revealing that 65.7%% of the farmers earn their living through crop farming and animal husbandry is significant to the availability of biogas technology requirements such as feed-stocks from livestock and farm wastes for biogas plants feeding. This is attributed to the detail that BGT relies primarily on cow dung which is readily available to the livestock farmers.

4.2.6 Relationship between farmer characteristics variables and adoption of biogas technology

An important component of effective farm management is the willingness and ability of farmers to adopt appropriate new technologies. The research sought to establish whether factors derived from the customs, traditions, perceptions and beliefs of an individual's

culture could be a key determinant towards adoption of alternative energy source. Farmer's characteristics such as age, beliefs, and education and current energy source previous experience, have a significant influence as they determine their reasoning in acceptance of the technology.

The study sought to establish a significant relationship between the age and adoption of biogas Technology. To test the hypothesis a correlation test was done and the results summarized in Table 4.7. Data shows that the age of household and adoption were significant ($R^2=0.045$, $P < 0.05$). In this study, age of household member was noted to have a positive significant relationship with biogas adoption. This study upholds Wawa's (2014) postulation on the effect of age in biogas adoption as preference and perception difference between the old and young people.

Table 4.7: Correlation on the age of household and adoption

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.218(a)	.048	.045	.38806
2	.287(b)	.083	.077	.38142
3	.319(c)	.102	.094	.37799

Source: Field Survey (2015)

According to Ajah, (2012) age, education level, and parental occupation may make a farmer more responsive and receptive to research and external change affecting the adoption potential.

From the data analysis it was established that education levels was at a significant level $R^2=0.094$, $P < 0.05$. Results indicated the high numbers of non-BGT adopters have

education levels beyond primary school. This study agrees with Parvan (2011) who stress that farmers with higher education are more aware of the existence of credit facilities which they can competitively solicit. Further a Stepwise linear regression was carried out on the effect of gender, age and educational level of the farmers on the adoption of BGT (Appendix 1). The result showed that, BGT adoption was significantly affected by the age, gender and educational level of the farmer ($R^2 = 0.045, 0.077$ and 0.094 respectively), $P < 0.05$.

Table 4.8: Regression results showing the relationship between ages, gender and education level with adoption

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.218(a)	.048	.045	.38806
2	.287(b)	.083	.077	.38142
3	.319(c)	.102	.094	.37799

a Predictors: (Constant), Age

b Predictors: (Constant), Age, GENDER

c Predictors: (Constant), Age, GENDER, Educational levels

4.2.7 Cooking energy Source, Availability and consistency of the fuel wood resources

The farmers were asked to identify the various sources of cooking energy available to them. Data presented on Figure 4.2 show that 66% of adopters wholly use BGT for their cooking needs (PLATE 2). Farmers mainly using gas for cooking were delighted to explain the benefits accruing from the adoption. One of the respondents GTAD4' reaffirmed that he is very comfortable with his BGT unit.



PLATE 2a,b: The Biogas cooking units in different households.

(a) The unit has an improvised gauge/meter (using food colour) rested and calibrated against the kitchen wall. (b) The desulphurizer (white-green container) is mounted against the wall.

Source: Field Survey (2015)

He adamantly indicated that he would never revert to use of firewood and proudly showed the researcher (an abandoned) pile of firewood which he had in stock before installing BGT. Now in a state of disuse, termites had already started infesting on the pile which he pointed out to the researcher (Plate 3a, b).



(PLATE 3a, b) A BGT adopter points out to his abandoned stack of firewood. **Source:** Field Survey (2015)

For him, the use of biogas plants does not in particular have the potential to reduce firewood use, but has completely gotten rid of the need to use firewood.

Further from the data collected, informal interviews and field observations revealed that adopter's households have supplemented BGT with other energy sources. 26.8% were also using firewood and 7 % charcoal in cooking. On the other hand, when Non BGT adopters were asked to identify the various sources of cooking energy that is available to them, 68.9% of the respondent indicated using firewood, while 22.5% used charcoal (Figure 4.3). From the comparative analysis (Figure 4.2 and Figure 4.3) with BGT adopters (above) it was noted that the farmers had access to more than one (1) energy source.

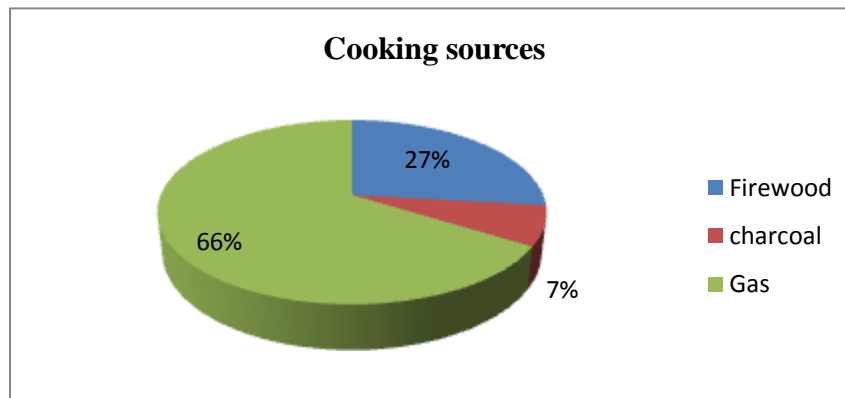


Figure 4.2: Cooking energy source for the BGT adopter farmer

It was observed that with Gakawa households, the use of fuelwood and charcoal is prevalent. This is due to its recognized ability to prepare *githeri* fast and the notion that *githeri* prepared using the traditional clay pot tastes much better. This avows IEA /OECD (2006) Report, which indicates that in developing countries as incomes increase and fuel options widen, the fuel mix may change, but wood is rarely entirely excluded. The substitution of traditional sources of cooking for the households is not a complete overhaul once a household adopts BGT. This agrees with Adkins *et al.*, (2012) who cites

it as the reason why most residents in the sub-Saharan Africa are reluctant to switch to more efficient household energy alternatives.

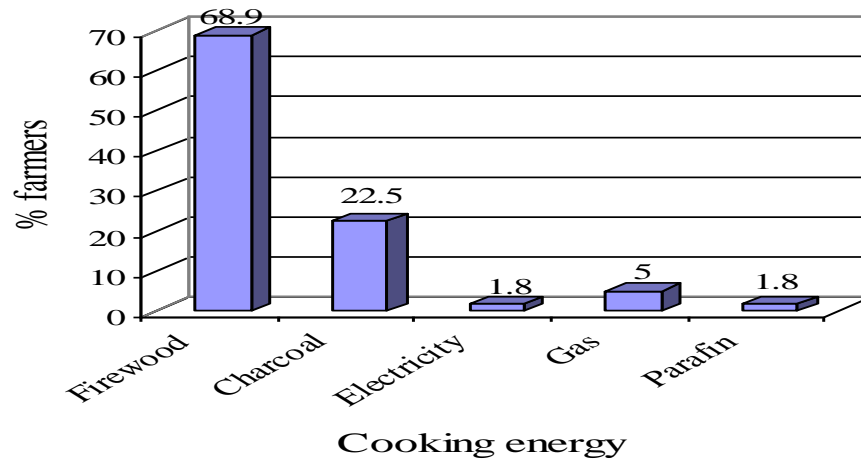


Figure 4.3: Cooking energy source for non BGT adopter farmers.

Source: Field Survey (2015)

The farmers were further asked to explain where they source firewood used in their kitchens and to rate the availability and reliability of wood fuel. They were asked to indicate whether the source and amount of firewood they accessed was enough based on its availability and consistency. The ratings were spelt out as ‘adequate’, ‘inadequate’, or ‘very scarce’ and for those who did not use firewood at all to indicate the same as ‘None committal’. Data represented on Figure 4.4 revealed that the source of firewood used by 40.0 % of the non BGT adopters comprised of broken branches, twigs, pruning and the occasional felling of mature trees in their homesteads. Farmers further supplement these by collecting dry wood and broken branches, from the nearby Gathiuru (Mt Kenya) forest. These findings relates to a baseline survey in Project Surya India (Hazra, 2014) which also revealed that the majority of families in the villages do not purchase fuel

wood, but collect it from roadside or their own fields. Their responses captured in Figure 4.5 show that 49.6% of the farmers, indicated their sources of firewood as inadequate appreciating the desire to seek alternative solution whilst acknowledging the existence of inadequate wood fuel.



PLATE 4: An indigenous and exotic forested region of Gathiuru area. A section of Mt Kenya visible in the background.

Source: Field Survey (2015)

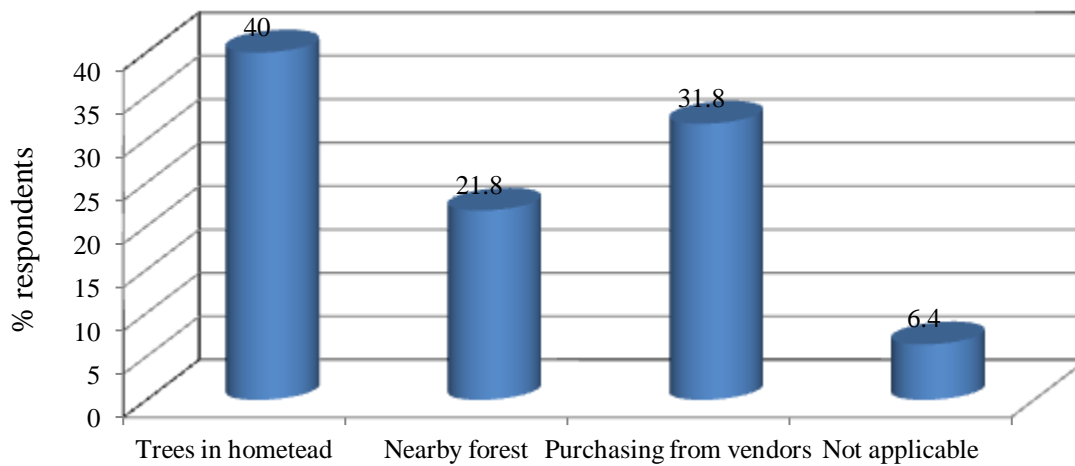


Figure 4.4: Non BGT Adopter Farmers' source of firewood

Source: Field Survey (2015)

Data presented on figure 4.4 shows that the 31.8% of the farmers and mostly from, Guara, Nyumba-Ithatu, Gatuanyaga villages purchase firewood from vendors to supplement whatever little stocks they may have sourced elsewhere. A further 21.8%, of the farmers, namely in Kiboya/Kianda Muriru, Burguret, Gathiuru, Ngerima, Kwa-Mwea whose farms are in close proximity to Mt Kenya, visit the nearby forest to get their firewood (Plate 4).

4.2.8 Availability and consistency of fuel wood by Non BGT adopters

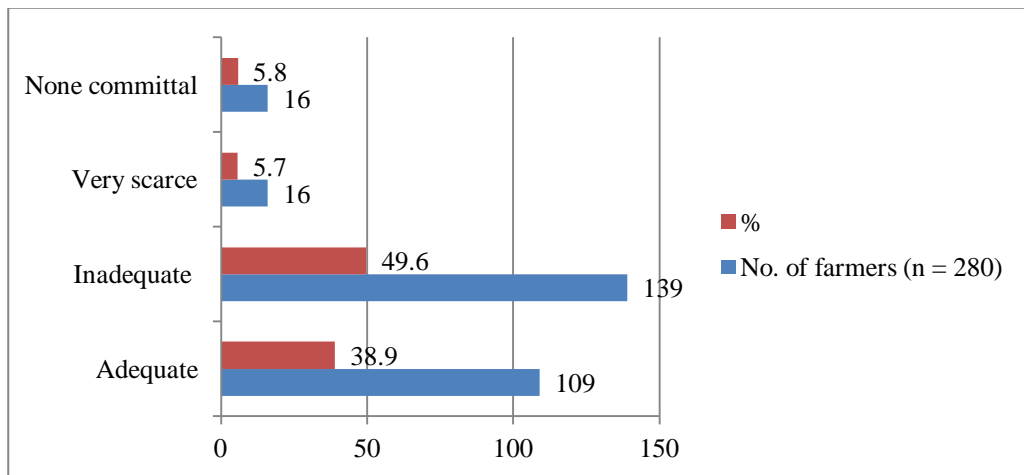


Figure: 4.5 Availability and consistency of fuel wood

Source: Field Survey (2015)

A further 5.7% indicated that the sources were very scarce, whilst 38.9% of the farmers indicated that the sources were adequate for them. The respondents who were not using fire wood at all represent the 5.8% interviewed. These included the farm hands and persons living in residential/commercial buildings. These were either using Meko (LPG) gas or charcoal.

4.2.9 Money spent by the non-BGT adopters on fuel

Whereas adopters had access to BGT with 66 % wholly using it the non-adopter who wholly depend on firewood were asked to detail the amount of money spent per load on wood fuel. Data presented on Table 4.10 show that 26.4% of the farmers spent more than Ksh. 500, 16.4% were spending Ksh 300–399, and while 15.0 % were spending Ksh. 400– 499 and 15.1% were spending Ksh 200-299 on wood fuel. Those spending less than Ksh. 100 – 199, were 27.1%. It was captured during the informal interview that the farmers spending between Ksh.100-199 had easy access to the neighbouring forests and uninhabited farms. Apart from using firewood they also have access to alternative energy sources like electricity; LPG and photovoltaic panels, charcoal and kerosene. These compete with the necessity to install BGT at the same time reducing time spent around the fire place.

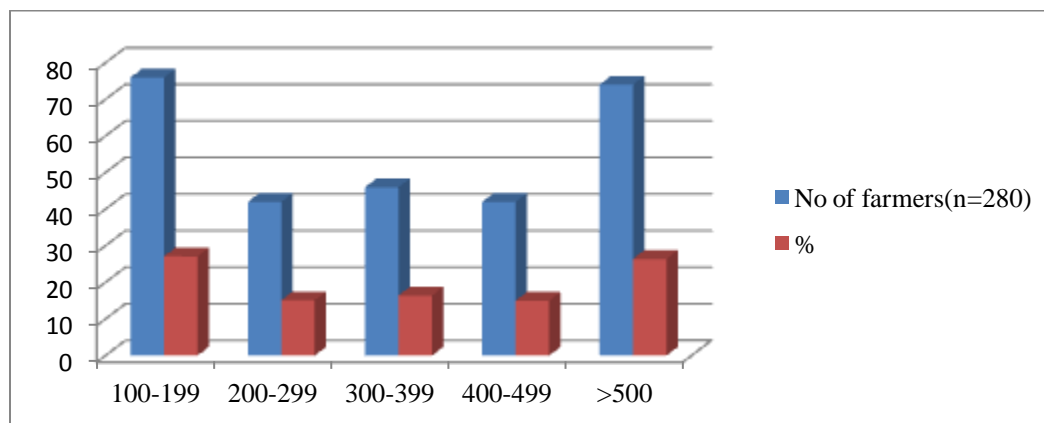


Figure 4.6: Amount of money (Ksh) spent by the farmers on wood fuel per load.

Source: Field Survey (2015)

This study sought to establish a relationship between the sources, availability, and consistency of fuel wood on adoption of Biogas Technology. To test this, chi-test was

performed. The results showed there was a significant association between the sources of firewood and their availability and consistency. $\chi^2 = 237.738$, $P = 0.0001$ (Appendix 7.)

Further a cross tabulation on source of firewood, availability and consistency was a done whose results have been captured in Appendix 8. The results indicated that out of the farmers spending more than Ksh 500, 47.2% purchased firewood from the vendors, 9.8% had trees in their homestead and 34.4% got firewood from nearby forest. Further examination revealed that 71.9 % of the farmers were those spending more than ksh.400 to purchase from vendors as compared to 57.4% who acquire it from nearby forest and 15.2 % gathering from trees in their homesteads. The amount of money spent on fuel significantly depend on the source of fuel used ($\chi^2 = 128.397$, $P = 0.0001$ (Appendix 9).

4.2.10 Energy saving technology practiced by some non-BGT adopter farmers

Whereas the BGT adopters had already installed BGT as a cost cutting measure the non-adopters were asked to explain established energy saving technologies they had adopted in scaling down on the amount of firewood used in their kitchens.

Table 4.9: Energy saving technologies adopted by the Non -BGT adopters Source

Technology	No. of farmers	%
ES cooking jikos	42	15.0
Kuni moja	37	13.2
TIST jiko poa	35	12.5
Saw dust	4	1.4
None	162	57.9
TOTAL	280	100

Data presented on Table 4.9 reveals that amongst the non-BGT adopters, an overwhelming 57.9% do not have any energy saving technologies in their kitchens. This has great implications on the adoption potential of BGT. During the informal interviews the researcher noted that the farmers still preferred the 3 stone jiko with its accrued benefits and were yet to recognise the existence of BGT as an alternative. GT’NAD 27 retorted:

“With the 3 stone we can sit around the fire warming ourselves .whiling away the time, roasting foodstuffs like green maize, green bananas, potatoes, by the firesides, something absolutely missing in these other jikos.”

This is a further indicator of a group that is contributing to environmental degradation. The rest of the non-adopters were using as follows: (15.0%) used Energy Saving cooking jikos/improved charcoal stove (KCJ), (13.2%) of the respondents were having the ‘Kuni moja’ and 12.55 %, had the ‘TIST’ jiko poa (captured on Plate 5).



PLATE 5: A saw -dust using jiko (parts not assembled) **Source:** Field Survey (2015)

However the research revealed in the research area were environmental conservation and sustainability initiatives being undertaken by among them, women ‘Chama’ groups, and

environmental conservation groups. For instance, an NGO- TIST in Kianda and Kiboya, offers jikos (PLATE 5a), and token (money) to farmers who successfully establish and manage tree lots and protect indigenous trees.

4.2.11 Source of lighting available among the respondents

The farmers were asked to name the source of lighting used in their households in terms of priority. Data presented in Table 4.10, show that among the non-BGT adopters, 38.6% were mainly lighting up their houses using photovoltaic panel.



PLATES 5a, b: Cooking Sources for non BGT adopters: **Source:** Field Survey (2015)

Table 4.10: Lighting sources used by the farmers

Source of light	Non BGT Adopters		BGT Adopters	
	No. of farmers (n=280)	%	No. of farmers (n=71)	%
Kerosene	79	28.2	-	-
Electricity	93	33.2	44	62
Photovoltaic Panel	108	38.6	27	38

Source: Field Survey (2015)

In 33.2% of the homes, the farmers were using electricity while in 28.2% of the homes, the farmers use kerosene for lighting. Whilst on the other hand, 59.2 % of the farmers who had adopted BGT, identified electricity as their main source of lighting. Five farmers (5) had BGT lanterns (Plate 6) which come in handy when there is interruption of electricity.

Using chi-test, (Appendix 2) there was a significant association between the adopters and the sources of lighting ($\chi^2 = 31.359$, $P = 0.0001$). None of the BGT adopters used kerosene for lighting while significantly fewer adopters used Photovoltaic panel (33.8%) for lighting.



***PLATE 6:** A Biogas lantern in use in one of the households.*

Source: Field Survey (2015)

The study sought to establish a significant relationship between source of firewood and lighting source on the adoption of BGT. To test the hypothesis a stepwise linear regression was carried out on the effect of source of firewood and lighting source on the adoption of BGT. The result showed that, BGT adoption was not affected by lighting

source but was significantly affected by the Cooking energy source ($R^2 = 0.219$), $P < 0.05$.

4.2.12 Land utilization by the farmers

The farmers were asked to specify the sizes of the farm they owned. Results in Table (4.11) demonstrate that 31.1% of the non BGT adopters, as compared to 7.0% of adopters owned merely 2 acres. A further 28.9% owned four acres as compared to 32.4 % of adopters.

Table 4.11: Sizes of the Farms owned by farmers

Farm size (acres)	Non BGT adopters (n = 280)		BGT Adopters (n = 71)	
	No. of farmers	%	No. of farmers	%
One	19	6.8	12	16.9
Two	87	31.1	5	7.0
Three	14	5.0	7	9.8
Four	81	28.9	23	32.4
Five	9	3.2	3	4.2
More than five	59	21.1	9	12.6
None responsive	11	3.9	12	16.9
TOTAL		100		100

Source: Field Survey (2015)

A further 6.8% owned only 1 acre piece of land while 5.0% owned three acres whilst the rest 21.1% owned more than five acres of land. The average number of land owned by non-adopters was 3.86 ± 0.15 acres of land whilst the BGT adopters were 3.82 ± 0.29 acres. The smallest size of land owned by the BGT adopters was one acre while the maximum farm size was 10 acres. The size of the farm owned is an important factor as it

is among other factors which are determinants of access to credit. This is a plight faced by farmers who want to install BGT kits. As Parvan (2011) asserts other factors held constant a farmer can borrow more money against a larger farm than a smaller farm. This concurs with Yehuala (2008) who has in his findings in Ethiopia identified among other teething problems, the size of the farm as a collateral requirement, by lending institutions to access to credit.



*PLATE 7 (a) An adopter feeds the dung into the biodigester mixing trough
(b)The mixture of the cow dung and water ready to be released into the digester*

Source: Field Survey (2015)

4.2.13 Land tenure

The respondents were also asked to provide information on how they acquired the pieces of land they reside on. The data in Table 4.12 shows that 67.1% of the non- BGT adopters and 91.5% of the BGT adopters had bought the land they occupy, 28.2% of non BGT adopters and 8.5% of the BGT adopters had inherited. It was established further that 2.5% of the non BGT adopters had leased land, and 2.1% of them were allotted land by their relatives. The study established that the land allotted by inheritance would be passed on by either deceased parents who would bequeath it to their offspring. The researcher found out that those on leased land were either squatters or farm hands and entrepreneurs

practicing agribusiness. The study further established that, only 82.7% of non BGT respondents had title deeds for their land while only 17.3%, did not have the title deeds for their farms (Figure 4.7).

Table 4.12: Method of land acquisition

Method of land acquisition	Non BGT Adopters		BGT Adopter	
	Number	%	Number	%
Inherited	79	28.2	6	8.5
Bought	188	67.1	65	91.5
Leased	7	2.5		
Given by a relative	6	2.1		
Total	280	100	71	100

Source: Field Survey (2015)

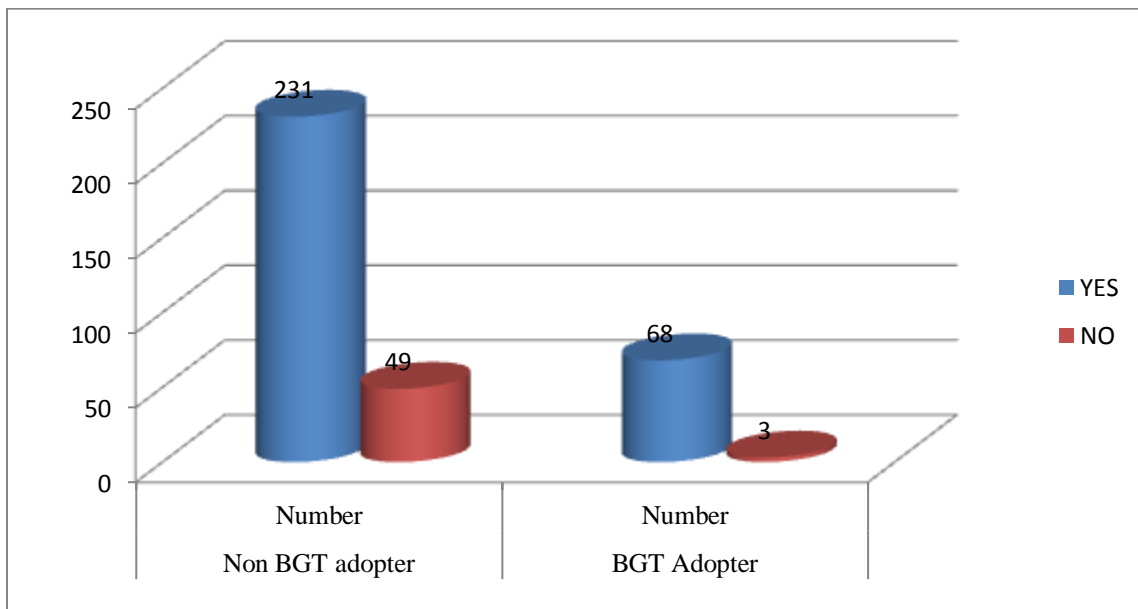


Figure 4.7: Cross Tabulation of Possession of Title Deed *state of adoption

Source: Field Survey (2015)

During informal interviews these farmers explained to the researcher that they ‘sit’ on the farms awaiting ownership to change hands from titles still being held by their relatives or even parents. This has direct implication on farm utilization. The households are apprehensive in making land improvements including installation of BGT kits without guarantee that they will use the improvements over the long term. It is important to note that farmers are able to make improvements on their farms with confidence, where there is greater tenure security.

4.2.14 Decision making on energy options used by the family

The farmers were asked to identify who makes decisions on the kind of energy used in the households. Table 4.13 shows that in 41.6 % of the homes, the decision is made by men whereas 48.1% is by women. From the field study, the women are assumed to be the ones using the energy as they are directly involved in cooking. The results also indicate 10.3 % shared decision making trend. Based on the data, this research indicates a 7.5% difference in who makes the ultimate decision (Table 4.13).

Table 4.13: Decision making Trends

Decision maker	Frequency	Percent %
Men	146	41.6
Women	169	48.1
Both/split	36	10.3
Total	351	100.0

Source: Field Survey (2015)

This positively relates to research findings by Pew Research Centre (2008) whose survey revealed that in 43% of all couples it’s the woman who makes decisions in more areas of domestic life than the man. And about three-in-ten couples (31%) split decision-making

responsibilities equally. The findings of this research concur with Danielsen, (2012) who has identified that investment in cooking technologies rests on gender relations within households.

Indeed, where men are the decision makers such facilities may not be priorities especially if it involves digging deeper into their pockets. This was confirmed from the interviews with the AOKI 1, 2, 3, and 5, who reported that women in the study area were more willing to adopt BGT than the men but were cautious. It endorses Miller and Mobarak (2013) study in rural Bangladesh, which established that women bear lopsided cooking expenses, have stronger preference for ICS, but they lack the authority to make the purchase. This therefore affects decision of the women to take up BGT. However the findings of this research indicate a declining role of the man in decision making in regard to energy. In 48.1 %, of the households, decision on the energy technological option and how it will be used is made by women pushing men away from the dominant traditional role that is expected across societies and cultures. These findings confirms World Development Report (2012) that indicates gender relations have evolved, and men are now also required to adapt to new demands, new expectations, new roles as well as to value their partner's voice in decision making. It is a pointer to the declining role of the man as the breadwinner (WDR 2012).

4.3 Attitudes and adoption of Biogas technology

In order to measure respondents' attitude several statements related to farmers' views on acceptance of biogas technology were developed. According to Beedell and Rehman (2000) beliefs are formed on the basis of the type of information an individual is exposed to, his/her experience and implied knowledge. Thus the questions were based on the

sources of information that may have affected the adoption potential. Respondents were required to indicate whether they agreed or disagreed to the statements. It is this awareness level that influences peoples' attitude towards the new technology. Attitudes were assessed on a likert scale basing it on strength attributes.

Majority of the non BGT adopters reported that they had heard about biogas but they have never given it any thought because of costs. During the field visit and interview elderly lady who in her lifetime had never heard about BGT wondered how she would be able to respond to queries on BGT (and did not!). It's with such kind of attitude that some data on BGT was not fully captured from the respondents who were reluctant to divulge information on concept they considered they didn't know.

When prodded further some non BGT adopters for example KNAD 67, KNAD 75, GNAD 93, KBNAD 9, KNAD 6, KHNAD 9, explained they thought it were expensive. It's peculiar though and probably points to an attitude problem of not desiring to find out how much it entails financially. Simply, the perception they '*cannot*' afford. Why even bother. For example KHNAD 3 retorted;

"I 'heard' it was expensive but I did not bother to find out how much".

Some non BGT adopters however failed to give all the responses as they deemed not to be having any information regarding BGT thus negatively influencing their attitudes towards adoption decisions of the technology.

4.3.1 Attitude towards social cultural factors affecting adoption of BGT

To examine the extent to which further specified social cultural factors affect BGT, the BGT adopters and non-BGT adopters were asked to rate their influence as perceived

obstacles using a scale of 1 – 5 (1 – strongly agree, 2-agree, 3-undecided, 4-disagree, 5-strongly disagree). The mean response was therefore established by summing up the farmers views and getting the average of the views.

The mean result obtained showed that, the BGT adopter (Table 4.14) farmers highlighted scarcity of development fund as the main obstacle (mean 1.86), followed by poor marketing policy (mean 2.57). The ineffectiveness of community development officers (mean 2.65) and extension officer’s failure to spend time with farmers (mean 2.67) contributes to weak perception of BGT as an alternative energy source.



PLATE 7, PLATE 8. Sources: Field Survey (2015)

From the interviews and observations on the ground, the failure of some units had contributed towards a negative attitude towards adoption. Observations on the ground confirmed that these were adopters who had installed flexi biogas types of digesters who were experiencing different setbacks as compared to those of the fixed dome (Plate 7). The flexi-biogas system/ the plastic tubular digesters (Plate 8, 9) is not as durable (KENDIP 2014).

Data obtained from the BGT adopters is presented in table 4.14 below.

Table 4.14: Socio cultural challenges to biogas adoption in the area noted by the BGT adopters

Obstacles	SA	A	UN	D	SD	Mean
Scarcity of development fund	39 (54.9%)	15 (21.1%)	3 (4.2%)	13 (18.3%)	-	1.86
Poor understanding of biogas concept	15 (21.1%)	15 (21.1%)	2 (2.8%)	20 (28.2%)	19 (26.8%)	3.18
Lack of education and technological skills among farmers	8 (11.3%)	17 (23.9%)	4 (5.6%)	21 (29.6%)	16 (22.5%)	3.30
Insecurity about land tenure	8 (11.3%)	3 (4.2%)	12 (16.9%)	20 (28.2%)	28 (39.4%)	3.80
Lack of harmony among family members	7 (9.9%)	14 (19.7%)	3 (4.2%)	20 (28.2%)	27 (38.0%)	3.65
Communication barriers	3 (4.2%)	6 (8.5%)	29 (40.8%)	26 (36.6%)	2 (2.8%)	3.27
Ineffectiveness of .community development officers	15 (21.1%)	29 (40.8%)	-	20 (28.2%)	7 (9.9%)	2.65
Extension officers failure to spend time with farmers	21 (29.6%)	16 (22.5%)	5 (7.0%)	22 (31.0%)	7 (9.9%)	2.67
Limited land	3 (4.2%)	3 (4.2%)	-	31 (43.7%)	21 (29.6%)	4.10
Limited land	8 (11.3%)	6 (8.5%)	11 (15.5%)	23 (32.4%)	23 (32.4%)	3.66
Negative publicity and awareness	17 (23.9%)	18 (25.4%)	7 (9.9%)	5 (7.0%)	24 (33.8%)	3.01
Poor marketing policies	27 (38.0%)	11 (15.5%)	7 (9.9%)	13 (18.3%)	11 (15.5%)	2.57
Low participation of women in leadership	3 (4.2%)	12 (16.9%)	11 (15.5%)	13 (18.3%)	32 (45.1%)	3.83

SA-Strongly agree, A-Agree, UN-Uncecided, D-Disagree, SD-Strongly disagree

Source: Field Survey (2015)

These findings agree with IFAD reports that the plastic tears when the system is moved, and due to normal wear and tear it has to be replaced after two years.

Table 4.15: Social cultural challenges affecting adoption of BGT noted by Non-adopters

Obstacle	SA	A	UN	D	SD	Mean
Lack of harmony	27 (9.6%)	32 (11.4%)	36 (12.9%)	80 (28.6%)	105 (37.5%)	3.80
Communication barrier	52 (18.6%)	50 (17.9%)	29 (10.4%)	82 (29.3%)	67 (23.9%)	3.22
Negative publicity	59 (21.1%)	75 (26.8%)	49 (17.5%)	47 (16.8%)	50 (17.9%)	2.84
Poor understanding of biogas concept	118 (42.1%)	69 (24.6%)	10 (3.6%)	58 (20.7%)	25 (8.9%)	2.29
Lack of education and technological skills	118 (42.1%)	62 (22.1%)	39 (14.0%)	44 (15.7%)	17 (6.1%)	2.32
Scarcity of development funds	206 (73.6%)	41 (14.6%)	11 (3.9%)	16 (5.7%)	6 (2.1%)	1.47
Women not being involved in decision making	46 (16.4%)	39 (13.9%)	35 (12.5%)	60 (21.4%)	100 (35.7%)	3.46

SA-Strongly agree, A-Agree, UN-Undecided, D-Disagree, SD- strongly disagree.

Source: Field Survey (2015)

Data collected from the non-BGT adopters (Table 4.15) show that scarcity of development funds (mean response 1.47) mainly hindered adoption of biogas technology. This confirms the Mulinda *et al.*, (2013) and Ngugi *et al.*, (2007) studies whose findings asserts that shortage of credit undermines farm performance and development. This is a hindrance towards adoption of BGT in Africa. From the interviews and observation (based on the farmers farm structures on the ground), the researcher attested a low level

of income among the farmers households. This is in contradiction to a government report that had indicated that the region has high levels of income (GoK 2009). This misrepresentation is significant as it rules them out from funds or initiatives that would normally target the low income earners in Arid and Semi-Arid Lands. Further the ecological climatic zone of the region associated with poor rainfall patterns, thus drought occasionally leaves many cows dead. This leaves the farmers with no source of dung for the digester. They thus see no need to install the BGT unit in case of such eventuality. Respondent K'NAD 134 lamented:

'After the death of my wife I had no one to take care of my animals, and one by one they all died leaving me with just this empty house'.

Replacement of the herds bring with it opportunity cost implications. From the field respondent KG'NAD 37, who had lost her whole herd, had her son, buying her one heifer had this to say regarding investing in BGT:

"Now that I had recently asked my son to buy me another cow, how then may I also ask of him to install for me a biogas unit? He too has other needs to attend to. I would be demanding of him, too much" (sic)

BGT adopters were also asked to identify hindrances and 35.2% rated lack of education and technological skills (mean 2.32) and, 49.3% negative publicity (mean 2.84) as the main obstacles. These findings and as also, Mwakaje (2008), reveals, there has been a strong link between education and adoption of BGT ; that poor technological skills is one of the obstacles to adoption of biogas technology in Africa.

LPG freak accidents had a negative influence. For instance respondent KHNAD 23 admitted of being apprehensive above installing it. She expressed her reservations about

her grandchildren, who being unable to operate it may suffer dire consequences in case it blew up.

A stepwise linear regression analysis was carried out on the socio-cultural factors that influence adoption of biogas technology (Appendix 3). The result of the regression findings showed that an adoption of BGT is mainly influenced by limited number of livestock (beta value 0.238) and poor understanding of biogas concepts (beta value 0.161). This positively relates to a study by (IISD 2013) that indicated that the women in many rural communities lack enabling factors like information and capacity about clean, efficient, cooking technologies that could trigger change in cooking trends. Other hindrances cited were, lack of harmony among family members (beta value -0.154), extension officers failure to spend time with farmers (beta value 0.202), lack of education and technological skills (beta value 0.120), and low participation of women in leadership (beta value 0.110).

The respondents identified having a limited number of livestock (beta value 0.238), as a factor that influences adoption. This has a double implication: Firstly, the farmers admitted that they have always had the notion that for one to install biogas unit one would need to have a (“roru”) ‘herd’ of cows. Secondly, the situation is worsened by diminishing income in rural areas in the wake of deteriorating weather patterns that reduce agricultural and livestock productivity. The effect of lack of harmony among family members (beta value -0.154), is directly connected to power relations at the family level. Many men feel their male authority and dominance is being challenged on multiple fronts.



PLATE 11a Source: Field Survey (2015). *An adopter explains to the researcher how he intends to cover up the biodigesters with a concrete slab.*



PLATE 11c Source: Field Survey (2015)

The farmer prepares to place the concrete slab over the pit



PLATE 11b.SOURCE: Field Survey (2015)

The open pit of a newly constructed bio-digester that has not yet been covered; clearly hazardous. Slurry is visible emerging from the digester overflow



Plate 11 d Source: Field Study (2015). *An adopter shows the researcher the valve used to regulate gas flow from the bio-digesters.*

From interviews conducted, the extension officers AOKI 7 CODE revealed that a high percentage of men attend farm barazas when the topic is on livestock or animal husbandry whilst the women perform domestic chores. They shared with the researcher, scenarios of financially capable women who wished to take-up the technology but the husbands were simply not willing. The men would adamantly demand to know the source of this money. This kind of suspicion would create conflicts. The officers attribute this to the perception that since the idea was not mooted by men, it should and cannot work.

4.3.2 Farmers views on ways to improve acceptance of biogas technology

Tables 4.14, 4.15, and 4.16 provides an oversight of factors that have had significant influence on the adoption that would have positive influence on the individual attitude and hence adoption of biogas technology. The analysis shows responses on farmer's views on ways to improve the acceptance and overcome the main obstacles to BGT.

Using a likert scale of 1 – 5 (1 – strongly agrees, 2-agree, 3-undecided, 4-disagree, 5-strongly disagree) the respondents were asked to rate their views. The mean response was established by summing up the farmers views on the attributes and getting the average of the views. From the non BGT adopters the findings showed that the major attribute that would improve adoption of biogas technology was using slurry by-products as fertilizer (mean 1.63). This was followed by improved household income (mean 1.77). With improved incomes farmers can divert some of the incomes towards such project of BGT installation.

Table 4.16: Non-BGT adopters Farmers views on ways to improve acceptance of biogas technology

Attributes	SA	A	UN	D	SD	Mean
Increased livestock numbers	92 (32.9%)	109 (38.9%)	39 (13.9%)	18 (6.4%)	13 (4.6%)	2.08
Positive publicity	114 (40.7%)	105 (37.5%)	31 (11.1%)	13 (4.6%)	8 (2.9%)	1.88
Water availability	106 (37.9%)	95 (33.9%)	27 (9.7%)	33 (11.8%)	10 (3.6%)	2.17
Improved household income	126 (45.0%)	101 (36.1%)	23 (8.2%)	18 (6.4%)	2 (0.7%)	1.77
Controlled livestock grazing	107 (38.2%)	97 (34.6%)	46 (16.4%)	14 (5.0%)	7 (2.5%)	1.96
Land sub division	31 (11.1%)	64 (22.9%)	78 (27.9%)	64 (22.9%)	34 (12.1%)	3.02
Security	61 (21.8%)	97 (34.6%)	39 (13.9%)	31 (11.1%)	43 (15.4%)	2.62
Using the slurry by product as fertilizer	169 (60.4%)	66 (23.6%)	12 (4.3%)	8 (2.9%)	14 (5.0%)	1.63

SA-Strongly agree, A-Agree, UN-Uncecided, D-Disagree, SD- strongly disagree

Source: Field Survey (2015)

4.3.3 Mode of stock keeping

From the data, 72.8% of the farmers indicated that controlled livestock grazing (mean 1.96) would improve the collection of dung for the biodigesters. This is important as collection of dung from animals under free range would be tedious and cumbersome. . This relates to the mode of stock keeping which would confine cows within reasonable bounds. This was captured from the farmers who admitted that they were inadequately prepared to what entails “having” a biogas digester unit. For instance BGT adopter, GAD2 expressed the dilemma he faced once the unit was set on his farm. He was not

properly guided as to what he would have to do to maintain the system. In regard to ‘cow dung amount’ the respondent GAD 2 expressed his assessment of the ‘start up-load’ that is, the amount of dung required, that he was to load his digester, up to ‘7 tonnes, as a big set back towards encouraging adoption.

“Farmers who may not have the capacity to have that amount of dung are not able to initiate it. It took me more than two weeks to get enough dung to feed the digester all the while looking for dung in the neighbouring pastures. Most of my neighbours saw this as dirty, tiresome, backbreaking especially the elderly farmers. They simply retorted, ‘why did he install the digester if he cannot even manage to feed it?’”.

This confirms Mulinda et al., (2013) findings that a big digester means more feeding materials and animal heads. This is a big concern for farmers whose free range mode of stock keeping creates more difficulties in collecting of dung. A concern also raised by respondent GAD7 who admitted that it took her about a month to gather enough dung whilst collecting and sometimes soliciting too from her neighbours who always wondered what she was doing with all that dung. She however pointed out that not all were positive to her request feeling she was ‘denying’ them manure for their farms.

The study revealed that there is a significant relationship between mode of stock keeping and adoption of biogas technology. Chi square results (Appendix 12) $\chi^2=43.677$ and P value $P=.0001$ showed there was significant relationship. The data presented on Figure 4.8 indicates that 80.3 % of non-BGT adopters have not been managing their livestock under zero grazing. Among the BGT adopters 77.5% have their livestock under zero grazing and paddocks, managed close to the homestead.

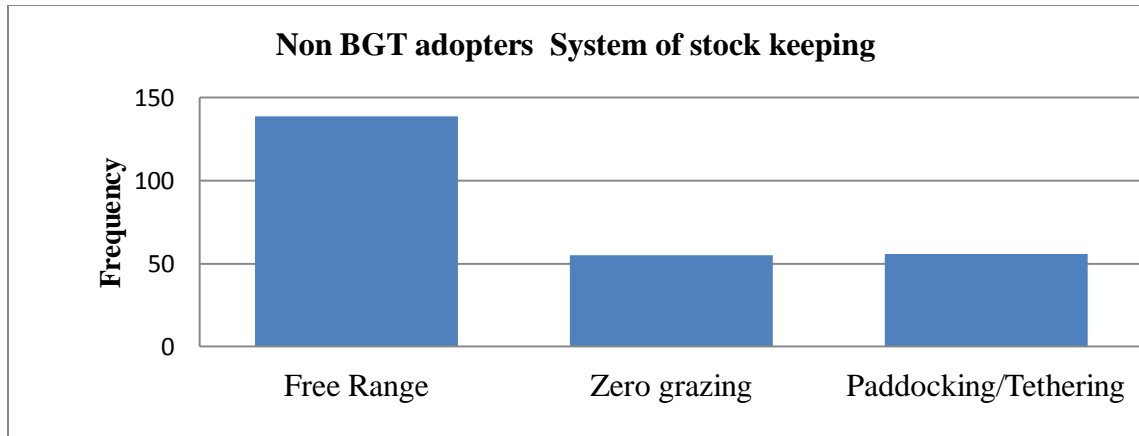


Figure 4.8: *Non BGT adopters system of stock keeping. Source: Field Survey (2015)*

The BGT adopters further explained that they have to adjust the mode of livestock keeping to zero-grazing whilst others have what can be called semi –intensive system. The BGT adopters have invested heavily in the zero grazing units with stockpiling of enough fodder for the cows that lasts through lean years: (Plate 12 and 13 below).



PLATE 12: (stored silage).**Source:** Field Survey (2015)

PLATE 13: *An interview session with one of the adopter as he explains zero grazing; the mode of stock keeping which has been a key ingredient towards him adopting BGT. Sources: Field Survey (2015).*

Table 4.17: BGT Adopters' assessments that would help increase adoption potential of biogas technology.

Attributes	SA	A	UN	D	SD	Mean
Increased livestock numbers	35 (49.3%)	2 (2.8%)	10 (14.1%)	7 (9.9%)	17 (23.9%)	2.56
Positive publicity and marketing	38 (53.5%)	22 (31.0%)	10 (14.1%)	-	-	1.60
Water availability	46 (64.8%)	18 (25.4%)	-	7 (9.9%)	-	1.55
Improved household income	38 (53.5%)	31 (43.7%)	-	2 (2.8%)	-	1.52
Controlled livestock grazing	14 (19.7%)	28 (39.4%)	22 (31.0%)	7 (9.9%)	-	2.31
Land sub-division	-	21 (29.6%)	30 (42.3%)	13 (18.3%)	7 (9.9%)	3.08
Security	26 (36.6%)	12 (16.9%)	3 (4.2%)	13 (18.3%)	17 (23.9%)	2.76
Using the slurry by product as fertilizer	39 (54.9%)	32 (45.1%)	-	-	-	1.45

SA-Strongly agree, A-Agree, UN-Undecided, D-Disagree, SD-Strongly disagree

Source: Field Survey (2015)

The BGT adopters were also asked to rate suggestions towards improvement of acceptance of BGT. Data obtained from adopters show an overwhelmingly 100% approval rating (with a mean 1.45), of using the slurry by products as fertilizers on their farms. The farmers revealed that they are reaping more from their farms than they were before adoption of BGT. This is a great incentive to the BGT adopters' farmers who have been faced with dwindling farm produce associated with poor farm practices among them the application of conventional fertilizers.



Plate 14: Bioslurry application on the farms

Source: Field Survey (2015)

From the researcher's observation, in homesteads where BGT had been installed, bioslurry was being applied in the fields reducing chemical fertilizer utilization. This concurs with Osak *et al.*, (2015) who advances that use of bioslurry have environmentally and healthy advantages for it improves the balance of soil nutrients and which adversely affects the health of food consumers. Data presented in Table 4.17 also showed that the availability of water is rated by 90 % of the respondents (with a mean 1.55), as one the measures to increase adoption and up take of biogas technology among non-biogas users in the study area. According to Brown, 2006, for a bio-digester to function properly, a biogas plant requires feeding a mixture of cow and water or urine, in the ratio of 1:1. This imposes a significantly higher daily water demand over domestic needs. One of the adopters KBAD 17, who had since stopped using the plant reported that one of the hurdles he faced was the unreliable amount of water availed by the water project in the area. He revealed that this was occasioned by water rationing during the dry season and total failure during the rainy season when it would be reported that water pipes had either been washed away or destroyed by surface run-off. The livestock extension officers in the

region interviewed also identified this as one of the basic essentials that farmers are lacking that could enable them set up biogas units. These results agree with views shared by Mwirigi *et al.*, (2009), who assert that limited water availability poses a constraint to biogas operation because biogas units typically require water and manure to be mixed in an equal ratio. 97.2 % of the BGT adopters viewed improving household income (mean 1.52) and therefore translating to more disposable income would make adoption of BGT feasible.

4.3.4 Benefits from adoption of biogas technology

The BGT non-adopter farmers were asked to state the most important benefits envisaged to be received from adoption of biogas technology. If the respondent was knowledgeable and appreciated the advantages of BGT it was assumed his or her attitude towards biogas would be positive and would adopt the technology. In a scale of 1 – 5 (1-No extent, 2-A little extent, 3- a moderate extent, 4- a large extent, 5-a very large extent), from the table 4.18, it was established that the farmers consider of great importance, time taken in collecting firewood to a large extent (mean 4.49). They believed it would reduce the drudgery and danger to personal safety to the vulnerable women and female children related with procuring fuel wood. This was a finding shared too by Kileo *et al.*, (2014). The respondents also indicated they would save time in preparing food (mean = 4.44), believed BGT is cheaper than electricity (mean 4.43) noting they will be able to save on the amount used on liquid petroleum gas (LPG), firewood and charcoal.

Table 4.18: Most important benefits in adoption of biogas technology (non- adopters)

Statement	NE	LE	ME	LARGE EXT.	V.L.E	Mean
Improvement of health	15 (5.4%)	13 (4.6%)	62 (22.1%)	73 (26.1%)	11 (39.6%)	3.92
Reduction in respiratory diseases	20 (7.1%)	25 (8.9%)	4 6 (16.4%)	85 (30.4%)	96 (34.3%)	3.90
Increased income	21 (7.5%)	45 (16.1%)	59 (21.1%)	54 (19.3%)	92 (32.9%)	3.58
Less time taken in collecting firewood	4 (1.4%)	12 (4.3%)	16 (5.7%)	57 (20.4%)	182 (65.0%)	4.49
Employment	41 (14.6%)	49 (17.5%)	66 (23.6%)	59 (21.1%)	58 (20.7%)	3.18
Effective utilization of cow dung	10 (3.6%)	12 (4.3%)	46 (16.4%)	60 (21.4%)	145 (51.8%)	4.18
Time saving in cooking	3 (1.1%)	13 (4.6%)	21 (7.5%)	62 (22.1%)	174 (62.1%)	4.44
Cheaper than electricity	4 (1.4%)	10 (3.6%)	20 (7.1%)	73 (26.1%)	166 (59.3%)	4.43
Easy to clean vessels after cooking	7 (2.5%)	22 (7.9%)	26 (9.3%)	53 (18.9%)	165 (58.9%)	4.28

NE-No extent, LE-little extent, ME-Moderate extent, LARGE EXT. large extent, V.L.E-Very large extent. Source: Field Survey (2015)

From the data 81.7% of the households indicated ease in cleaning vessels after cooking with biogas as an added benefit scoring a mean of 4.28. In addition their kitchen will no longer be covered in soot since with biogas they can look forward to a bright and soot free house. Employment was not perceived to be of great significance scoring a mean rate of (3.18).

Table 4.19: Main benefits to biogas adoption in the area noted by the BGT adopters

Statement	1	2	3	4	5	Mean
Improvement of health	6 (8.5%)	10 (14.1%)	2 (2.8%)	12 (16.9%)	33 (46.5%)	3.89
Reduction in respiratory diseases	6 (8.5%)	-	21 (29.6%)	9 (12.7%)	27 (38.0%)	3.81
Increased income	3 (4.2%)	15 (21.1%)	-	13 (18.3%)	30 (42.3%)	3.85
Less time taken in collecting firewood	12 (16.9%)		3 (4.2%)		48 (67.6%)	4.14
Employment	13 (18.3%)	6 (8.5%)	8 (11.3%)	17 (23.9%)	17 (23.9%)	3.31
Effective utilization of cattle dung	-	10 (14.1%)	-	12 (16.9%)	41 (57.7%)	4.33
Time saving in cooking	-	-	10 (14.1%)	7 (9.9%)	46 (64.8%)	4.57
Cheaper than electricity and firewood	-	-	2 (2.8%)	3 (4.2%)	58 (81.7%)	4.89
Easy to clean vessels after cooking	-	-	-	-	58 (81.7%)	5.00

1-No extent, 2-A little extent, 3-moderate extent, 4- A large extent, 5- A very large extent Source: Field Survey (2015)

The most important benefits received by BGT adopters from adoption of biogas technology was established by getting the mean response (1-No extent, 2-little extent, 3-moderate extent, 4-large extent, 5-very large extent) for all the statements (Table 4.19).

The findings indicated that the most important benefits received was the ease of cleaning

vessels after cooking (mean 5.00). They pointed out that it was not only cheaper than electricity and firewood (mean 4.89), but it was saving them time spent in cooking (mean 4.57). For instance, among the adopters K'AD33 had this to say:

“If today I were given the option between electricity and BGT I would opt out of electricity since am getting electricity bills at the end of the month. These are very stressing. The electricity was installed by my daughter as I didn't have the 30 thousand (Ksh 30,000) needed for installation. But given the benefits I have received from BGT, I wouldn't wish for anything else”.

They were also effectively utilizing cattle dung (mean 4.33) realizing its superior quality than conventional fertilizer. This concurs with Abbey *et al.*, (2005), survey in Uganda that indicated that approximately 50% to 60% of the farmers use the plants under the Kulika Charitable Trust in high populated districts. They appreciate their benefits citing reduced expenditure on fuel, time, lost in gathering fuel wood and accrued benefits of application on the farms of the bioslurry. From the data, 22.1% of the respondents indicated improvement in health while 38.1% indicated reduction in respiratory diseases as major benefits resulting from BGT adoption. These findings positively relate to Barnes and Kumar (2012) who prioritise the beneficial effect of smoke free kitchens over energy saving in their related study on improved cooking stoves research in India.

4.4 Institutional arrangements and BGT adoption

The study investigated several institutional factors influencing the adoption decision. Formal and informal institutions with experience and expertise do provide, not only the requisite awareness through promotion and marketing strategies but also post installation support through sustained promotional and incentives programs. This study thus sought to establish an association between extension officers' role as the information source, the promotion agent credibility and adoption decision.

4.4.1 Farmer's response towards Extension services in the area

The role of extension services in the study area is to provide information to farmers to facilitate them make better use of available resources by increasing technological options and organizational skills. The farmers were asked to respond to cognizance of the existence of extension officers in the locality who provide details on biogas information or otherwise.

The research finding shows that 78.9% of the respondents were not cognizant of the existence of extension services officers in the location whilst 15.4% of them were aware of their existence (Figure 4.9).

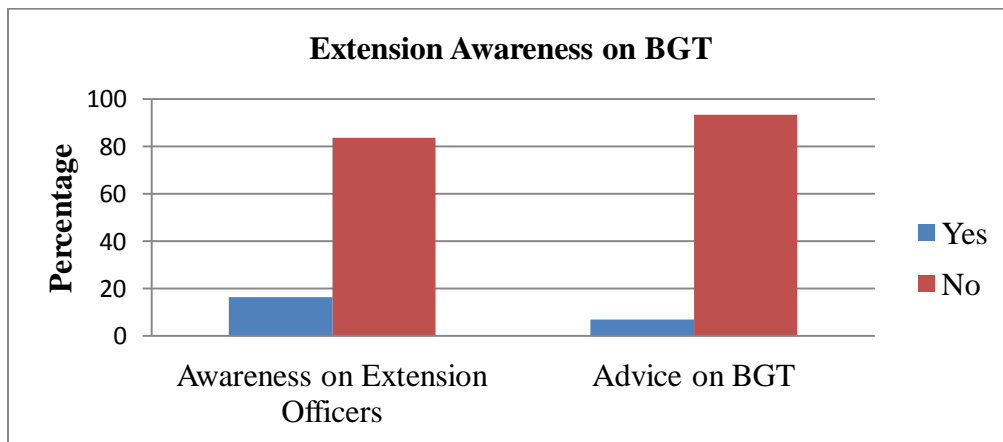


Figure 4.9: Farmers who were aware about extension officers and received advice given regarding biogas

Source: Field Survey (2015)

The respondents were asked to indicate the regularity at which they had been receiving information from the extension officers on how to incorporate or adopt the biogas technology. Further the respondents were asked to indicate occasions when they would be visited by the extension officers to guide them on agricultural technologies. They were to indicate as weekly, monthly, bi-monthly or never.

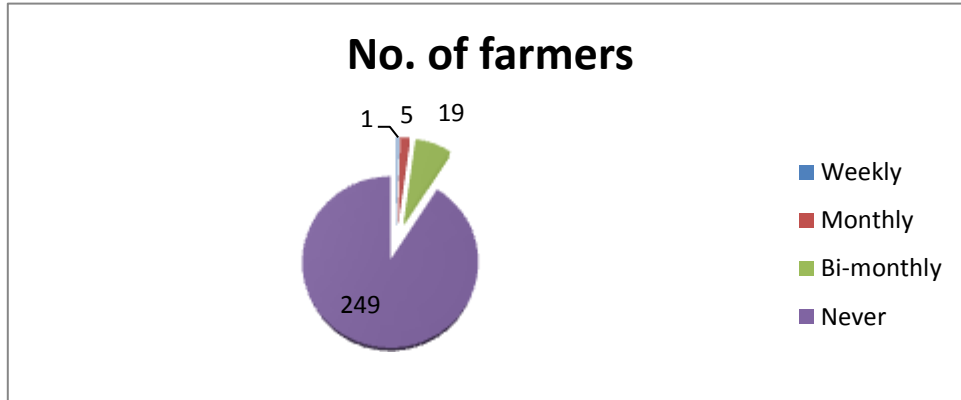


Figure 4.10: Frequency of inspection of the farms by CDOs

Source: Field Survey (2015)

From the data represented in Figure 4.10 the community development officers (CDOs) visit to the farms for inspections was indicated by 19 respondents as mainly bi-monthly. 249 persons representing 88.9% of the respondents reported never to have been visited by individuals having information of biogas technology like extension officers or any other. During interviews the farmers visited unequivocally expressed their view that the information the agricultural officers share, is on farming, ways of improving livestock, and pesticides application, and information on government policies but apparently not on BGT.

The farmers expressed their displeasure over this scenario. They felt that the extension officers of the area are not helpful since they are not accessible neither are they committed to their work, and as such are not useful.

Some of their comments are captured below:

KBNAD 147: I have never seen them or been visited by them, they have to avail themselves more often as there are various problems that need to be addressed.

They seem not to know their work and should visit the area to assist the farmers.

GY NAD 137: *They do not do their work accordingly because they do not teach us.*

GY NAD 79: *They are available but they bring their meetings far away from the village.*

In the study region farmers who received information on BGT were only 3.90 % whereas 96.10 % had never got any official communication regarding adoption of biogas from either agricultural extension officer community development officer or any other government or private entity (Figure 4.9). The researcher was faced with the dilemma of having to explain the concept to some farmers who in their lifetime had never heard about BGT. There was simply the awe fascination captured in some of their reactions:

Are you suggesting there is an alternative to fuel wood? Is this for real or are you pulling our legs? This is too good to be true? How can we access it? Can we pay it in installments? Can you make it affordable? Are you promoting it? When can you avail the technology?

The study established that the neighbouring BGT adopters were the sources of information regarding BGT. (However, the study established that this information shared was not sufficient as regards the specifications of the plant or units, cost of installation among other considerations pointing to an information gap.) Indeed confirming Oreszczyń *et al.*, (2010) who have pointed out in their studies that family members, other farmers, scientists, extension practitioners and other social groups significantly influence technological adoption, that is, social pressure. It is this group or source of information that increases the adoption potential. These findings approve Kossmann 1999 and KENAFF 2014 reports that in areas where the first installed plant performed well, word of mouth from satisfied users encouraged other potential users to install their own plants. On the other hand where plants failed, the failure created a negative impact on the technology, discouraging potential users in the process.

Table 4.20: Farmers taking up the recommendation of the advice from the visits

Frequency of implementation	No. of farmers	Percent
Always	1	0.4
Frequently	6	2.1
Rarely	30	10.7
Never	243	86.7
TOTAL		100

Source: Field Survey (2015)

Data on Table 4.20 indicates that even after the visits majority of the farmers, (86.7%) the never implement the recommendations given by the officers from the visits. Only a paltry 0.4% acknowledged following the guidelines of the officers. The failure of a proper follow up further confirms (Kahan 2013) findings that an extension worker job does not end with merely informing the farmers about improved practices, he/she should ensure practical application by the farmers. This has not been actualized by the officers in the study region leading to poor reception and adoption of the new technology. This is demonstrated by various respondents as captured below who shared their experiences.

GTNAD188: their services are inadequate, are only involved when farmers themselves have embarked on a project, then they appear, to inspect [sic].

KGNAD240: They provide information on what seeds to plant, good farming practices, but only make visits during the planting season. GTNAD 228 and GYNAD 276: retorted that they cannot comment because “they are not aware whether they exist” [sic].

GRNAD 106 reported that community and agricultural officers have not been helpful at all, as they always wait for farmers to prod them on issues before they respond.

During the interviews with the Agricultural officers AOKI, key informants, it was established that majority of biogas units in the Kahurura and Gatuanyaga region had been introduced mainly through dairy cooperatives. In Kahurura in particular, the donor established direct link with the farmers and signed a memorandum of understanding spelling out terms and conditions of engagement. In this case the officers are not involved but are invited as government representatives or agencies to oversee or give technical assistance. On the allegation that the extension officers deal with other things other than biogas,

KBNAD 122 had this to say:

They share information about farming, rabbit keeping well, but they have never taught about biogas.

GRNAD 247: *They do not provide any information regarding BGT.*

They are sleeping on the job.

KGNAD 277: *They are only available on call, never on the ground.*

Further data on Table 4.21 shows the level of awareness of the presence of extension officers in the division was very low (81%) among the males whilst among the female it stood at (76.7%).

However awareness on availability of the extension officers was high among the women than among the men. 16.5% of the women were aware of the extension officers while 11.6% of the men were aware of the extension services in the location. However, there was no significant association in awareness of the officer among the gender of the farmers ($\chi^2 = 4.011$, $P = 0.260$).

Table 4.21: Awareness of the extension officers in the location

Aware of extension officers	Gender of the Non BGT farmers	
	Male	Female
No	119 (81.0%)	102 (76.7%)
Yes	17 (11.6%)	26 (16.5%)
Total	147 (100%)	133 (100%)

Source: Field Survey (2015)

4.4.2 Institutional Challenges faced by the respondents in Biogas Technology adoption

BGT adopter farmers were asked to identify the challenges faced in adoption. The results presented in table 4.22 show that the main challenges were institutional. A summary of these factors showed that, scarcity of development funds (69.8 %), ineffectiveness of community development officers (46.2 %), extension officers' failure to spend time with the farmers (48.4 %), were the main reasons that hinder adoption. This analysis confirms the earlier analysis of challenges faced by non-adopters in adoption of biogas technology. Other factors identified and which have already been discussed in this paper were lack of education (35.9 %) poor marketing policies (33.0 %) negative publicity and awareness (21.7%) strongly agreed that were affecting adoption of BGT. This was attested by GTAD 4 who in relation to extension services further pointed out that visits are normally conducted to farmers who are well off financially forsaking those who have low income.

Table 4.22: Challenges faced in BGT adoption

Challenges	SA	A	U	D	SD
Lack of education	126 (35.9%)	79 (22.5%)	7 (2.0%)	41 (11.7%)	33 (9.4%)
Scarcity of development funds	245 (69.8%)	56 (16.0%)	15 (4.3%)	29 (8.3%)	6 (1.7%)
Ineffectiveness of community dev. officers	162 (46.2%)	92 (26.2%)	23 (6.6%)	40 (11.4%)	34 (9.7%)
Extension officers failure to spend time with farmers	170 (48.4%)	84 (23.9%)	17 (4.9%)	55 (15.7%)	25 (7.1%)
Poor marketing policies	116 (33.0%)	105 (29.9%)	39 (11.2%)	61 (17.4%)	30 (8.5%)
Negative publicity and awareness	76 (21.7%)	93 (26.5%)	55 (15.7%)	52 (14.8%)	74 (21.1%)

SA-Strongly agree, A-agree, U-Undecided, D-Disagree, SD – Strongly disagree

Technical knowhow of a new invention and its adoption is associated with extension contact. From the table 4.22, 72.4% of the farmers indicated the ineffectiveness of community development officers whilst 72.3% agreed that extension officers' failed to spend time with the farmers. Thus the farmers expressed inadequate contact was a major constrain towards adoption. GYAD14 was categorical that lack of finances isn't a major handicap where there is technical assistance.

“Even without education, but one has money, one needs to simply tap to in to those that have the technical know how to set the unit, that’s it” [sic]

The same sentiment has been shared by young men in Poland in regard to education and opportunities.

“I think that education has lost its significance. Everything is now about political connections.” (WDR 2012 –the decline of the bread winner pg. 195)

These findings correlate with Kituyi (2009) who in his research identified that the few farmers with operating plants decried the absence of competent technicians. They also do not have owner’s operating guidelines or manual to refer to when necessary. From the study area some adopters, attested to having had problems at the onset for failure to get technical assistance. For instance, KBAD 4 revealed that she has had problems with over flow of dung, blockage of pipes, and lack of technicians to assist in maintenance or respond to issues that would arise (See Plate 15 Below).



PLATE 15 a: *An overflowing tubular bio-digester unit, spilling the slurry, overgrown with weeds, an expression of poor maintenance. Source:* Field Survey (2015)

GYAD 6 reported noting the amount of gas had reduced. He had not known that over production in his unit had led to blockage. GRAD 55 was experiencing leakages that were affecting the amount getting to the kitchen and he was not so sure about how to handle it as there were no technicians. This further confirms Bond and Templeton (2011) review which cites failure rates of as high as 70% stressing the significance of infrastructure to support biogas users should plants break down. Stepwise Linear

regression analysis however, showed that, the main effect on adoption of BGT was by extension officers' failure to spend time with the farmers ($r=0.196$) and lack of education and technological skills ($r=0.155$). These findings concur with Xi, *et al.*, (2014) who report that it's obvious that the presence of a technical team affects the adoption potential. Such teams increase the chances of sustainable use of BGT in their timely interventions to resolve problems plaguing BGT use.

When a Pearson moment correlation analysis was done on these factors to establish which of the factors had a significant effect on adoption of BGT, the result indicated that, adoption was significantly affected by; lack of education ($r = 0.180$, $P = 0.001$), ineffectiveness of community development officers ($r = 0.198$, $P = 0.0001$), extension officers' failure to spend time with the farmers ($r = 0.228$, $P = 0.0001$), limited land for installation ($r = 0.178$, $P = 0.001$). A significant F value was obtained indicating that the identified institutional factors influenced the adoption potential of BGT. Hence, the researcher did not reject the null hypothesis that institutional factors significantly influence the adoption of BGT.

A combined effect of farmer's attitudes, socio-cultural and institutional factors influences an individual household's willingness to invest and eventually adopt BGT technology. No factor works on its own; these factors are dependent on each other in determining whether the farmer adopts the BGT or not.

CHAPTER FIVE

5.1. SUMMARY OF THE FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

This study was based on three objectives: First, to examine the extent to which Social cultural factors influence the level of adoption of biogas as alternative energy source. Secondly, it was to examine the attitude of farmers towards the use of biogas technology as an alternative energy. Lastly, to investigate the extent to which institutional arrangements influence the level and rates of adoption of biogas as alternative energy source. This study has shown that socio cultural, attitudinal and institutional factors determine adoption potential and consequently affect the uptake of biogas as an alternative energy source. It's important to emphasize that these factors do not occur in isolation, but rather interact; producing more severe compounded impacts compared to the additive impacts of any one single factor acting on its own.

The research established that biogas adoption was significantly affected by educational level ($R^2=0.094$). With higher levels of education the propensity to appreciate environmental concerns and sustainability is higher. One is unlikely to knowingly be concerned about the environment or deliberately act in pro-environmental ways if one knows nothing about the problem or potential positive actions of conserving the environment. The region is facing the problem of dwindling and scarce firewood sources with 55.3% of non-adopters indicating sources of firewood as scarce and inadequate. The study revealed that 66.7 % of the respondents have poor understanding of biogas concept. 54.3 % of farmers had heard or been informed by their neighbours who have adopted it. However, they were not interested in adopting it for among other reasons they felt they did not have a problem accessing fuel source. Further it is only 21.4% who ever

envisaged utilising it as an alternative energy source. They perceive BGT as being expensive, thus unaffordable with there being no tangible evidence or prerequisite information for them to support that claim.

The results of this study show that the duration of residence is a relevant factor in the adoption potential. 50.7% of the adopters had spent many more than 20 years of their lives in this area as compared to 2.8% who had moved in within a period of 3-5 years. This further relates to age of respondent that was found to have a significant effect on adoption decision. (Regression results $R^2=0.045$). A lengthy period of stay was an impetus towards adoption of biogas as the farmers have gradually over the years seen forests disappear and now are faced with fuel wood shortage. Further this category of farmers was more likely to have established permanent abodes.

The results indicated the extension officers' failure to spend time with the farmers (48.4 %), and ineffectiveness of community development officers (46.2 %), as the main reasons that hinder adoption. The effect of this breakdown in communication or lack of it essentially was captured in the analysis that showed that farmers eventually had inadequate information. The adopter farmers strongly agreed that among other challenges poor marketing policies (33.0 %) negative publicity and awareness (21.7%) were affecting adoption decisions of BGT.

The study established that there was hardly full and direct support for farmers through provision of credit. The study identified two sets of BGT adopters in the research area. Those that are self-sponsored which means they undertake the total costs of installation. The other set is of those farmers who have received partial donation or NGO –cost

sharing. However interesting was where the capital was availed by the sponsor, it was not always enough as the farmer would have to supplement further by providing manual labour and capital to cost share.

The research identified the role of community based project groups in facilitating uptake of BGT. Whereas the initial purpose of the cooperative group in Kahurura was to have farmers appreciate their roles in environmental management by reforestation, this became the entry ground for USAID who were able to target the member since they had already established themselves and their operations on the ground were evident.

5.2.1 Social cultural factors influence the level of adoption of biogas as alternative energy source.

Cultural beliefs have an influence on adoption of biogas technology. In this research study, age of household head was noted to have a significant positive relationship with biogas adoption. This study shows that farmer's personal characteristics significantly influence biogas technology adoption in Gakawa. Specifically, the probability of a household adopting biogas technology increases with increase in age of head of household, increased income, and length of residence. Cultural values were found to underlie the decision making trends highlighting the constraints faced by women in adoption of biogas technologies. Among others, lack of harmony amongst family members affected the adoption of biogas. Rarely do the households sit and deliberate on major projects, and particularly the children's input is only welcome when it has serious financial implications. Failure to mull over gendered benefit and the different wishes of men and women can curtail the success of energy programmes and policies and in

particular the adoption of BGT. The study reveals the need to harness the input of “others” as it’s important in pointing out the direction of a desired activity.

The research established that the source of income for majority of the respondents is from the farms, most of them being farmers who rely on farm produce. From the research findings and from field observation the millipedes ‘menace’ has not only been destroying crops on the farms but also in the stores threatening food security in the region. This has costly implications on the disposable income available for the farmers to install Biogas units. Scarcity of development funds proved to be a key factor in influencing a household’s decision to adopt biogas technology; it was also positively related to the adoption rate.

5.2.2 The attitude of farmers towards the use of biogas technology as an alternative energy source

In agreement with Ahmad (2010) findings, this study reveals that awareness and knowledge are important and have significant influence on attitudes and behaviours of public. The research established that the respondents’ attitudes were based on several perspectives, including farmer’s personal characteristics discussed above. The research established that though biogas was availed to the BGT adopters, the use of multiple energy sources was still prevalent among the BGT adopters. Majority of the farmers use firewood because it’s the most availed source of energy. The farmers admitted that cooking of *githeri* using the biogas was not an option since *Githeri* takes a long time to prepare which the amount of gas produced cannot sustain.

In this study a majority of the respondents acknowledge that there is an energy problem and that there is need to have alternative means of energy as fuelwood which is not sustainable. However, the research established that there is a lower propensity to adopt among residents in Gathiuru region. Ostensibly due to the nature of the setting; harvesting trees in the homestead and proximity to the forests has created a scenario where they have not enshrined environmental consciousness in their everyday lifestyles. This confirms Robelia & Murphy, (2012) surveys in the US, who further stress that, making informed a pro-environmental choice is difficult if one has incorrect or no knowledge.

The research established that in households where young children of school going years were in, parental attitudes, and educational aspirations had a role in influencing their attitude and perception practices of energy consumption and conservation. They showed great interest in the biogas concept. During the interviews they would occasionally engage the researcher and their parents in a heated discussion on the state of energy needs from their perspective.

The research established that the attitude towards adoption have also been attributed to poor understanding which negatively affected the uptake. The poor understanding had brought in many misconceptions about what the technology is, what it demands, its affordability, its associated risks, perceived obstacles and benefits? For instance, majority of the non-BGT adopters, who albeit had cows were remotely aware of the existence of the BGT technology. The farmers believed in their mind that they could not install or adopt biogas units as they were convinced wrongly, that biogas required them to have '*roru*' (a large herd of cows).

The research also revealed an overlying problem identified as what can be referred to as the '*serikali saidia* "syndrome" (government dependency syndrome) -Where the farmers expected the donors to do everything for them whilst they sat back and wait for the completion of the digester to be handed over to them. This is a very worrying trend. To create responsible and accountability over installed kits, the feeling that the kit is a donation, leads to lacklustre supervision, and neglect of the kit, after all they reason, their input was negligible. Most residents are not willing to get into debt in order to install biogas. From the analysis it has come out that the institutions mandated with providing extension services, promotional, maintenance, regulatory support that would improve the attitude and increase propensity towards adoption were identified as the main culprit that has affected BGT adoption potential.

5.2.3 Institutional arrangements influence on the level and rates of adoption of biogas as alternative energy source.

The study established poor presence and uncoordinated effort by different biogas actors including biogas extension officers seconded to the ministry of livestock. The impact of institutional agents and extension officers who have the onus of disseminating correct knowledge that has been shown to predict behaviour, Levine & Strube, (2012), was put to question. The study revealed great gaps in the extension services envisaged to provide the requisite information. There was a direct relationship between levels of awareness and level of contact between officers and farmers. It is clear that the number of times a farmer has been visited by an extension agent were significant in adoption of biogas technology. It was established that the absence of extension officers on the ground has brewed a lot of discontentment and disdain towards extension services. According to

Rezvanfar *et al.*, (2009), farmers with favourable attitude will more probably accept agents' useful advice enthusiastically and follow their instructions. This therefore calls for agricultural stakeholders to consider extension methods used by researchers and extension agents in promotion of biogas technology.

It was revealed that no field campaigns had been done in the division to raise awareness on feasibility of biogas as an alternative energy use among the residents. The respondents have developed lethargy towards the officers who they felt have shunned them because of their poverty level. It is clear that the compromised quality of services rendered to biogas clients, reduces customer satisfaction thus denting and diluting the reputation of the BGT, a finding too shared by KENAFF (2014).

The researcher also found out a sorry state of reliance on project sponsors to not only provide the requisite fund but also expected to maintain the unit .Even in situations where the unit seemed to have minor problem, a majority of the adopters in Guara had adopted to simply sit back and simply do that, “wait” and wait for what they considered expert opinion. It would seem that members were not briefed on how to identify any technical hitches that would warrant simple routine maintenance. For instance a BGT adopter in Gatuanayaga had the BGT unit not “functioning” as she had not homed well on how to operate the valves, properly. This was a clear sign of lack of adequate technical knowledge transfer.

The study found out that access to Biogas credit has remained a challenge for most farmers, in the study. As confirmed by Mr Nyamu from KENAFF, Biogas loan products continued to be perceived as unpopular, unfeasible and risky by most financial institution.

The study also recognized the importance of community resource group's, "chamas" and Dairy Farmers cooperative societies towards sensitizing the residents on matters regarding environmental conservation and sustainability.

5.3. Recommendations

The study established that women are more directly affected than men and are aware of the energy needs than men do. Thus emphasis should be put on targeting women who are the beneficiaries, across all age groups. It is important to carry out gender mainstreaming in decision making processes towards achieving resource conservation and adoption of BGT as an alternative energy means.

The study established poor patterns of water availability that had halted some units from functioning as a result of water shortage. Biogas digester fermentation is dependent on water availability. This study recommends that a reliable source of water be a condition of setting up the unit. The government and stakeholders need to put in place strategies that would increase water availability by harvesting rain water in water pans. Water tanks to harvest water from the roofs should be availed at costs that are affordable to the farmers.

There is need to research and develop biogas units that meet requirements of accessibility, maintenance, and durability for this improves adopter's confidence. The research established poor workmanship as one of the reason why majority of the biogas units were not functioning properly. This calls for stakeholders such as KENDBIP in partnership with the National Industrial training Authority and the Kenya Curriculum Development Institute to urgently develop a National Biogas training curriculum that is

to be adopted in all vocational training institutes in the country to ensure continuous supply of qualified artisans in the sector. In addition, on matters of policy and regulation, KENDBIP in partnership with key players including the Kenya Bureau of Standards, Kenya Industrial Research and development Institute (KIRDI), the Energy Regulatory Authority should fast track the development of the National Domestic Biogas Standards. These standards will define the qualifications, code of conduct and customer rights from the sector actors. It will also define the approved designs, materials to be used, biogas products and other regulations.

Majority of the respondents are risk averse and are apprehensive about adoption. They are not willing to take chances with vagaries of weather having in mind they lose their animals to the occasional dry spells. There is therefore need to cushion such farmers. Research needs to be carried out by National and county governments agricultural research workers to identify the best suited breed not only for the study area but also for the entire division and assist farmers establish breeds of cattle that can withstand the drought prevalent in the region; thus sustain enough feed for the biodigesters.

5.4 CONCLUSIONS

For a successful roll out and adoption of BGT, stakeholders have to put into consideration vital aspects that revolve not only on the personal characteristics of individual but also more importantly address entry points of such interventions. Thus socio-cultural perspectives detailing decision making trends have to be harmonized in the programmes. Unsustainable incomes and poor access to credit means that costs and affordability are prohibitive for the majority of the rural farmers. As such it calls forth for identifying the needs and financial resources of the beneficiaries to assess the appropriate

renewable energy technologies. By better understanding the decision frameworks of these factors, public and private institutions can then design more effective promotion and extension strategies. Community Based Organisations and farmer associations groups are important entry points. As such, the government and other stakeholders should formulate means of improving and supporting these Community Based Organisations and agricultural based institutions so that they can spearhead the initiative of rolling BGT uptake amongst their members.

It is foolhardy to believe that adoption of BGT will totally eradicate the presence or need to have firewood as an energy source. With the current use of multiple sources of energy in the kitchens calls forth for a multi- pronged approach that does not only encourage adoption but also do takes into consideration a future that is sustainable. A sustainable approach to addressing fuel wood inadequacy coupled with wanton forest destruction needs to be developed where farmers receive incentives. Farmers need to be informed about the benefits of establishing tree lots in their farms as contributions to the conservation of biodiversity and thus earning from carbon credits. Educating the local population of the consequences of unsustainable use of the environment and awareness creation on the benefits of BGT as an alternative energy source is paramount.

5.5 AREAS FOR FURTHER RESEARCH

It is clear that extension officers have significantly affected the adoption decision. There is therefore need to establish the social demographic characteristics of the extension officers in the region. This should establish the level of competency, the communication methods used by the extension officers and their effectiveness. These variables would

serve as a guide to other biogas stakeholders to determine levels of competency and communication channels to be used in the transfer of information on BGT.

A similar study should be carried out in the entire division among farmers and households facing dwindling firewood stocks and farmers facing similar problems to assess whether similar findings can be established. Further a study should be carried out on the impact of economic livelihoods on adoption potential so as to have another measurable impact assessment for comparison with this study.

A study should be carried out on the households that do not own livestock that were excluded from this study. This is to determine the feasibility of having the households accepting production of biogas from human waste in their pit latrines.

A study should be carried out targeting non BGT adopters only, those that wish to adopt and those not. This is to discern those who are comfortable in their current state and do not wish or have no impetus to adopt from those who have the adoption potential. This would get rid of biases from response given by BGT adopters and thus limit an analysis on those who have not yet adopted the technology.

REFERENCES

- Abbey, A. T. (2005). Biogas in Uganda: A new experience. *Leisa*, 21:13-15 Retrieved on January 26, 2014 from <http://lib.icimod.org/record/11902/files/1855.pdf>
- Adkins, E., Opielstrup, K., and Modi, V. (2012). Rural household energy consumption in the millennium villages in Sub-Saharan Africa. *Energy for Sustainable Development*, 16(3), 249-259. DOI: 10.1016/j.esd.2012.04.003
- AEPC. (2000). *Renewable Energy Perspective Plan of Nepal, 2000-2020: an approach*. Online available:http://www.snvworld.org/en/Documents/Renewable_energy_perspective_plan_2000-2020_Vol_II_Nepal.pdf. Lalitpur: Nepal.
- African Development Bank (ADB). (2010). A Study Report on Sustainable Livestock Development in the Greater Horn of Africa Regional (GHA) Retrieved from: www.afdb.org/.../Final_Synthesis_Report. Accessed on 19/12 /2015
- Ahmad, S., N. B., Juhdi, N., & Shaikh A. A. (2010). Examination of environmental knowledge and perceived pro-environmental behaviour among students of University. Tun.Abdul Razak.Malaysia. *International Journal of Multidisciplinary Thought*. 1(1), 328-342.
- Ajah, J., (2012). Effects of Farmers' Level of Education and Cooperative Membership on Access to Agricultural Extension Services in Abuja, Nigeria. *Trends in Agricultural Economics*, 5: 104-114.
- Amigun, B., Sigamoney, R., and Von Blottnitz., H. 2008. Commercialisation of biofuel industry in Africa: A review. *Renewable and Sustainable Energy Reviews*, 12:690-711.
- Arjun S. B, Lorenzo P., and Luca, T, (July 2014). Caught between necessity and feasibility. *The effects of Rwanda's Biogas Programme on energy expenditure and fuel use*. Working Paper No. 589 ISSN 0921-0210
- Babbie, E. (2004). *The practice of social research* (10th Ed.). Belmont: Wadsworth/Thomson.
- Bacon, R., Battacharya, S. and Kojima, M. (2010). 'Expenditure of low income households on energy: Evidence from Africa and Asia', Oil, Gas, and Mining Policy Division Working Paper, The World Bank, Washington DC.
- Bajgain, S. and Shakya I.S, (2005). *The Nepal Biogas Support Program: A Successful Model of Public Private Partnership for Rural Household Energy Supply*. Accessed on March 21, 2013 from http://www.snvworld.org/en/Documents/BSP_successful_model_of_PPP_Nepal_2005.pdf

- Barnes D. F., Kumar P. and Keith, O. (2012). *Cleaner Hearths, Better Homes New Stoves for India and the Developing World*. Oxford University Press YMCA Library Building, 1 Jai Singh Road, New Delhi 110 001, India
- Beedell, J., & Rehman, T. (2000). *Using social-psychology models to understand farmers' conservation behaviour*. *Journal of Rural Studies*, 16(1), 117-127.
- Bernhard H., (2013). *How Could the Uptake of Biogas Technology be increased in Uganda?* Unpublished Master Thesis: McMaster University.
- Biogas World (2016). *Biogas plant development workbook*. Accessed on August 15, 2016 from http://www.biogasworld.com/biogas-plant-development-handbook/#energy_handbook
- Blunck M., (2007). *Electricity and Sustainable Development: Impacts of Solar Home Systems in Rural Bangladesh*. Unpublished Student Thesis: University of Mainz.
- Bond, T., and Templeton, M. (2011). History and future of domestic biogas plants in the developing world. *Energy for Sustainable Development*, 15(4), 347-354. DOI: 10.1016/j.esd.2011.09.003
- Bonjour, S., H. Adair-Rohani, J. Wolf, N.G. Bruce, S. Mehta, A. Prüss-Ustün, M. Lahiff, E.A. Rehfuess, V. Mishra, & Smith, K. R. (2013). "Solid fuel use for household cooking: country and regional estimates for 1980–2010." *Environmental Health Perspectives* 121 (7): 784-790.
- CAK. Communications Authority of Kenya (2014). Rural Broadband Trials Laikipia County Kenya. Summary findings of 12 month trial of television white spaces technologies. August 2014. Retrieved from: [www:dynamicspectrumalliance.org/assets/TVWS_Report_for_Kenya_final_final_24_Aug.pdf](http://www.dynamicspectrumalliance.org/assets/TVWS_Report_for_Kenya_final_final_24_Aug.pdf)
- Camillo, D. and Nicole, G. (2011). Methane digesters and biogas recovery - masking the environmental consequences of industrial concept. *Journal of Environmental Law & Poli*. Fall, 2011 Issue.
- Carey, J. & Elton, C. J. (2010). When Media Are New: Understanding the Dynamics of New Media Adoption and Use. *Page*, 17-20. Accessed on December 17, 2015 from <http://dx.doi.org/10.3998/nmw.8859947.0001.001> Accessed 17/12 /2015
- Cassie B., Dieo, M. Lee, J., & Jenifer A. (2010). *Methane Creation from Anaerobic Digestion .An Interactive Qualifying Project Report.*, Worcester polytechnic Institute.
- Chel, K. (2011). Renewable energy for sustainable agriculture. *Agronomy for Sustainable Development*, Spring, 31 (1), 91-118. Accessed on April 3, 2014 from www.researchgate.net/publication/46484530_Renewable_energy_for_sustainable_agriculture
- Chiavenato, I. (1983). *Introduction to general theory of administration* (3rd Ed.). São Paulo: McGraw-Hill do Brasil.

- Costa, F. P., & Rehman, T. (2005). Unravelling the rationale of 'overgrazing' and stocking rates in the beef production systems of Central Brazil using a bi-criteria compromise programming model. *Agricultural Systems*, 83, 277-295.
- Danielsen. K. (2012). "Gender Equality, women's rights and access to energy services: An inspiration paper in the run-up to Rio+20", Ministry of Foreign Affairs of Denmark
- Davis, D., Bagozzi, R. P., & Warsaw, P. R. (1989). User acceptance of computer technology: A comparison of two theoretical models. *Management Science*, 35, 982-1003.
- Daydé, C., Stéphane C., Frédérick G., & Roger M., C., (2014). *Investigating operational decision-making in agriculture*. International Environmental Modelling and Software Society (iEMSS) 7th Intl. Congress on Env. Modelling and Software, San Diego, CA, USA Daniel P. Ames, Nigel W.T. Quinn and Andrea E. Rizzoli (Eds.) <http://www.iemss.org/society/index.php/iemss-2014-proceedings>.
- Dengerink J. (2011). *Experiences with renewable energy in Uganda: A participatory evaluation of the Uganda Domestic Biogas Programme*. Unpublished Thesis: University of Amsterdam.
- Doss, C. (2001). How does gender affect the adoption of agricultural innovations? The case of improved maize technology in Ghana. *Agricultural Economics*, 25(1), 27-39. DOI: 10.1016/s0169-5150(00)00096-7
- Egbue, O. & Long, S. (2012). Barriers to widespread adoption of electric vehicles: An analysis of consumer attitudes and perceptions. *Energy Policy*, 48, 717-729. DOI: 10.1016/j.enpol.2012.06.009
- Eseonu C., I., and Egbue, O., (2014). Socio-Cultural Influences on Technology Adoption and Sustainable Development. *Proceedings of the 2014 Industrial and Systems Engineering Research Conference*, Y. Guan and H. Liao, eds., m
- EUROSERV'ER. (2012). Biogas Barometer. *le journal des énergies renouvelable*, 212, 66–79.
- FAO. (2000). *The Energy and Agriculture Nexus: Environment and Natural Resources*. Working Paper No. 4, Rome.
- FAO. (2006). *Livestock a major threat to environment; remedies urgently needed*. Available November 29, 2014 from: www.fao.org/newsroom/en/news/2006/1000448/index.html.
- FAO. (2009). *Enabling agriculture to contribute to climate change mitigation*. FAO, Rome. Food and Agricultural Organization (FAO), (2009). Enabling agriculture to contribute to climate change mitigation. FAO, Rome.
- FAO. (2011): Chap 3 *Documenting the Gender gap in Agriculture*; Women in agriculture: Closing the gender gap for development. The State of Food and Agriculture 2010-11:

- Fazio, R., H.; Williams, C. J. (1986). Attitude accessibility as a moderator of the attitude–perception and attitude–behaviour relations: An investigation of the 1984 presidential election. *Journal of Personality and Social Psychology*, 51(3), 505-514.
- Flett, R., Alpass, F., Humphries, S., Massey, C., Morris, S., and Long, N. (2004). *The technology acceptance model and use of technology in New Zealand dairy farming*. *Agricultural Systems*, 80(2), 199-211.
- Foote, E. M., Laura G., Tracy A., Ibrahim S., Sitnah H. F. ,Benjamin J. Silk, Adam L. Cohen, Were V. , James M. Hughes, Robert E. and Quick.(2013). Impact of Locally-Produced, Ceramic Cookstoves on Respiratory Disease in Children in Rural Western Kenya. *The American Journal of Tropical Medicine and Hygiene*, 88(1), 132-137.
- Frangos, A, Fern S., Yadama, G., and Bhatia, V. (2011). *Uptake of alternative energy technologies by energy poor households in rural Rajasthan, India*. In: Proceedings of the 29th International Conference of the System Dynamics Society, 2011, 24-28 July 2011, Washington DC. Lyneis JM, Richardson GP eds. Red Hook, NY: Curran Associates, 607–628
- Global Alliance for Clean Cookstoves (2014). Cook stove Technology. Washington, D.C.: GACC. Accessed on February 18, 2014 from <http://www.cleancookstoves.org/our-work/the-solutions/cookstove-technology.htm>
- Gathui, T., and Ngugi, W. (2010) - 2, *Bioenergy and Poverty in Kenya: Attitudes, Actors and Activities*. Working Paper. Practical Action Consulting.
- Gathui, T., Mugo, F., Ngugi, W., Wanjiru, H. and Kamau, S. (2011). *The Kenya Charcoal Policy Handbook*. Current regulations for a sustainable charcoal sector. Prepared for PISCES by Practical Action, Consulting East Africa
- Ghulam, M. and Malikyar, B. S. (2009). *Renewable Energy Technologies for Rural Development* .Mountain Development Resource Book for Afghanistan, The International Centre for Integrated Mountain Development (ICIMOD), GPO Box 3226, Kathmandu, Nepal. Published 2009.
- Gladwin, C. H. (1989). *Ethnographic decision tree modelling* (Vol. 19). Beverly Hills: Sage Publications.
- Godwin, U. and Guimarases T., (1994). Improving Organization Absorption of emerging Technologies: A socio-technical approach. *Information and Management*, 23, 207-213
- Goldemberg, J. (2000). Chair, *World Energy Assessment. Energy and the challenge of sustainability*. Communications Development Incorporated, Washington, D.C United

Nations Development Programme Bureau for Development Policy One United Nations Plaza New York, NY 10017

- GoK. (2007). *Kenya Vision 2030: A globally Competitive and Prosperous Kenya*. Ministry of Planning and National Development and Vision 2030. Government of Kenya (GoK): Nairobi.
- GoK. (2009). *Nyeri North District Development Plan 2008-2012*, Office of the Prime Minister, Ministry of state for planning, national development and vision 2030, Government Printer 2009.
- GoK. (2010) Ministry of Energy (2010a). *Feed-in-Tariffs for Renewable Energy Resource Generated Electricity Guide for Investors*, Nairobi: Government Printer
- GoK. (2012). *Scaling Up Renewable Energy Program (SREP). Investment Plan for Kenya*. (May). The Government Printers. Nairobi, Kenya.
- GoK (2016). Kenya Gazette Supplement No 68 Acts No 11. 13th May 2016, Climate Change Act 2016. Government Printers, Nairobi.
- Greiner, R., Patterson, L., and Miller, O. (2009). Motivations, risk perceptions and adoption of conservation practices by farmers. *Agricultural Systems*, 99(2-3), 86-104.
- GTZ. (2010). *Agro-Industrial Biogas in Kenya – Potentials, Estimates for Tariffs, Policy and Business Recommendations*. Study of Deutsches Biomasse Forschungs Zentrum (DBFZ) on behalf of GTZ, Renewable Energy Project Development Programme East Africa.
- Halwagi, E., and Mahmoud, M. (Ed.) (1986). *Biogas Technology, Transfer and Diffusion Elsevier Applied Science Publishers LTD Crown House, Linton Road, Barking, Essex. IGII 8JU, England*
- Hazra, S., Jessica, L., Ipsita, D. and Ashok, K. S. (2014). Anaerobic Biogas Generation for Rural Area Energy Provision in Africa. *SANDEE's Policy Brief Series, Number 80-14*.
- Hazra, S., Jessica, L., Ipsita, D. and Ashok, K. S. (2014). *Intergovernmental Panel on Climate Change, Press Release, and Potential of Renewable Energy Outlined in Report by the Intergovernmental Panel on Climate Change, 2011*
- Hazra, S., Jessica, L., Ipsita, D. and Ashok, K. S. (2014). *Adoption and Use of Improved Stoves and Biogas Plants in Rural India* (South Asian Network for Development and Environmental Economics SANDEE Working Papers, ISSN 1893-1891; WP 86–14) Kathmandu, Nepal
- Helmke, G., and Levitsky, S. (2004). Informal Institutions and Comparative Politics: A Research Agenda. *Perspectives on Politics*, 2(04), 725-740. DOI: 10.1017/s1537592704040472

- Heywood, A. (2000). *Key Concepts in Politics*. Palgrave Macmillan, Basingstoke, England.
- Hivos (2009). Africa Biogas Partnership Initiative. Accessed on February 24- 2014 from <http://www.hivos.nl/eng/community/partner/10009895>
- Hofstad, O, Köhlin G, and Namaalway F. (2009). *How can emissions from wood fuel be reduced?* In: Realising REDD+: National Strategy and Policy Options (Angelsen A, Brockhaus M, Kanninen M, Sills E, Sunderlin WD, Wertz-Kanounnikoff S, eds). Bogor, Indonesia: Centre for International Forestry Research, 237–248.
- Horta, A., Wilhite, H., Schmidt, L. and Bartiaux, F. (2014). Socio-Technical and Cultural Approaches to Energy Consumption. *An introduction to Nature and Culture* 9 (2), 115–121.
- Howley, P., Donoghue O., Cathal, H., & Kevin, K. (2016). Factors Affecting Farmers' Adoption of Agricultural Innovations: A Panel Data Analysis of the Use of Artificial Insemination among Dairy Farmers in Ireland. *Journal of Agricultural Science*, 4(6), 171-189.
- IEA. (International Energy Agency) World Energy Outlook 2011, Global Energy Assessment.
- IEA. (International Energy Agency). World Energy Outlook 2006. Organization.
- IEA. and OECD. (2006). Energy for cooking in developing countries- Chapter 15. Retrieved from [/www.iea.org/publications/freepublications/publication/cooking.pdf](http://www.iea.org/publications/freepublications/publication/cooking.pdf)
- IFAD. (2012), Livestock and renewable energy, livestock thematic papers. The International Fund for Agricultural Development (IFAD).
- IFAD (2010). KENYA Environmental and Climate Change Assessment Prepared for IFAD's Country Strategic Opportunities Programme 2013-2018. East and Southern Africa Division Environment and Climate Division Programme Management Department.
- IPCC (2000). Land Use, Land Use Change and Forestry. A special report of the IPCC, Cambridge University Press, Cambridge.
- Ishara Mahat (2011) Gender, energy, and empowerment: a case study of the Rural Energy Development Program in Nepal, *Development in Practice*, 21:3, 405-420, DOI: 10.1080/09614524.2011.558062
- Josue D. (2005), Director, Food Security and Sustainable Division, Economic Commission for Africa United Nations Economic Commission for Africa Sustainable Development Report on Africa *Managing Land-Based Resources for Sustainable Development*
- Kadlec, J. E. (1985). Farm management: decisions, operation, control. Englewood Cliffs, N.J.: Prentice-Hall.

- Kahan, D., (2013): *The role of the farm management specialist in extension*. Retrieved from <http://www.fao.org/uploads/media/6-SpecialistInternLores.pdf>
- Karekezi, S. (2014). (AFREPREN/FWD, Kenya), McDade, S., (UNDP) Boardman B., (University of Oxford, UK), Kimani J., (AFREPREN/FWD, Kenya. Lustig N., (Tulane University, USA. *Global energy assessment (GEA). Toward a Sustainable Future Chapter 2 - Energy, Poverty, and Development. pp. 151-190*. Cambridge University Press.
- Karekezi, S., and Majoro, L. (2002). Improving modern energy services for Africa's urban poor. *Energy Policy*, 30(11-12): 1015-1028. DOI: 10.1016/s0301-4215 (02)00055-1
- Kariuki. M. (2013). Access to Energy as a Constitutional Right in Kenya. Center for Advanced Studies in Environmental Law & Policy (CASELAP), University of Nairobi Concept Paper. November 2013 Accessed on 31st July 2014.
- Kathleen C., and Gale, C. (2009). Training for Rural Development: Agricultural and Enterprise Skills for Women Smallholders. *City & Guilds Centre for Skills Development: 24-30*.
- Kay, R. D., Edwards, W. M., & Duffy, P. A. (2008). *Farm management* (6 ed.). New York: McGraw-Hill.
- Kenya Institute for Public Policy Research and Analysis (KIPPRA) (2010). A Comprehensive Study and Analysis on Energy Consumption Patterns in Kenya. A Synopsis of the Draft Final Report. 2nd Floor, Bishops Garden Towers, Bishops Road Nairobi Kenya.
- Kenya National Domestic Biogas Programme (KENDIP) (2014). Report for 2009 -2013. Annual Report. Nairobi, Kenya.
- Kenya National Domestic Biogas Program (KENDBIP). (2015). Annual Report. Nairobi, Kenya.
- Kenya Forest Working Group (2005). Changes in Forest cover in Kenya's five "water Towers" 2003-2005 (www.kfwg.org accessed on 3/10/2014).
- Kenya Open Data (2011) Accessed from www.opendata.go.ke on 17/2/2015
- Khoiyangbam, R. (2008). Greenhouse Gases Emission from Energy Production in Conventional Biogas Plants in India. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, 30(8), 689-697. DOI: 10.1080/15567030601082118
- Ki-moon, B. (2011). *Sustainable Energy for All: A Vision Statement*. United Nations Organization, New York. Accessed from February 21, 2014 from www.sustainableenergyforall.org
- Kileo, J., O. and Akyoo, A. M. (2014). Technology Transfer and Farm-based Renewable Energy Sources: *The Potential of Biogas Technology for Rural Development in Tanzania*. NAF

International working Paper Series 2014 paper 14/2 Accessed on September 14, 2014
from <http://economia.unipv.it/naf/>

- Kimenye, L. (2005). Understanding Low Rates of Technology Adoption by Women Farmers: A Case Study of the Determinants of Adoption of Improved Sorghum Varieties by Women Farmers in Mbeere District, Kenya. *Journal of Agriculture, Science and Technology*, 3(1). DOI: 10.4314/jagst.v3i1.31687
- Kimuyu, P, Mutua J, and Wainaina, J., (2012) ,The role of renewable energy in promoting inclusive and sustainable development in Kenya a background paper to the European Report on Development 2011/2012: *Confronting scarcity: Managing water, energy and land for inclusive and sustainable growth*. School of Economics, University of Nairobi.
- King, W. R. and He, J. (2006). A meta-analysis of the technology acceptance model. *Information & Management*, 43, 740-755. doi:10.1016/j.im.2006.05.003
- Kituyi, E. (2009). Feasibility Assessment for the Preparation of a Carbon Trading Biogas Project. Retrieved on February 27, 2014 from http://www.biogas.org.uk/images/upload/news_7_Bio-SNG-Feasibility-Study.pdf
- Köhlin, G., Sills, E. O., Pattanayak, S. K., and Wilfong, C. (2011). Energy, Gender and Development. Policy Research Working Paper, No. WPS 5800. Washington, DC: Social Dimensions of Climate Change Division, World Bank.
- Kossmann, W., Pönitz, U., Habermehl, S., Hoerz T, Kramer, P., Klingler B., Kellner, C., Wittur, T., Klopotek F. Krieg, A., and Euler, H. (1999.) Biogas Digest Volume I Biogas Basics Information and Advisory Service on Appropriate Technology (ISAT). GTZ and ISAT (undated). Accessed on March 31, 2015 from <http://www.gtz.de/de/dokumente/en-biogas-volume1.pdf>
- Lauterbach, C. and Zuckerman, E. (2013): Assessing the effectiveness of World Bank investments: The gender dimension, WIDER Working Paper, No. 2013/017, ISBN 978-92-9230-594-9
- Lee, C. and Chang, P. (2008). Energy consumption and economic growth in Asian economies: a comprehensive analysis using panel data. *Resource and Energy Economics* 30: 50–65.
- Leidner, D E, Kay worth, T. (2008). Business & Economics .Global Information System.: 252 Retrieved on April 12, 2014 from <https://books.google.com/books?isbn=1136400591>
- Lekhanya, L. M. (2013). Cultural influence on the diffusion and adoption of social media technologies by entrepreneurs in rural South Africa. *The International Business & Economics Research Journal (Online)*, 12(12), 1563.

- Levine D.S., and Strube M. J., (2012). Environmental attitudes, knowledge, intentions and behaviours among college students. , *J Soc Psychol.*, 152(3):308-26.
- Lewis, J. J., and. Pattanayak, S. K (2012). “Who adopts improved fuels and cook stoves”? A systematic review. *Environmental Health Perspectives*, 120(5), 637-45.
- Lin, C. H., Shih, H. Y., and Sher, P. J. (2007). *Integrating technology readiness into technology acceptance: The TRAM model. Psychology & Marketing*, 24, 641-657. doi:10.1002/mar.20177
- Lin, C. H., Shih, H. Y., Sher, P. J., and Wang Y. L. (2005). Consumer adoption of e-service: Integrating technology readiness with the technology acceptance model. *Proceedings of PICMET '05: Technology Management: A Unifying Discipline for Melting the Boundaries, Portland, Oregon, USA*, 483-488. doi:10.1109/PICMET.2005.1509728
- Liu, E., (2013). “Time to Change What to Sow: Risk Preferences and Technology Adoption Decisions of Cotton Farmers in China” *The Review of Economics and Statistics*, 95(4): 1386–1403
- Marra, M., Pannell, D. J., and Ghadim, A. (2003). The economics of risk, uncertainty and learning in the adoption of new agricultural technologies: where are we on the learning curve? *Agricultural Systems*, 75(2-3), 215-234.
- Mattis, M. Seashore, K., Kenneth, L., Wahlsrom, K, L., and Anderson, S. E. (2010). *Learning from Leadership: Investigating the Links to Improved Student Learning Final Report of Research to the Wallace Foundation July 2010 at www.wallacefoundation.org.*
- Mati, B, Mulinge, W., Adgo, E., Kajiru, G., Nkuba, J., and Akalu, T (2011). "Rainwater harvesting improves returns on investment in smallholder agriculture in Sub-Saharan Africa", *Integrated Watershed Management in Rain fed Agriculture.*
- Matsumoto, D. (2007). Culture, Context, and Behaviour .San Francisco State University *Journal of Personality* 75, 6. DOI: 10.1111/j.1467-6494.2007.00476.x
- Merriam-Webster (Ed.). (2011). *Dictionary and Thesaurus: Merriam-Webster Online.* Springfield: Merriam-Webster.
- Michelle, B. (2012.) Under-Secretary-General and Executive Director, UN Women. *The Future Women Want; A Vision of Sustainable Development for All.*
- Miller, G. and Mobarak, M. (2013). *Gender Differences in Preferences, Intra-household Externalities, and the Low Demand for Improved Cook stoves.* Working Paper. Standard Medical School and Yale School of Management.

- Money, W., and Turner, A. (2005). Assessing Knowledge Management System User Acceptance with the Technology Acceptance Model. *International Journal of Knowledge Management*, 1(1), 8-26. DOI: 10.4018/jkm.2005010101
- Mpele L., and Lawrence, K. (2013). Cultural Influence on the Diffusion and Adoption of Social Media Technologies by Entrepreneurs in Rural South Africa. *International Business & Economics Research Journal*, 20(3), 234-245.
- Mulinda, C., Qichun H. and Ke, P. (2013). *Dissemination and Problems of African Biogas Technology Biogas*. Institute of Ministry of Agriculture, Chengdu, China
- Mwakaje, A. (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.
- Mwakaje, A. G. (2012). *Dairy Farming and the Stagnated Biogas Use in Rungwe District, Tanzania: An Investigation of the Constraining Factors*, Biogas, Dr. Sunil Kumar (Ed.), ISBN: 978-953-51-0204-5, In Tech, Retrieved on April 4, 2014 from <http://www.intechopen.com/books/biogas/the-stagnated-biogas-use-in-rungwe-district-what-is-the-cause>.
- Mwirigi, J. W. Makenzi, 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*, 13: 106–115
- Myles, R. (2007). *Empowering Rural Poor Women by Enhancing Income through Biogas Plant by Inseada and Wafid in Bhartapur, India* Secretary General-Cum-Chief Executive, Inseada and Regional Coordinator, Inforce, South Asia
- Nachmias, Seem, J., D., and Nachmias, C. (1988). Research Methods in the Social Sciences. *Teaching Sociology*, 16(2), 217. Accessed on May 10, 2014 from <http://dx.doi.org/10.2307/1317432>
- Napier, T. L. and Napier, A. S. (1991). Perceptions of conservation compliance among farmers in a highly erodible area of Ohio. *Soil Water Conservation*, 48(3): 220–224.
- Ngugi A. (2007), Biogas for better life. October 2007: An African initiative Promoting Biogas Systems in Kenya. A feasibility Study.
- Nowak, P. J. and Korsching, P. J., (1983). *Social and institutional factors affecting the adoption and maintenance of agricultural BMPs*. In: Schaller, F., Bauley, H. (Eds.), *Agricultural Management and Water Quality*. Iowa State University Press, Ames, IA. pp. 349-373.
- Nuthall, P. (2010) *Farm Business Management; The human Factor*. ISBN 13:978-84593-598-6 CPI Antony Rowe UK .Oxford shire: Cabi.

- OECD. (2015). *Contribution to the United Nations Commission on Sustainable Development* (Uncsd-15) Energy for Sustainable Development – 222 Rosewood Drive Danvers, MA 01923, USA,
- O'Mara, F. (2004). Greenhouse gas production from dairying: reducing methane production. *Advances in Dairy Technology*, 16:295-309
- Ohlmer, B. (1998). Understanding farmers' decision making processes and improving managerial assistance. *Agricultural Economics*, 18(3): 273-290. Accessed on March 10, 2013 from [http://dx.doi.org/10.1016/s0169-5150\(97\)00052-2](http://dx.doi.org/10.1016/s0169-5150(97)00052-2)
- Okello, C., Pindozi, S., Fugna, S., and Boccia, L. (2013). Development of bioenergy technologies in Uganda: A review of progress. *Renewable and Sustainable Energy Reviews*, 18: 55-63.
- Olson, K. D. (2003). *Farm management: principles and strategies*. Ames, Iowa: Iowa State Press.
- Oreszczyn, S., Lane, A., & Carr, S. (2010). The role of networks of practice and webs of influencers on farmers' engagement with and learning about agricultural innovations. *Journal of Rural Studies*, 26(4), 404-417. Retrieved on April 24, 2014 from <http://dx.doi.org/10.1016/j.jrurstud.2010.03.003>
- Osak, R. F, Hartono B., Fanani Z. and Utami H. D. (2015). Biogas and bioslurry utilization on dairy-horticulture integrated farming system in Tukur Nongkojajar, District of Pasuruan, and East Java, Indonesia. *Livestock Research for Rural Development. Volume 27, Article #65*. Retrieved January 30, 2016, from <http://www.lrrd.org/lrrd27/4/osak27065.htm>
- Parasuraman, A. (2000). Technology readiness index (TRI): A multiple-item scale to measure readiness to embrace new technologies. *Journal of Service Research*, 2, 307-320.
- Parawira, W. (2009). Biogas technology in sub-Saharan Africa: status, prospects and constraints. *Reviews in Environmental Science and Bio/Technology*, 8(2), 187-200. DOI: 10.1007/s11157-009-9148-0
- Parvan, A. (2011). *Agricultural technology Adoption: Issues for consideration when scaling up* Accessed on July 3, 2013 from <http://blogs.cornell.edu/policyreview/2011/07/01/agricultural-technology-adoption-issues-for-consideration-when-scaling-up/>
- Pegels, A. (2009). *Prospects for renewable energy in South Africa mobilizing the private sector*. Discussion Paper.
- Pereira, M. A., (2011). *Understanding technology adoption and non-adoption: A case study of innovative beef farmers from Mato Grosso do Sul State, Brazil*. Unpublished Master

Thesis: Fohn University. Accessed on June 20, 2016 from <https://www.researchgate.net/publication/277191750>

Petty, R., E., and Krosnick, J. A. (1995). *Attitude strength: Antecedents and consequences*. Hillsdale, NJ: Erlbaum.

Pew Research Center, (2008). *Women Call the Shots at Home; Public Mixed on Gender Roles in Jobs*. Galworth publishers, Illinois.

Phiri, H. (2007). *The role of credit in the adoption and use of improved dairy technologies in Malawi: A Case of Central and Northern Milk shed Areas*. Unpublished Student Thesis: Bunda College, Malawi.

Porter, C. E. and Donthu, N. (2006). Using the technology acceptance model to explain how attitudes determine internet usage: The role of perceived access barriers and demographics. *Journal of Business Research*, 59, 999-1007. DOI: 10.1016/j.jbusres.2006.06.003

Practical Action. (2012). *Poor people's energy outlook: Energy for earning a living*, Practical Action Publishing, Rugby, UK. Accessed on December 3, 2014 from <http://policy.practicalaction.org/policy-themes/energy/poor-peoples-energy-outlook/poor-peoples-energy-outlook-2012>

Prakash, C. G. (2007). *Asia/Africa Biogas Programme Netherlands Development Organisation (SNV). Final Report on Technical Study of Biogas Plants Installed in Pakistan*.

Rambo, M.C, (2013). Renewable energy project financing risks in developing countries: Options for Kenya towards the realization of vision 2030. *Int. J. Bus. Financ. Manage. Res.*, 1(1): 1-10.

Rehman, I., Bhojvaid, V., Jeuland, M., Kar, A., Lewis, J. J., Pattanayak, S. K., Ramanathan, N., H. (2014). How do People in Rural India Perceive Improved Stoves and Clean Fuel? *Evidence from Uttar Pradesh and Uttarakhand*, 33, 1341–1358. DOI: 10.3390/ijerph110201341

Renwick, M., Sagar P., Subedi and Hutton G. (2007). *Biogas for Better Life: An African Initiative; A Cost-Benefit Analysis of National and Regional Integrated Biogas and Sanitation Programs in sub-Saharan Africa*. Winrock International.

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

Republic of Kenya (2013). *Nyeri County Integrated development plan Kenya; Towards a Competitive and Prosperous County*. Nairobi: Government Printers.

- Rezvanfar, A., Eraktan, G., Olhan, E. (2011). Determine of factors associated with the adoption of organic agriculture among small farmers in Iran. *African Journal of Agricultural Research*, 6(13): 2950-2970.
- Robelia, B., & Murphy, T. (2012). What do people know about key environmental issues? A review of environmental knowledge surveys. *Environmental Education Research*, 18(3), 299-321.
- Rogers, E. M. (1962) *Diffusion of Innovations*. First Edition. New York: Free Press.
- Rogers, E.M. (1995). *Diffusion of Innovations*. New York: Free Press.
- Ross, F., Fiona, A., Humphries, S., Claire, M., Stuart, M. and Nigel, L., (2004). The technology acceptance model and use of technology in New Zealand dairy farming. *Agricultural Systems*, 80:199–211.
- ShiChao, W., WeiLi, L., GuiYan, W., Hong Zhan, L. (2011). Analysis of farmers' willingness to adopt small scale household biogas facilities. *Chinese Journal of Eco-Agriculture*, 19(3): 718-722.
- Smith, J. and Scherr, S. J., (2002). *Forest carbon and local livelihoods: Assessment of opportunities and policy recommendations*, CIFOR Occasional Paper no. 37, Bogor Barat, Indonesia.
- Smith, J.U (2012) *The Potential of small-scale biogas digesters to improve livelihoods and long term sustainability of ecosystem services in sub-Saharan Africa*. University of Aberdeen, Institute of Biological and Environmental Science. Retrieved from: <http://r4d.dfid.gov.uk/Output/191841/Default.aspx>
- SNV (2007). *SNV. and FMO. Provide Bio-Digesters and Micro Loans to Farmers in Cambodia*. Netherlands Development Organisation (SNV). . Accessed on March 12, 2014 from www.snvworld.org/en/aboutus/news/Pages/Bio%20digesters%20for%20Cambodian%20farmers.aspx
- SNV (2010). Paper for UNCTAD Expert Meeting on Green and Renewable Technologies as Energy Solutions for Rural Development, Geneva. Accessed on February 9, 2010 from https://www.ctc-n.org/sites/www.ctc-n.org/files/resources/biogas_support_programme_nepal_2010.pdf
- Steinfeld, H., Gerber, P., Wassenaar, T., Castel, V., Rosales, M. and de Haan. C. (2006). *Livestock's long shadow: environmental issues and options*. Food and Agriculture Organization: Geneva.

- Sulo, T., Koech P., Chumo, C. and Chepng'eno, W. (2012). Socioeconomic Factors Affecting the Adoption of Improved Agricultural Technologies among Women in Marakwet County Kenya. *Journal of Emerging Trends in Economics and Management Science*, 3(4): 312-317.
- Szerszynski, B., & Urry, J. (2010). Changing Climates: Introduction. *Theory, Culture & Society*, 27(2-3), 1-8
- The World Bank Group. (2009). Energy Strategy Approach Paper. Sustainable Development Network .Washington, DC.
- Triandis, H. C. and Eunkook, M. S. (2002). Cultural Influences on Personality *Annu. Rev. Psychol.*, 53:133–60.
- Triandis, H. (2002). Subjective Culture. *Online Readings in Psychology and Culture*, 2(2), 24-32. DOI: 10.9707/2307-0919.1021
- UN. (2010). Advisory Group on Energy and Climate Change (AGECC) 2010, summary report: *energy for a sustainable future: Report and recommendations*. New York, NY
- UN/FAO. (2014). Asian Development Bank, “Gender Equality and Food Security” www.adb.org/publications/gender-equality-and-food-security-womens-empowerment-tool-against-hunger?ref=sectors/agriculture/publications Accessed on 8/11/2015
- UN (2012). Sustainable Energy for All. United Nations: New York. Accessed on December 15, 2014 from <http://UnitedNations.Sustainableenergyforall.org>
- UN. (2010): *The Millennium Development Goals Report*. United Nations (UN), New York
- UNDP and WHO (2008). Report adopted by the International Conference on Renewable energy in Africa. UNDP: New York.
- UNDP. (2012). Gender and energy, Policy brief 3-Gender and Climatic change -Africa United Nations Development Programme. UNDP: New York, NY.
- UNDP. (2015) -Sustainable energy for all-*the Secretary-General's Advisory Group on Energy and Climate Change (AGECC)*. UNDP: New York, NY.
- UNDP and WHO. (2009). *The Energy Access Situation in Developing Countries, A Review Focusing on the Least Developed Countries and Sub-Saharan Africa* .United Nations: New York, NY .
- UNDP. (2006). *Energizing Poverty Reduction. A Review of Energy-Poverty Nexus in Poverty Reduction Strategy Paper*. United Nations Development Programme (UNDP), New York, NY.

- UN-Energy/Africa. (2011). Energy for sustainable development: Policy Options for Africa. Publication to CSD15
- UNEP. (2011). *Global Trends in Renewable Energy' Analysis of Trends and Issues in the Financing Renewable Energy*, Investment Report 2011, and Nairobi: UNEP.
- UNFCCC. (2008). Report of the conference of the parties serving as the meeting of the parties to the Kyoto Protocol on its first session. New York, NY
- UNIDO. United Nations Industrial Development Organization. (2010). *Scaling up Renewable Energy in Africa*. 12th Ordinary Session of Heads of State and Governments of the African Union, Addis Ababa, Ethiopia. Vienna: UNIDO.
- Uppuluri, A. F., .Rupal, S., Devon, T., and Weatherill, M. (2008). *Sustainable Energy for Rural India Bhudapada Village A Case Study*. Student Master's Thesis, University of Michigan.
- United States Environmental Protection Agency. (2014). AgStar Biogas Recovery System Accessed on 23 /3 2014 from http://epa.gov/agstar/documents/biogas_recovery_systems_screenres.pdf
- Vale, S. M. L. R., and Mâncio, A. B. (2005b). Human resource management in beef cattle farms at Triângulo Mineiro region. Paper presented at the International Farm Management Association Conference, Campinas, Brazil
- Wake, J. L., Kiker, C. F., and Hildebrand, P. E. (1988). Systematic learning of agricultural technologies. *Agricultural Systems*, 27:179-193.
- Wakhungu, J. W. (2010). Gender Dimensions of Science and Technology: African Women in Agriculture. African Centre for Technology Studies, Nairobi, Kenya.
- Waris, V. S. and. Prakash, C. A. (2014). Fuelwood Scarcity, Poverty and Women: Some perspectives. *IOSR Journal of Humanities and Social Science*, 19(8), 21-33. Retrieved December 19, 2015 from <http://www.iosrjournals.org>
- Warriner, G. K., and Moul, T. M. (1992). Kinship and personal communication network influences on the adoption of agriculture conservation technology. *Journal of Rural Studies*, 8(3), 279-291.
- Watson, J. (2001). *How to Determine a Sample Size: Tip-sheet #60*, University Park, PA: Penn State Cooperative Extension. .Accessed on March 30, 2014 from <http://www.extension.psu.edu/evaluation/pdf/TS60.pdf>
- Wawa, A., I. (2012). *The Challenges of Promoting and Adopting Biogas Technology as Alternative Energy Source in Semi-Arid Areas of Tanzania: The Case of Kongwa and*

- Bahi Districts of Dodoma Region*. Unpublished PhD Thesis: The Open University of Tanzania.
- WDR. World Development Report (2012). SPREAD 2. *The decline of the breadwinner: Men in the 21st century*, WDR 2012 team calculations, based on “Defining Gender in the 21st Century: A Multi-Country Assessment” (dataset)
- WHO. (2007). *Indoor air pollution: national burden of disease estimates*. World Health Organization (WHO): Geneva.
- WHO. (2009). *Global Health Risks: Mortality and Burden of Disease Attributable to Major Risks*. Geneva: World Health Organization.
- Wilk, R. R. (2006). *Culture and Energy Consumption*. Anthropology Department Indiana University Bloomington, Indiana
- Wingenbach, G. and Bielecki, C. (2014). Rethinking improved cook stove diffusion programs: A case study of social perceptions and cooking choices in rural Guatemala. *Energy Policy* 66: 350-358.
- Winkler, H. (2005). Renewable energy policy in South Africa: Policy options for renewable electricity. *Energy Policy*, (33): 27-38.
- Wirth, S. Markard, J., Truffer, B., and Rohrer, H. (2013). Informal institutions matter: *Professional culture and the development of biogas technology Environmental Innovation and Societal Transitions* 8 (2013)20–41. Retrieved from www.elsevier.com/locate/eist, <http://dx.doi.org/10.1016/j.eist.2013.06.002>
- World Bank. (2015). Progress toward Sustainable Energy-Global Tracking Framework 2015 Retrieved from: <http://trackingenergy4all.worldbank.org/>
- World Bank. (2011). *Household Cook stoves, Environment, Health, and Climate Change: A New Look at an Old Problem*. Washington, DC: World Bank.
- World Energy Outlook (2006). Focus on key Topics *Chapter 15-energy for cooking in developing countries*.
- World Watch Institute (2014). *State of the World Series*. Hackman, Geneva.
- Xi Yu, Getu H., and Jessica C., (2014). *Risk Attitudes, Social Interactions and the Adoption of Genotyping in Dairy Production* Selected Paper Prepared for Presentation at Agricultural and Applied Economics Association’s 2014 AAEE/EAAE/CAES Joint Symposium “Social Networks, Social Media and the Economics of Food”, Montreal, Quebec, Canada, May 28-30, 2014.
- Yehuala, S. (2008). *Determinants of smallholder farmer’s access to formal credit: the case of Metema Woreda, North Gondar, ETHIOPIA*. Student thesis Haramaya University.

- Yu, L., Yaoqiu, K., Ningsheng, H., Zhifeng, W., & Lianzhong, X. (2008). Popularizing household-scale biogas digesters for rural sustainable energy development and greenhouse gas mitigation. *Renewable Energy*, 33(9), 2027-2035
- Zia, S., Ahmad, F., Anil, C. N., Gurung, M. B. and Leduc, B. (2009). *Working with Mountain Communities .Mountain Development Resource Book for Afghanistan*. The International Centre for Integrated Mountain Development (ICIMOD): Nepal.

APPENDICES

Appendix 1. Regression result of the influence of Farmers characteristics on adoption of Biogas Technology

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
3	(Constant)	.960	.124		7.716	.000
	Age	.058	.013	.234	4.458	.000
	GENDER	-.138	.041	-.172	-3.336	.001
	Educational levels	.072	.027	.142	2.700	.007

a Dependent Variable: state of adoption

This gives a regression equation of; a Dependent Variable: state of adoption

a: Predictors: (Constant), Age

b: Predictors: (Constant), Age, GENDER

c: Predictors: (Constant), Age, GENDER, Educational levels

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3$$

$$Y = 0.960 + 0.234X_1 - 0.172X_2 + 0.142X_3$$

Where

β_0 - Constant

Y- BGT Adoption

X_1 –Age of the farmer

X_2 – Gender of the farmer

X_3 – Education level

Appendix 2. Regression result of the influence of sources of firewood, lighting availability and consistency on adoption of Biogas Technology
Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.468(a)	.219	.216	.33237

a Predictors: (Constant), cooking energy source

This gives a regression equation of;

$$Y = \beta_0 + \beta_1 X_1$$

$$= 0.945 + 0.468X_1$$

Where Y- BGT Adoption

β_0 - Constant

X_1 – Cooking energy source

Coefficients (a)

Model		Un standardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.945	.029		32.208	.000
	cooking energy source	.119	.012	.468	9.681	.000

a Dependent Variable: state of adoption

Appendix 3. Regression analysis on the Socio cultural factors influencing the adoption of Biogas technology
Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.241(a)	.058	.055	.36366
2	.326(b)	.106	.101	.35480
3	.366(c)	.134	.126	.34987
4	.392(d)	.154	.143	.34634
5	.410(e)	.168	.155	.34397
6	.423(f)	.179	.164	.34217

Coefficients (a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
6	(Constant)	.769	.078		9.910	.000
	limited number of livestock	.060	.013	.238	4.528	.000
	Poor understanding of biogas concepts	.041	.015	.161	2.682	.008
	lack of harmony among family members	-.034	.012	-.154	-2.959	.003
	Extension Officers failure to spend time with farmers	.037	.015	.134	2.491	.013
	Lack of education and technological skills	.020	.010	.120	2.125	.034
	Low participation of women in leadership	.028	.013	.110	2.097	.037

a Dependent Variable: state of adoption

The regression equation therefore;

$$Y = \beta_1 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6$$

Y- BGT Adoption

β_1 - Constant

X_1 – limited number of livestock

X_2 – Poor understanding of Biogas concept

X_3 – Lack of harmony among family members

X_4 - Extension Officers failure to spend time with farmers

X_5 – lack of education and technological skills

X_6 - Low participation of women in leadership

Appendix 4. Correlations relationship between the age and adoption of biogas Technology

		state of adoption	Age
state of adoption	Pearson Correlation	1	.218**
	Sig. (2-tailed)		.000
	N	351	351
Age	Pearson Correlation	.218**	1
	Sig. (2-tailed)	.000	
	N	351	351
**. Correlation is significant at the 0.01 level (2-tailed).			

Appendix 5: Regression analysis on factors having influence by the respondents in Biogas Technology adoption

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.215(a)	.046	.043	.38654
2	.264(b)	.070	.064	.38233

a Predictors: (Constant), Extension Officers failure to spend time with farmers

b Predictors: (Constant), Extension Officers failure to spend time with farmers, Lack of education and technological skills

Coefficients (a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.063	.038		27.742	.000
	Extension Officers failure to spend time with farmers	.063	.015	.215	4.060	.000
2	(Constant)	1.003	.043		23.347	.000
	Extension Officers failure to spend time with farmers	.057	.015	.196	3.709	.000
	Lack of education and technological skills	.028	.010	.154	2.921	.004

a Dependent Variable: state of adoption

Appendix 6: Source of firewood * Availability and consistency of fuel wood Cross tabulation

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	237.738 ^a	9	.000
Likelihood Ratio	157.080	9	.000
Linear-by-Linear Association	82.244	1	.000
N of Valid Cases	279		

a. 5 cells (31.3%) have expected count less than 5. The minimum expected count is .91.

Appendix 7: Source of firewood * money spent

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	128.397 ^a	12	.000
Likelihood Ratio	154.668	12	.000
Linear-by-Linear Association	31.567	1	.000
N of Valid Cases	280		

a. 5 cells (25.0%) have expected count less than 5. The minimum expected count is 2.70.

Symmetric Measures					
		Value	Asymp. Std. Error ^a	Approx. T ^b	Approx. Sig.
Interval by Interval	Pearson's R	.024	.041	.455	.649 ^c
Ordinal by Ordinal	Spearman Correlation	.081	.046	1.519	.130 ^c
N of Valid Cases		351			
a. Not assuming the null hypothesis.					
b. Using the asymptotic standard error assuming the null hypothesis.					
c. Based on normal approximation.					

Appendix 8: Cross tabulation on source of firewood*availability and consistency on fuel wood

Source of firewood	Availability and consistency of fuelwood				Total
	Adequate	Inadequate	Very scarce	N/A	

Trees in the homestead	80	71.4%	28	25.0%	1	0.9%	3	2.7%	112
Nearby Forest	15	24.6%	39	63.9%	7	11.5%	0	0.0%	61
Purchasing from vendors	13	14.6%	68	76.4%	8	9.0%	0	0.0%	89
N/A	1	5.9%	4	23.5%	0	0.0%	12	70.6%	17
Total	109	39.1%	139	49.8%	16	5.7%	15	5.4%	280

Appendix 9: Cross tabulation; Fuel source and the amount of money spent on fuel by the farmers – (Ksh)

Source of fuel	100-199	200-299	300-399	400-499	>500	Total
Trees in the homestead	55 (49.1%)	25 (22.3%)	15 (13.4%)	6 (5.4%)	11 (9.8%)	112
Nearby forest	7 (11.5%)	8 (13.1%)	11 (18.0%)	14 (23.0%)	21 (34.4%)	61
Purchasing from vendors	0 (0.0%)	6 (6.7%)	19 (21.3%)	22 (24.7%)	42 (47.2%)	89
N/A	14 (77.8%)	3 (16.7%)	1 (5.6%)	0 (0.0%)	0 (0.0%)	18
Total	76 (27.1%)	42 (15.0%)	46 (16.4%)	42 (15.0%)	74 (26.4%)	280

Appendix 10: Correlation table for the challenges to adoption of BGT

Challenges		State of adoption
Lack of education and technological skills	Pearson Correlation	.180(**)
	Sig. (2-tailed)	.001
Ineffectiveness of Community Development Officers	Pearson Correlation	.198(**)
	Sig. (2-tailed)	.000
Extension Officers failure to spend time with farmers	Pearson Correlation	.228(**)
	Sig. (2-tailed)	.000

Limited land for installation	Pearson Correlation	.178(**)
	Sig. (2-tailed)	.001
Poor marketing policies	Pearson Correlation	.069
	Sig. (2-tailed)	.196
Positive publicity and marketing	Pearson Correlation	.047
	Sig. (2-tailed)	.385
	N	342

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

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

Appendix 11: Regression Analysis on the state of adoption by extension officers and lack of education and technological.

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2.466	1	2.466	16.580	.000 ^b
	Residual	50.871	342	.149		
	Total	53.337	343			
2	Regression	3.724	2	1.862	12.796	.000 ^c
	Residual	49.614	341	.145		
	Total	53.337	343			

a. Dependent Variable: state of adoption

b. Predictors: (Constant), Extension Officers failure to spend time with farmers

c. Predictors: (Constant), Extension Officers failure to spend time with farmers, Lack of education and technological skills

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	1.061	.038		27.801	.000
1 Extension Officers failure to spend time with farmers	.063	.015	.215	4.072	.000
(Constant)	1.002	.043		23.397	.000
2 Extension Officers failure to spend time with farmers	.057	.015	.196	3.719	.000
Lack of education and technological skills	.028	.010	.155	2.940	.004

a. Dependent Variable: state of adoption

Appendix 12: Chi-square Results on the relationship between mode of stock keeping and adoption of biogas technology

Chi-Square Tests			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	43.677 ^a	3	.000
Likelihood Ratio	47.120	3	.000
Linear-by-Linear Association	.207	1	.649
N of Valid Cases	351		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 6.47.

Appendix 13: Cross tabulation Mode of Stock keeping * state of adoption

Mode of Stock keeping	state of adoption		Total
	None BGT adopters	B GT adopters	

free range	137	16	153
zero grazing	55	39	94
Paddock /tethering	56	16	72
N/A	32	0	32
Total	280	71	351

Appendix 12: Budget

Item description	cost
Writing and production of research proposal	
Transport and subsistence for researcher	7,000
Research assistant's training @ 1000 per day for 2	2,000
pilot testing	5,000
Sub total	14,000
Field work	
Stationery(pens and note books)	5,000
Photocopying	10,000
Airtime	4,500
Transcribing (hiring recorders) 45 days@ 1000 per day	45,000
Transport-researcher 20 days –commuter and sustenance allowance,3000per day	60,000
Research assistants(2) –commuter and sustenance allowance@2000per day for 20 days	40,000
Sub total	164,500
Proposal write up and presentation	
Making of copies	5,000

Binding	3,000
Stationery	3,000
Data analysis Computer service	9,000
Transcribing and Translating	4,000
Miscellaneous	10,000
Sub total	34,000
Cumulative Totals	202,500

Appendix 13: QUESTIONNAIRES

Field Work Study: Biogas Adoption

QUESTIONNAIRE-FOR NON-ADOPTERS

This survey is being conducted by the researcher as part of his Master of Environmental Studies programme at Kenyatta University. It is meant to help him assess the factors affecting adoption of biogas technology as an alternative energy source in Gakawa location, Nyeri County.

The information given to the researcher will be used only for academic research and analysis. Responses to these questions will be treated as confidential. Please tick (✓) where appropriate or fill in the required information on the spaces provided.

Kindly participate in the study by completing this questionnaire accurately and exhaustively. Your co-operation is highly appreciated.

DATE OF INTERVIEW.....

SECTION A: BACKGROUND CHARACTERISTICS OF RESPONDENTS

	ATTRIBUTES	RESPONSES	
1	NAME:		
2	GENDER:	1. Male..... 2. Female.....	
3	SUB-LOCATION:		4. VILLAGE:
5	HOUSEHOLD SIZE	MALE	FEMALE

6	7	8	9	10	11
AGE	EDUCATIONA L LEVELS	MARITAL STATUS	PRIMARY OCCUPATION	SECONDARY OCCUPATIO N	PERIOD OF RESIDENCY
1.>20 years	1. NONE	1. SINGLE	1. FORMAL EMPLOYMEN T		1. > 2yrs
2.21- 30	2. PRIMARY	2. MARRIED	2. INFORMAL EMPLOYMEN T. Specify		2. 3-5 yrs.
3.31-	3.	3. SEPARATED/DIVORCE			3. 6-10

40	SECONDARY	D			yrs.
4.41-50	4. TERTIARY	4. WIDOWED			4. 11-15yrs
5.51-60	5. INFORMAL				5. 16-20yrs.
6.<61 years					6. >20yrs

Main occupation: Farmer, casual labourer, business person, formal employment, retired civil servant, skilled occupation, e.g. tailor, plumber in school, unemployed, others (specify) _____

PROPERTY OWNERSHIP

FARM		SIZE	
Animals (specify type)		Number	Mode of stock keeping

FARM UTILIZATION

a.	Particulars	Land in use	Land not in use	Total	Reason for idle land
b.	Land(ha) owned	(ha)	(ha)		
c.	Land (ha) leased in	(ha)	(ha)		
d.	Land (ha)leased out	(ha)	(ha)		

How did you acquire the piece of land you have today?

I. Inherited from father [] Bought []
 Leased [] Given by a relative []

II. Do you have a title deed? _____ YES/NO _____

1. Cooking energy source?: Firewood [] Charcoal [] Grass [] Electricity []
 Gas [] Paraffin [] Any other (specify) _____

2. Lighting source: Kerosene [] Electricity [] photovoltaic panels [] None []

SECTION B: ENERGY NEEDS AND BIOGAS TECHNOLOGY AWARENESS

1. Where do you get your firewood from? (Source).....
 - Trees in the homestead.....
 - Nearby forest.....
 - Purchasing from vendors.....
2. What is the availability and consistency, of the fuel wood resources?

.....
3. What is the estimated distance of getting firewood? (In km)..... Time taken (in hrs.).....
4. Do you employ hired labour to get you firewood?/.....
 - a. If hired, how much do you pay hired workers? Ksh
 - b. How much is the load? Ksh
 - c. How many days does the load sustain you?
5. Which energy saving technology(ies) do you practice on your farm
 - a. Energy Saving Cooking stoves (ESC).....
 - b. Biogas.....
 - c. Other. (Specify).....
6. How has the adoption of the different energy options being used in the household benefited the household?.....
7. Have you **ever** been **informed** about biogas technology as an alternative energy source? YES [], NO []

Sources of information:

 - a. Since you were informed about biogas technology as an alternative energy source, have you put thought of trying it? YES [], NO []
 - i.
 - ii.
 - iii.
 - iv.
8. Have neighbours (who have tried the technology) informed you about the benefits they have got after installing the biogas units?

NO[], YES[]

SPECIFY.....

.....

.....

SECTION C: SOCIO-CULTURAL FACTORS

9. What do you think is the main obstacle to biogas adoption in your area?: Indicate as follows

SA¹/-Strongly Agree: A²/-Agree, UN³/-Undecided, D⁴ /-disagree, SD⁵ /-Strongly Disagree

Obstacle	SA	A	UN	D	SD

Scarcity of development fund					
Poor understanding of biogas concept					
Lack of education and technological skills among farmers					
Insecurity about land tenure					
Lack of harmony among family members					
Women not being involved in decision making					
Ineffectiveness of Community Development Officers					
Extension officers failure to spend time with farmers					
Limited land for installation					
Limited number of livestock					
Negative publicity and awareness					
Poor marketing policies					
Low participation of women in leadership					

10. What do you consider the most important benefits to be received from adoption of biogas technology? Please indicate.

No extent, A little extent, A moderate extent, A large extent, A very large extent					
	1	2	3	4	5
Statement	1	2	3	4	5
Improvement of health					
Reduction in respiratory diseases					
Increased income					
Less time taken in collecting firewood					
Employment					
Effective utilisation of cattle dung					
Time saving in cooking					
Cheaper than electricity and firewood					

Easy to clean vessels after cooking					
-------------------------------------	--	--	--	--	--

11. Do you think the following would improve acceptance?

SA¹:-Strongly Agree, A²:-Agree, UN³:-Undecided, D⁴:-Disagree, SD⁵:-Strongly Disagree

Attributes	SA	A	UN	D	SD
Overcrowding					
Increased human population					
Environmental degradation					
Increased livestock numbers					
Positive publicity and marketing					
Water availability					
Improved household income					
Controlled livestock grazing					
Land sub division					
Security					
Using the slurry by-product as fertilizer.					

12. Do you obtain credit for developments on the farm from any person or institution
YES.....NO.....

If yes, where do you get it from?

13. Who makes decisions in the household on the energy /technological option and how it will be used. Men()
Women () and give reasons

.....

Section D: EXTENSION SERVICES

1. Are you aware of any extension officers in the location? NO[], if YES [], what kind of
information do they share with
you?.....

.....

2. Has any person from extension service, (s) come to you to give advice on how to incorporate or adopt biogas technology? NO..... (if)YES.....specify.....

3. How frequent do Community Development Officers visit your farms for inspection?

4. After inspection, do the officers give feedback to you for positive improvement? [] Yes [] No

5. How do you implement the recommendations from these visits?

[] Always [] Frequently [] Rarely [] Often [] Never

6. If rarely or never implement the recommendations, give the reasons

.....
.....

Comment on the extension services of the area.

.....

Respondents general comments on the status of Biogas energy as an alternative energy source:

.....

Field Work Study: Biogas Adoption

OBSERVATION SHEET FOR NON-ADOPTERS

GENERAL COMMENTS : (*By the enumerator on the respondent: [√] tick where appropriate*)

1. Characteristics of family house

- a. Building materials? Stones [] bricks [] Timber [] Iron sheets [] Mud []
- b. Roofing materials? Iron sheets [] Thatch [] Any other (specify -----

- c. Toilet facility? Pit latrine [], Water closets(WC)[], Any other (specify -----

- d. Source of drinking water Well [] River [] Piped [] Stream []
Borehole [] Harvested rain Water []

2. Farm characteristics

- a. Presence of a zero grazing unit? Permanent [] semi-permanent []
- b. Location (Slope) well drained[] poorly drained[]
- c. Condition? well-constructed[] poorly constructed[]
- d. Presence of a farm house []

3. What do you think is the income level of the farmer?

High..... Low.....

Others:

.....
.....
.....
.....

Field Work Study: Biogas Adoption

QUESTIONNAIRE-FOR ADOPTERS:

This survey is being conducted by the researcher as part of his Master of Environmental Studies programme at Kenyatta University. It is meant to help him assess the factors affecting adoption of biogas technology as an alternative energy source in Gakawa location, Nyeri County.

The information given to the researcher will be used only for academic research and analysis. Responses to these questions will be treated as confidential. Please tick (√) where appropriate or fill in the required information on the spaces provided.

Kindly participate in the study by completing this questionnaire accurately and exhaustively. Your co-operation is highly appreciated.

DATE OF INTERVIEW.....

SECTION A: BACKGROUND CHARACTERISTICS OF RESPONDENTS

	ATTRIBUTES	RESPONSES	
1	NAME:		
2	GENDER:	1. Male..... 2. Female.....	
3	SUB-LOCATION:		4. VILLAGE:
5	HOUSEHOLD SIZE	MALE	FEMALE

6	7	8	9	10	11
AGE	EDUCATIONAL LEVELS	MARITAL STATUS	PRIMARY OCCUPATION	SECONDARY OCCUPATION	PERIOD OF RESIDENCY
1.>20 years	1. NONE	1. SINGLE	1. FORMAL EMPLOYMENT		1.> 2yrs
2.21-30	2. PRIMARY	2. MARRIED	2. INFORMAL EMPLOYMENT. Specify		2.3-5 yrs.
3.31-40	3. SECONDARY	3. SEPARATED/DIVORCED			3.6-10 yrs.

4.41-50	4. TERTIARY	4. WIDOWED			4.11-15yrs
5.51-60	5. INFORMAL				5.16-20 yrs.
6.<61 years					6.>20yrs

Main occupation: Farmer, casual labourer, business person, formal employment, retired civil servant, skilled occupation, e.g. tailor, plumber in school, unemployed, others (specify) _____

PROPERTY OWNERSHIP

FARM		SIZE	
Animals (specify type)		Number	Mode of stock keeping

FARM UTILIZATION

e.	Particulars	Land in use	Land not in use	Total	Reason for idle land
f.	Land(ha) owned	(ha)	(ha)		
g.	Land (ha) leased in	(ha)	(ha)		
h.	Land (ha)leased out	(ha)	(ha)		

How did you acquire the piece of land you have today?

- III. Inherited from father [] Bought []
 IV. Leased [] Given by a relative []
 V. Do you have a title deed? YES[], NO []

SECTION B: ENERGY NEEDS AND BIOGAS TECHNOLOGY AWARENESS

1. Cooking energy source? Firewood [] Charcoal [] Grass [] Electricity [] Gas [] Paraffin [] Any other (specify) _____
2. Lighting source Kerosene [] Electricity [] photovoltaic (solar) panels [] None []
3. When did you start using biogas as alternative energy source? Year.....
4. Where did you get information about biogas as an alternative energy source?
 - a. Community development officers..... Fellow farmers..... Cooperative Society..... extension officers..... NGO. (Specify)

..... other.....
 - b. What is the name of the biogas unit?
 - c. Approximate costs of unit installation Ksh.....
5. Did you obtain credit from any person or institution YES..... NO.....
6. If yes, where did you get it from?

Specify.....
7. Are you still using it? YES [] if NOT.....Specify why.....

.....

.....

.....
8. Specify source of water for the biogas unit. how reliable is this source?
9. How can you compare biogas technology with the technologies you are using in your kitchen?
 - i.
 - ii.
 - iii.
10. Have you had any problems related with the uptake of biogas technology? please specify

.....

.....

.....

.....
11. In your opinion can these problems be curbed?

.....
12. Will you continue using the technology?

Yes [], if no []

Why?.....

.....

.....

SECTION C: SOCIO- FACTORS

13. What do you think is the main obstacle to biogas adoption in your area?: please indicate as follows
 a. SA¹/Strongly Agree, A²/Agree, UN³/Undecided, D⁴/disagree, SD⁵/Strongly Disagree indicate as follows

OBSTACLE	SA	A	UN	D	SD
Scarcity of development fund					
Poor understanding of biogas concept					
Lack of education and technological skills among farmers					
Insecurity about land tenure					
Lack of harmony among family members					
Communication barriers					
Ineffectiveness of Community Development Officers					
Extension officers failure to spend time with farmers					
Limited land for installation					
Limited number of livestock					
Negative publicity and awareness					
Poor marketing policies					
Low participation of women in leadership					

14. What do you consider the most important benefits you have received from the adoption of biogas technology? Please indicate as follows

Statement	No extent, A little extent, A moderate extent, A large extent, A very large extent				
	1	2	3	4	5
Improvement of health					
Reduction in respiratory diseases					
Increased income					
Less time taken in collecting firewood					

Employment					
Effective utilisation of cattle dung					
Time saving in cooking					
Cheaper than electricity and firewood					
Easy to clean vessels after cooking					

15. Do you think the following would improve acceptance? SA¹/Strongly Agree, A²/Agree, UN³/Undecided, D⁴/disagree, SD⁵/Strongly Disagree

Attributes	SA	A	UN	D	SD
Overcrowding					
Increased human population					
Environmental degradation					
Increased livestock numbers					
Positive publicity and marketing					
Water availability					
Improved household income					
Controlled livestock grazing					
Land sub division					
Security					
Using the slurry by-product as fertilizer.					

Section D: EXTENSION SERVICES

1. Has any person from extension service, (s) come to you to give advice on how to improve on biogas technology? NO..... (if)YES.....
2. How frequent do Community Development Officers visit your farms for inspection? Weekly [] monthly [] annually [], none [] any other
3. After inspection, do the officers give feedback to you for positive improvement? [] Yes [] No
4. How do you implement the recommendations from the visits?

[] Always [] Frequently [] Rarely [] Often []
Never

5. If rarely or never implement the recommendations, give the reasons

.....
.....
.....

6. Comment on the extension services of the area?

.....
.....
.....

Field Work Study: Biogas Adoption

OBSERVATION SHEET FOR ADOPTERS

GENERAL COMMENTS:

(By the enumerator on the respondent :[√} tick where appropriate)

Characteristics of family house

- e. Building materials? Stones [] bricks [] Timber [] Iron sheets [] Mud []
- f. Roofing materials? Iron sheets [] Thatch [] Any other (specify -----

- g. Toilet facility? Pit latrine [],Water closets(WC)[],Any other (specify -----

- h. Source of drinking water Well [] River [] Piped [] Stream []
Borehole [] Harvested rain Water []

Farm characteristics

- e. Presence of a zero grazing unit? Permanent [] semi-permanent []
- f. Location (Slope) well drained[] poorly drained[]
- g. Condition? well-constructed[] poorly constructed[]
- h. Presence of a farm house in which the appliance is located []
- i. Collection of dung manually []gravity flow []
- j. Use of slurry observed [] not observed []

Farm operations

Evidence of wood stock piles. Specify quantity.

Evidence of fodder [] specify type

Farming activities

Type of crops in the field cash crops [] food crops []

Any other

What do you think is the income level of the farmer?

High..... Low.....

Others

.....
.....
6. What are the farmers' reactions to the biogas technology adoption?

.....
.....
.....
.....

7. How do you rate the attitudes of the farmers towards adoption of biogas as an alternative energy source?

.....
.....
.....
.....

8. What are the key factors that influence the attitudes of farmers towards the biogas adoption?

.....
.....
.....
.....

9. In terms of capital and technical aspects of the biogas units, how well are the farmers prepared?

.....
.....
.....
.....

10. Do you always discuss your findings on the farmers' perceptions, with the individual farmers and other development agencies? E.g. other NGOs, sponsors if any?

i. If Yes, how

.....
.....
.....
.....

ii. If No, why

.....

.....
.....

11. To which extent are your recommendations to enhance biogas adoption implemented in Gakawa location?

.....
.....
.....
.....

12. What challenges do you face in relation to acquisition of biogas equipment and resources in the promoting of biogas technology as an alternative energy source?

.....
.....
.....
.....

13. What challenges do you face in relation to the biogas plants construction and maintenance?

.....
.....
.....
.....

14. How can CDO/Extension officers/ your NGO be assisted to enhance the effective uptake of biogas technology by farmers in Naromoru Division and particularly Gakawa location?

.....
.....
.....
.....

15. What are your comments regarding the services offered by your office in this Division?

.....
.....
.....
.....
.....