SOCIO-ECONOMIC FACTORS INFLUENCING ADOPTION OF IMPROVED BIOMASS ENERGY TECHNOLOGIES IN RURAL AND URBAN HOUSEHOLDS IN KITUI, KENYA

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Declaration

This project paper is my own original work and has not been presented for examination to any other university.

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Dedication

This project is dedicated to the Almighty God, to Him be all the Glory and Honour for by his Mercy and Grace, I have been able to accomplish this work. To my beloved parents Silas Mutea and Alice Mutea, who saw the importance of educating their baby girl. To my siblings Franklin Kathurima and Sylvia Muthoni for your moral support and to my late grandma Rebecca Mwari.

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MAY THE ALMIGHTY GOD ABUNDANTLY BLESS YOU ALL!

Abstract

Improved biomass energy technologies and alternative biomass fuels were introduced in Kitui (Kenya) as alternative renewable source of energy following domestic energy crisis. Despite these noble efforts, the adoption level of the technologies and fuels has remained low. Thus, this study aimed at investigating the socio-economic factors that influence the current adoption of improved biomass energy technologies for cooking and households' acceptance and willingness to switch from one fuel and technology to another in rural and urban Kitui Central with a view to future uptake of alternative biomass fuels and improved biomass energy technologies for cooking.

The study was conducted in rural and urban regions of Kitui Central. A conceptual framework based on adoption theories guided the analysis of factors influencing adoption of technologies and fuels. It focused on five different biomass fuels: firewood, charcoal, briquettes, biogas, and Jatropha oil and on eight different improved biomass energy technologies for cooking.

The study used both qualitative and quantitative approaches of data collection and analysis. The research study used questionnaires, interview schedule, photography and observation in data collection. For the structured survey of 100 households, it employed a stratified sampling procedure involving disproportionate stratification of rural and urban households. Chi square and Phi tests were used to analyse statistical relationships of variables. The results are presented in bar charts, percentages and means.

The study found out that household wealth play an important role in adopting improved biomass energy technologies for cooking. Adoption of biogas and briquette fuels and improved firewood technologies is low in the study area. No adoption of liquid biofuel and briquette technology in the study area. Rural and urban households show a distinct pattern of adoption with regard to biomass fuels and technologies due to different level of awareness, household wealth, perceptions and constraints.

Various stakeholders are focusing on improving access to affordable and reliable alternative biomass fuels and technologies for cooking. They have generally not achieved their targets due to lack of infrastructure, inadequate man power and misguided perceptions by the households. Overall, the study reveals that rural and urban households show quite a distinct pattern of acceptance with regard to the five biomass fuels due to their different availability, current knowledge about the fuels and different socio-economic situations of the households. There is

a distinct pattern on the specific improved biomass energy technologies households are willing to adopt due to different preferences. The rural and urban households' acceptance of biomass fuels and improved biomass technologies and willingness to switch to alternative fuels indicates possibilities and options for the future uptake.

The study recommends creation of awareness on the available alternative biomass fuels and improved technologies. There is need to train households on the effective use of the available biomass energy technologies. Quality and performance standards as outlined by government and regulatory bodies should be ensured. Selection of clean cooking technologies should incorporate user preferences and be based on the local context. Knowledge sharing by the adopters should also be encouraged in the area and more data on stove efficiency and emissions under field conditions are required.

Acronyms

AFREPREN	-	African Energy Policy Research Network
BC	-	Black carbon
CETRAD	-	Centre for Training and Integrated Research in ASAL Development
COPD	-	Chronic obstructive pulmonary disease
DEEP	-	Developing energy enterprises project
DME	-	Dimethyl ether
ERC	-	Energy Regulatory Commission
GACC	-	Global Alliance for Clean Cookstoves
GERES	-	Group for the Environment, Renewable Energy and Solidarity
GHGs	-	Greenhouse gases
GIZ	-	Deutsche Gesellschaft für Internationale Zusammenarbeit
GVEPI	-	Global Village Energy Partnership International
HAP	-	Household air pollution
HIV/AIDS	-	Human immunodeficiency virus / Acquired immunodeficiency syndrome
IEA	-	International Energy Agency
ICS	-	Improved cookstoves
IUCN	-	International Union for Conservation of Nature
KEBS	-	Kenya Bureau of Standards
KIRDI	-	Kenya Industrial Research and Development Institute
KCJ	-	Kenya ceramic jiko
KNBS	-	Kenya National Bureau of statistics
KWFT	-	Kenya Women Trust Fund
LPG	-	Liquefied petroleum gas

NEMA	-	National Environment Management Authority
OECD	-	Organization for Economic Co-operation and Development
SE4ALL	-	Sustainable energy for all
SES	-	Social-economic status
SPSS	-	Statistical package for social sciences
UN	-	United Nations
UNDP	-	United Nations Development Programme
UNCED	-	United Nations Conference on Environment and Development
UNICEF	-	United Nations Children's Fund
UNFCC	-	United Nations Framework Convention on Climate Change
USAID	-	United States Agency for International Development
WBA	-	World Bioenergy Association
WEC	-	World Energy Council
WSSD	-	World Summit on Sustainable Development
WEHAB	-	Water Energy Health Agriculture and Biodiversity
WEO	-	World Energy Outlook
WHO	-	World Health Organization
EnDev-K	-	Energising development Kenya country programme

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CHAPTER 1: INTRODUCTION

1.1 Background to the study

Over half the households' worldwide still uses solid biomass or coal fuels for basic cooking and heating (Smith, *et al*., 2000). There are different biomass energy carriers not only wood based fuels but also biogas, liquid biofuel and farm residues. Increasing attention is being paid to the consumption of wood fuels because of their role in producing damages at three distinct levels (Pattanayak & Jeuland, 2012). At the household and village level, combustion of solid fuels produces pollution that is damaging to health and a large contributor to the global burden of disease (Smith, *et al.,* 2000) and imposes a high workload and time-consuming burden on those collecting fuelwood, typically women and girls. At the community and national level, when fuel wood is harvested in unsustainable ways, its consumption contributes to the loss of forest and associated ecosystem services. Finally, at the regional and global scale, the burning of biomass and coal in inefficient household stoves, which represent roughly 15% of global energy use, releases large amounts of black carbon and carbon-based greenhouse gases (Ramanathan & Carmichael, 2008: 223). Many of these gases fall into the category of products of incomplete combustion, which are more damaging in terms of global warming potential than the carbon dioxide released from fossil fuel-burning stoves (Pattanayak & Jeuland, 2012). These emissions contribute to global warming, particularly where such fuels are harvested non-renewably. In fact, much of the renewed push today for improved biomass energy technologies for cooking stems from concerns over the contribution of traditional stoves to global climate change. In Kenya, wood fuel provides the basic energy needs of the rural communities, urban poor, and the informal sector. An analysis of the national energy by Energy Regulatory Commission (2004: 6) shows heavy dependency on wood fuel and other biomass that account for 68% of the total energy consumption (petroleum 22%, electricity 9%, others account for 1%).

Improved biomass energy technologies and alternative technologies are devices that have been developed to replace traditional biomass energy technologies (GACC, 2013). Additionally, there are also alternative technologies that now allow use of other biomass energy for cooking such as biogas and Liquid biofuel. They are designed to improve combustion efficiency of biomass, consume less fuel, save cooking time, increase convenience in cooking processes and create a smokeless environment in the kitchen or generally lead to a reduction in the volume of smoke produced during cooking.

Improved biomass energy technologies not only reduce pressure on forest for firewood but also help to reduce the greenhouse gas emission as a result of reduced unsustainable consumption of wood based and substituted fossil fuels. Improved biomass energy technologies can have a positive impact on the environment and also bring in financial benefits to the country through trade of emission credits in the international carbon market.

1.2 Statement of the problem

Seventy-eight percent of Kenya's rural households is still using traditional stone fires while in urban areas slightly above 9% of the households use these highly polluting and environmentally damaging traditional biomass energy technologies for cooking (UNDP, 2012: webpage). Access to other modern energy services such as LPG for cooking and heating is better in urban areas than rural areas where poverty is more acute (UNDP, 2012).

Improved biomass energy technologies for cooking are crucial in addressing the adverse health and livelihood impacts of traditional biomass energy technologies. They reduce the amount of fuel required, fuel gathering time, and cooking time—all of which have the potential to improve health and increased household income (Sagar & Kartha, 2007). In addition, these efficiencies can benefit the local environment and global climate because of reductions in fuelwood harvesting and particulate emissions (Sagar & Kartha, 2007). Despite clear scientific evidence of the effectiveness of these innovations, initial efforts to promote improved biomass energy technologies have run into challenges surrounding diffusion, dissemination, and implementation. The available statistics by Gobal Alliance of Clean Cookstoves (GACC) and GVEP international, (2012: 35) indicates an approximately 2.25m (6.4%) households with improved stoves in Kenya. In Kitui, improved biomass energy technologies have been promoted but the adoption is low and disproportional (NEMA & GOK, 2009; ESPA & Practical Action East Africa, 2010).

Limited adoption of improved technologies by reluctant households forms the focus of this research with the aim of identifying the factors of adoption or non-adoption. The adoption-side of thinking has been bolstered by a small yet growing body of literature suggesting that potential consumers often do not invest in or maintain use of environmental health technologies (e.g., piped water, water filters, private latrines, insecticide treated bed nets, improved stoves), because they do not know about or are not able to value the benefits of the technology (Pattanayak & Pfaff, 2009). In some cases, consumers are unwilling to finance or are unable to pay the prevailing prices for the technologies (Pattanayak & Pfaff, 2009). Yet other authors have linked the adoption and diffusion challenges to improved biomass technologies that are unsuitable for local customs, ineffective financing, poor distribution channels, or insufficient social marketing (Mitchell, 2010).

Several initiatives to enhance adoption of efficient biomass technologies have been promoted by various institutions, for example, the World Bank. The influence of such initiatives is further strengthened by general trends in low-income countries such as the rising cost of fuelwood due to the increasing scarcity and forest sector reforms. Collectively, these initiatives have led to increased attention on improved biomass energy technologies for cooking culminating in the recent formation of the Global Alliance for Clean Cookstoves (Mitchell, 2010; GACC, 2011) which aims to have 100 million households adopt clean cookstoves by 2020. Additionally, Kenya launched Energising Development Kenya Country Programme (EnDev-K) in 2012. The activities of EnDev-K include support for the Kenya Bureau of Standards in establishing new standards for the approval of biomass-burning stoves. It is also working with the Energy Regulatory Commission on the development of controls to regulate the actors, design and use of improved biomass technologies for cooking. Despite these local and global efforts adoption of improved biomass technologies for cooking is still low.

According to Gifford (2010) over 100 cookstove programs were running in the world in 2010, ranging in size, scope, type of stove disseminated, approach to technology design and dissemination and financial mechanisms. So far, however, the attention has concentrated in developing new stove designs, improving large-scale manufacturing process, marketing techniques and financial incentives for stove dissemination (Ruiz-Mercado, *et al*., 2011). Relatively few efforts have been devoted to understand how stoves are actually adopted and how to sustain their long-term use regardless of the dissemination program objectives (Anderson, 2007; Hessen, *et al*., 2001). Indeed, there seems to be little systematic information available about the factors that have been most important for the successful adoption of cookstoves in practice (Ruiz-Mercado, *et al*., 2011).

Sketchy information indicate that initially households respond most to fuel savings (when fuel is very scarce or monetized), speed of cooking, convenience, compatibility with local cooking practices, and status of modernity, and relatively less so to pollution-related issues (Ruiz-Mercado, *et al*., 2011). There is also evidence that the main factors affecting the adoption of stoves can be different at the household level (Pine, *et al*., 2011). Few studies on different demographic and socio-economic factors explain low rates of adoption but there are almost no studies that try to understand, from the users' perspective, the factors involved when choosing among different cooking technologies like the compatibility of the stove with local cooking practices seem more important for sustained use (Troncoso, *et al*., 2007). Part of the reason for the lack of more conclusive data, however, is that until recently there has not been objective and comprehensive monitoring of the actual stove adoption and use (Ruiz-Mercado, *et al.*, 2011)

Therefore, there is need for much firmer empirical bases for the many outstanding questions regarding the factors of adoption and diffusion of improved biomass energy technologies for cooking. Currently, knowledge about factors enabling or hindering adoption and diffusion of improved biomass energy technologies is still limited and scattered (IEA, 2010; Karakezi, 2004; Jessica & Subhrendu, 2012).

1.3 Research questions

1.3.1 General research question

What are the socio-economic factors that influence the current adoption of improved biomass energy technologies for cooking and what are acceptance levels of households and willingness to switch from one fuel and technology to another in rural and urban Kitui Central?

1.3.2 Specific research questions

1. What are the socio-economic characteristics of rural and urban households that have an influence on the use of biomass fuels and improved biomass energy technologies for cooking?
2. What are the households' perceptions, adoption and constraints faced in relation to the use of efficient cooking technologies?
3. What are the households' perceptions, adoption and constraints faced in relation to the use of biomass fuels?
4. How are stakeholders involved in the promotion of the different types of improved biomass energy technologies for cooking?
5. What is the households' level of acceptance and willingness to switch from current fuels and technologies to another?

1.4 Objective of the study

1.4.1 General objective

The general objective of the study was to investigate the socio-economic factors that influence the current adoption of improved biomass energy technologies for cooking and households' acceptance and willingness to switch from one fuel and technology to another in rural and urban Kitui Central.

1.4.2 Specific objectives

1. To document the socio-economic characteristics of rural and urban households that have an influence on the use of biomass fuels and improved biomass energy technologies for cooking.
2. To assess the households' perceptions, adoption and constraints faced in relation to the use of biomass fuel.
3. To assess the households' perceptions, adoption and constraints faced in relation to the use of improved biomass energy technologies for cooking.
4. To examine the involvement of institutional actors and their effectiveness in promoting improved biomass energy technologies for cooking.
5. To analyze households' level of acceptance and willingness to switch from one biomass-based fuel and one cooking technology to another.

1.5 Research hypotheses

1. H_o: There is no relationship between household income and gender of the household head and adoption of improved biomass energy technologies for cooking by households.
2. H_o: There is no significant difference of adoption of biomass fuels between rural and urban households.
3. H_o: There is no significant difference of adoption of improved biomass energy technologies between rural and urban households.
4. H_o: Promotion of improved biomass energy technologies does not influence adoption of improved biomass energy technologies
5. H_o: There is no significant difference in the willingness by rural and urban households to change biomass fuels and cooking technologies.

1.6 Justification of the study

The use of wood-based energy (charcoal and firewood) is on increase as a result of rapid population growth in developing countries. As a result, deforestation and consequently changes in the ecosystem are happening that in turn leads to loss of ecosystem services and climate change. Therefore, use of improved biomass energy technologies, instead of traditional biomass energy technologies for cooking can ensure efficiency in use of biomass energy.

Moreover, improved stoves reduce smoke emission and health hazards especially to the women and children. Improved technologies saves 50-70% fuels compared to traditional ones. In the case of chimney stove, flue gases are also taken out of the kitchen so that the kitchen becomes more comfortable for the cook. Other benefits of improved stoves are: save cooking time, less smoke, less blackening of the utensils, saving of fuels, portable stove can be shifted easily during rainy season, etc.

Cooking habits and needs depend to a great extent on the socio-economic context of a household but also on the individual perception and attitudes of households related to improved technologies. In order to better understand the socio-economic factors that may influence current cooking practice and the use of technologies, there is a need to analyze in-depth the socio-economic situation of households and how this relates to current practices and perceptions. Currently, data on the socio-economic situation of rural and urban households is limited and scattered and there is a need for such a comprehensive analysis.

In addition, there is need for improved learning about implementation of promotion (Madon *et al.*, (2007)) and practice-based evidence of adoption (Green, *et al*., 2009; Martin, *et al*., 2011). The adoption cannot afford to focus only on a few adoption factors while ignoring contextual drivers (Glasgow, *et al*., 2003). Thus, it was imperative to match types of improved biomass energy technologies for cooking and cooking preferences and to consider the effectiveness of promotion activities such as provision of credit, information campaigns, and stakeholders.

Consequently, the present study investigates the socio-economic factors that influence the adoption of improved biomass energy technologies and acceptance as well as the households willingness to switch from their current cooking fuels and practices. There is a need to generate more in-depth knowledge about adoption and diffusion processes of improved technologies in order to guide future investments, further assessments and promotion of the improved biomass energy technologies for cooking. In addition, the study aims at contributing evidence for planning and designing more effective policies, implementation programs and projects to increase the adoption of improved biomass energy technologies by households in Kenya.

The findings of this study are intended to contribute to a better understanding of the adoption of these improved biomass energy technologies and people's perceptions and constraints faced. Additionally, the findings of this study could be used as inputs for decision-making by the policy makers, planners, non-governmental organizations, and implementers of bio-energy technologies and other projects of similar nature. Following the establishment of the Energy

Regulatory Commission in 2007 the findings of this study could expose some areas which need improvement as far as development of biomass energy programmes is concerned. Moreover, the findings provided additional knowledge on the present body of literature on biomass energy technologies. It was anticipated also that the study would also stimulate interest on more researches in the field of renewable energy sources.

1.7 Scope of the study

This study is part of a project on "Knowledge Support for Sustainable Renewable Energy Policies: The prospects of pro-poor biomass energy value chains in rural–urban contexts in East Africa". The project is composed of three work packages (WPs): WP1 investigates alternative biomass energy solutions from a value chain perspective; WP2 assesses the sustainable bio-physical potential for producing different biomass fuels; and WP3 develops a GIS based decision support tool that aims at informing actors in the energy sector about sustainable and viable biomass energy solutions. This study contributes to work package one. It was carried out in Kitui Central (Kenya).

1.7.1 Thematic scope

The study investigates the adoption of improved technologies for cooking using five different biomass energy fuels mainly for household purposes. The five biomass energy carriers are firewood, charcoal, biogas, Liquid biofuel and farm residue. All these biomass fuels can be produced locally, in the study area, and provide a potential source of income to the rural households. Firewood and charcoal energy carriers are widely used whereas biogas, Liquid biofuel and briquette are not yet widely used.

In the frame of the study not all improved biomass energy technologies for cooking available in Kitui can be included. During a participatory workshop in July 2014 in Kitui, a group of stakeholders and researchers selected these cooking technologies that were assessed as most promising with regard to environmental sustainability and viable for rural households and urban poor households (Table 1.1). The selection of technologies forms also the base for this in-depth study.

Table 1.1: Selection of improved biomass energy technologies

Cookstove (name)	Fuel uses	Description (very short)
Envirofit	Firewood	Efficiency: 35% Costs: KES 2, 500
Maendeleo	Firewood	Efficiency: 24% Costs: Small size-KES 300-350; Big size-800-900
Rocket	Firewood	Efficiency: 24-32% Costs: KES 3,000
Kenya Ceramic Jiko (KCJ)	Charcoal	Efficiency: 24% Costs: KES Size 10' KES 350; Size 12' KES 550; Size 15'KES 1,900; Size 19' KES 2,400
Liquid biofuel stove	Liquid biofuel	Efficiency: 39% Costs: KES 3,500-4,000
Briquette stove	Briquette	Efficiency: Not recorded Costs: KES 1,700-1,900
Single burner	Biogas	Efficiency: Not recorded Costs: KES 2,000-2,800
Double burner	Biogas	Efficiency: Not recorded Costs: KES 6,000-9,000

(Inventory Report, 2014)

1.7.3 Area of study

1.7.3.1 Selection of the study area

The increasing demand for firewood and charcoal to satisfy the needs of growing urban and rural populations, coupled with rapidly disappearing woody biomass, the near-absence of affordable alternative cooking fuels and a large population of poor people makes Kitui Central a highly suitable area for this study. Additionally, practical action is engaged in sustainable charcoal technologies under the PISCES Research Project of the UK Department of

International Development in Kitui. Furthermore, Kitui is one of the few counties that has benefited from the national government through development of a renewable energy center. These are important asset that led to choosing Kitui Central the best study area.

1.7.3.2 Location and land size

The study was done in Kitui Central sub-county (Figure 1.1) with an area of 808.6 km2. According to (KNBS, 2009), the sub county has an estimated population of 131,715 people. It has 8 locations, 30 sub-locations and 30,203 households comprising both large-scale and small-scale farmers (KNBS, 2009). The sub county, located 160km from the capital Nairobi, is characterized by hilly ridges separated by wide low lying areas and has slightly low elevation of between 600m and 900m above the sea level to the eastern side of the sub-county, the main relief feature is the Yatta plateau, which stretches from the North to the South between rivers Athi and Tana (Kenya meteorological services, 2014). The plateau is almost plain with wide shallow spaced valleys. The study area has no infuence on the use of biomass energy for cooking from Nairobi due to its geographical positioning.

1.7.3.2 Climate and vegetation

Due to the high altitudes, Kitui Central Sub County receives more rainfall than other parts in the county and is one of the most productive areas. This has resulted to most of the farms being converted to agriculture. The climate can be divided into two climatic zones (Louis Berger International Inc., 1983). The Western part of the District has a semi-arid climate. The Eastern and Southern parts of the District have lower average rainfall and higher temperatures (approximately 4°C higher compared to the western parts); and fall within the arid climatic zone. Temperatures in the Kitui District are high throughout the year, ranging from 16°C to 34°C (County Government of Kitui, 2014). The warmest periods are between June and September and January and February. These overall high temperatures in combination with the low and erratic rainfall, result in high rates of evaporation estimated around 1552 mm/yr (Borst en de Haas, 2006) to 1800 mm/yr (County Government of Kitui, 2014). It can be assumed that use of open fires with the aim of heating homes due to very cold weather in the area is not a prerequisite and this can influence their decision on adopting improved technologies.

The rainfall pattern is bimodal. The ‘long rains’ fall in April-May; the ‘short rains’ last from October to December, and are more reliable. Annual precipitation ranges from 500 to 1050 mm/yr, but is highly erratic and unreliable, both spatially and temporally. Overall, approximately 90% of the annual precipitation falls during the rain seasons (Hoogmoed, 2007).

Elevation and topographical features of the landscape strongly influence the amount of rainfall at a regional scale: the higher areas and hill masses in the West receive most rainfall (700-1050 mm/yr), these amounts decline tothe South and East where the annual rainfall is less than 500 mm (County Government of Kitui, 2014). The rainfall received offers a great potential of harvesting water for use during the dry seasons and for use in the biogas technologies which requires plenty water.

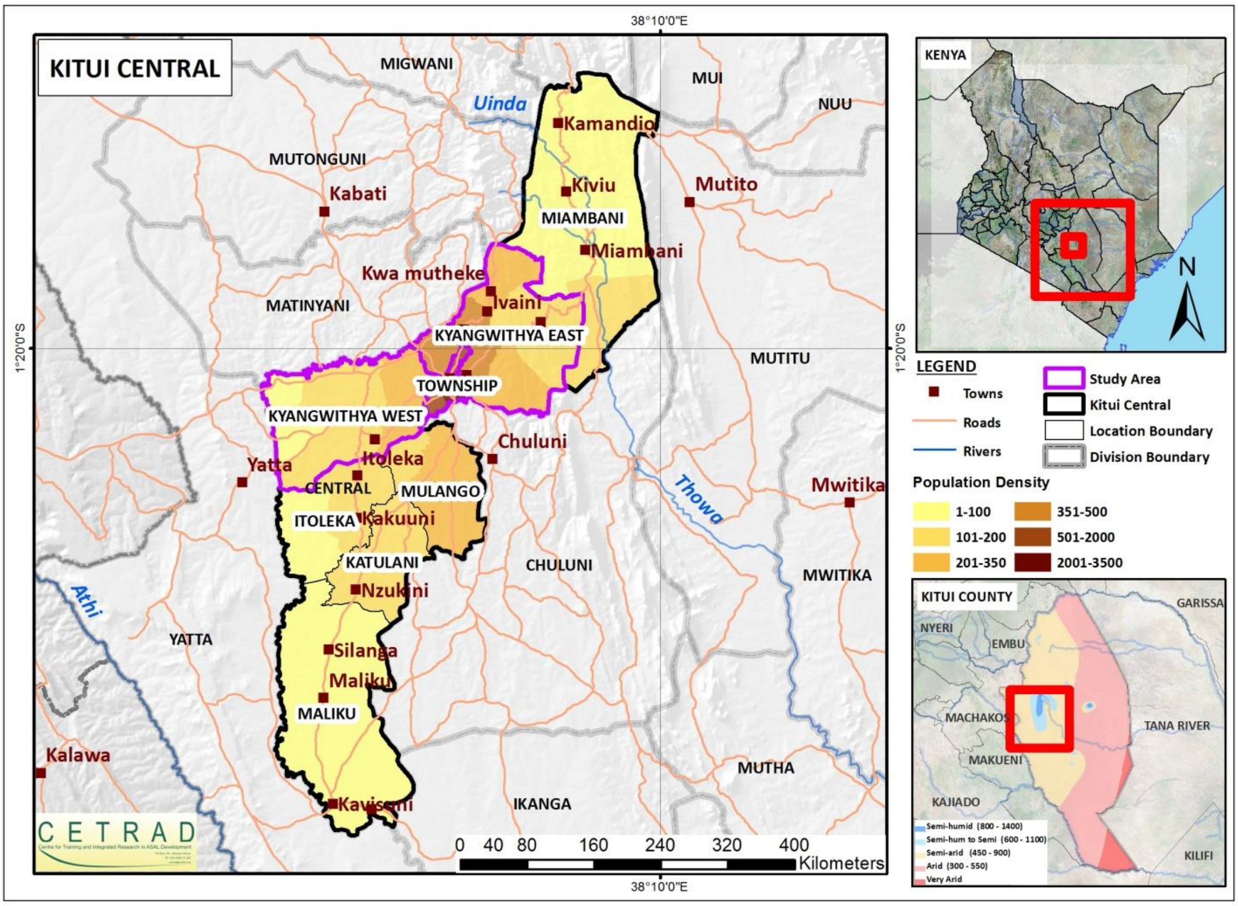

Figure 1.1: Map of Kitui Central

(Source: CETRAD, 2014)

1.7.3.3 Vegetation

The vegetation in the District is drought resistant, consisting predominantly of semi-arid deciduous thicket and bush land. In the driest areas (below 900 mm/year) the thorn bushes grade into semi-desert vegetation. The vegetation consists mainly of Acacia's and other thorny bushes (for example Acacia spp., Terminalia combretumand Commiphora spp.) in grassland (Borst & Haas, 2006). These trees and bushes are also the main vegetation in the study area. Close to the river more types of vegetation occur. Forestland covers little less than 18.000 ha, serving mainly as water catchment areas. Most of the hills used to be forested, but have been cleared for agricultural purposes and charcoal burning. Only patches, corridors of forest and dry forest in vast grazing lands remain. (District Commissioner Kitui, 2002). At present, local people are still cutting down trees and shrubs for firewood, charcoal burning and building material. This results in large areas of bare land, which are more vulnerable to erosion. This is an indication of diminishing biomass and the need to use the remaining sustainably.

1.7.3.4 Livelihood situation and energy use patterns in Kitui Central

Agricultural development in Kitui Central just as in other marginal lands is problematic due to low rainfall and the menace of wildlife and pests. Crop production has been made quite unreliable and unevenly distributed in the recent years the district has been experiencing crop failure of almost 90% thus rendering the majority of people in the sub county destitute and in dear need of food (Kenya meteorological services, 2014). The people of Kitui Central are engaged in various economic activities for their livelihoods. Whereas the majority is engaged in agriculture, livestock keeping still remains the main income source in the district and especially in the drier area. People practice mixed farming because livestock acts as a buffer during poor rain seasons. Most of what is harvested is consumed domestically, and there is hardly any net surplus. The sub-county is famine-prone; whatever is produced has to be supplemented with external food aid to avert starvation (NEMA & GOK, 2009).

Major commercial activities like wholesale, retail shop keeping process of food products, honey farming harvesting and refining are other economic activities taking place in urban centers and market places. Not to be underrated in their capacity to absorb the labor force are the Jua–kali workshops (informal sector in Kenya) spread out in all towns and markets centers. Cotton ginning, formerly a major commercial activity has greatly declined due to worsening climatic conditions, while charcoal burning and sales has gone up considerably However, Kitui Central is poverty prone due to, persisted droughts and famine, illiteracy and lack of employment opportunities. It has been estimated that the sub county faces serious crop failure five out of every eight seasons (NEMA & GOK, 2009). The economic power of people in Kitui Central is a bit low which may hinder adoption of technologies which require a huge start up capital.

Generally the overall welfare of the people of Kitui Central is not good and this can be gauged by use of several indicators including mortality rate, child mobility and malnutrition, occurrence of common Diseases like Malaria, Diarrhea, Tuberculosis, HIV/Aids, School enrolment to mention but a few (Population Action International, 2014) .

Food availability and nutrition per capita calories and protein intake are other measures of the welfare of a given society. The incidence of destitute and families on famine relief are social welfare indicators. The sub county relies on famine relief almost on a yearly basis. Education in the Kitui Central is also affected by the recurrent famine and quite a number of them have to be assisted through bursaries and food –for fees programs that are sometimes have to be used to keep students in school (Population Action International, 2014).

The main sources of energy are firewood in the rural areas while in the urban centers it is charcoal. Only about 3.8% of Kitui Central households and less than 1% in the rural areas are connected to the national grid (County Government of Kitui, 2014: 16). Use of firewood and charcoal in the study area remain high in spite of an indication of the high diminishing rate of the sources of these biomass energy carriers. Thus, efforts to sustainably use these fuels is needed as well the need to shift to other alternative fuels in the area.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter is a review of the literature relating to biomass energy situation at global scale, in developing world, Sub-Saharan Africa, East Africa and Kenya's perspectives which necessitate the need for improved cookstoves. The review includes factors that influence adoption of the improved biomass energy technologies as well as the empirical studies and a summary for the review. Finally, knowledge gaps are identified for further research.

2.2 Global energy consumption and the role of bioenergy

The world's energy demand in 2006 amounted to about 490 EJ (11,730 Mtoe3) and was made up of about 81% fossil fuels (oil, gas and coal), about 10% biomass, about 6% nuclear and about 2.2 and 0.5% hydropower and other energy as shown in Figure 2.1 (IEA, 2008: 66).

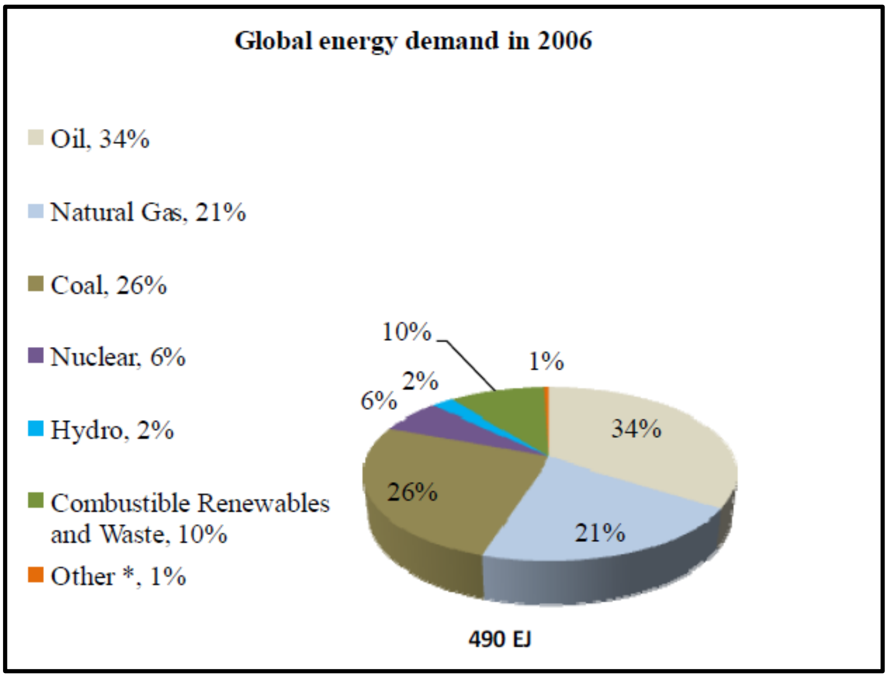

Figure 2.1 Constitutes of the Global Energy Demand in 2006

(Source: IEA, 2008: 66)

Bioenergy is attractive at all stages of development due to its potential integration with all possible development strategies worldwide. The potential of bioenergy is widely recognized and bioenergy offers opportunities to address questions other than energy. Thus, bioenergy can be a solution for matters relating to economic, national, environmental and political security (Svetlana & Vinterback, 2009). Moreover, bioenergy is based on resources that can be utilized on a sustainable basis all around the globe and can provide an effective option for the provision of energy services from a technical perspective. Svetlana and Vinterback adds that the benefits accrued go beyond energy provision, creating unique opportunities for regional development. Bioenergy production generally has a higher capital cost than fossil fuel alternatives, however the lower cost of the wood fuel provides a quick commercial payback and increasing savings 12 over the longer term. Energy policies in Europe can potentially affect prices for wood raw materials and can create markets for such materials as well (Hashiramoto, 2007). Unfortunately, many potential investors in bioenergy projects do not have a solid understanding of all the technical, social and environmental issues involved (Sims, 2003).

2.3 Biomass as a renewable energy source globally and factor of food security

In the past decade, the number of countries exploiting biomass opportunities for the provision of energy has increased rapidly, and has helped make biomass an attractive and promising option in comparison to other renewable energy sources. The global use of biomass for energy increases continuously and has doubled in the last 40 years (Figure 2.2), this according to the Svetlana & Johan, (2009). Concerns about sustainable energy supplies, commitments to the Kyoto Protocol (i.e., the additional cost of carbon imposed through carbon trading increases the cost of fossil fuels and therefore makes "carbon-lean" biomass more competitive, increasing prices for fossil fuels and availability of stocks of wood raw material) have been major influences on the promotion of wood energy policies e.g., Hashiramoto (2007) and Sims (2003). Renewability and versatility are among many other important advantages of biomass as an energy source (Svetlana & Johan, 2009).

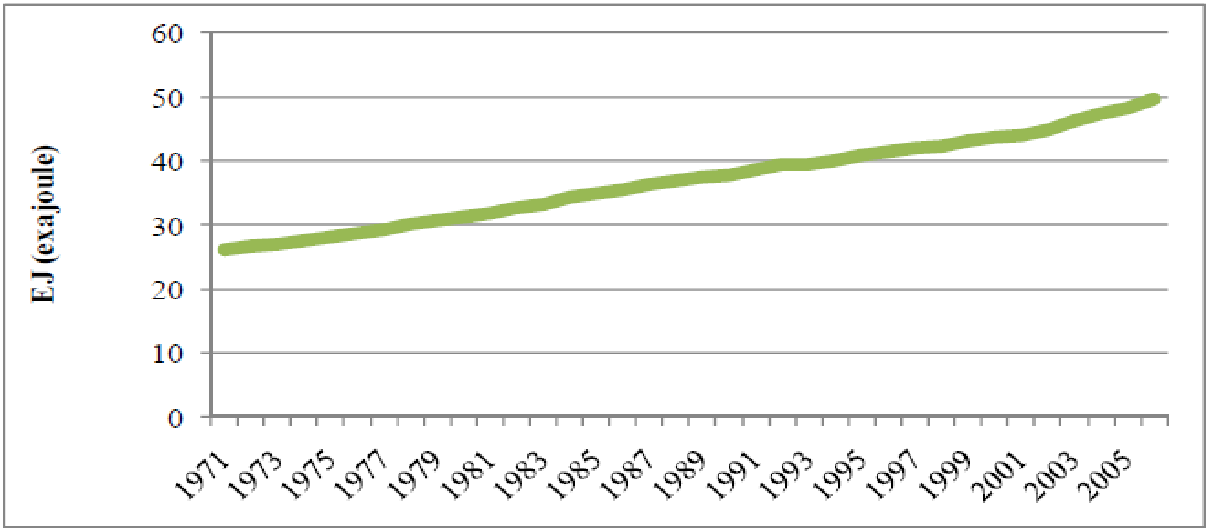

Figure 2.2: World Use of Combustible Renewables and Waste 1971 – 2006.

(Source: Svetlana & Johan, 2009: 12)

Contribution of biomass to the global energy use of 470 EJ in 2007 is only 10%, mainly in the form of traditional non-commercial biomass (Figure 2.3). Moreover, we know that biomass can be used to produce different forms of energy, thus providing all the energy services required in a modern society. Furthermore, compared to other renewables, biomass is one of the most common and widespread resources in the world (WEC, 2004). Thus, biomass has the potential to be a source of renewable energy, both locally and in large parts of the world. Worldwide, biomass is the fourth largest energy resource after coal, oil, and natural gas - estimated at about 10% of global primary energy (and much higher in many developing countries) (Figure 2.3). Compared to other renewables, biomass is currently the largest renewable energy source (Figure 2.3).

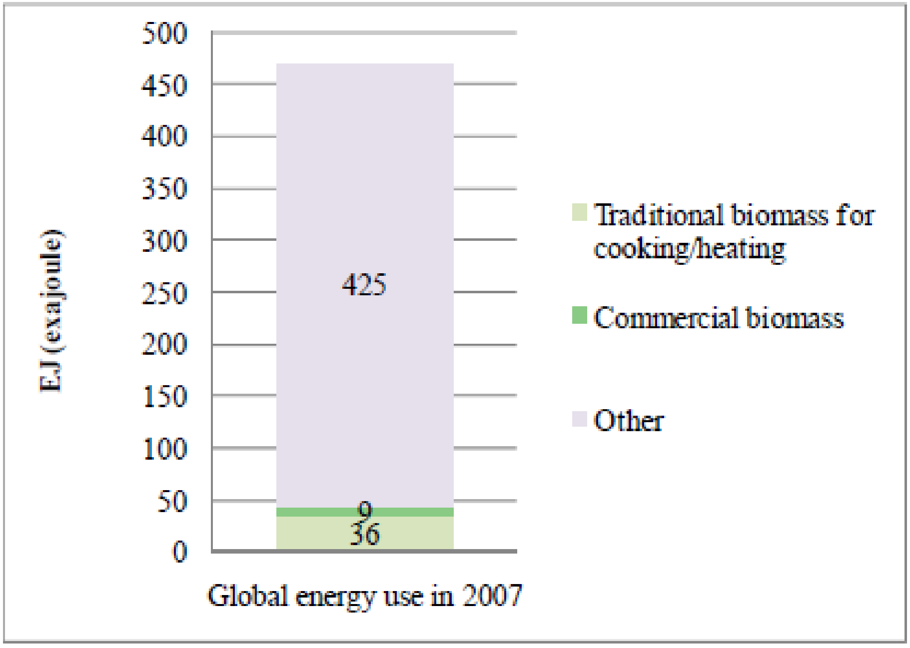

Figure 2.3: Contribution of biomass to global energy use of 470 EJ in 2007

(Source: Svetlana & Johan, 2009: 14)

The production of biomass for bioenergy may affect the availability dimension of food security in several ways. First, through land: if land is used for the production of biomass for bioenergy, it may no longer be available for food production, and thus in principle, it negatively affects food production. Biomass production can have a positive effect on producer prices: when food production decreases, food prices will increase. This, in turn, may lead producers to grow more food and less biomass for energy, until a new equilibrium is found. Shortfalls in domestic food production could require increases in food imports expenses, and thus negatively affect food trade.

2.4 Household use of biomass energy developing countries

Household use of biomass energy in developing countries alone accounts for almost 7% of world primary energy demand. In OECD countries, biomass demand comes mostly from the power generation and industry sectors, while in developing countries these sectors represent only 12% (WEO, 2006: 420). World Energy Outlook reports that households generally use a combination of energy sources for cooking that can be categorized as traditional (such as dung, agricultural residues and fuelwood), intermediate (such as charcoal and kerosene) or modern (such as LPG, biogas, ethanol gel, plant oils, dimethylether (DME) and electricity).

Over 2.4 billion people, or 52% of the population in developing countries, depend on biomass as their primary fuel for cooking (WEO, 2006: 421) . Over half of these people live in India, China and Indonesia (Table 2.1). However, the proportion of the population relying on biomass is highest in sub-Saharan Africa. In many parts of this region, more than 90% of the rural population relies on firewood and charcoal. The share is smaller in China, where a large proportion of households use coal instead. Poor households in Asia and Latin America are also very dependent on fuelwood.

Table 2.1: People relying on biomass resources as their primary fuel for cooking, 2004

	Total population		Rural		Urban	
	%	million	%	million	%	million
Sub-Saharan Africa	76	575	93	413	58	162
North Africa	3	4	6	4	0.2	0.2
India	69	740	87	663	25	77
China	37	480	55	428	10	52
Indonesia	72	156	95	110	45	46
Rest of Asia	65	489	93	455	35	92
Brazil	13	23	53	16	5	8
Rest of Latin America	23	60	62	59	9	25
Total	**52**	**2 528**	**83**	**2 147**	**23**	**461**

(Source: WEO, 2006: 426)

Heavy dependence on biomass is concentrated in, but not confined to, rural areas. Almost half a billion people in urban areas also rely on these resources. Although urbanization is associated with lower dependence, the use of fuels such as LPG in towns and cities is not always widespread. According to WEO (2006), in sub-Saharan Africa, over half of all urban households rely on fuelwood, charcoal or wood waste to meet their cooking needs. Over a third of urban households in some Asian countries also rely on these fuels (WEO, 2006). Further, World Bank (2011) adds that use of multiple fuels provides a sense of energy security, since complete dependence on a single fuel or technology leaves households vulnerable to price variations and unreliable service. Some reluctance to discontinue cooking with fuelwood may also be due to taste preferences and the familiarity of cooking with traditional technologies (WHO, 2006).

2.5 Harmful effects of current cooking fuels and technologies

2.5.1 Health

The World Health Organization (WHO) estimates that 1.5 million premature deaths per year are directly attributable to indoor air pollution from the use of solid fuels. More than 85% of these deaths (about 1.3 million people) are due to biomass use, the rest due to coal (OECD & WHO, 2006: 425). This means that indoor air pollution associated with solid biomass use is directly responsible for more deaths than malaria, almost as many as tuberculosis and almost half as many as HIV/AIDS (Figure 2.4). It is estimated that indoor air pollution causes about 36% of lower respiratory infections and 22% of chronic respiratory disease (OECD & IEA, 2006: 427). As incomes increase and fuel options widen, the fuel mix may change, but wood is rarely entirely excluded. Over the long term and on a regional scale, however, households in countries that become richer will shift away from cooking exclusively with biomass using inefficient technologies (Smith, *et al*., 2009).

In developing regions reliant on biomass, women and children are responsible for fuel collection, a time-consuming and exhausting task. The average fuelwood load in sub-Saharan Africa is around 20 kg but loads of 38 kg have also been recorded (OECD & IEA, 2006). Women can suffer serious long term physical damage from strenuous work without sufficient recuperation.

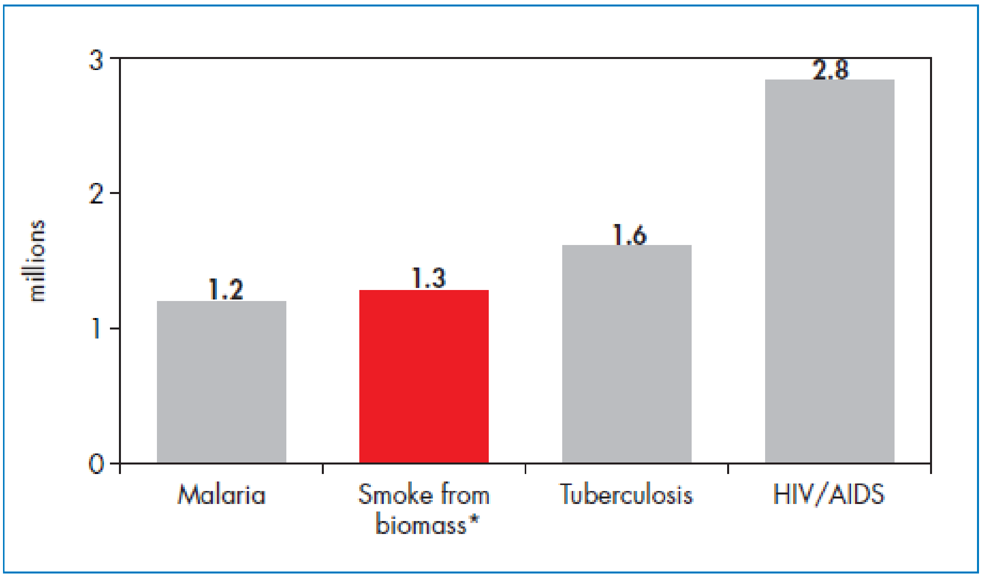

Figure 2.1: Annual deaths worldwide by cause IEA estimate based on WHO Figure for all solid fuels

(Source: OECD & IEA, 2006: 425).

2.5.2 Environment

Inefficient and unsustainable cooking practices can have serious implications for the environment, such as land degradation and local and regional air pollution. There is some localised deforestation, but depletion of forest cover on a large scale has not been found to be attributable to demand for fuelwood (Arnold *et al.*, 2003). Displacement for agriculture appears to be the most important driver for deforestation in humid forest areas, with permanent losses of carbon stocks, and charcoal often a by-product of forest clearance Production of charcoal, in turn, can have a significant land-scape-level impact on land degradation due to multitudes of tree cuttings at production site level even when not driving overall forest cover loss. With rapid urbanization and population growth in SSA, the negative impacts of charcoal production on forests and woodlands such as reducing natural regeneration, will increase markedly (Iiyama, *et al*., 2014).

2.6 The context of improved cookstoves within East Africa

The task of cooking is an essential part of life for people around the globe, yet in East Africa it is a task that can consume many hours of the day and have far reaching consequences on health and the environment as well as social and economic impacts (GVEPInternational, 2012). In the developing world nearly 3 billion people rely on traditional cooking methods such as an open fire or basic cookstoves to prepare their meals, using solid fuels such as wood, charcoal, crop residues and animal dung (GACC, 2011). A study by the United Nations Development

Programme (UNDP) and the World Health Organization (WHO) in 2009 looking at the energy access situation in developing countries, reported that 600 million of these people live in sub-Saharan Africa where access to modern fuels is as low as 17% and 69% of the population rely on wood as their primary cooking fuel. According to the UNP/WHO, (2009: 17) report in Table 2.2 shows that within East Africa itself access to modern fuels is highest in Kenya at 17% with around 13% of the population relying on kerosene, 4% on gas and less than 1% on electricity to meet their cooking needs. Access to modern fuels is lower in neighboring countries - 3% in Tanzania and estimated at less than 1% in Uganda (Table 2.2).

The majority of people in East Africa rely heavily on wood as their primary cooking fuel with charcoal following as the second most common fuel (WHO, 2009). However, significant differences exist between fuel use in urban and rural settings. Although access to modern fuel is 17.3% for the total population of Kenya, 58.4% of the urban population has access to modern fuels compared to 3.6% of those living in rural area, highlighting the uneven spread of modern energy resources within these countries (WHO/UNDP, 2009: 19).

Table 2.2: The percentage of the population in sub-Saharan Africa that use different types of cooking fuel

Primary Cooking Fuel Used	Percentage of total population in each region			
	sub-Saharan Africa	Kenya	Uganda	Tanzania
Electricity	6	0.6	0	0.3
Gas	4	3.5	0.1	0.2
Kerosene	7	13.2	0.3	2.3
Charcoal	11	13.3	13	19
Wood	69	68.7	85.8	77.6
Dung	1	0	0	0
Coal	1	0	0	0
Other	1	0.7	0.8	0.5
Year of data		2005 - 2006	2007-2008	2006

(Source: WHO/UNDP, 2009: 19)

2.7 Improved cookstoves in Kenya

Improved cookstoves have been promoted in Kenya since the 1980s following the UN conference on new and renewable sources of energy held in Nairobi (Partnership for Clean Indoor Air., 2012). GVEP further reports that the stakeholders involved in the initial dissemination activities included The Ministry of Energy, GIZ (formerly GTZ), Practical Action (formerly Intermediate Technology Development Group), Bellerive Foundation, USAID and UNICEF. Some of the initial programmes promoting improved cookstoves included the Kenya Renewable Energy Programme and Women and Energy Project which aimed to develop, design and dissemination improved stoves through providing training and technical assistance to local artisans (USAID/Winrock, 2011).

One of the first improved stoves developed for charcoal burning was the Kenya Ceramic Jiko (KCJ) which was adapted from the Thai Bucket Stove (Partnership for Clean Indoor Air., 2012). Over the years the design has improved and today it has become a widely used charcoal stove available in the Kenyan market. Wood burning stoves were also introduced through early stove dissemination activities including the Mandeleo stove and the Jiko Kisasa, both low cost fixed wood burning stoves that can be assembled in homes using locally available materials. Later on rocket stove technology was introduced through GIZ both in a portable and fixed variety offering a high efficiency stove, although at a higher cost to the end user. Over the decades local innovation in stove design has occurred resulting in new variations such as the multipurpose Kuni Mbili and Uhai stove.

2.7.1 Industry overview

Over the years these early stove designs have gained user acceptability and the training of local artisans has resulted in production centers establishing around the country. As a result, GVEP International, 2012 reports that the stove sector in Kenya has experienced some commercialization and is more developed than its neighbors in East Africa. During the DEEP programme, GVEP International suggest that between 50-60% of charcoal users use some sort of improved stove with uptake in Nairobi and Mombasa as high as 80%. In addition overall uptake of improved stoves in Kenya is estimated at 47% but the uptake of wood stoves is much lower than charcoal at around 4% - although it is higher in areas that have been the target of stove programs (GVEP International, 2012: 26).

The cookstove value chain in Kenya is fragmented with the majority of cookstove production done on a small to medium scale (Ingwe & Anna, 2005). According to GVEP, production of liners is often done separately in areas where good clay is available such as around Kisumu and Muranga. These liners are then transported to other areas of the country where assembly is done, often within the ‘Jua Kali’ artisan sector. Liner producers often work in groups or close to each other, sharing tools and a kiln to reduce on business costs. In addition, distribution costs can be high and road networks poor and many producers rely on wholesale buyers collecting products direct from them. The majority of production is done by hand with the exception of Fine Engineering who use mechanization to produce the Jiko Poa stove. Burn Manufacturing are also planning to set up mechanized production of their stoves in country (GVEPInternational, 2012).

2.7.2 Enabling environment in kenya for disseminating improved stoves

The government has been involved in stove dissemination since the first country activities and has partnered with programs mainly through the Ministry of Energy and Ministry of Agriculture. The resources they provide however have been limited and biomass energy often loses out to higher priorities around electricity access and generation. Recent initiatives around climate change prevention, universal energy access and Vision 2030 relate to the biomass sector and these issues are being incorporated into new policies, but so far action on the ground has been limited (GVEPInternational, 2012). Kenya has also joined the SE4All global initiative (Partnership for Clean Indoor Air, 2012) led by the UN-Secretary-General, and has completed a rapid assessment to help determine the main challenges and opportunities in achieving the three goals of SE4ALL (Partnership for Clean Indoor Air., 2012).

Stove testing facilities exist at universities such as The University of Nairobi and a further facility is being developed by GIZ and KIRDI. Kenya Bureau of Standard (KEBS) has developed a biomass stove standard but this has only been attained by a few producers and wider enforcement of the standard is challenging and has not taken place.

Accessing finance from financial institutions has proved a struggle for small producers in the past; however some institutions such as Faulu Advisory, (Kenya Women Finance Trust) KWFT and Unitas SACCO are starting to develop energy portfolios. Kenya has a relatively well resourced and developed carbon market with five registered cookstove Gold Standard projects and five POAs in validation focusing on cookstoves with Kenya as a host country although many of these projects such as the Paradigm Project and CO2 Balance partner with local stove producers, local manufacturers have yet to benefit directly from the carbon revenue (Smith & Kirk, 2011).

GVEP recommends that interventions should take account of differences between the structures of the market in each country. For example in Kenya where the market is more fragmented and components are made by different businesses more focus would be given to linking up the manufacturers of components to ensure quality is carried through the value chain.

2.8 Household cooking fuels and technologies

The development of policies, strategies and programs to achieve universal access to clean cooking fuels requires understanding of how both stove and the cooking fuels are used in practice.

2.8.1 Cooking biomass energy types

Different terminologies and definitions are used in categorizing household cooking biomass energy types (OECD & IEA, 2006; IEA, 2005). Based on the way these cooking energy types are produced or extracted, they are sometimes termed as "primary" and "secondary". Primary energy is directly obtained from natural resources such as fuelwood, farm waste, and animal dung. Secondary energy types, which come from transformation of primary energy types, include charcoal and wood pellets from fuelwood, biogas produced from animal dung and farm residue (OECD & IEA, 2006).

2.8.2 Cooking technologies

Several types of cookstoves are used by households and these stoves are often associated with specific energy types (WorldBank, 2011; Barnes, *et al.,* 2012a). For example, traditional (3-stones), simple non-traditional (e.g., clay pot-style or simple ceramic liners), chimney, rocket, charcoal and gasifier stoves use solid fuels which are common in rural areas of developing countries. In contrast, more modern cooking stoves, such as LPG, natural gas and electric, are common in urban areas of both developing and developed countries. In recent years, biogas cookstoves are also gaining popularity in rural areas of developing countries (WorldBank, 2011; Barnes, *et al.,* 2012b)

2.9 Factors influencing adoption of improved cookstoves

Adoption of technical innovation depends on various factors; these factors may differ across regions and sometimes are location specific. Several studies by Baidu-Forson (1999); Bartz, *et al.,* (1999); Nhembo (2003) and Simon (2006) have pointed out that adoption and dissemination of new technologies depend to a larger extent on demographic characteristics, environmental characteristics, institutional support services, nature of the technology and its benefits as perceived by the clientele. Such characteristics of improved biomass technologies for cooking make adoption responses unique as they are related to the individual, some to the situation in which the individual is and some to the nature of the practice (Lionbergen & Gwin, 1991). In addition some innovations are also subject to the control and manipulation of change agents while some are not and specific to the study area and often incomparable.

- **Socio- economic characteristics of households influencing adoption of innovations**

These are specific attributes of an individual and his /her families that make him/her adopt or reject a certain technology. These attributes can include, educational level, age, income and wealth, gender family size, ethnicity, and religion (Nhembo, 2003)

Educational level is associated with greater access to information and enhanced capacity for creativity, so educated individuals are expected to be more aware of and have more knowledge on a new technology. According to Akinola & Young (1985) knowledge reduces uncertainty and thereby induces adoption. However some skills are not correlated with years of schooling. Adoption of rainwater harvesting technologies in western Pare was not significantly explained by education but rather by other factors like experience in farming and perceived technology benefits (Senkondo, *et al.*, 1998).

Age and experience have a range of influences on household decision making in adoption. Older ages, according to Nhembo (2003) may influence an individual in the direction of not adopting new ideas due to conservatism. However, with regard to experience, older people may have more experience and more resources that allow them to adopt capital-intensive technologies than younger people (Shiferaw & Holden, 1998). However, there are some innovations where the younger the age of the individual, the higher is the probability of adopting the technology. This, according to Shiferaw and Holden (1998) is due to the fact that younger people are more likely to accept risks associated with the new technologies. Young people have longer planning horizons and are therefore more innovative. Young people were more likely to adopt formalized land conservation approaches in Kilosa and Kiteto districts than were older people (Sebyiga, 2008). Household size may have positive or negative influence on adoption of technologies. For labor intensive technologies, family size positively influences adoption (Simon, 2006).

Income is also an important factor in adoption of technologies. Availability of cash enables an individual to meet costs associated with a technology to be adopted. A research conducted by (Alavalapati, *et al.*, 1995) in India revealed that rich farmers were the main beneficiaries of farm forestry programs since they could invest in such programs. Recognition of a problem to be solved by a new technology is another household factor influencing adoption of a technology. People being rational have their own priority of problems they want to solve for their development and they may not be ready to invest their time and resources to what they do not perceive to be a problem. Simon (2006) observed that adoption of rotational woodlot was associated with an acute shortage of fuelwood supplies due to natural forest depletion.

However, beside recognition of a problem people usually compare benefits from the available technology and the newly introduced one and select the one with more preferred benefits. In Gairo – Tanzania tree planting was the most preferred soil conservation practice not only because of relatively low labor demand but also because of trees having multipurpose uses that provide a number of benefits to farmers (Kalineza, 1999).

Gender can influence adoption of a technology positively or negatively depending on gender responsibilities and ownership of resources (Simon, 2006). Different gender responsibilities can be reflected in different tasks among men and women regarding energy supply and management systems or in differences in resource ownership such as livestock, houses and land. Kaliba *et al* (1997) in their study found that gender had a significant influence in the adoption of stall-feeding technology in semi-arid areas of Tanzania. In another research work Nhembo (2003) argues that if a technology to be adopted is expected to reduce women workload, then women may prefer to adopt it.

The burden of unpaid workload in developing countries is largely and mostly done by women. Gwalema (2002) argues that hierarchical relationship within family organization which takes the form of male dominance and female subordination, allocates women the more time-consuming labor, low status and poorly rewarded tasks in the home. Worse many men do not regard labor performed by women as work. The unpaid tasks performed by women include firewood collection and water fetching, food preparation, home maintenance, domestic sanitation and waste disposal management, family care, especially care for children, old and sick people (Fontana & Natali, 2008). In rural areas in developing countries men and women play very distinct and definite roles in domestic energy management. Women in these countries have traditionally shouldered the responsibility of managing the domestic energy requirements for their families. The tasks of cooking are carried out by women. These have been perceived by many African societies as women's tasks. It is only when wood is collected for sale, or where social or religious constraints restrict women from leaving their homes, that men participate (Dutta, 1997). Analysis done by Budlender (2008) in Tanzania shows that women are more involved in firewood collection than men. Location wise women in rural areas are more involved in fuelwood collection than women in urban area.

Fontana and Natali (2008) further comment that public investment policy has an important role to play in redressing gender inequalities and reducing poverty by promoting initiatives that reduce time spent by women in the above mentioned tasks. In India for instance, over the last two decades or so, efforts have been made by the government to ameliorate the problems in the rural energy sector. These efforts have mainly been in the form of national programmes for promoting renewable energy technologies like biogas, improved energy serving cookstoves and solar cookers (Dutta, 1997). Evaluation of these programmes, according to Dutta (1997), has shown a wide variation in the way they function and long-term acceptability of the technologies. Lack of involvement of women at all stages in the project cycles has been identified as one of the major causes of projects limited sustainability. Several studies (Dutta, 1997; Gwalema, 2002) have identified a number of factors which form barriers to the effective participation of women in rural energy dissemination programmes. These factors include traditional decision-making roles in the society, women's workload, level of economic independence, educational constraints leading to lack of access to information, skills and technical expertise, and ideological barriers among extension workers.

Women traditionally tend to have limited decision-making power about household purchases including technologies. Chungu *et al.,* (2001) in their study on the processing plants and the individual sugarcane growers in Tanzania observed that the ownership patterns follow patriarchal lines. The head of the household (husband/father) owned the family property namely land, production tools and domestic animals. This, according to Chungu *et al.,* (2001), has been taken as an indication that ownership and management of the technology is male dominated. The above case study suggests that for a capital intensive technology like biogas, it is automatically a man who will decide on its adoption or non-adoption. Since firewood is often and wrongly considered by the society as something free of charge and mainly collected by women and children; men who are decision makers of the household might not see the advantage of less time consumed by women for firewood collection and men might be reluctant in deciding for biogas installation (Chungu, *et al.,* 2001).

The majority of women particularly in rural areas are among the poor strata of the population and are entirely depended on natural environment and hit the most by environmental degradation (Wawa, 1999). Women have local knowledge of natural environment and are most familiar with household fuel supply problems as well as the need and preferences of the immediate environment and energy systems. But since extension officers interact primarily with men, this source of indigenous knowledge remains untapped hence technologies and innovations which were targeted for women are based on perceptions and preferences of men. It is therefore not surprising that women are reluctant to adopt the technologies.

Karlsson (2003)comments that because women are the primary users of energy, it is therefore important that they are involved in decision making on energy issues specifically, in designing and implementing projects to meet their needs. He identifies lack of education and technical training as an important constraint on women's participation in energy decision-making processes and in activities involving energy use. Women already have valuable knowledge about local conditions and resources, additional education about energy technologies and solutions would increase their ability to contribute to energy solutions and to adopt new cleaner fuels and equipment. Women, who have learned new skills and obtained improved access to energy for households and income generating activities, can create new resources for investing in better conditions for themselves, their families and their communities (Karlsson, 2003).

Karlsson (2003) describes a case study in India where rural women in Huluvangala village rejected the stove technology disseminated under the government programme. However the two NGOs in the area, realized the need for new dissemination strategy and engaged themselves in a dialogue with rural women on various aspects of stoves design, performance, durability and efficiency so as to select a stove that would cater for women's needs and their expectations. A training programme was tailored to meet the site specific conditions and women were trained in stove construction. The results were that not only the women in the village used the stove, but also they were able to sell their services to other women and more women used the stoves.

Another case study in Kenya shows that the widespread adoption of fuel-efficient "Upesi" stoves was achieved by training local women in stove production, distribution and installation. Besides learning how to produce the stoves they also received training in costing and pricing, record keeping, forging marketing links and responding to consumer demands. Furthermore, because of the women's many domestic and community responsibilities, the training had to be fit into their other activities. As a result women producers went on to train others on a free basis and others applied the skills they acquired to other business ventures.

The case studies above express the importance of involving women on energy projects where women participation has contributed to adoption and sustainability of energy projects. In order to encourage women's participation education is required to raise their awareness and confidence on alternative technologies.

- **Institutional characteristics that influence adoption of innovations**

Institutional support is another factor affecting adoption of a technology. According to Kalineza *et al.,* (1999) rejection or acceptance of a new idea largely depends on how the information is relayed from the source, which is mainly the extension service to the people. Extension is known to catalyze awareness and information exchange and technology promotion among individuals. The study by Baidu-Forson (1999) observed that adoption was higher for farmers having contacts with extension agents working on agro forestry technologies than farmers who had never experienced any extension contacts.

Information dissemination is a key process in bringing awareness about the presence of a new technology. After being aware of an innovation, people would accumulate knowledge and then test the innovation and adoption is expected to happen after people become satisfied with the results of the test. Abadi-Ghadim and Pannell (1999) points out that adoption is a multistage decision process involving information acquisition and learning by doing. Consequently information is one of the crucial software aspects of innovation and information acquired during any given period is, in part, a decision variable (Burton, et al., 1999). People with more access to information are expected to benefit more from the technology introduced in their areas. Accumulation of information over time is hypothesized as one of the main dynamic elements of innovation adoption process for it raises the level of knowledge. Provided that the innovation is beneficial, the accumulation of favorable experiences will eventually induce the individual attitude towards adoption of a new innovation (Anin, 1999). Extension provides access to information and makes a substantial contribution to motivating adoption or influencing an increase in the intensity of use of the technology (Baidu-Forson, 1999). It can therefore be concluded that before adopting of an innovation a certain level of cumulative information must be attained while on the other hand, information problems may limit people's ability to correctly anticipate the long-term benefits of a given technology.

Other factors like availability of credit facilities, market, policy and other institutions are also important in encouraging adoption. In Nigeria for instance, farmers' ability to obtain credit from informal sources was a statistically significant explanatory variable of adoption of tractor hiring services (Akinola, 1987). Policies also play an important role in adoption of technologies. In their study on the effects of agricultural policies on adoption of soil and water conservation technologies in semi-arid areas of Tanzania-Hatibu *et al.,* (1999) revealed that sustainable adoption of soil and water conservation practices required policies and strategies which ensured strict but fair customs, rules and by-laws on soil and water conservation and direct tangible benefits for the individuals.

Tendler (1993) mentioned a number of factors for success stories in agricultural research and extension in poverty stricken northeast Brazil. These include the strong demand from farmers for a solution to a particular problem and localized credit subsidies to bring about rapid and wide spread adoption. Other factors are municipal level actors, offer of financial incentives, provision of technical assistance and rewarding good performers while keeping funds away from bad performers. The role of local and extra-local actors, use of entrepreneurial farmers as model farmers, support from village leaders, and use of experienced and well-regarded extension workers and; decisive influence of other development actors formed another group of factors for successful adoption (Tendler, 1993).

- **Technological attributes that influence adoption of innovations**

Technological characteristics of improved biomass energy technologies for cooking are also a factor influencing adoption of a technology. Rogers (2003) identified five major technological characteristics of an innovation associated with high rate of adoption of technologies. They include the relative perceived advantage, compatibility with the local culture, low technical complexity, train-ability and afford-ability. Prior to adoption people do their analysis and finally adopt those technologies that meet their preference. Another technology specific characteristic is the performance of a technology under individuals' conditions. Poor performance of a technology can discourage people from adopting it.

In Tabora rural Tanzania, the low survival rates of trees discouraged farmers in afforestation program (SADC/ICRAF, 1996). Bartz *et al.,* (1999) further observed that technologies with short-term benefits are more preferred than those perceived to have long term benefits since long periods required for realization of benefits of the technology make them more uncertain and less attractive. Governmental support to such technologies is more crucial, where the support can be in form of subsidies, loans and provision of technical services to encourage people to adopt the technologies.

- **Environmental Characteristics that influence adoption of innovations**

Geographical characteristics of improved biomass technologies for cooking such as environmental conditions also play part in adoption of a technology. Simon (2006) in his study on adoption of rotational woodlot technology observed that a majority of adopters lived in either urban, division centers or sub urban areas. However, the low adoption rate in remote areas, according to Simon (2006), could have been caused by the fact that people were closer to natural forests where the problem of fuelwood shortage was lower as compared to urban or sub urban areas.

2.10 Sustainability criteria of production of biomass energy

Today, bioenergy can be used to generate heat and electricity as well as Liquid biofuels and biogas for transport. However, without structural changes of the current energy system, the production of energy crops and removal of residues from forest and agricultural systems for energy production can result in negative environmental, economic, or social impact. Moreover, unsustainable biomass production would erode the climate-related environmental advantage of bioenergy. In addition, there are risks related to such factors as supply, fuel quality, and price increases, as well as issues such as competition for land area and the degree of regeneration of given resources. Sustainability reduces such risks, and can be supported by certification of substrates' origin (Svetlana & Johan, 2009). Taken as a whole, it's more important than ever to reliably demonstrate that the advantages of Liquid biofuels made from biomass exceed the cost of potential environmental damage caused by their production.

Therefore, sustainable production of biomass for use as fuels is the major issue in order to increase bioenergy production. Generally, the sustainable development debate is based on the assumption that societies need to manage three types of capital (economic, social, and natural), which may be non-substitutable and the consumption of which might be irreversible (Figure 2.5). Following the controversial public debate and more scientific evidence about the downsides of Liquid biofuels, the EU has set rigorous sustainability criteria for biofuels and bio liquids. According to EU (2015) article 17 (2) , for Liquid biofuel to be considered sustainable, biofuels must achieve greenhouse gas savings of at least 35% in comparison to fossil fuels (EU, 2015). This savings requirement rises to 50% in 2017. In 2018, it rises again to 60% but only for new production plants. All life cycle emissions are taken into account when calculating greenhouse gas savings. This includes emissions from cultivation, processing, and transport. Biofuels cannot be grown in areas converted from land with previously high carbon stock such as wetlands or forests. Biofuels cannot be produced from raw materials obtained from land with high biodiversity such as primary forests or highly bio diverse grasslands (European Commision, 2015)

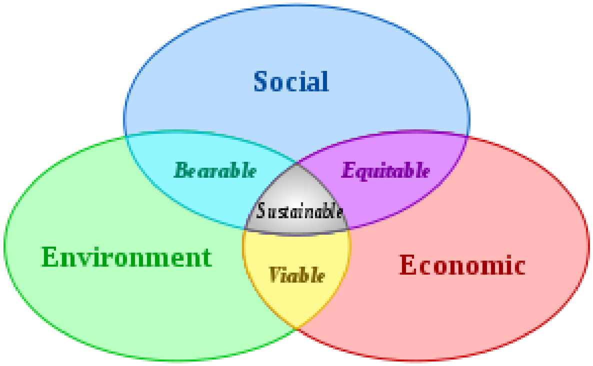

Figure 2.2: Scheme of sustainable development: at the confluence of three constituent parts (IUCN, 2006)

Growing biofuels on existing agricultural land can displace food production to previously non-agricultural land such as forests. Because trees absorb CO_2 from the atmosphere, removing them for biofuel production may result in an increase in net greenhouse gases instead of a decrease (EU, 2015). The establishment of Roundtable on Sustainable Biomaterials (RSB) has led to development of a certification system is based on sustainability standards encompassing environmental, social and economic principles and criteria (Roundtable on Sustainable Biomaterials, 2013). The certification schemes are mainly developed with regard to large-scale production but also small-scale production should consider sustainability criteria.

2.11 Summary and knowledge gap

The literature review shows that biomass remains an important source of energy in developing countries and also offers a good and sustainable potential to contribute to the energy needs of modern society if improved production and consumption technologies are used. Despite remarkable contribution of biomass to world energy balance its use is in a traditional and inefficient manner in developing countries which has led to a host of adverse effect on human health, environment, and social wellbeing.

Several studies provide evidence of significant negative health impacts caused by indoor air pollution from biomass burning for cooking in developing countries, mainly among women and young children. Existing studies also find that biomass combustion for cooking is a key source of black carbon emissions that has an adverse influence on the climate system.

The review of existing literature finds that wide range of factors, including socio-economic status, health, behavioral, cultural, local environment, technologies, policies and access to infrastructure, affect household's cooking fuel choice and adoption of improved biomass energy technologies. Although households with higher income and education are more likely to use modern fuels, their decision for cooking fuel choice and adoption of improved biomass energy technologies are quite complex and multi-dimensional; deep understanding of the interaction of these factors is necessary for designing government plans, policies and strategies to improve access and adoption of improved biomass energy technologies.

However, there was a knowledge gap relating to the adoption levels of improved biomass technologies in both rural and urban areas of Kenya. Additionally, there is no comparison of the acceptance between the different biomass energy carriers i.e. firewood, charcoal, biogas, briquettes, Liquid biofuel. Research on social economic factors influencing adoption and use of the same technologies in Kenya was scarce and thus a need for further research to better understand the adoption of improved biomass energy technologies over time in Kenya was necessary.

2.12 Theoretical framework

2.12.1 Innovation and diffusion theory

The process of adopting new innovations has been studied for many years, and one of the most popular adoption models, diffusion of innovation theory, is developed by Rogers (2003). For Rogers (2003), adoption is a decision of "full use of an innovation as the best course of action available" and rejection is a decision "not to adopt an innovation". Rogers defines diffusion as "the process in which an innovation is communicated through certain channels over time among the members of a social system". According to Rogers (2003), there are four components of diffusion process namely; Innovation, communication channels, time and social systems.

Innovation

"An *innovation* is an idea, practice, or project that is perceived as new by an individual or other unit of adoption" (Rogers, 2003). An innovation may have been invented a long time ago, but if individuals perceive it as new, then it may still be an innovation for them. The newness characteristic of an adoption is more related to the three steps (knowledge, persuasion, and decision) of the innovation-decision process.

Uncertainty is an important obstacle to the adoption of innovations. An innovation's consequences may create uncertainty: "*Consequences* are the changes that occur in an individual or a social system as a result of the adoption or rejection of an innovation" (Rogers, 2003). To reduce the uncertainty of adopting the innovation, individuals should be informed about its advantages and disadvantages to make them aware of all its consequences. Moreover, Rogers claimed that consequences can be classified as desirable versus undesirable (functional or dysfunctional), direct versus indirect (immediate result or result of the immediate result), and anticipated versus unanticipated (recognized and intended or not).

Communication Channels

For Rogers (2003), communication is “a process in which participants create and share information with one another in order to reach a mutual understanding”. This communication occurs through channels between sources. Rogers states that “a *source* is an individual or an institution that originates a message. A channel is the means by which a message gets from the source to the receiver”. Rogers states that diffusion is a specific kind of communication and includes the following communication elements: an innovation, two individuals or other units of adoption, and a communication channel. *Mass media* and *interpersonal communication* are two communication channels. While mass media channels include a mass medium such as TV, radio, or newspaper, interpersonal channels consist of a two-way communication between two or more individuals. On the other hand, “diffusion is a very social process that involves interpersonal communication relationships” (Rogers, 2003). Thus, interpersonal channels are more powerful to create or change strong attitudes held by an individual. In interpersonal channels, the communication may have a characteristic of *homophily*, that is, “the degree to which two or more individuals who interact are similar in certain attributes, such as beliefs, education, socio-economic status, and the like,” but the diffusion of innovations needs at least some degree of heterophily, which is “the degree to which two or more individuals who interact are different in certain attributes.” In fact, “one of the most distinctive problems in the diffusion of innovations is that the participants are usually quite heterophilous” (Rogers, 2003).

Time

According to Rogers (2003), the time aspect is ignored in most behavioral research. He argues that including the time dimension in diffusion research illustrates one of its strengths. The innovation-diffusion process, adopter categorization, and rate of adoptions all include a time dimension. The passage of time is necessary for innovations to be adopted; they are rarely adopted instantaneously.

Social System

The social system is an additional important element in the diffusion process. Rogers (2003) defined the social system as “a set of interrelated units engaged in joint problem solving to accomplish a common goal”. Since diffusion of innovations takes place in the social system, the diffusion is influenced by the social structure of the system. For Rogers (2003), structure is “the patterned arrangements of the units in a system”. He further claimed that the nature of the social system affects individuals’ innovativeness, which is the main criterion for categorizing adopters.

2.12.2 The innovation-decision process

Rogers (2003) described the innovation-decision process as “an information-seeking and information-processing activity, where an individual is motivated to reduce uncertainty about the advantages and disadvantages of an innovation”. For Rogers (2003), the innovation-decision process involves five steps: (1) knowledge, (2) persuasion, (3) decision, (4) implementation, and (5) confirmation. These stages typically follow each other in a time-ordered manner. This process is shown below.

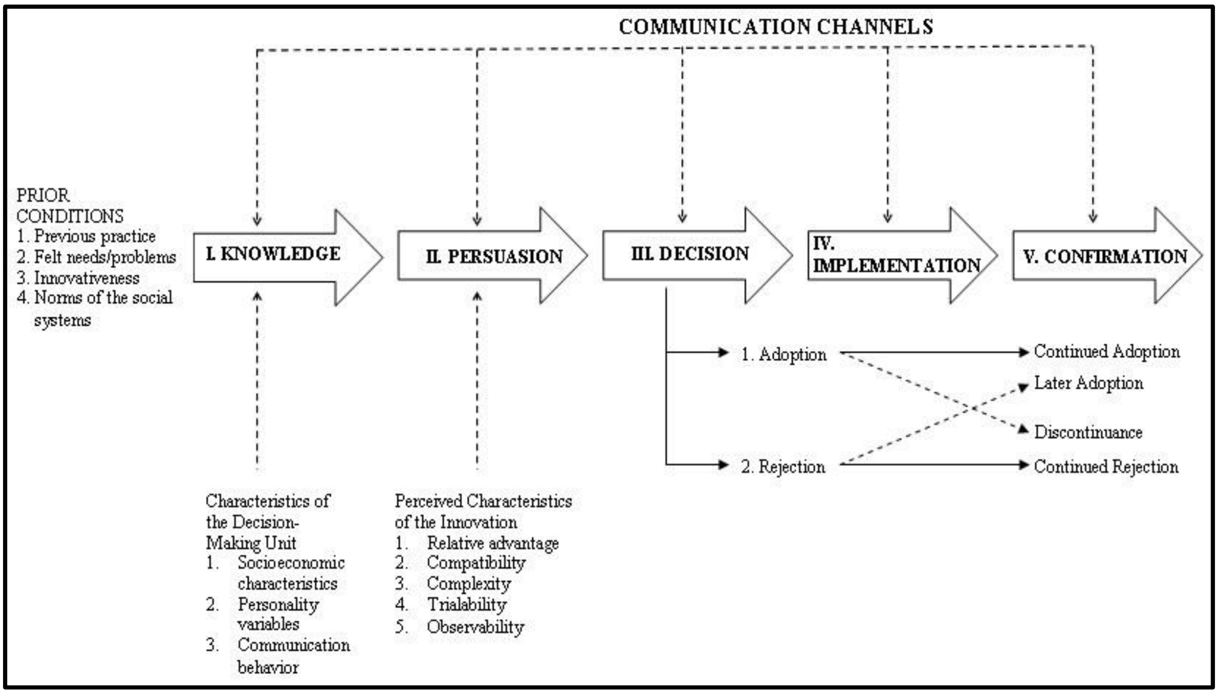

Figure 2.3: A Model of Five Stages in the Innovation- Decision Process.

(Rogers, 2003)

The Knowledge Stage

The innovation-decision process starts with the knowledge stage. In this step, an individual learns about the existence of innovation and seeks information about the innovation. “What?”, “how?”, and “why?” are the critical questions in the knowledge phase. During this phase, the individual attempts to determine “what the innovation is and how and why it works” (Rogers, 2003). According to Rogers, the questions form three types of knowledge: (1) awareness-knowledge, (2) how-to-knowledge, and (3) principles-knowledge.

- **Awareness-knowledge**

Awareness-knowledge represents the knowledge of the innovation’s existence. This type of knowledge can motivate the individual to learn more about the innovation and, eventually, to adopt it. Also, it may encourage an individual to learn about other two types of knowledge.

- **How-to-knowledge**

How-to-knowledge contains information about how to use an innovation correctly. Rogers saw this knowledge as an essential variable in the innovation-decision process. To increase the adoption chance of an innovation, an individual should have a sufficient level of how-to-knowledge prior to the trial of this innovation. Thus, this knowledge becomes more critical for relatively complex innovations.

- **Principles-knowledge:**

This knowledge includes the functioning principles describing how and why an innovation works. An innovation can be adopted without this knowledge, but the misuse of the innovation may cause its discontinuance. To create new knowledge, technology education and practice should provide not only a how-to experience but also know-why experience. In fact, an individual may have all the necessary knowledge, but this does not mean that the individual will adopt the innovation because the individual’s attitudes also shape the adoption or rejection of the innovation.

The Persuasion Stage

The persuasion step occurs when the individual has a negative or positive attitude toward the innovation, but “the formation of a favorable or unfavorable attitude toward an innovation does not always lead directly or indirectly to an adoption or rejection” (Rogers, 2003). The individual shapes his or her attitude after he or she knows about the innovation, so the persuasion stage follows the knowledge stage in the innovation-decision process. Furthermore, Rogers states that while the knowledge stage is more cognitive- (or knowing-) centered, the persuasion stage is more affective- (or feeling-) centered. Thus, the individual is involved more sensitively with the innovation at the persuasion stage. The degree of uncertainty about the innovation's functioning and the social reinforcement from others (colleagues, peers, etc.) affect the individual's opinions and beliefs about the innovation. Close peers' subjective evaluations of the innovation that reduce uncertainty about the innovation outcomes are usually more credible to the individual: Individuals continue to search for innovation evaluation information and messages through the decision stage.

The Decision Stage

At the decision stage in the innovation-decision process, the individual chooses to adopt or reject the innovation. While adoption refers to "full use of an innovation as the best course of action available," rejection means "not to adopt an innovation" (Rogers, 2003). If an innovation has a partial trial basis, it is usually adopted more quickly, since most individuals first want to try the innovation in their own situation and then come to an adoption decision. The vicarious trial can speed up the innovation-decision process. However, rejection is possible in every stage of the innovation-decision process. Rogers expressed two types of rejection: *active rejection* and *passive rejection*. In an active rejection situation, an individual tries an innovation and thinks about adopting it, but later he or she decides not to adopt it. A *discontinuance* decision, which is to reject an innovation after adopting it earlier, may be considered as an active type of rejection. In a passive rejection (or non-adoption) position, the individual does not think about adopting the innovation at all.

The Implementation Stage

At the implementation stage, an innovation is put into practice. However, an innovation brings the newness in which "some degree of uncertainty is involved in diffusion". Uncertainty about the outcomes of the innovation still can be a problem at this stage. Thus, the implementer may need technical assistance from change agents and others to reduce the degree of uncertainty about the consequences. Moreover, the innovation-decision process will end, since "the innovation loses its distinctive quality as the separate identity of the new idea disappears" (Rogers, 2003).

Reinvention usually happens at the implementation stage, so it is an important part of this stage. Reinvention is "the degree to which an innovation is changed or modified by a user in the process of its adoption and implementation" (Rogers, 2003). Also, Rogers (2003) explained the difference between invention and innovation. While “invention is the process by which a new idea is discovered or created,” the adoption of an innovation is the process of using an existing idea” (Rogers, 2003). Rogers further discussed that the more reinvention takes place, the more rapidly an innovation is adopted and becomes institutionalized. As innovations, computers are the tools that consist of many possible opportunities and applications, so computer technologies are more open to reinvention.

The Confirmation Stage

The innovation-decision already has been made, but at the confirmation stage the individual looks for support for his or her decision. According to Rogers (2003), this decision can be reversed if the individual is “exposed to conflicting messages about the innovation”. However, the individual tends to stay away from these messages and seeks supportive messages that confirm his or her decision. Thus, attitudes become more crucial at the confirmation stage. Depending on the support for adoption of the innovation and the attitude of the individual, later adoption or discontinuance happens during this stage.

Discontinuance may occur during this stage in two ways. First, the individual rejects the innovation to adopt a better innovation replacing it. This type of discontinuance decision is called *replacement discontinuance*. The other type of discontinuance decision is *disenchantment discontinuance.* In the latter, the individual rejects the innovation because he or she is not satisfied with its performance. Another reason for this type of discontinuance decision may be that the innovation does not meet the needs of the individual. So, it does not provide a perceived relative advantage, which is the first attribute of innovations and affects the rate of adoption.

2.12.3 Attributes of innovations and rate of adoption

Rogers (2003) described the innovation-diffusion process as “an uncertainty reduction process”, and he proposes attributes of innovations that help to decrease uncertainty about the innovation. Attributes of innovations includes five characteristics of improved biomass technologies for cooking of innovations: (1) relative advantage, (2) compatibility, (3) complexity, (4) trialability, and (5) observability. Additionally, “individuals’ perceptions of these characteristics of improved biomass technologies for cooking predict the rate of adoption of innovations”. Also, Rogers noted that although there is a lot of diffusion research on the characteristics of improved biomass technologies for cooking of the adopter categories, there is a lack of research on the effects of the perceived characteristics of improved biomass technologies for cooking of innovations on the rate of adoption.

Rogers (2003) defined the *rate of adoption* as “the relative speed with which an innovation is adopted by members of a social system”. For instance, the number of individuals who adopted the innovation for a period of time can be measured as the rate of adoption of the innovation. The perceived attributes of an innovation are significant predictors of the rate of adoption. Rogers reported that 49-87% of the variance in the rate of adoption of innovations is explained by these five attributes. In addition to these attributes, the innovation-decision type (optional, collective, or authority), communication channels (mass media or interpersonal channels), social system (norms or network interconnectedness), and change agents may increase the predictability of the rate of adoption of innovations. For instance, personal and optional innovations usually are adopted faster than the innovations involving an organizational or collective innovation-decision. However, for Rogers, relative advantage is the strongest predictor of the rate of adoption of an innovation.

- **Relative Advantage**

Rogers (2003) defined relative advantage as “the degree to which an innovation is perceived as being better than the idea it supersedes”. The cost and social status motivation aspects of innovations are elements of relative advantage. For instance, while innovators, early adopters, and early majority are more status-motivated for adopting innovations, the late majority and laggards perceive status as less significant. Moreover, Rogers categorized innovations into two types: preventive and incremental (non-preventive) innovations. “A preventive innovation is a new idea that an individual adopts now in order to lower the probability of some unwanted future event” (Rogers, 2003). Preventive innovations usually have a slow rate of adoption so their relative advantage is highly uncertain. However, incremental innovations provide beneficial outcomes in a short period.

To increase the rate of adopting innovations and to make relative advantage more effective, direct or indirect financial payment incentives may be used to support the individuals of a social system in adopting an innovation. Incentives are part of support and motivation factors. Another motivation factor in the diffusion process is the compatibility attribute.

- **Compatibility**

In some diffusion research, relative advantage and compatibility were viewed as similar, although they are conceptually different. Rogers (2003) stated that “compatibility is the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters". If an innovation is compatible with an individual's needs, then uncertainty will decrease and the rate of adoption of the innovation will increase. Thus, even naming the innovation is an important part of compatibility. What the innovation is called should be meaningful to the potential adopter. What the innovation means also should be clear. This is part of the complexity attribute.

- **Complexity**

Rogers (2003) defined complexity as "the degree to which an innovation is perceived as relatively difficult to understand and use". As Rogers stated, opposite to the other attributes, complexity is negatively correlated with the rate of adoption. Thus, excessive complexity of an innovation is an important obstacle in its adoption.

- **Trialability**

According to Rogers (2003), "*trialability* is the degree to which an innovation may be experimented with on a limited basis". Also, trialability is positively correlated with the rate of adoption. The more an innovation is tried, the faster its adoption is. As discussed in the implementation stage of the innovation-decision process, reinvention may occur during the trial of the innovation. Then, the innovation may be changed or modified by the potential adopter. Increased reinvention may create faster adoption of the innovation. For the adoption of an innovation, another important factor is the vicarious trial, which is especially helpful for later adopters. However, Rogers stated that earlier adopters see the trialability attribute of innovations as more important than later adopters.

- **Observability**

An additional characteristic of innovations is observability. Rogers (2003) defined *observability as* "the degree to which the results of an innovation are visible to others". Similar to relative advantage, compatibility, and trialability, observability also is positively correlated with the rate of adoption of an innovation.

In summary, Rogers (2003) argued that innovations offering more relative advantage, compatibility, simplicity, trialability, and observability will be adopted faster than other innovations. Rogers does caution, "getting a new idea adopted, even when is has obvious advantages, is difficult", so the availability of all of these variables of innovations speed up the innovation-diffusion process.

2.12.4 Theory of planned behavior

The Theory of Planned Behavior was proposed by Ajzen (1985). The theory consists of three conceptual determinants of the adoption of a new technology, these include the attitude towards the technology, social factors termed as subjective norm which refers to the perceived social pressure on either to use or not to use the technology and facilitating conditions such as availability of government support and technology support (Figure 2.7).

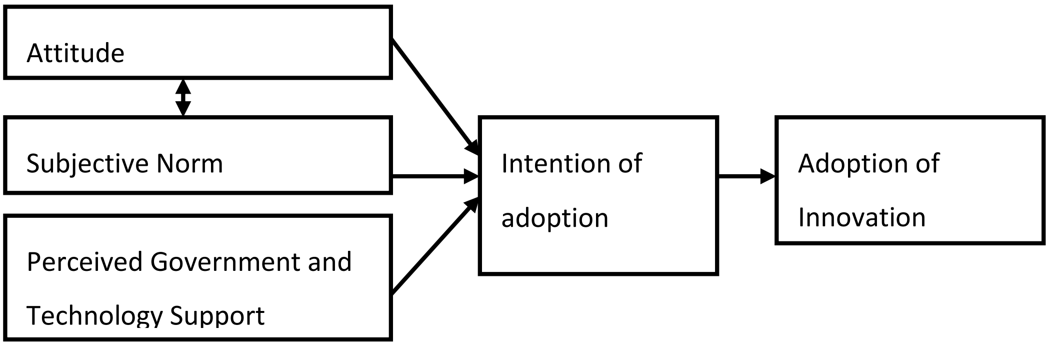

Figure 2.4: Theory of planned behavior.

(Ajzen, 1985)

2.13 Conceptual framework of the study

The conceptual framework of this study (Figure 2.8) was adapted from (Simon, 2006), based on the two theories: Diffusion of Innovation Model and Theory of Planned Behavior. The diffusion of Innovation theory is incorporated due to its consideration of demographic characteristics and communication channels as significant determinants of technology adoption. Theory of Planned Behavior on the other hand is incorporated as it considers the facilitating conditions such as government and technology support as factors influencing individuals' attitude towards technology adoption.

The overall assumption of this study is that inadequate support from stakeholders particularly the government institutions has got an influence on adoption and non-adoption of improved biomass energy technologies for cooking. Government institutions and other stakeholders' support involves among others; effective information dissemination and promotion strategies through communication channels such as media which assumed to influence awareness and peoples' perceptions towards the technology adoption.

According to adoption theories awareness is the first stage in the adoption process which implies that before any adoption of the technology is made, people must be aware of the new innovation and its benefits. Awareness occurs when people get access to information on the technology. In this work the sources of information include government institutions such as the Ministry of Energy and Minerals, Non-governmental organizations and financial institutions. Government institutions in particular can influence the adoption of improved biomass energy technology for cooking through policies, extension services, and awareness creation campaigns and through financial support. Other sources of information include improved biomass energy technologies for cooking projects and non-governmental organizations dealing with energy issues, media channels and improved biomass energy technologies beneficiaries. These are expected to promote the technologies through implementation of policies, projects, advertisements, demonstrations, motivation, and provision of technical support services. Once people are aware of the improved technologies and accumulate knowledge on their benefits they develop a positive attitude towards the improved technologies.

According to Simon (2006) after the initial stage of awareness and knowledge the potential adopters are still faced with the decision whether or not to adopt a technology. The decisions are influenced by various factors including socio-economic factors such as education level, age, household size, income level gender and the main economic activity of the household head. These characteristics of improved biomass technologies for cooking are determinants of the individual's ability to receive information, knowledge and perception towards the technology benefits which in turn influence one's decision to adopt the improved technologies or not to adopt. Furthermore, socio-economic factors determine the capability of individual households to afford maintenance costs, installation costs and operation.

Furthermore, the framework showed the influence of technological characteristics of improved biomass technologies for cooking in adoption of the technologies. According to Calliope, et al., (2011) for a technology to be adopted it should be affordable, efficient and its potential benefits should be easily visible. A combined effect of attitudes towards a technology, and environmental factors would influence the individual household's willingness to invest in the technology resulting into adoption of improved biomass technologies. It was noted that no factor works in its own; these factors influence one another and in turn influence the adoption process.

Dependent and independent variables

- **Dependent variablesAdoption of the Technologies** - This is the act of adopting the improved biomass energy Technologies by a household.

- **Independent variable**

Household and setting characteristics of households-This includes Household income (KES), Household headship and size (numbers), type of food cooked, Type of the house, Land ownership and Land use, Water availability and cooking fuels.

Perceptions- This is a way of regarding, understanding, or interpreting biomass fuels and improved technologies

Acceptability- The action or process of the improved biomass technologies being received as adequate or suitable, typically to be adopted by households.

Awareness - knowledge the existence of various biomass fuels and improved technologies

Promotion- This is activity that supports or provides active encouragement for the adoption of various biomass fuels and improved technologies

Technology and fuel characteristics - These are features or qualities of various biomass fuels and improved technologies; Easy to use, affordable, efficiency, smoke, durability.

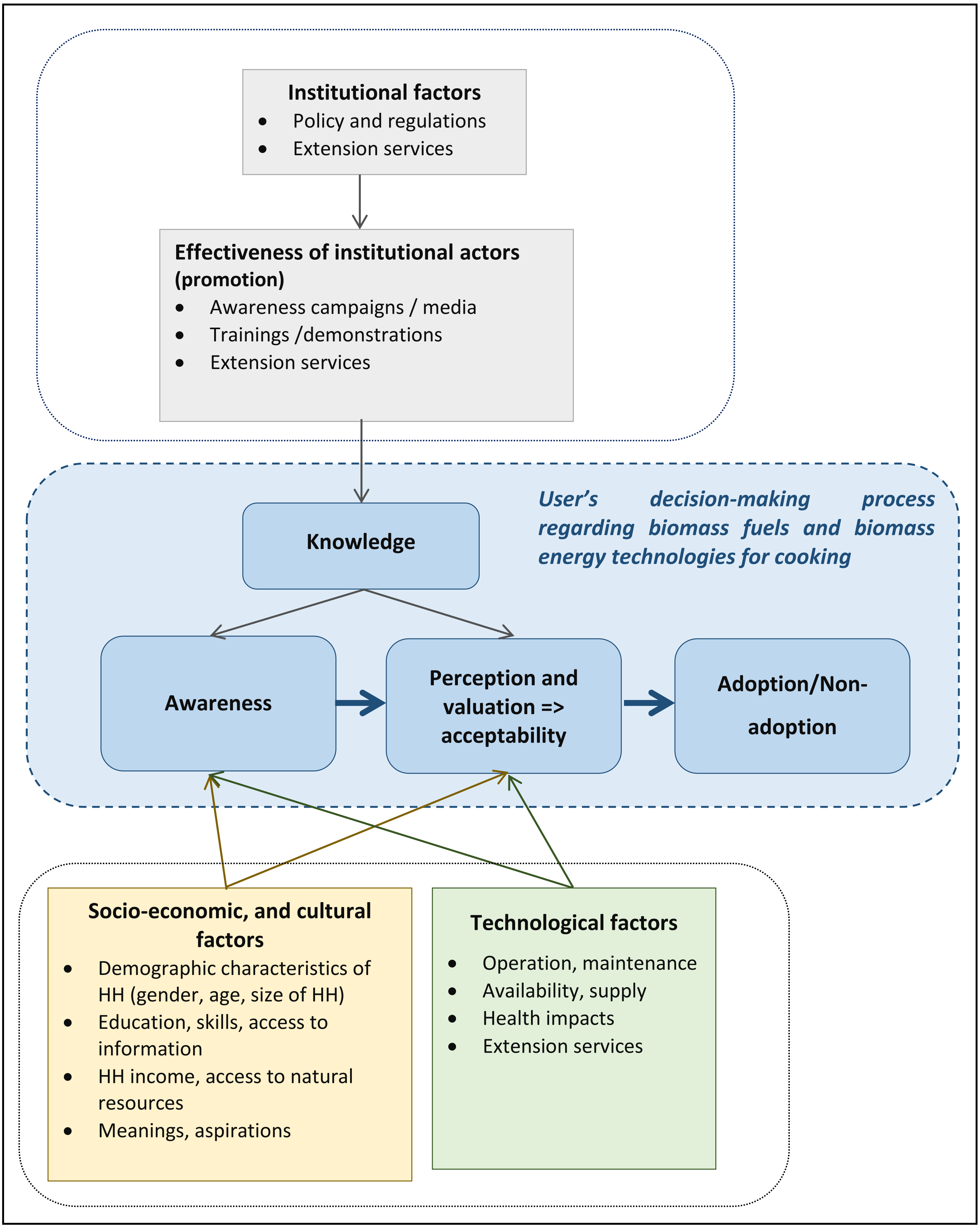

Figure 2.5: Conceptual framework

(Adapted from Simon, 2006)

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

This chapter provides the explanation on how the study was conducted including sampling procedures, data types and their sources, data collection techniques and the methods used to process and analyze data.

3.2 Research design

A case study design was used in order to answer the research questions. The study employed triangulation method to improve the validity of the data. But it was dominantly qualitative. Research methods helped to address the socio-demographic characteristics of the respondents, something which is best explained in numbers. The choice of triangulation methods comes from the fact that each method complements the other resulting in a stronger research design, and more valid and reliable findings are derived from triangulation (Robert, 1994).

On the other hand, the research methods strives to understand the perceptions of participants or a situation by looking at first-hand experience to provide meaningful data (Patton, 1980). Qualitative methods are preferred in this study because evidence indicates that it is most appropriate for giving causal explanation. This is because, qualitative methodology is based on direct quotation, careful description and interpretation of the respondents' views, seeking to capture what the people say about their lives, experiences and their interactions, in their own words (Patton, 1980) in response to open ended questions. (Robert, 1994); (Patton, 1980) identify observation, individual and group interviews as techniques useful in collecting qualitative data.

3.3 Sampling methods

3.3.1 Study population and sampling frame

The population was taken as the total number of households in Kitui Central which is 30,203 (KNBS, 2009). The sampling frame was the list of all administrative locations and the list of all the households per location.

3.3.2 Sample size and sampling procedures

Sampling is the process by which inference is made to the whole population by examining a part of it (GMU, 2004). May (1993) mentions advantages of sampling to include: first, the data collection being cheaper; secondly, it requires fewer people to collect and analyze data; thirdly, it saves time; fourthly, it permits a higher level of accuracy as the sample size allows a check on the accuracy of the design and administration of the questionnaires; and finally fewer cases make it possible to collect and deal with more in-depth information.

The sample size (**n**) was calculated by use of the Fishers formula (Mugenda & Mugenda, 2003; Freund & Williams, 1983).

$$n = \frac{Z^2\,(p)(q)}{d^2}$$

Where:

- Z refers to the confidence limits of the study results, i.e. 95% where Z = 1.96
- P refers to the proportion of the population who had acquired and using the improved biomass energy technologies. Estimation (0.07)
- Q = (1-p) refers to the proportion of the population who had not acquired nor used improved biomass energy technologies. Estimation (0.93).
- D refers to the desired precision of the estimates (within a range of plus or minus 5%)

So, using (Fischer, et al., 1983) equation above, one gets:

$$n = \frac{(1.96^2)(0.07)(0.93)}{0.05^2}$$

=100.03

Therefore the sample size ≅ 100

According to Freund & Williams, (1983) and Nyariki, (2009) any number equal to or greater than the statistically large sample of 30 sample units is appropriate. In addition to taking into consideration the statistical requirement to have a minimum size of 30 sample units, the ultimate size arrived at must bring into view the possibility of non-response (which, by ‘playing it safe’, may be given a 40–50% chance) (Freund & Williams, 1983), limited financial outlays, the nature of the research, and time—as most research categories are time-bound.

Stratified sampling was used to select the study sample because of common heterogeneity among population, it is usually desirable to undertake population stratification. First the sampling frame was stratified by use of rural-urban localities as stratification variable (Nyariki, 2009). It is usually economical to sample specific groups (stratum) and then obtain data from each eligible unit sampled (household). Secondly, Kyangwithia Weat and East were selected purposevely because the available sources of biomass energy is very minimal compared to other rural locations. Thirdly, equal number of households were sampled from urban and rural locations (Table 3.1). Disproportionate stratification was most appropriate where one or more of the subgroups is very small in comparison to other groups, or where the target of the study is specific and oversampling of a group may provide more accurate results (Charles & Fen, 2007). Fourthly, proportional stratified sampling was used to get the sample size for each rural location (Table 3.1). Finally, simple random sampling was used to sample the households which constituted the sample size (Krishnaswam & Ranganathan, 2005). This gave each household an equal chance of being selected.

Table 3.1 Number of households sampled per location

Location	**No. of Households**	**Samples**
Kyangwithya East (Rural)	6,838	32
Kyangwithia West (Rural)	3,820	18
Kitui Township (Urban)	6,243	50
TOTAL	**16,690**	**100**

(Source: Researcher)

3.4 Source of data

3.4.1 Primary data

The study collected primary data from of the households by use of semi- structured questionnaire, interview schedules, focused group discussions, key informants interviews and observations.

Semi-structured questionnaire

Semi-structured questionnaire (see Appendix I) were administered by means of personal interviews in order to encourage the respondents to participate and to allow probes, clarification by the interviewer as observed by Kothari (1990). The open-ended questions were used to allow the respondents to give their own opinions. Closed questions were presented with a series of choices to allow the respondents to choose one answer. The questionnaire were used to gather information on educational level, gender status, number of children, income level, types of improved biomass energy technologies in use, source of fuel and other information important for the study. Likert scale, developed by Renis Likert in 1930s was be used to gather information on the level of awareness and levels of acceptance of the improved technologies and various biomass fuels (Likert, 1932).

Piloting of questionnaire

The semi-structured questionnaire was pre-tested before by piloting in order to gauge its reliability in gathering the required data. A sample of 20 households was selected randomly outside the area of the study and involved in filling the questionnaire. The number 20 was chosen for pre-test because according to (Kothari, 1990). The required corrections were made on the questionnaire/interview schedule before they were administered to the households involved in the study.

Key informants interviews

Interviews were used to collect factual information. In addition, the interview questions (see Appendix II) were used to retrieve information meanings, perspective and opinions of residents with regards to the promotions and perceptions. The manner in which the questions were structured was such that the residents were able to provide information to the best of their knowledge without any feeling of coercion. Oral interviews were preferred in this study because they helped solicit high response (Kothari, 1990). The respondents used the opportunity to raise new issues and challenge the researcher's agenda (Kothari, 1990). Six actors involved in the promotion and dissemination of the improved biomass energy technologies were interviewed.

Focus group discussions

Three focus group discussions were conducted in selected sub-location each representing one location. The focus groups comprised of 15 participants who were selected from rural and urban households putting in consideration members of community based organizations, gender balance and self-help groups. From focus group discussions, qualitative information such as general opinion, awareness and perceptions towards improved biomass technology were collected. A checklist (see Appendix III) was the basic tool for conducting focus group discussions. Participants' responses were recorded in a notebook during the discussions or immediately thereafter (May, 1993).

Field observation

Field observation were used to verify the type of improved biomass technologies in use by households as well as the type of technologies being promoted by the actors in the study area.

Photography

Photography was used during data gathering. Areas affected by unsustainable use of biomass were photographed as well as the types of improved biomass energy technologies promoted in the study area.

3.4.2 Secondary data

Secondary data was sought from annual reports of relevant ministries, NEMA, journals and books in the libraries relevant to the area of research.

3.5 Data analysis matrix

Research questions	**Data needs**	**Sources of data**	**Data collection methods**	**Data analysis**	**Data presentation**	**Expected output**
1) What are the socio-economic characteristics of rural and urban households' that have an influence on the adoption of improved biomass energy technology for cooking?	-Gender (Male/Female) -Age (years) -Marital status (Married, single, divorced/separated) -Education level -Occupation -Household Income (KES) -Household headship (1-male headed, 2-female headed or 3-child headed) -Household size (number) -Type of food cooked (included as an nominal scale)	<u>**Primary Data**</u> Questionnaires FDG	Questionnaire administration -Interviews -Observations - Focused group discussions	Quantitative analysis using SPSS	Figures Tables Reports	Socio-economic profile of rural and urban households.

	-Livestock (number) -Housing structures (included as an nominal scale) -Land tenure (included as an nominal scale) and farming systems (acres) -Water availability (water shortage included as an ordinal scale (1-YES; 2-NO) -Fuel availability(number of biomass fuels)					
2) What are the households' perceptions, adoption and constraints faced in relation to the use of efficient cooking technologies and biomass fuels?	-HH Criteria while choosing cooking technology and biomass-fuel to use -HH's perception in relation to fuel and technology us	**<u>Primary Data</u>** Questionnaires FDG	-Questionnaire administration -Interviews -Observations	Quantitative analysis using SPSS	Figures Report Photos	HH Criteria while choosing cooking technology and biomass-fuel to use HHs' perceptions in relation to fuel and Cooking technologies

3. What are the households' perceptions and constraints faced in relation to the use of biomass fuels?	-HHs' current constraints in relation to the use of improved biomass energy technologies and biomass Fuels		- Focused group discussions			HHs' current constrains and propose solutions to the constraints
4) How are stakeholders involved in the promotion of improved biomass energy technologies for cooking?	- Awareness of promotion activities - Promoters of improved technologies for cooking -Nature of promotion -Level of promotion	**Secondary data**- -Journals articles -Publications -Reports **Primary data** Questionnaires FGD Key informants	Questionnaire administration Key informants discussions Focused group discussions	Quantitative analysis using SPSS	Figures Photos Reports	Awareness of promotion activities, different promoters of improved technologies for cooking, Nature of promotion and Level of promotion

5) What is households' level of acceptance and willingness to switch from current fuels and technologies to another?	HHs' level of acceptance of **various** improved biomass energy technologies and biomass fuels HH's willingness to switch from current fuels and technologies to another Technologies and fuels HHs' are willing to switch to Reasons for their answers	**Secondary data**- -Journals -Publications -Reports -Census reports -Statistical abstracts **Primary data** Questionnaires FGD Key informants	- Literature review -Questionnaire administration - Interview -FDGs - Photography	Qualitative and quantitative analysis using SPSS, MS-Access and MS-Excel Likert Scale	Charts Tables Photos Reports	HHs' level of acceptance of various improved biomass energy technologies and biomass fuels HH's willingness to switch from current fuels and technologies to another and their ability

3.6 Data analysis

3.6.1 Descriptive and inferential statistics

Descriptive statistics were used to analyse the characteristics of the population studied. According to Trochim (2006) descriptive statistics are used to describe the basic features of the data in a study providing simple summaries about the sample and the measures. The data is summarised in form of means, standard deviation, frequency tables, bar charts and percentages were used. These were used to describe demographic data such as age, education, employment status, number of dependent etc. Descriptive statistic e.g. use of bar graphs, tables and percentages were used to analyse the Likert scale questions.

According to Smith, (2011) inferential statistics are used to make inferential statements about a population. Pearson's Chi square and Phi test was used to test the research hypotheses.

3.7 Ethical consideration

The study was conducted in accordance with the standard research ethics. Informed consent was sought prior to data collection. Anonymity and confidentiality was also maintained. An appointment for administration of questionnaires to the respondents was prepared with the assistance of the chief. The researcher guided and supervised the fieldwork during data collection. The instruments were then administered to members of the household above 18years of age (not necessarily the head) to collect the required data in face-to-face interview and their responses recorded accordingly.

CHAPTER 4: RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter present the answers to the research questions and responds to the objectives initially set out in the study. The results in this section originated from the questionnaire responses, focused group discussions, key informants interviews, the researcher‘s own observations and also through relevant literature review. The chapter includes a description of the background information, **socio-economic** characteristics of households, the **perceptions, current adoption** and **constraints** of current biomass fuels and cooking technologies, the **promotion** of various improved biomass energy technologies and the level of **acceptance** and **willingness** to switch fuels and cooking technologies for future development of biomass energy.

4.1.1 Socio-economic and demographic characteristics of the repondents

This study was carried out in Kitui Central Sub-County. Kyagwithia East and Kyagwithia West locations represented the rural population while Kitui Township location represented the urban population.

<u>4.1.1.1 Gender</u>

Majority of the respondents (78%) were females, while the rest (22%) were males (Table 4.1). However, 78% of the rural respondents interviewed were females and 24% males compared to 80% females and 20% males of the urban respondents. There were more females respondents in both urban and rural regions because women are mostly left at home and involved in domestic chores while men move out daily in search of income to meet the needs of the family. Thus, women are well versed with problems associated with use of fuelwood and type of biomass energy technologies in use for cooking and heating activities. Due to involvement in the domestic chores, women and children are also the most affected by indoor air pollution by use of inefficient energy stoves (Muchiri, 2008).

Table 4.1: Gender of the Respondents

		Gender of the respondents	
		Male %	Female %
Location	Rural	24	78
	Urban	20	80
Total		22	78

(Field Data, 2014)

Kaleba *et al.*, (1997) in their study found that gender had a significant influence in the adoption of stall-feeding technology in semi-arid areas of Tanzania. Similar results were reported by Kalineza (2000) who observed that gender played a significant role in influencing adoption of soil conservation measures in Kilosa District. In another research work by Nhembo (2003) it is argued that if a technology to be adopted is expected to reduce women workload, then women may prefer to adopt it.

4.1.1.2 Age

The study findings indicate that majority of the respondents (27%) were aged between 26 to 33 years (Table 4.2). The urban respondents were composed mainly of young people since many of them have migrated to the urban areas in search of income as compared to the rural area where the older generation retire after active live in the urban areas during their younger age.

Table 4.2: Age of the respondents

		Age of the Respondent						
		18-25	26-33	34-41	42-49	50-57	58-65	66 and above
Location	Rural	4%	18%	18%	16%	20%	0%	24%
	Urban	6%	36%	18%	12%	16%	4%	8%

(Field Data, 2014)

The youth are more adaptive to new ideas compared to the old. In a study carried out in Kathiani, Kenya, Karanja (1999) found out that the age bracket 26-36 years had adopted more energy saving technologies as compared to those over 45 years. She attributed her findings to the fact that middle age respondents are in their reproductive and productive years and this age group had adopted energy conservation technologies for effective performance of both reproductive and productive activities.

4.1.1.3 Marital status

Most of the respondents (81%) are married, 9% are single and 5% are widowed while 5% are separated/divorced (Table 4.3). Majority (86%) of the rural respondents and 76% of urban respondents are married. The marital status can influence acquisition and use of a technology where one is needed to consult before a decision is made.

Table 4.3: Marital status

		Respondent's Marital Status			
		Married	Single	separated/divorced	Widower/widowed
Location	Rural	86%	10%	2%	2%
	Urban	76%	8%	8%	8%

(Field Data, 2014)

4.1.1.4 Education

Forty eight percent (48%) of the rural households have attained primary school education, 42% have attained secondary school education and half of the urban respondents have primary school education (Table 4.4). Of the rural respondents, 2% have college education, while in urban 7% and 2% have acquired college and university education respectively. This implies that the educated tend to migrate to the urban areas in search of employment while the less educated stay in the rural areas and get involved in menial jobs.

Table 4.4: Education level of the respondents

		Highest level of education				
		None	primary	secondary	tertiary	University
Location	Rural	6%	48%	42%	4%	0%
	Urban	6%	50%	26%	14%	4%

(Field Data, 2014)

Education level of the respondents tends to influence adoption of technologies as learned people usually adapts to new ideas faster than those who have not been to school. According to Hirok and Ashok (2010), people with higher education level have better access to information and knowledge that is beneficial in their domestic activities. They also tend to have higher analytical capability of the information and knowledge necessary to implement new technology and realize the expected result. Hence, the higher education level allows households to make efficient adoption decisions Rahn and Huffman, 1984) and be the early adopters who can take advantage of new technology and profit from it Gardner and Rausser, (2001).

4.1.1.4 Main occupation

Over three quarters of the respondents are unemployed, 30% are self-employed and only 19% are formally employed (Table 4.5). Majority (90%) of the rural respondents are unemployed compared to 72% of the urban respondents. About 40% of the urban respondents are self-employed, compared to 20% of the rural population.

Table 4.5: Main occupation

		Main Occupation of the respondent				
		Farming %	Business %	Salaried%	Casual work %	Others%
Location	Rural	66	20	10	2	2
	Urban	16	40	28	4	12

(Field Data, 2014)

The respondents who are formally employed meant that they have a guaranteed salary at the end of every month and thus, there is a likelihood of acquiring the improved biomass energy technologies. The findings of the high rate of unemployment in both urban and rural might be misleading due to the fact that even where the respondents mostly female reported that they were unemployed they still had their husbands working and thus guaranteed of some income at the end of the month.

4.2 Socio-economic characteristics of the households

In the following sections, results are presented that address objective one of the study and documents the socio-economic characteristics of rural and urban households that influence adoption of biomass fuels and biomass energy technologies for cooking. The independent variables considered are household income, household size and headship, household nutrition, housing structures, land tenure and farming systems, water availability and fuel used for cooking. Phi test was used to determine the strength of a relationship between the selected sets of data. It is often used as a statistical method to aid with either proving or disproving a hypothesis.

4.2.1 Household income

Household income was measured as total sum of money in Kenya shillings (KES) as earned by all on-farm members of the household per month and remittances from off-farm members. Generally, the study area is composed of low and middle income earners and a small proportion of high income earners. The rural people are mostly engaged in farming activities while majority of the urban respondents are employed in the urban area and others are small scale traders.

The respondents who are formally employed means that they have a guaranteed salary at the end of every month and thus there is a likelihood of acquiring the energy saving technologies. The household average mean income is KES 19,189 which is quite high income for the study area. The range in both localities is quite high (KES 12,802); with the rural households' average income being KES 12,788 and that of urban respondents being KES 25, 590.

Six percent (6%) of the rural households and 24% of the urban households have an income of over KES 25,000 (Figure 4.1). Household income can be used as a proxy of working capital because it determines the available capital for the investment in the adoption of technologies and it is a means through which the effect of poverty can be assessed. According to the World Bank (2003) poverty is the main cause of environmental degradation. Household income has a bearing also on the socio-economic status of family. According to GTZ (2008) low level of income of the households influences the type of innovation to adopt. In cases where an innovation presents a high initial investment cost it prevents households from adopting it. The lower the level of income the lower the adoption of any technology while the higher the level of income, the higher the level of acquiring and usage of a new technology. This is because most of the new technologies have a cost implication and only those with money are able to adopt the technology faster.

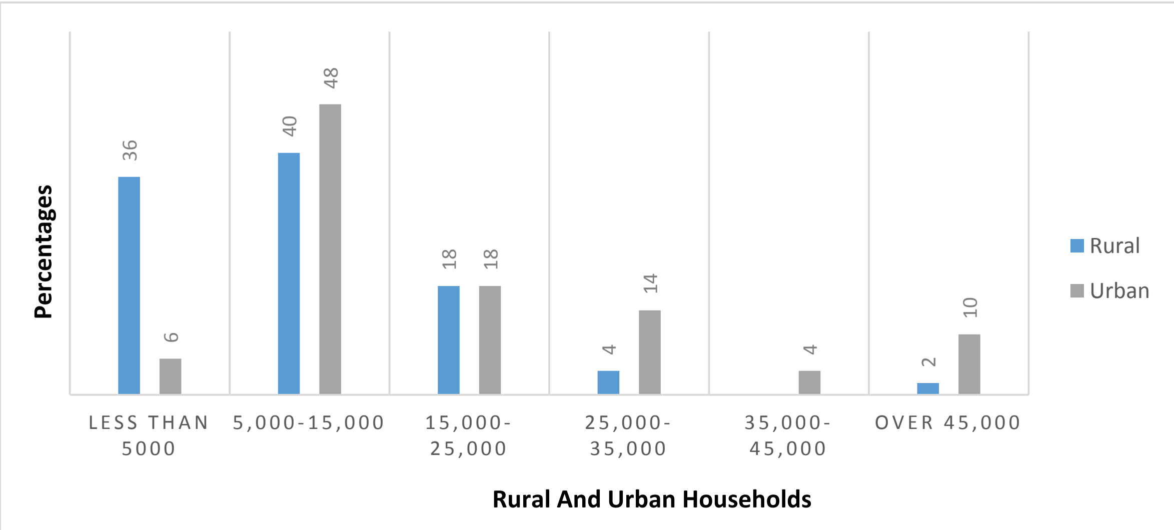

Figure 4.1: Average household income of surveyed households in Kitui Central

(Field Data, 2014)

4.2.2 Household headship and household size

Household headship was defined as the head of the household because the respondents are not necessarily the heads of the household. In as far as household headship is concerned, the results in Table 4.6 show that the majority of the households are male headed (75%). Additionally, 74% of the rural and 76% of the urban households are male headed.

Table 4.6: Household headship

		Household Headship		Overall
		Male headed	Female headed	
Location	Rural	37 (74%)	13 (26%)	50 (100%)
	Urban	38 (76%)	12 (24%)	50 (100%)
Overall		75 (75%)	25 (25%)	100 (100%)

(Field Data, 2014)

The average household size in the study area is 5. Rural households have larger households compared to urban households because the cost of raising children in urban areas is higher compared to rural areas. It is assumed that this medium household size can make the collection of firewood quite tedious for these families due to its scarcity and long distances in its search. Thus, energy saving technologies are necessary in these areas. This average family size can however provide enough labour for biogas technology.

4.2.3 Type of food cooked

Githeri (mixture of dry maize and beans) is the main food type for all rural households and 92% of the urban households (Figure 4.2). There is no quite distinct difference in the diets of rural and urban household. Rural households perceive firewood to be the most economical fuel to cook *githeri* which takes around 3-4 hours to boil using the traditional cookstoves while urban households prefer charcoal to LPG and Kerosene to boil the same which takes approximately 2 hours to cook using Kenya Ceramic Jiko. Rural households need to adopt improved technologies to save on fuel used and cooking time. Other foods include *chapattis* (flat wheat breads), rice and *ugali* (a dish of maize floor). Mainly households use charcoal to cook *chapatti* because charcoal is perceived to cook tasty *chapatti*. Rural households feel that they cannot fully switch from firewood because it is the suited best for cooking their staple food.

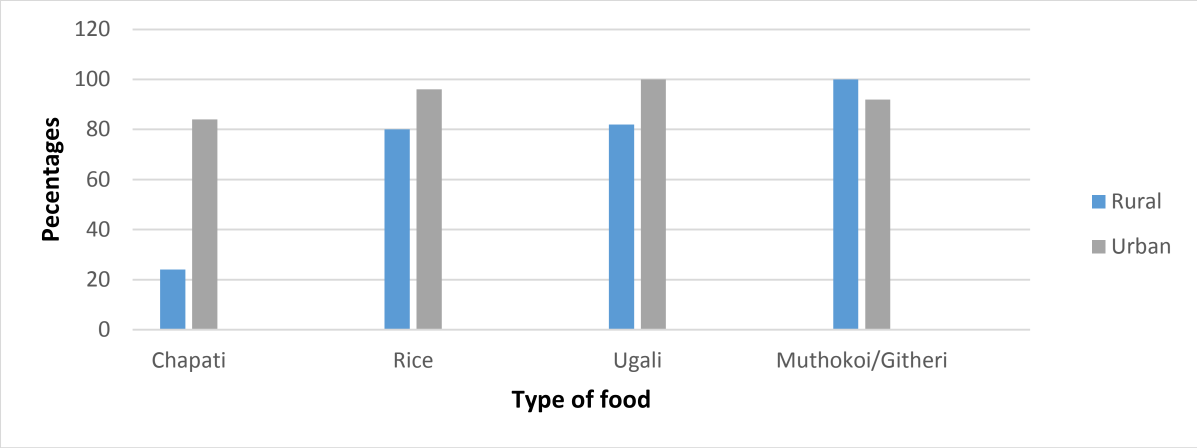

Figure 4.2: Types of food consumed by respondents

(Field Data, 2014)

4.2.4 Type of houses

Type of the house was determined by the construction materials used. During the study it was revealed that type of the house and house ownership has an influence on the decisions on which improved biomass energy technology to adopt by the household. Generally, all rural households have semi-permanent houses with enough space inside/around the house for positioning a cooking stove. Figure 4.3 shows that 48% of the rural households have kitchens with an earthen floor which is one of the limiting factors for them to adopt some improved technologies of their choice such as Rocket stove which requires a permanent kitchen. The urban households have permanent houses but lack ownership which limits them from adopting fixed stoves.

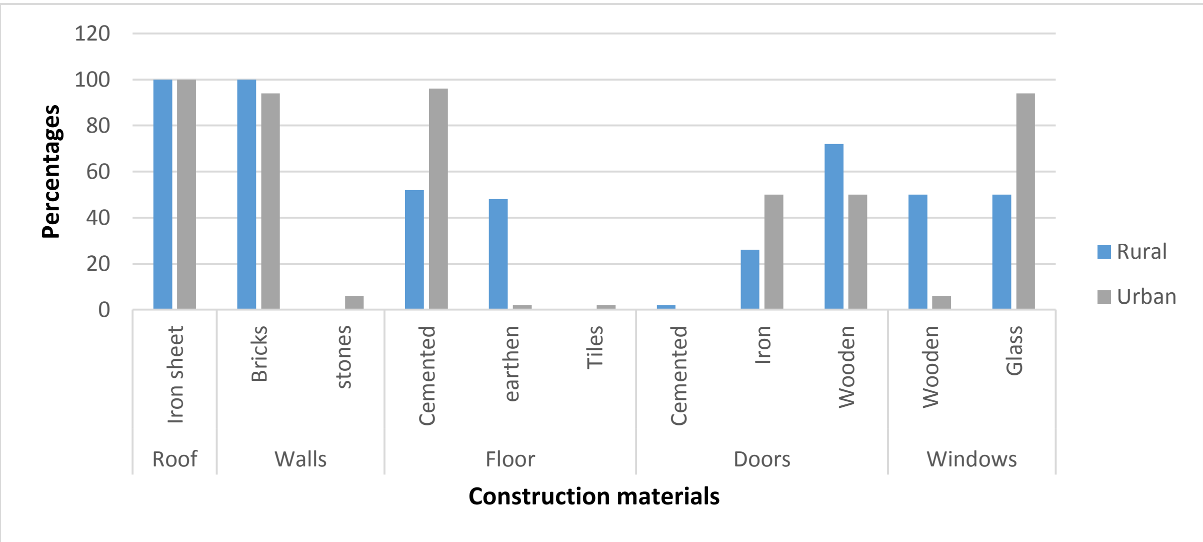

Figure 4.3: Construction materials of houses in rural and urban areas

(Field Data, 2014)

4.2.5 Household and farm hedges

Sixty four percent (64%) of the rural households have no fence for their households, 54% have farms without fences and 28% of the urban households have no fence for their farms (Figure 4.4). This is an indication that households have not yet seen hedges for fuelwood or Jatropha as an opportunity to tap as source of fuel for cooking.

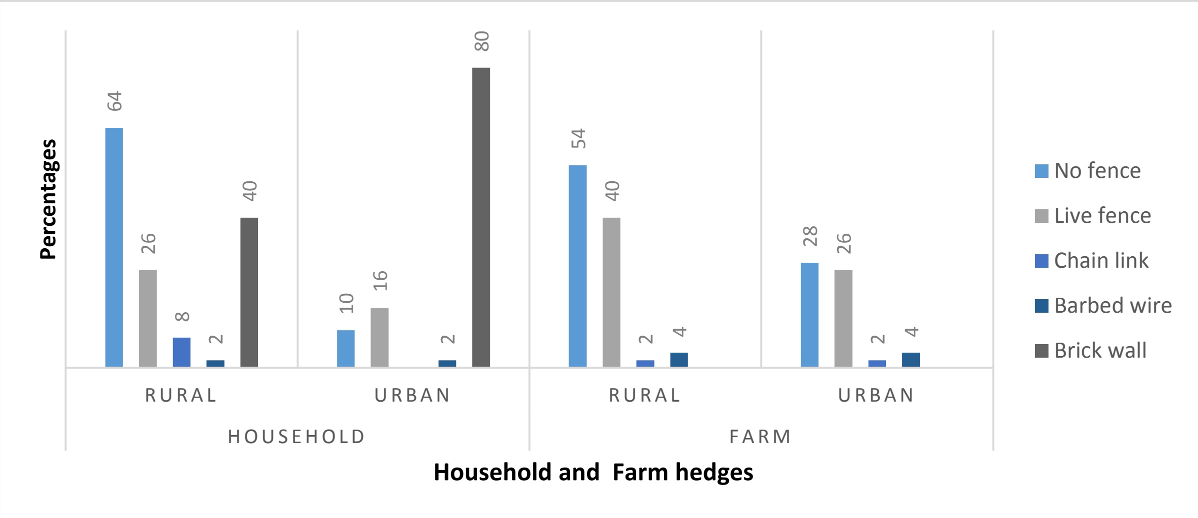

Figure 4.4: Household and farm hedges

(Field Data, 2014)

4.2.6 Land ownership and land use

Land ownership herein refers to ways of owning land whereas land use refers to ways in which households use their land. Analysis of the data shows that majority (88%) of the rural households do not have legal document, 44% of the rural households and 40% of the urban households have only a verbal agreement for the land (Figure 4.5). This happens especially during land inheritance with no clear demarcation and no title deeds which hinder them from having long term investment such as planting trees which is seen as a claim of that portion of land since trees are long lasting. Households with no right to land ownership are reluctant from doing long term investments such as building permanent houses which can allow them to adopt improved technologies such as Rocket stove and three chamber stove. Biogas installation is a permanent investment which cannot be adopted by the same households with no right to land ownership. Land tenure is a relevant, but disputed, factor in technology adoption studies, particularly in developing countries (Ramirez & Shultz, 2000). The effect of land tenure on technology adoption varies due to the profitability and riskiness associated with the new technology.

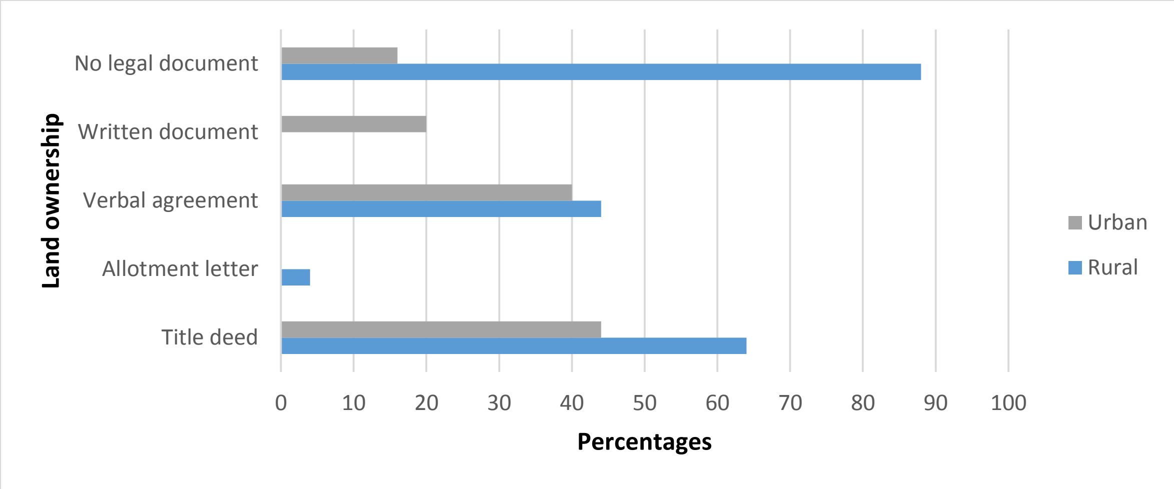

Figure 4.5: Land ownership

(Field Data, 2014)

Sixty eight percent (68%) of the rural households and 42% of the rural households have farms that are below four acres (Figure 4.6). It is assumed that perhaps land sizes may influence household's ability to set aside a portion of the land for wood production which in turn may affect availability of fuel and hence the ability to use energy saving stoves. It is expected that households with small landholding will be more likely to adopt the energy saving technologies because of the high cost of buying or gathering fuel and the inadequate land to establish woodlots for fuelwood. For Kaliba et al (1997), farm size may be a proxy of farmers 'wealth and, as such, relates directly to their investment capacity to adopt new technology. This explained the higher adoption of stall-feeding management among small dairy producers in Tanzania relative to large farmers: the latter were wealthy and had access to other, more suitable technologies.

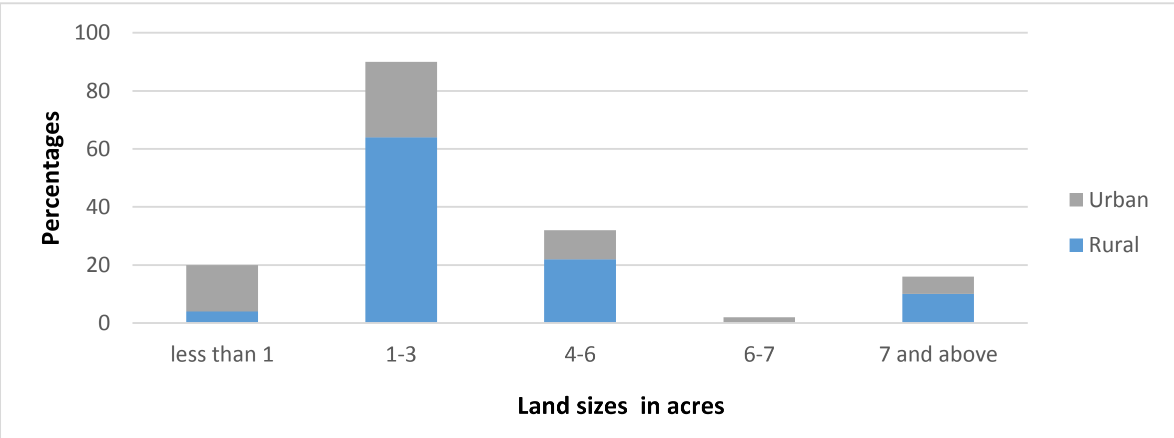

Figure 4.6: Land sizes

(Field Data, 2014)

Ten percent (10%) of the rural households and 6% of the urban households with land have set aside a piece of land for woodlot/forest (Figure 4.7). This finding shows that most households do not have their own woodlot or forest for firewood collection or charcoal burning for ease and convenience in collection and burning. Thus, they either collect from the government land, buy from vendors or from neighbors' land. Probably, there is need to educate households on the importance of setting aside small portions of land for wood lot or forest.

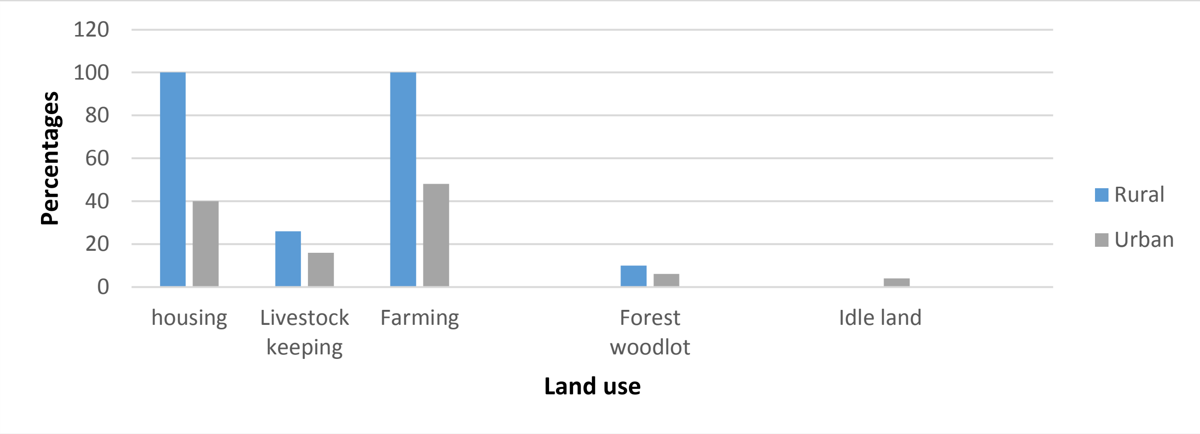

Figure 4.7: Land uses

(Field Data, 2014)

Livestock keeping is carried out in the study area mainly for the production of milk and income generation. Livestock keeping is done by 26% of the rural households and 16% of the urban households. Over half of the rural households have at least one type of livestock. Livestock keeping is essential for the success of biogas plant at household level a component lacking in many households. Findings by Walekhwa et al (2009) shows that the probability of a household adopting biogas technology in Central and Eastern Uganda increases with increasing number of cattle owned. Zero grazing is only practiced by 13% of the rural households with livestock. Other mode of grazing such as free range are common for both rural and urban households which can make it difficult to accumulate sufficient feed stock for use especially in biogas plant compared to zero grazing (Figure 4.8).

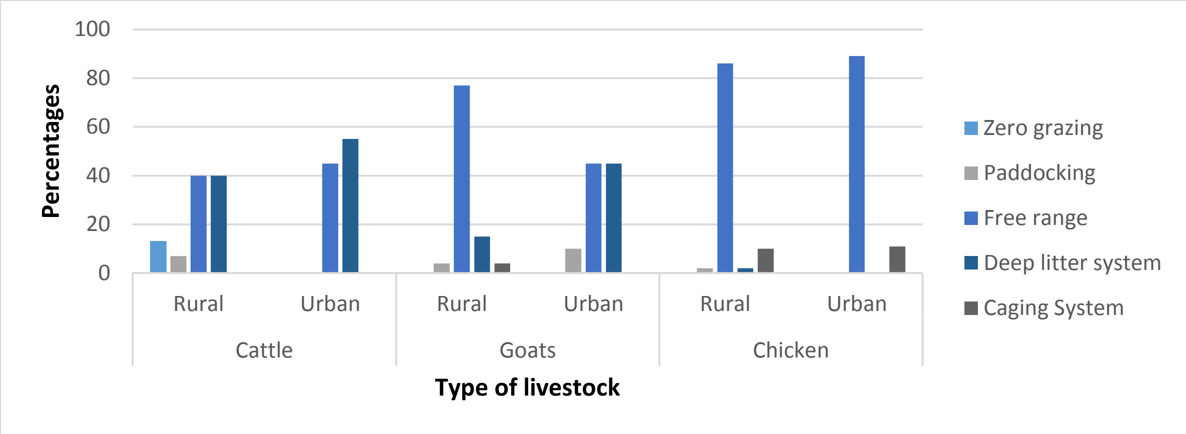

Figure 4.8: Mode of Grazing

(Field Data, 2014)

4.2.7 Water availability

The main sources of water for the rural households are rivers and wells while for the urban households are piped water from the municipal and boreholes. However, 72% and 78% of rural and urban households respectively face water shortage mainly during the months of August to November each year. Alternative sources of water during dry seasons include buying from vendors and use of stored water. The main storage facilities include plastic tanks and jerry cans whose capacity is very small to carry a household throughout the dry season. For instance, 36% of the rural households and 52% of the rural households have storage facilities with a capacity less than 300 liters (Figure 4.9). This poses a great challenge especially for the biogas technology where water availability is an essential component and its deficiency is an impediment to the technology.

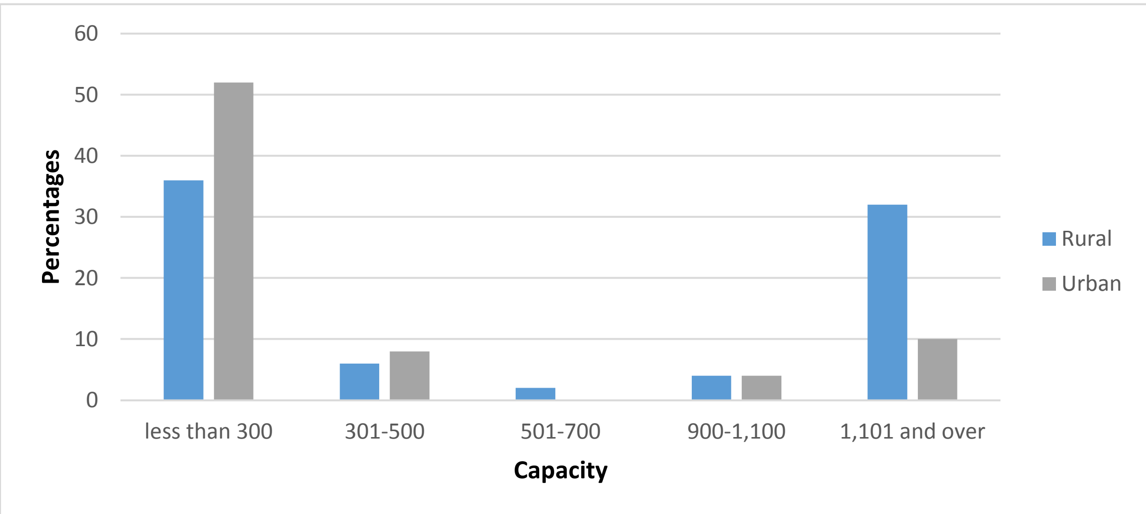

Figure 4.9*: Water capacity of storage facilities*

(Field Data, 2014)

4.2.8 Cooking fuels

Findings in Table 4.7 indicate that 72% of the rural households use at least two biomass fuels while 68% of the urban households use one biomass fuel to cook.

Table 4.7: Number of biomass fuels used

		Number of Biomass fuels used				Total
		0 (%)	1 (%)	2 (%)	3 (%)	
Location	Rural	0 (0)	8 (16)	36 (72)	6 (12)	50 (100)
	Urban	2 (4)	34 (68)	14 (28)	0 (0)	50 (100)
Total		2 (2)	42 (84)	50 (50)	6 (12)	100 (100)

(Field Data, 2014)

Twelve percent (12%) of the rural households use biogas for cooking and 6% of the urban households use briquette. Firewood and charcoal is used for cooking by 98 % and 86 % of the rural households respectively. On the other hand, firewood and charcoal is used for cooking and heating by 32% and 88% of the urban households respectively (Figure 4.10). The high rate of firewood and charcoal use by households has implication on wood fuel demand since most of the wood fuel come from the surrounding forests and also the woodlands near the study area.

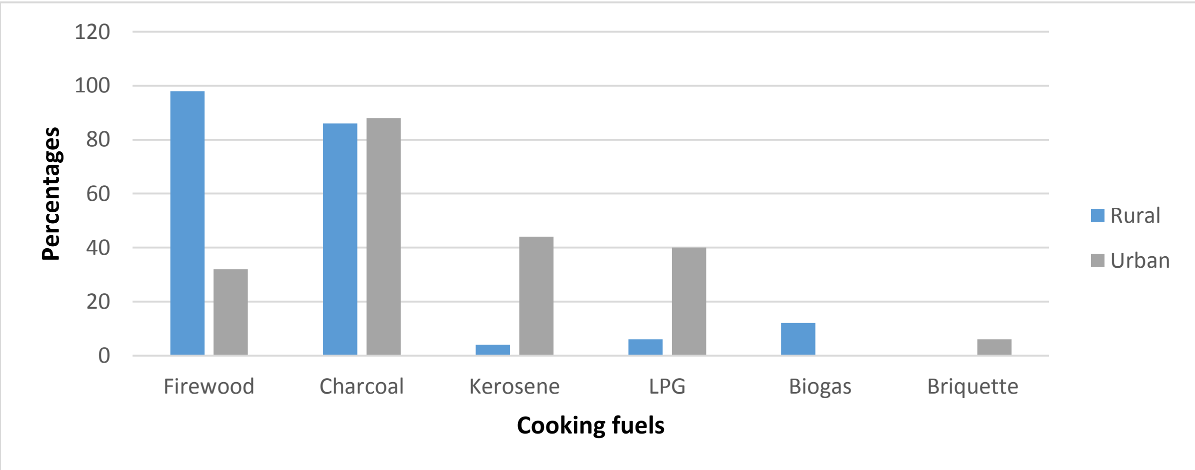

Figure 4.10: Cooking fuels

(Field Data, 2014)

4.2.9 Analysis of the variables

The First null hypothesis stated: There is no significant relationship between household income, gender of the household head and adoption of improved biomass energy technologies for cooking by households. The independent variable is adoption of improved biomass energy technologies while the dependent variable is households' income and gender of household head. Values of measurement for independent and dependent variables are adoption/non-adoption of improved biomass energy technologies and Kenya shillings (Appendix V) and male/female respectively (Table 4.8). Gender and adoption variables are categorical while income is interval in nature. The hypothesis is tested by use of Pearson's Chi square and Phi test to test the significance of the relationship.

Table 4.8: Cross Tabulation of Gender of the Household Head and Adoption of Improved Biomass Energy Technologies

		Gender of the Household head		Total
		Male	Female	
Households that have adopted ICS	Yes	65	21	86
	No	11	3	14
Total		76	24	100

(Field Data, 2014)

Household income

As shown in Table 4.9, the analysis of household income and adoption of improved biomass energy technologies between rural and urban households indicates that the calculated chi square value (43.338) is smaller than the critical value (55.76) while the p value which is 0.587 is greater than 0.05. The null hypothesis is adopted since there is no enough evidence to reject it. Thus, there is no significant relationship between household income and adoption of improved biomass energy technologies by rural and urban households. This implies that high income for a household does not significantly influence adoption of improved biomass energy technology.

Table 4.9: Pearson's chi square test

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	40.338[a]	43	.587
Likelihood Ratio	38.760	43	.656
N of Valid Cases	100		

(Field Data, 2014)

Further analysis in Table 4.10 indicates that there is no statistically significant correlation between household income and the adoption of improved biomass energy technologies in the area with 0.587 approximate significant value. It is more often assumed that income is an important factor in adoption of technologies mainly because of the availability of cash which enables a household to meet costs associated with a technology to be adopted. Additionally, there is a likelihood of a household to shift from current biomass energy technology as their income increases due to increased capacity to purchase biomass fuels despite the increase in prices. For instance, a research conducted by Puzzolo et al. (2013) finds that high household income favors adoption of improved biomass energy technologies, while low household income acts as a barrier. However, recognition of a problem to be solved by a new technology is another household factor influencing adoption of a technology. People being rational have their own priority of problems they want to solve for their development and they may not be ready to invest their time and resources to what they do not perceive to be a problem. To sum up, Barnes et al. (2005) states how income is not necessarily the hindering factor but that stove availability and initial cost of the service are.

Table 4.10: Phi test

		Value	Approx. Sig.
Nominal by Nominal	Phi	.635	.587
	Cramer's V	.635	.587
N of Valid Cases		100	

(Field Data, 2014)

Gender of the household head

As shown in Table 4.11, the analysis of gender of the household head and adoption of improved biomass energy technologies between rural and urban households indicates that the calculated chi square value (0.059) is smaller than the critical value (3.84) while the p value which is 0.808 is more than 0.05. The null hypothesis is adopted since there is no enough evidence to reject it. Thus, there is no significant difference between gender of the household head and adoption of improved biomass energy technologies by rural and urban households.

Table 4.11: Pearson's chi square test

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.059[a]	1	.808		
Continuity Correction[b]	.000	1	1.000		
N of Valid Cases	100				

(Field Data, 2014)

There is no statistically significant correlation between the adoption of improved biomass energy technologies and the gender of household head in the area with 0.808 approximate significant value (Table 4.12). This is an indication that gender of the household head does not significantly influence adoption of improved biomass energy technologies. The interviewees reported that decision making on which technology to adopt is not solely left to the household head. There is usually involvement of other family members especially the spouse in decision making. This was confirmed during focused group discussions. These findings contradict with Jessica & Subhrendu, (2012) where they found out that households with a female head of household were more likely to use cleaner fuel (54% of studies found positive significance).

Table 4.12: Phi test

		Value	Approx. Sig.
Nominal by Nominal	Phi	-.024	.808
	Cramer's V	.024	.808
N of Valid Cases		100	

(Field Data, 2014)

4.3 Perceptions, adoption and constraints of biomass fuels

In the following sections, results are presented that address objective two of the study and describes the perceptions, adoption and constraints of biomass fuels. The widespread cooking practice with biomass fuels, such as firewood and charcoal, can have severe implications for human health, forest/land degradation and climate change. Recognizing the importance of adopting alternative biomass fuels and sustainable use of solid biomass fuels is essential in reducing these severe implications. Thus, this finding is important as it helps in understanding perceptions toward various fuels, constrains in the use of cooking fuels and the factors influencing the choice of fuels for cooking which have an impact in policy formulation.

4.3.1 Perceptions

Perception was determined by a way in which households judge various biomass fuels for cooking. Rural households have a perception that biogas (36%), Liquid biofuel (32%) and briquette (14%) requires some technical skills during its operation (Figure 4.11). This perceived lack of technical knowhow has led to low adoption of these fuels. Biogas is perceived easy to use because it is usually compared to LPG but more economical compared to LPG where a household has to incur some money to fill the LPG cylinder. Additionally, Biogas is perceived an expensive investment which might not be affordable to many households.

Briquettes are perceived easy to use and to burn longer than charcoal thus making them more economical to use.

Firewood and charcoal are perceived readily available, easy to use and affordable compared to other fuels such as biogas. This is because many rural households collect firewood and burn charcoal in their farms. Charcoal on the other hand is always sold by traders in almost every street of Kitui town in different quantities. This makes it affordable and easily accessible by urban households. The two fuels are also perceived economical for cooking their stable food which is *githeri* compared to using biogas or LPG (Figure 4.11). Firewood is perceived as a rural fuel by urban households which is not suitable to use in the urban areas.

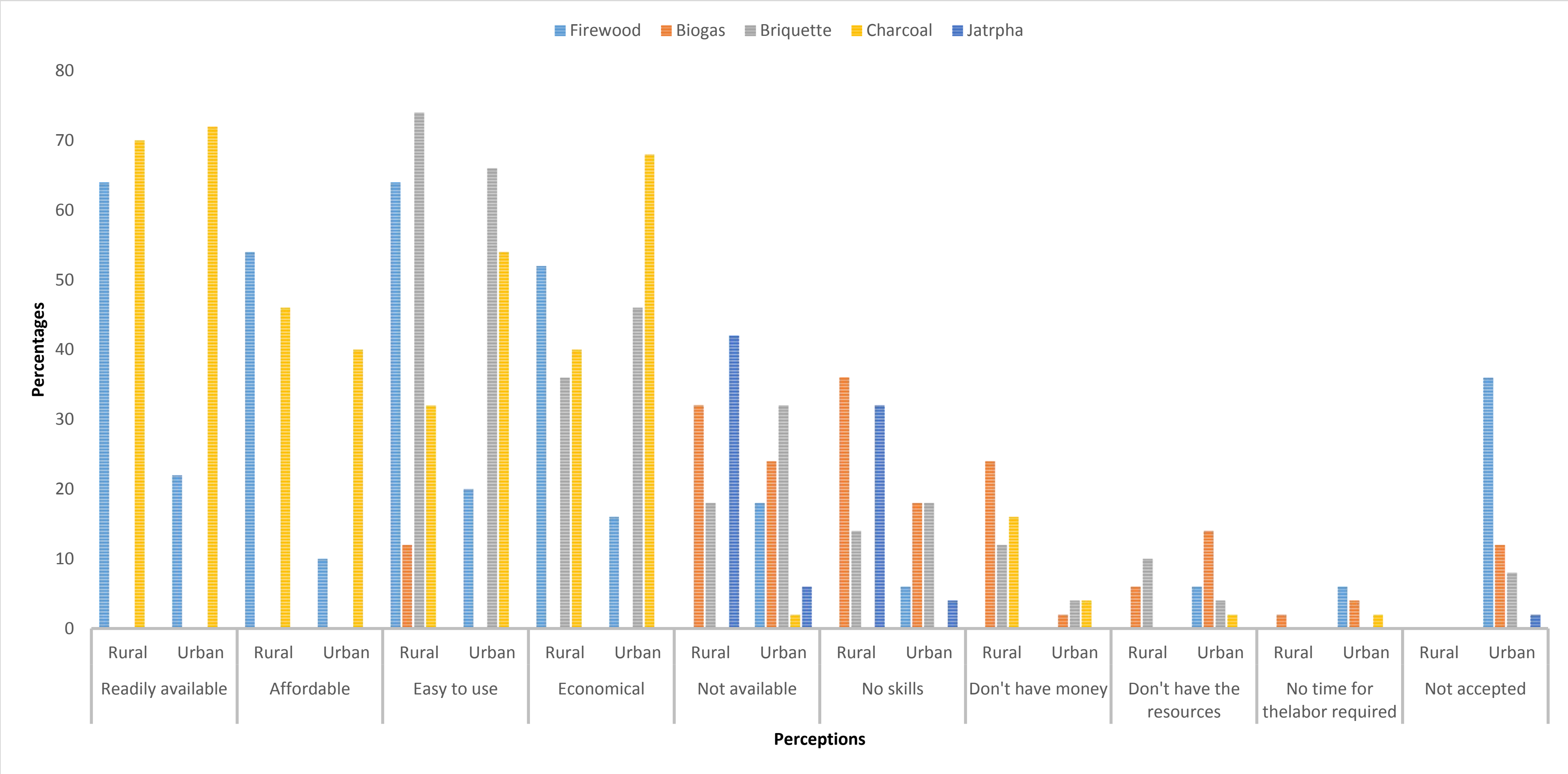

Figure 4.11: Rural and urban perceptions of various biomass fuels

(Field Data, 2014)

4.3.2 Adoption

Adoption herein refers to the actual use of various biomass fuels for cooking.

- **Biogas technology**

For a household to use biogas, they have to produce it at the household level since there is no packaging of biogas in Kenya for now. In the study area biogas technology is only adopted by 12 % of the rural households with no adoption by urban areas despite the high levels of awareness (Figure 4.12). The biogas technology installed in the study area is plastic digester (Plate 4.1). It is made up of a black polythene (plastic) tube (4 feet in diameter) of a thicker gauge (1000mm).

Plate 4.1: Plastic Digester is a biogas technology placed inside a trench with inlet and outlet pipes tied on both sides.it should slant at a slight angle for free flow of slurry. (Source: Field Data, 2014)

This makes it most suited to both rural smallholders and peri-urban farmers with at least 1 mature cow under zero grazing. Installation of plastic digester is an ongoing project by Musekavo Community Forest Association in association with Community Development Trust Fund (CDTF). The project provides 90% of the total cost which is KES 15,000 and the household is expected to pay 10% of the cost. During an indepth interview with Musekavo Community Forest Association officials, it was revealed that adoption is still low mainly due to low economic power to raise the 10% of the cost and lack of the necessary resources. As discussed earlier, zero grazing is not highly practised in the study area and this makes it hard for households to accumulate enough feed stock. It is worth noting that the projects directly targets the households around catchment i.e. Museve and Kavondo forest. This means that the indirect beneficiaries have to fund the whole installation which is not affordable.

- **Briquette**

Briquettes can be used as a supplement or alternative to firewood and charcoal. In this way they make use of a waste product and reduce some pressure on forestry resources. The briquettes in the study area are produced from charcoal dust, cartons, sawdust and sand. None of the briquettes are produced from farm residue. It is a matter of debate how far charcoal dust briquettes can be considered sustainable, since they rely on the existence of a charcoal industry that most agree is currently operating unsustainably. Figure 4.12 shows that only 6% of the urban households have adopted briquette for cooking and rural household do not use briquette at all in spite of 40% and 42% of the rural and urban households being aware of briquette respectively (Table 4.11). Low adoption levels are contributed by lack of necessary skills to make briquette and lack of briquette in the market for purchase.

- **Liquid biofuel**

Besides the biomass fuels adopted by households, Table 4.13 shows awareness of other biomass fuels but not currently adopted by households. For instance, awareness of Liquid biofuel as an alternative source of fuel is very low with only 6% of the urban households having heard of it and none of the rural households are familiar with it (Table 4.13). Low awareness levels have led to lack of its adoption. The study revealed that there was a project by Green Africa Foundation to provide Jatropha seedlings for the households to plant and in return sell the seedlings to the organization which was to sell the processed oil back to the households. This project was well embraced but it failed after providing few households with seedlings due to lack of necessary infrastructure.

Table 4.13: Awareness of alternative biomass fuels

Households	Firewood	Charcoal	Biogas	Briquette	Liquid biofuel
Rural Households	2%	16%	44%	40%	0%
Urban Households	46%	10%	41%	42%	6%

(Field Data, 2014)

- **Firewood and charcoal**

Firewood and charcoal are traditional biomass fuels which are widely known and perceived easy to use, affordable and available for use hence high adoption. Firewood is used for cooking by 32% of the urban households (Figure 4.12). Urban households do not prefer firewood because of lack of storage space and restriction by landlords due to its high smoke production.

4.3.3 Constraints in relation to the currently adopted biomass fuels

There are several challenges experienced by households in relation to the various biomass fuels adopted. Of the households using biogas, they reported some biogas technology challenges. The plastic paper used for the construction of plastic digester is not durable (Figure 4.12). This was confirmed during key informants' discussions. The plastic digester can only last for 4 years in arid and semi-arid environments compared to floating drum technology which can last for over 25 years. The polythene can easily be torn by domestic animals such as chicken and thus fencing around the plant is an additional cost to the household but it is necessary.

The gas produced by the plastic digester can only be used to cook light meals like rice and tea. This is an indication that the digester is not capable of producing enough gas to cook heavy meals. One of the reasons for the production of small gas quantities is because of the varying climatic conditions which slows the microbial activity especially during cold weather leading to incomplete decomposition hence little gas is produced. Secondly, households do not feed the plant with enough slurry and water to produce enough gas. It was also reported that it is difficult to get maintenance services due to lack of extension services. A discussion with key informants revealed that the biogas project has inadequate staff to offer extension services and to make follow ups.

Households highly compared briquette with charcoal in order to make a better decision on whether to replace charcoal with briquette. Briquette users reported that briquette produce smoke though less than charcoal smoke because they are not carbonated (Figure 4.12). During focused group and key informants discussions it was noted that briquette still require use of charcoal for them to lit meaning a household cannot fully shift from charcoal to briquette. Additionally, once briquettes are lit they cannot be put out for later use nor add more briquettes in the stove compared to charcoal.

As shown in Figure 4.12, majority of the households agree that firewood scarcity (56%) is the main upcoming constrain, followed by smoke production (33%) while cooking with firewood is regarded uncomfortable by 14% of the households. The uncomfortable nature of firewood was reported because one needed to keep an eye and adjust the firewood constantly while cooking. Smoke production is a big issue because majority of the households do not have decent kitchens with chimney. Charcoal was reported to produce an irritating gas by 42% of the households which is a life threatening gas. This indicates a greater level of awareness of health problems due to the use of charcoal. Another constrain reported regarding use of charcoal is low quality charcoal that is being traded. Households reported that some vendors sell charcoal that burn very fast and others sell charcoal that is slow to burn. Furthermore, price fluctuations occur when charcoal production is hampered during the rainy season which makes it very expensive.

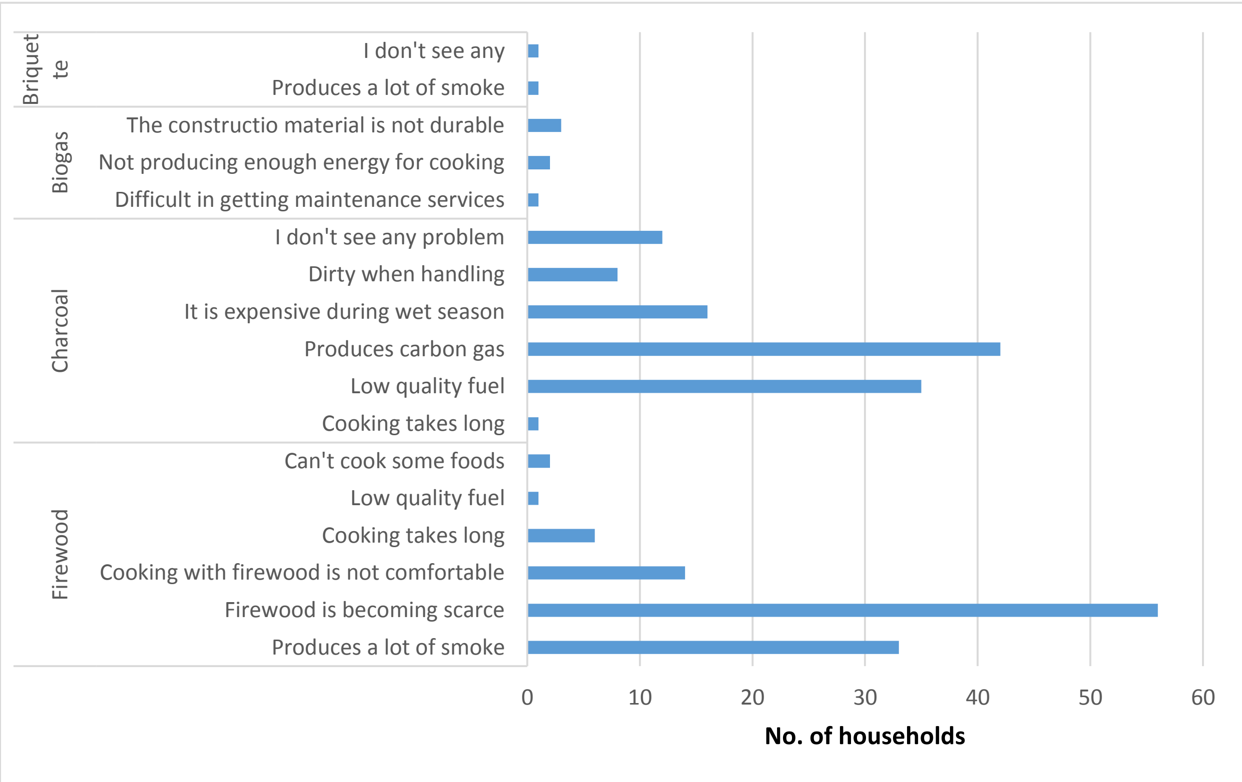

Figure 4.12: Constraints from biomass fuels

(Field Data, 2014)

4.3.4 Criteria for choosing biomass fuel

This refers to the standard of judgment in choosing a fuel to adopt. It will provide insights on the household's preference while choosing biomass fuels which is an important finding for the future development of the biomass fuels**.** Sustainability is defined as the ability of a household to maintain the adopted biomass fuels for cooking for a long period of time. Affordability (89%) and availability (51%) are characteristics of biomass fuels valued most by households when deciding which biomass fuel to adopt (Figure 4.13). If the cost of getting a fuel is high it reduces the likelihood of adoption.

Sustainability was reported by 82% of the households as an important feature considered while choosing biomass fuels (Figure 4.13). Availability of raw materials for alternative fuels is necessary for a household to sustain alternative biomass fuels such as biogas and Liquid biofuel. Households in the study area are majorly concerned on how to sustain biogas plant especially due to its demand for slurry and water. Water is a critical requirement for biogas technology because an equal amount of water and/or urine needs to be mixed with feed stocks like cow dung before it is fed into a biogas plant bearing in mind that water availability in this area is a menace.

Eighty three percent (83%) of the household are more likely to adopt fuels that are easy to use compared to fuels they perceive to require some technical skills in order use (Figure 4.13). For instance, extracting Liquid biofuel is perceived to be a technical process that requires some special skills. On the other hand, biogas technology is too perceived to be technical to handle and this decreases the likelihood of households to adopt biogas and Jatropha.

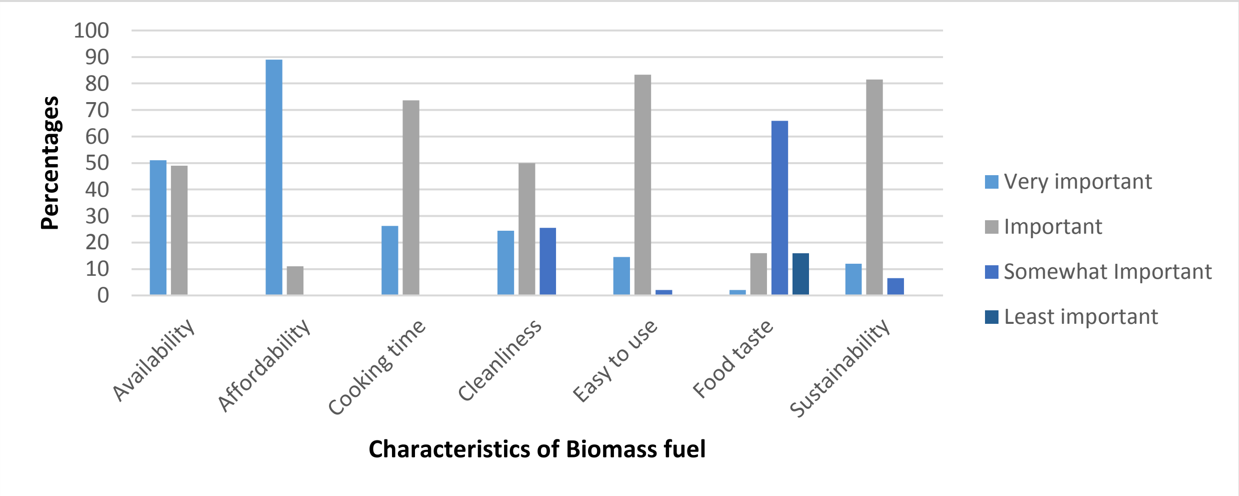

Figure 4.13: Criteria for choosing biomass fuels

(Source: Field Data, 2014)

4.3.5 Analysis of the variables

The second null hypothesis stated: There is no significant difference in the adoption of biomass fuels between rural and urban households. The independent variable is rural and urban households while the dependent variable. Values of measurement for independent and dependent variables are rural or urban households and adoption or non-adoption of biomass fuels respectively (Table 4.14). Both variables are categorical in nature. The hypothesis is tested by use of Pearson's Chi square and Phi test to test the significance of the relationship

Table 4.14: Location and adoption of biomass fuels cross tabulation

		Households that use biomass fuels		Total
		Yes (%)	No (%)	
Location	Rural	50 (100)	0 (0)	50
	Urban	48 (96)	2 (4)	50
Total		98 (98)	2 (2)	100

(Source: Field Data, 2014)

As shown in Table 4.15, the analysis of biomass fuels adoption between rural and urban households indicates that the calculated chi square value (2.041) is smaller than the critical value (3.84) while the p value which is 0.153 is greater than 0.05. The null hypothesis is adopted since there is no enough evidence to reject it. Thus, there is no significant difference of biomass fuels adoption between rural and urban households. This is attributed to the use of biomass fuels by both rural and urban households.

Table 4.15: Hypothesis testing 2

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	2.041[a]	1	.153		
Continuity Correction[b]	.510	1	.475		
N of Valid Cases	100				

(Source: Field Data, 2014)

Further analysis, as shown in Table 4.16, indicate that there is no statistically significant correlation between the adoption of biomass energy by rural and urban households with 0.153 approximate significant value. This again is attributed by use of at least one biomass fuels by both rural and urban households.

Table 4.16: Phi test

		Value	Approx. Sig.
Nominal by Nominal	Phi	.143	.153
	Cramer's V	.143	.153
N of Valid Cases		100	

(Source: Field Data, 2014)

4.4 Perceptions, adoption and constrains of improved biomass energy technologies

In the following sections, results are presented that address objective three of the study and describes the perceptions, adoption and constraints of improved biomass energy technologies. The contribution of improved biomass energy technologies in addressing the adverse health and livelihood impacts of traditional technologies can only be realized when they are widely adopted. An understanding of households' perceptions, factors affecting their choice of improved biomass energy technologies and constrains faced is essential both for researchers studying the determinants of adoption, traders, promoters and manufacturers of such technologies. This will aid in scaling up adoption of improved biomass energy technologies in rural and urban households.

4.4.1 Perceptions

Perception was determined by the way in which households judge various biomass energy technologies for cooking. The perceptions were drawn during questionnaire administration, key informants and focused group discussions. Households' perception on use of technology is generally attached with the advantage of technology components. Households examine the advantages from the point of view of compatibility to their current situation, with labour demand, profitability, and other social necessities to adopt a technology. If households' perception is positive towards the advantages of a technology they may adopt it. Overall, improved biomass energy technologies are perceived superior to traditional cookstoves in terms of cooking and fuel efficiency but less affordable and not readily available. Households perceive improved biomass energy technologies to produce less smoke than traditional stoves; however, very often the reduction is not perceived 'significant'. Most households agreed that improved biomass energy technologies reduce smoke but this is obviously not significant enough to rate the improved biomass technologies very high on this parameter.

Households in the study area have a perception that improved technologies have an impact on the taste of food. This is because it is easy to control the amount of heat from the stove suitable for the type of food being cooked which enhances the taste of the meal. Improved technologies are also perceived expensive compared to the traditional stoves. This has highly affected households' interest in adopting the stoves.

Cooking is perceived faster, easier and more comfortable while using improved cookstoves. This is because there is no need to constantly blow air for the flame to be strong. There is also no need to feed fuel and to adjust it frequently during cooking.

In urban areas, cooking with a portable improved technology is perceived easier than with a fixed improved cooking technology. This is because a portable stove allows a household to cook small meals, heat water or milk at any convenient place.

Some improved technologies such as Envirofit stove (Plate 4.3) are perceived not suitable for cooking full meals and large quantities of staple dishes such as githeri (a mix of maize and beans) and it is best suited for traditional stoves. Additionally, improved stoves are perceived best for cooking in the evening or for less than six family members.

4.4.2 Adoption

Adoption herein refers to the use of improved biomass energy technologies for cooking. The term comfortable in this context implies a technology that provides physical ease and relaxation while cooking. Quite a few households use improved charcoal stoves, particularly in urban areas; however, only a small percentage of people use improved stoves for firewood (Figure 4.15). It is assumed that awareness of various improved biomass energy technologies plays a very great role in influencing adoption. Findings in Figure 4.15 shows that awareness of many improved stoves is quite high. However, awareness of some stoves such as briquettes and liquid biofuel is very low with only 8% of the households being aware of it (Figure 4.14). Generally, there is no much difference in the overall level of awareness of improved stoves in rural and urban households.

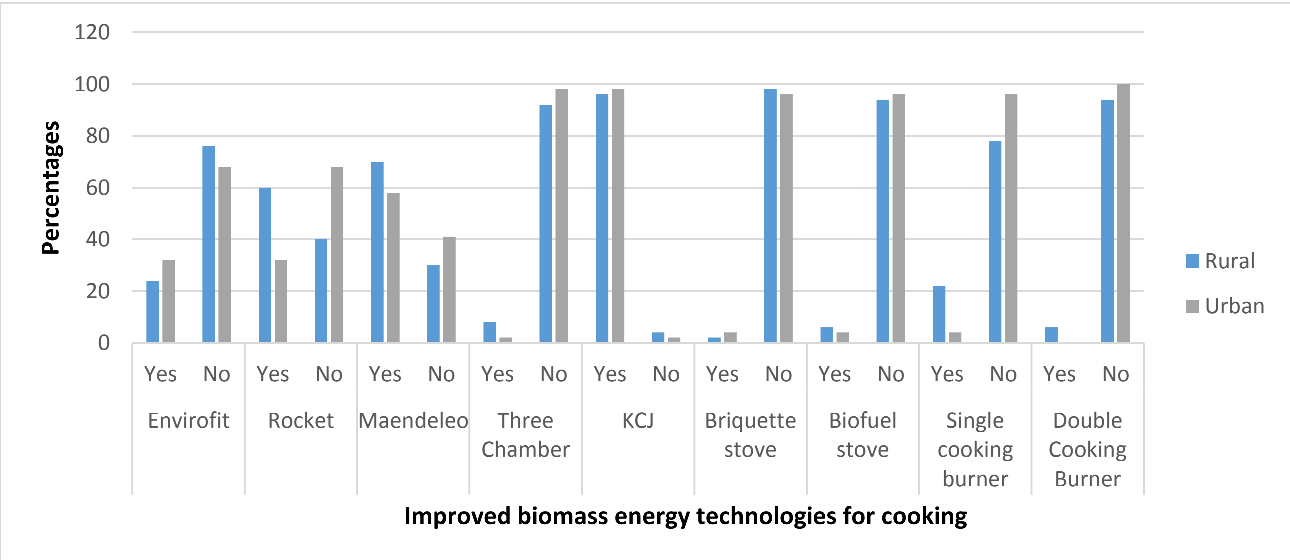

Figure 4.14: Awareness of various improved technologies

(Field Data, 2014)

- **Firewood technologies**

Envirofit stove

Findings in Figure 4.15 shows that only 4% of the rural households have adopted Envirofit stove (Plate 4.2) despite 24% of the rural households being aware of the stove (Figure 4.14). The non-adopters reported that the cost of the stove (KES. 3,000) is high for them to afford. Envirofit users highlighted that the stove is easy to light and uses less fuel. More findings in Figure 4.14 indicate that 32% of the urban households are aware of Envirofit but only 6% have adopted the stove primarily because of its portable nature (Figure 4.15). The low adoption levels by urban households are contributed by the fact that majority do not use firewood for cooking.

Plate 4.2: Envirofit Stove (M 5000) is a light weight, easily portable, easy to use and designed to maximize stove quality and heat efficiency while minimizing emissions and weight (Source: Field Data, 2014)

Rocket stove

Over half of the rural households are aware of rocket stove (Plate 4.3) but surprisingly only 12% have adopted the stove (Figure 4.15). The domineering feature of the rocket stove that attracts households is the presence of two pot holders. This allows several meals to be cooked at the same time thus saving time. Additionally, this saves households the need to have an extra stove while preparing several meals. Households also appreciate the fact that fuel do not need to be fed or adjusted frequently during cooking. As noted earlier, adoption is still low due to the high cost of the stove and the lack of construction materials.

Plate 4.3: The Rocket Stove is a fixed model of firewood stove with two pot holders which makes it highly desired by rural households. The raw materials for construction include bricks, sand and cement. (Source: Field Data, 2014)

Diocese of Kitui has an ongoing project which provides red oxide and cement while the household is expected to pay 800 KES for labor, sand and bricks which are unaffordable by most households. 20% of the rural households reported that they do not have a permanent kitchen for constructing a permanent stove such as rocket stove hence not in a position to adopt. (Figure 4.18).

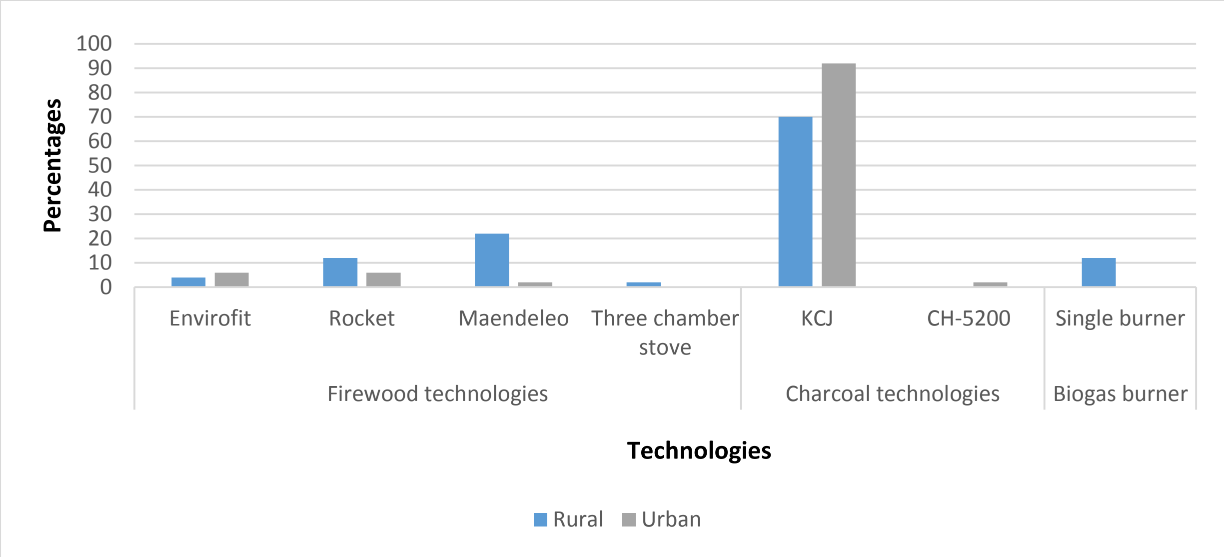

Figure 4.15: Adoption of improved technologies for cooking

(Field Data, 2014)

Maendeleo stove

As shown in Figure 4.14, 70% of the rural households and 58% of the urban households are aware of Maendeleo stove (Plate 4.4) but the adoption is very low with 22% of the rural households and 2% of the urban households having adopted the stove (Figure 4.15).

Plate 4.4: The fixed Maendeleo Stove is a firewood stove with two parts, a simple pottery cylinder with pot rests (known as the liner) that is built into a mud surround in the kitchen. Fuel is fed into the fire through an opening in the front of the stove, and it has no chimney, but it produces much less smoke than an open fire. (Source: Field Data, 2014)

Rural households reported that regardless of hand full advantages of maendeleo stove such as less fuel consumption, less cooking time and less smoke production (Figure 4.16) they have not adopted it primarily because it is not durable. Some households aware of the stove had once adopted it but after the liner broke they have not replaced it. Low adoption in the urban areas is because urban households rarely use firewood for cooking.

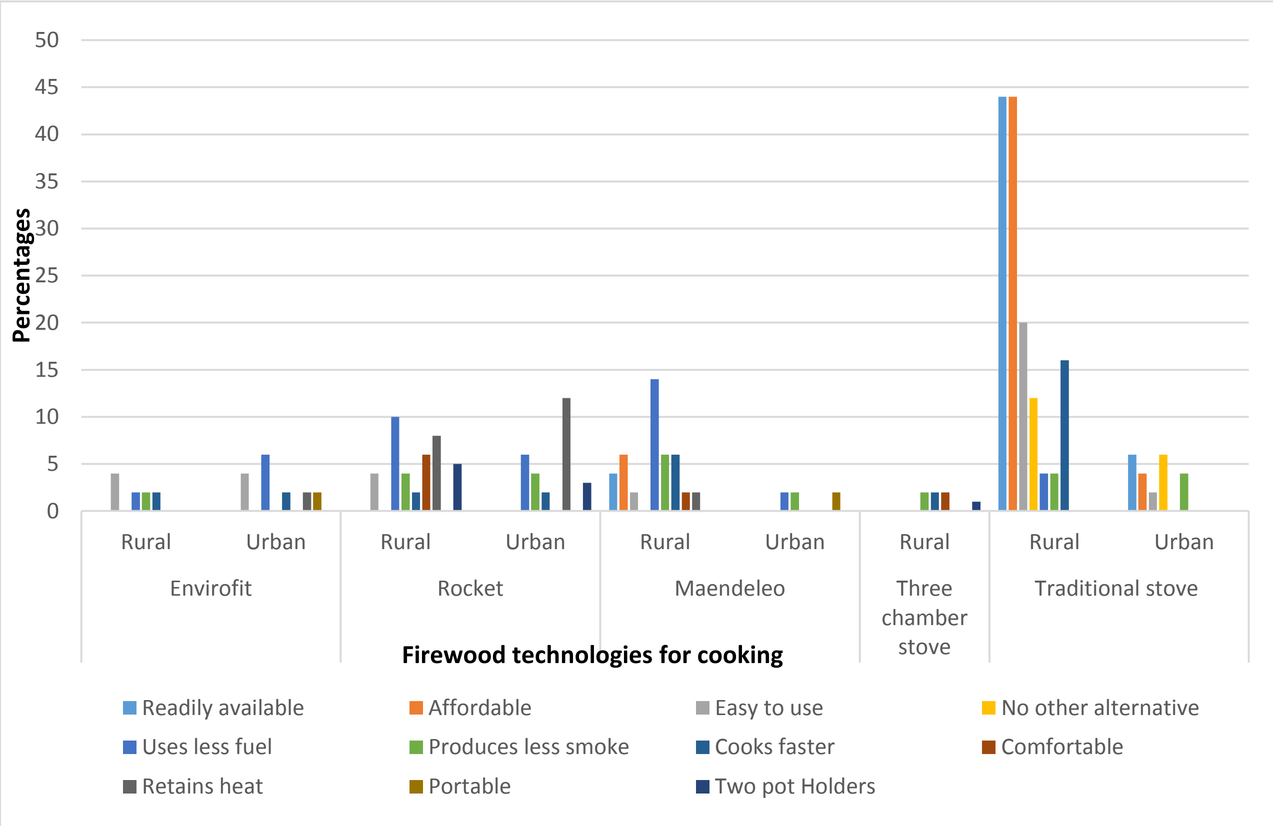

Figure 4.16: Reasons for adopting firewood technologies

(Field Data, 2014)

Three chamber stove

The adoption of three chamber stove (Plate 4.5) in the study area is very small with only 2% adoption level (Figure 4.15). This is despite its hand full advantages such as use of less fuels, it cooks faster and it produces less smoke which makes it comfortable to use (Figure 4.16). This is largely as a result of low levels of awareness and the high cost of installation.

Plate 4.5: Three Chamber Stove is a firewood stove which is available in different sizes. It is adopted from institutional jikos. A chimney is fitted on the outside to emit smoke, wood is feed on the bottom of the stove then lit before placing the pot. Extra wood is feed through the inlet. (Source: Field Data, 2014)

- **Charcoal technologies**

The adoption of the KCJ (Plate 4.6) is quite high in both rural and urban households. According to the implementation scenario in the integrated assessment (IAP) of energy policy prepared by UNEP in collaboration with the Government of Kenya, the target of 100% adoption in urban areas by the year 2030 is achievable (UNEP, 2006). 70% of the rural households and 92% of the urban households have adopted KCJ (Figure 4.15). This high adoption is because of its ability to use less charcoal, its portable nature and its availability (Figure 4.17). KCJ is also considered as a subsidiary stove by rural households to cook meals such as *chapatti* and for use during rainy season. The small percentage of the households in the study area who have not adopted KCJ reported that it is not durable due to constant breaking of the liner (Figure 4.18).

Plate 4.6: KCJ is a charcoal stove which was developed in 1983 by the Ministry of Energy. It has proved efficient with a potential to cut fuel requirements and easily portable. The ceramic liner is made of clay that is then cured and finally metal clads is fitted. (Source: Field Data, 2014)

During key informant discussions, it was revealed that more durable KCJ and maendeleo stoves are available especially at Kitui Renewable Energy Centre at a higher cost which makes some households to prefer the cheaper but less durable stoves. Only 2% of the urban households have adopted Envirofit CH-5200 due to the ability to use less charcoal and being portable (Figure 4.15).

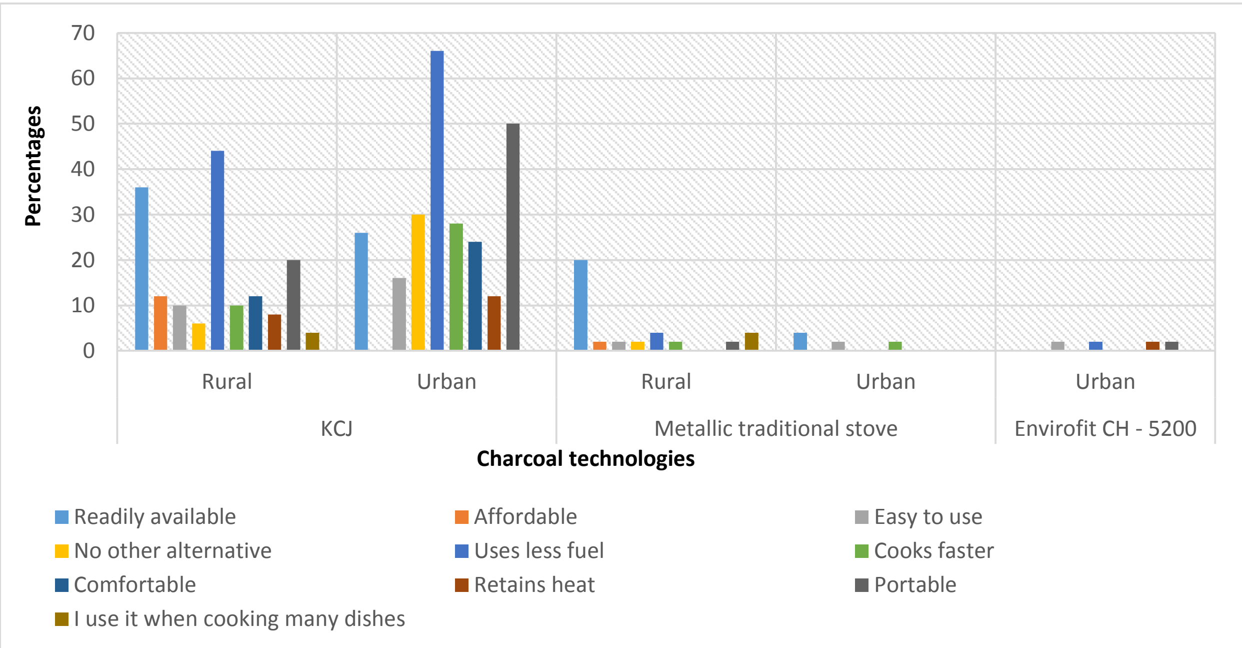

Figure 4.17: Households' perceptions on charcoal technologies

(Field Data, 2014)

- **Briquette and Liquid biofuels stove**

None of the households in the study area has adopted specific briquette and Liquid biofuels stoves. The awareness of these two stoves is very low. For instance only 2% of the rural households and 4% of the urban households are aware of briquette stove (Figure 4.14). Due to unavailability of briquette stove households use KCJ while using briquette for cooking.

- **Single and double burners**

As shown in Figure 4.15, single burners (Plate 4.7) are used by 12% of the rural households who use biogas for cooking. Its awareness is higher in rural areas compared to urban areas. The 6% of the rural households aware of the double burner have not adopted it because it is not available (Figure 4.14).

Plate 4.7: Single burner cooking stove is a locally modified biogas burner. It is equipped with medium nozzle and adjuster to control the gas flow. (Source: Field Data, 2014)

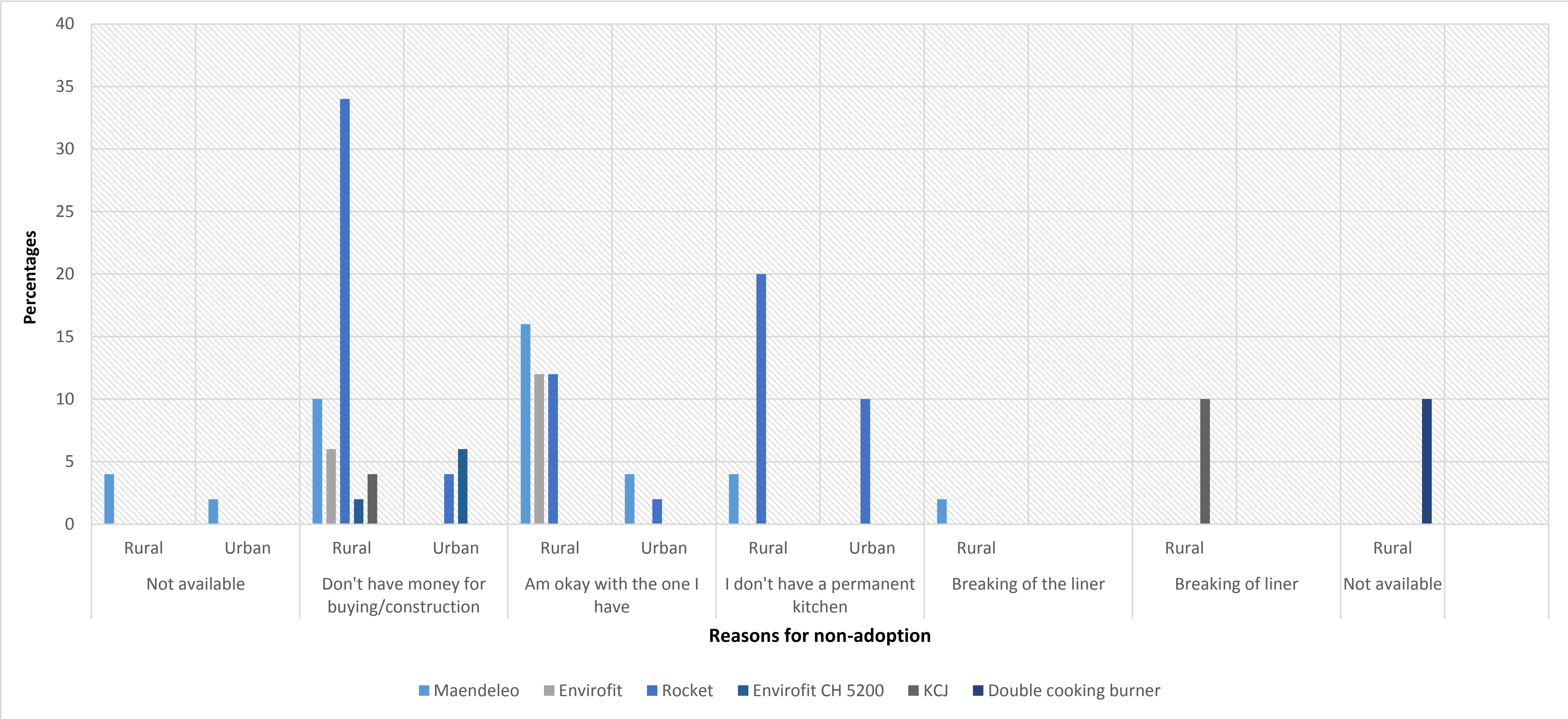

Figure 4.18: Reasons for non-adoption of various technologies

(Field Data, 2014)

4.4.3 Constraints of improved biomass energy technologies for cooking

The question on the constraints of improved biomass energy technologies was only answered by the households that have adopted that specific technology. Constraints in this context refer to the limitations in the use of improved biomass technologies. Too many constraints for a technology can limit its widespread adoption. Thus, this finding is very important for future improvement of specific improved biomass technologies. Interestingly, no constraints were reported for three chamber stove. Additionally, only two constraints were reported at most. This is an indication that improved technologies have met most of the required characteristics by households

Envirofit stove was reported to have a small combustion chamber which fills up with ash very fast; thus the need to empty it frequently while cooking. There is also need to feed and frequently adjust fuel during cooking because the elevated grate is small (Figure 4.19). This reduces the comfort while cooking.

The valve installed in single biogas cooking burner wears out fast leading to leakage of biogas. The main limitation of rocket stove is production of a lot of smoke while using wet firewood (Figure 4.19). This limitation can only be solved at the household level to ensure they dry firewood prior to using.

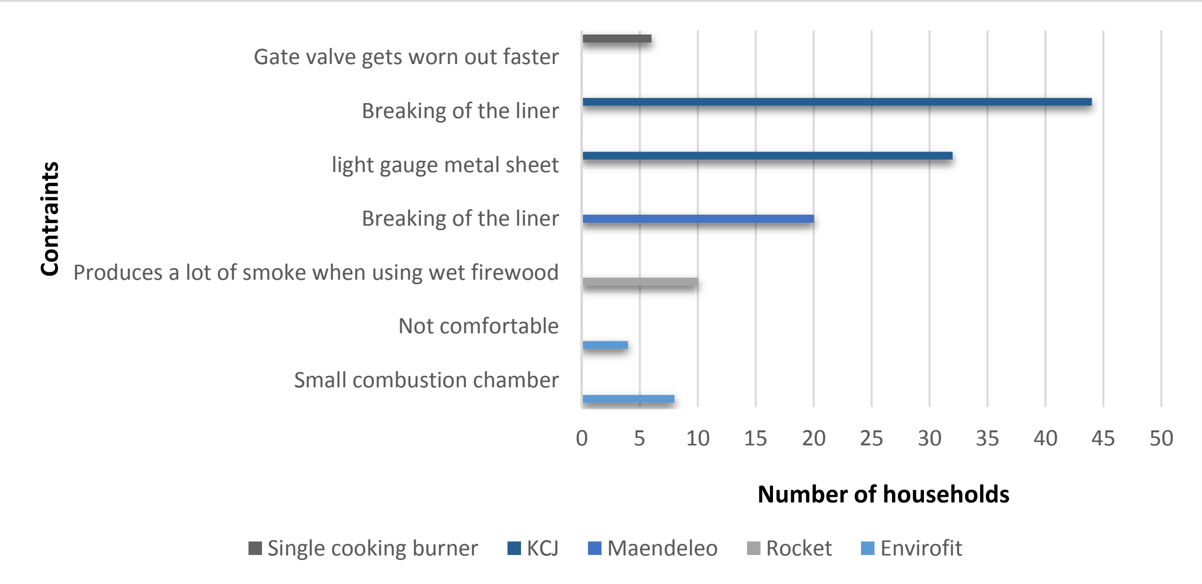

Figure 4.19: Constraints from improved biomass technologies

(Field Data, 2014)

KCJ and Maendeleo stoves were rated as the least durable stoves (Figure 4.20). This is mainly because of the breaking of the liner for both stoves and light gauge metal sheet for KCJ (Figure

4.19). Respondents reported that the liners are never fired after molding and this is the greatest contributor to breakages.

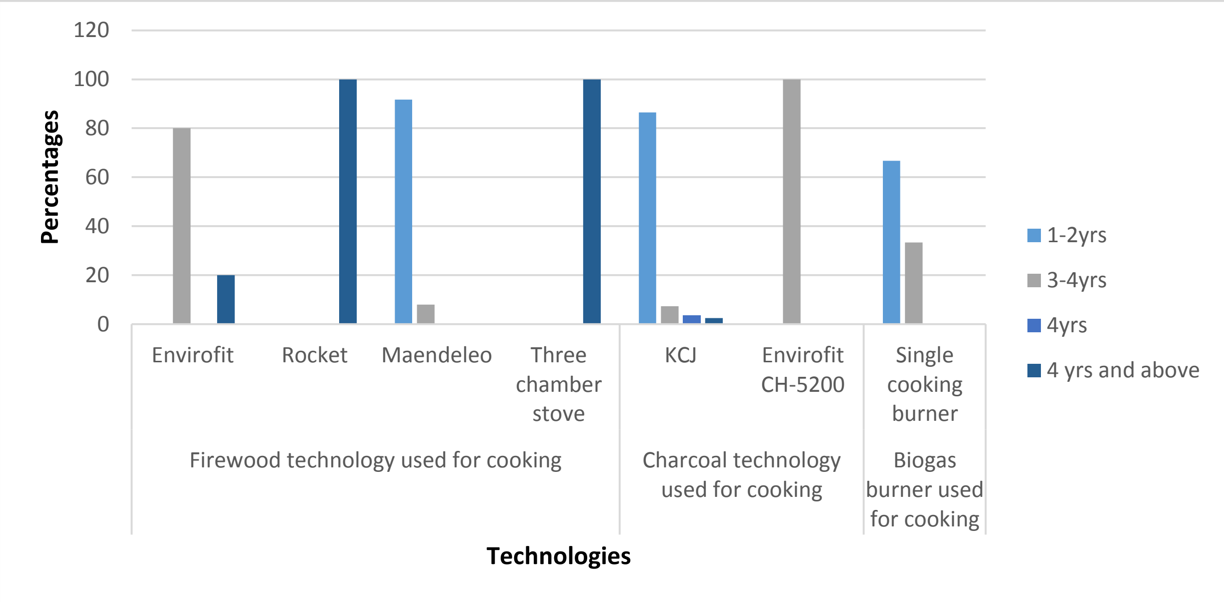

Figure 4.20: Durability

(Field Data, 2014)

4.4.4 Criteria for choosing improved biomass energy technologies

This refers to the standard of judgment in choosing a technology to adopt. It is necessary to understand how households decide which technology to adopt and the most valued features of a technology. This will help the manufactures, promoters and traders of the technologies to make necessary improvements.

- **Rural households**

All rural households assigned affordability the highest rating of importance. This is an indication that affordable technologies are adopted faster compared to their expensive counterparts. Secondly, 78% of the rural households view durability of a stove to be a very important feature (Figure 4.21). This is because a durable stove is more economical to purchase since it will last for a longer time unlike a less durable stove where a household is required to replace it more often. Thirdly, 48% and 42% of the rural households assigned fuel consumption and availability of the stove respectively the highest rating of importance (Figure 4.21). A stove that uses less fuel is more valued by rural households because wood fuel is becoming scarce. Readily available stoves are more adopted than stoves which are unavailable. These findings are also confirmed by Louise and Kimberly (2013) in Vientiane, Lao where durability, fuel consumption and cooking time are characteristics of improved biomass technologies for cooking valued most by respondents.

Ease of cooking was assigned by 90% of the rural households the second highest rating of importance (Figure 4.21). Households prefer technologies that do not require any special skills when cooking mainly because they are used to stoves that are easy to use such as three stone stove. This saves them the time and the need to learn new skills just to operate a cooking stove. A technology that accommodates different pot sizes was rated as important by 64% of the rural households (Figure 4.21). Rural households have different pot sizes due to family sizes and different occasions. Thus, having a stove that can accommodate various pots is viewed more advantageous than a stove that can accommodate specific pot sizes.

Portability was rated as the least important feature by 46% of the rural households (Figure 4.21). Equal percentage of the rural households assigned the portability as not important. 48% of the rural households have permanent or semi-permanent kitchens meaning they can have inbuilt stoves (Figure 4.3). A portable stove is only needed as a subsidiary stove by rural households.

Food taste is somewhat important for 54% of the rural households and least important for 34% of the rural households (Figure 4.21). This is because rural households perceive food taste to be dependent on the person cooking the food and not dependent on the stove. USAID came up with the same findings in Bangladesh where consumers felt that the taste of their food was the same when cooked on an ICS versus a traditional stove (USAID, 2013).

- **Urban households**

Durability, affordability, cooking time and portability were assigned the highest rating of importance by over half of the urban households (Figure 4.21). Urban households prefer portable stove due to their mobility from one rental house to another. Durability is the most preferred feature, followed by affordability. This may indicate that urban households are willing to spend more on a durable stove. Urban households highly value a stove that cooks faster due to their busy schedules at work and in their businesses.

Smoke production, fuel consumption, availability, ease of cooking and a stove that accommodates different pot sizes were assigned the second highest rating of importance (Figure 4.21). Smoke production in the urban areas is a hazard mainly due to the congestion in the rental houses and restrictions by the landlords. This makes them prefer a stove that produces no or little smoke. Fuel in the urban areas is expensive especially firewood and thus, urban households are attracted to stoves that consume less of this expensive fuel.

Over half (54%) of the urban households' assigned the food taste to be somewhat important (Figure 4.21). The study revealed that urban households have a perception that some cookstoves cook tasty foods than others. For instance, KCJ is perceived to cook the tastiest chapattis and rice. This is mainly because while cooking one can control the fire by closing the ventilation of air to suit the required amount of heat for the meal being cooked.

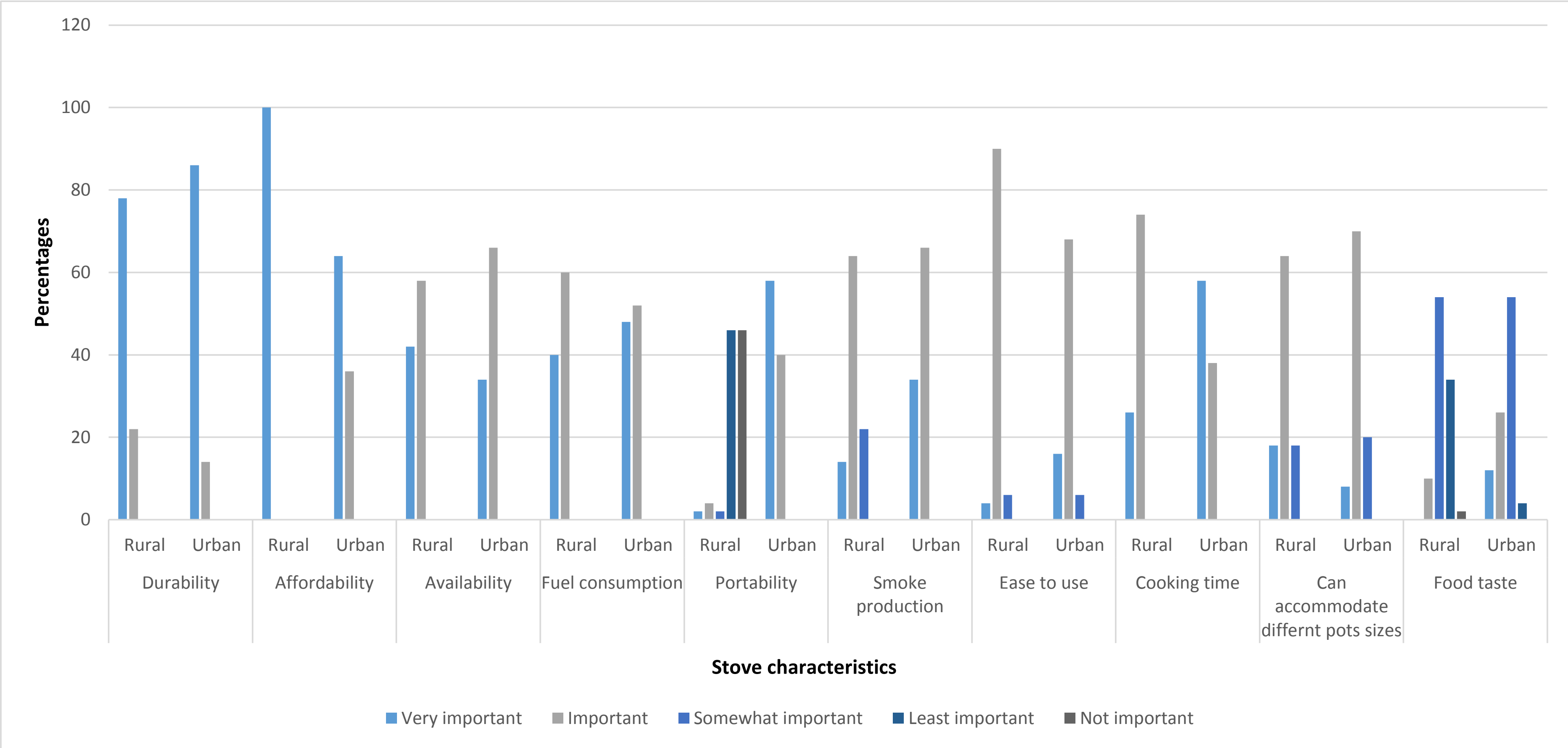

Figure 4.21: Criteria for choosing cooking technologies

(Field Data, 2014)

4.4.5 Analysis of the variables

The third null hypothesis was: There is no significant difference in the adoption of improved biomass energy technologies between rural and urban households. The independent variable is rural and urban households while the dependent variable is adoption of improved biomass technologies. Values of measurement for independent and dependent variables are rural or urban households and adoption or non-adoption of the technologies respectively (Table 4.17). Both variables are categorical in nature. The hypothesis is tested by use of Pearson's Chi square and Phi test to test the significance of the relationship.

Table 4.17: Location and adoption of improved biomass energy technologies

		HH that have adopted at least one improved biomass energy technology		Total
		Yes (%)	No (%)	
Location	Rural	38 (76)	12 (24)	50
	Urban	48 (98)	2 (4)	50
Total		86 (86)	14 (14)	100

(Field Data, 2014)

As shown in Table 4.18, the analysis of the improved biomass energy technologies adoption between rural and urban households indicates that the calculated chi square value (8.306) is greater than the critical value (3.84) while the p value which is 0.004 is less than 0.05. The null hypothesis is rejected and the alternative hypothesis is adopted. Thus, there is a significant difference of improved biomass energy technologies adoption between rural and urban households. This is attributed to use of at least one improved biomass energy technologies by more rural households due to use of multiple biomass fuels.

Table 4.18: Chi square test for hypothesis 2

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	8.306[a]	1	.004		
Continuity Correction[b]	6.728	1	.009		
N of Valid Cases	100				

(Field Data, 2014)

Further analysis indicate that there is a statistically significant correlation between the adoption of improved biomass energy technologies by rural and urban households with 0.004 approximate significant value (Table 4.19). This is attributed to increased adoption of biomass fuels by rural households leading to increased adoption of improved biomass energy technologies and a shift from biomass fuels to modern fuels by urban households which decreases adoption of improved biomass energy technologies.

Table 4.19: Phi test

		Value	Approx. Sig.
Nominal by Nominal	Phi	-.288	.004
	Cramer's V	.288	.004
N of Valid Cases		100	

(Field Data, 2014)

4.5 Promotion of improved biomass energy technologies for cooking

In the following sections, results are presented that address objective four of the study and describes the promoters of improved biomass energy technologies as well as the nature and level of support. Household decisions about whether or not to adopt and continue to use improved biomass energy technologies may not always follow from simple comparisons of economic costs and benefits. Lack of awareness of improved biomass energy technologies and exposure to existing technologies among targeted users (especially in terms of understanding their maintenance requirements), peer influences, credit constraints, all influence decisions about whether or not to adopt an unknown technology with highly uncertain returns. Given the strong positive externalities associated with adoption of such technologies, outside intervention and subsidy may also be justified (Pattanayak & Pfaff, 2009); as such, the effectiveness and nature of the institutions promoting them become critical. Successful promotion strategies for improved biomass energy technologies have worked to address some of these barriers, by engaging with institutions that are able to effectively implement social mobilization campaigns or by providing financing options and reducing the risk of adoption and thus reducing uncertainties related to new technologies.

More than half of the households (54%) in the study area are aware of various promotion activities. Figure 4.22 indicates that majority (66%) of the rural households are aware of various promoters of improved biomass energy technologies and compared to 42% of the urban households. This shows that rural households are more aware of these promoters and the improved technologies they promote unlike the urban households. During key informants' discussions, it was noted that promoters are more involved in promoting improved biomass energy technologies in the rural areas mainly because of wood fuel scarcity.

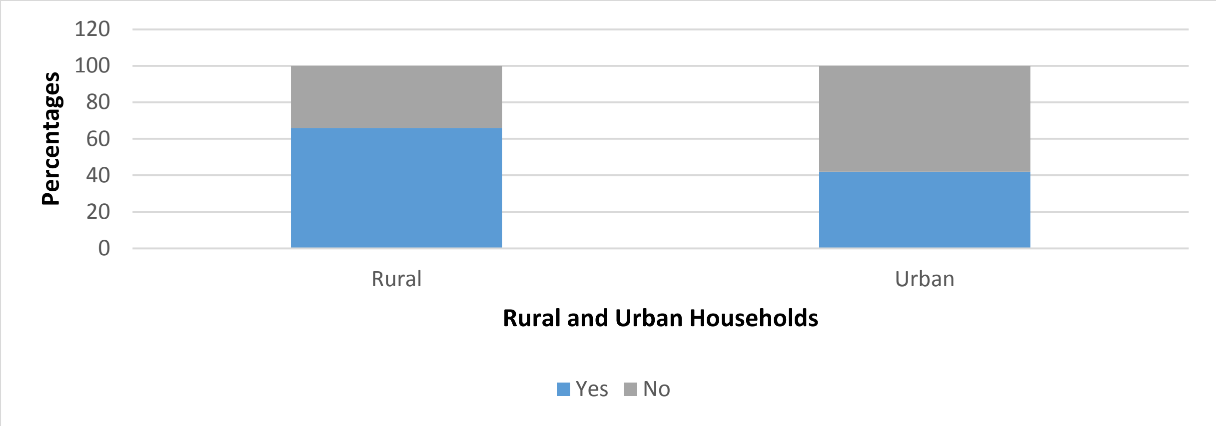

Figure 4.22: Awareness of promotion activities

(Field Data, 2014)

4.5.1 Promoters of improved biomass energy technologies

In general, actors from various sectors are involved in the promotion of various improved technologies. There are actors in the non-governmental organizations, government, traders and community organizations that promote improved stoves in the area. The government is represented by Kitui Renewable Energy Centre which promotes KCJ and Maendeleo stove. The NGOs in the area include Green Africa Foundation, Musekavo Community Forest Association (CFA), Kitui Teachers Sacco, Financial Services Association (FSA) and Kenya Women Finance Trust (KWFT) and they are involved in different types of promotions. Kitui Teachers Sacco, FSA and KWFT promote Envirofit and Maendeleo stove. Green Africa Foundation is involved in the promotion of briquette stove and Liquid biofuel stove, Catholic Diocese of Kitui promotes Rocket stove and Musekavo CFA promotes biogas technology, KCJ and Maendeleo stove (Table 4.20).

Table 4.20: Promoters and nature of promotion of improved biomass energy technologies

Organization	Technology	Financial support	Training	Marketing	Supply of construction material
Financial Service Association	Envirofit	X		X	
Musekavo CFA		X	X		
Women groups	Envirofit, KCJ		X	X	
Kitui Teachers Sacco	Envirofit	X			
Catholic Diocese of Kitui	Rocket stove		X		X
KWFT	Rocket stove, Maendeleo	X			
Kitui Renewable Energy Centre	KCJ, Maendeleo		X	X	
Green Africa Foundation	Liquid biofuel stove, briquette stove		X		
Traders	KCJ			X	

(Field Data, 2014)

4.5.2 Nature of promotion

There are different promotion types in the study area which include financial support, training and marketing. Table 4.20 shows that most promoters are involved in training the community on improved biomass technologies they are involved in. The only promoters who were reported not offer training for the stoves they promote are FSA, Kitui Teachers Sacco and KWFT. Construction materials are only provided by one rocket stove promoter i.e. Catholic Diocese of Kitui. Briquette stove, Liquid biofuel stove and biogas burners are the only stoves with only one promoter with the rest having more than one promoter. This is an indication of less focus to these stoves. This has an implication on their adoption for instance none of the households in the study area has adopted briquette or Liquid biofuel stove.

4.5.3 Nature and level of support

Various promotion types are perceived differently. As shown in Figure 4.23 financial support and provision on construction materials are highly valued followed by training. This is an indication that economic power of the households in the study is very low. Thus, stoves perceived expensive are less likely to be adopted compared to stoves perceived affordable.

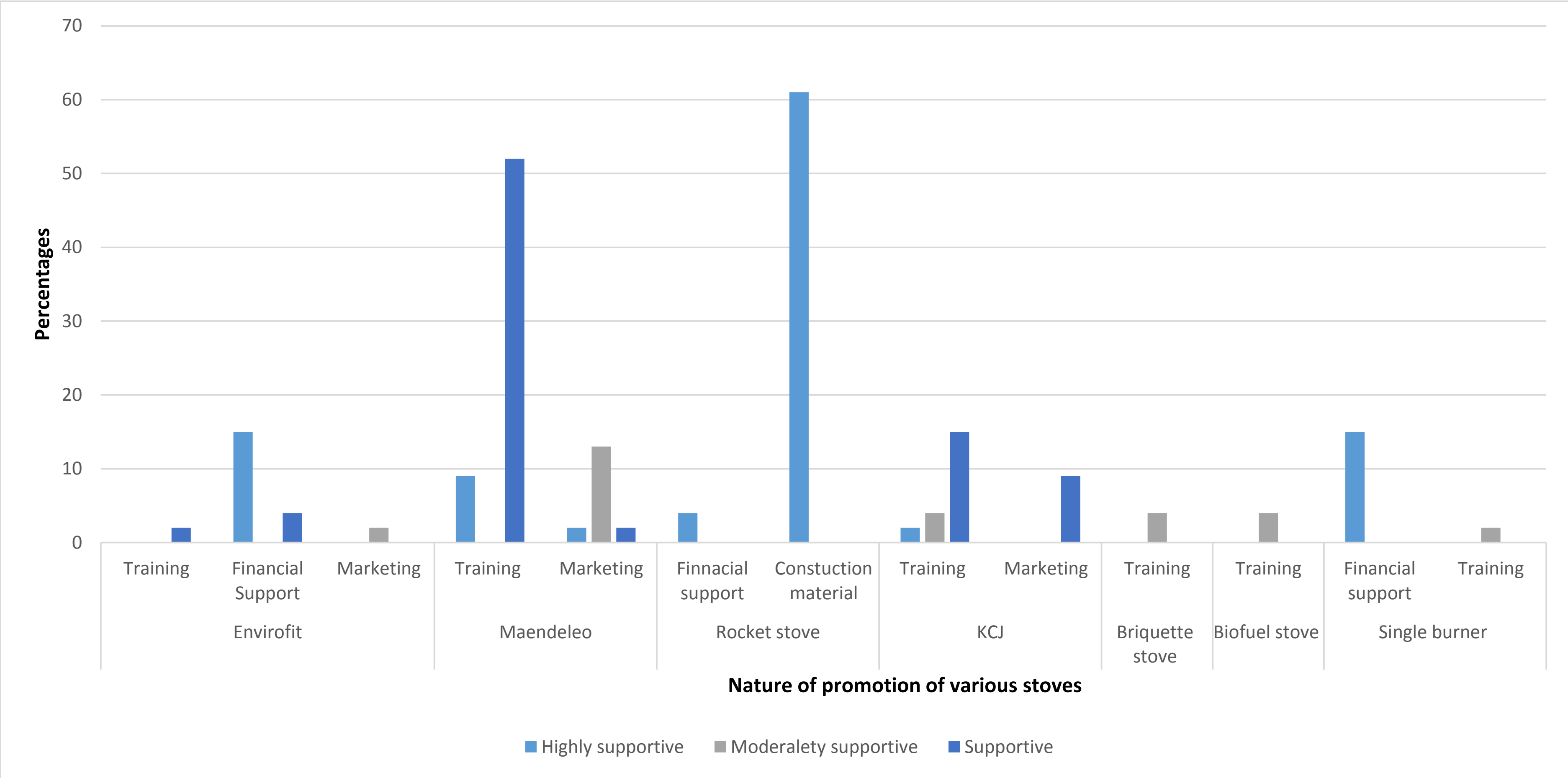

Figure 4.23: Nature and level of support

(Field Data, 2014)

4.5.4 Promotion of different improved stoves

- **Envirofit stove**

Envirofit stove (plate 4.2) is adopted by 4% of the rural households and 6% of the urban households; quite low adoption (Figure 4.15). Envirofit stove is being promoted in the study area through marketing, training and provision of financial support with the main promoters being Kitui Teachers Sacco, women groups and Financial Services Association (FSA). It was reported that Kitui Teachers Sacco and FSA are the main providers of financial support for Envirofit stove. Kitui Teachers Sacco and FSA provide the stove to its members who then repay the total cost of the stove at an installment (Table 4.21).

However, the main beneficiaries are the households with at least one member of the households being a member of these two financial service providers. During the study it was revealed that these two financial service providers are the early introducers of Envirofit in the study area. Marketing and training has helped to disseminate information about Envirofit especially to the non-members of Kitui Teachers Sacco and FSA. These efforts are not widely spread as it is evident on the low adoption of the stove.

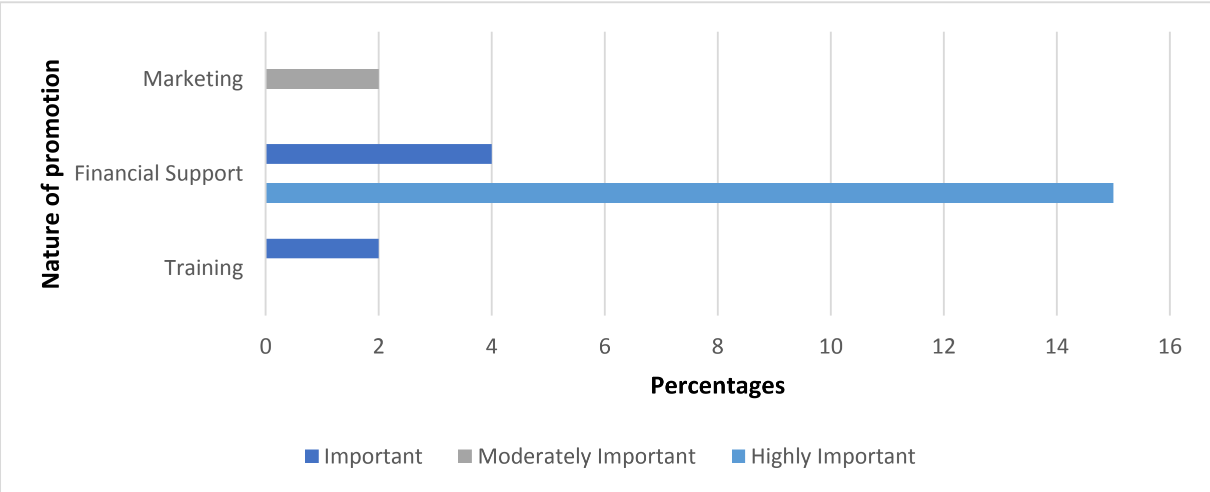

Figure 4.24: Nature and level of support of Envirofit stove promotion

(Field Data, 2014)

Financial support from promoters of Envirofit stove is highly supportive according to 15% of the households who have heard of promotion activities (Figure 4.24). The households perceive Envirofit to be an expensive stove compared to other stoves. For this reason any financial aid provided to them on the stove is highly appreciated. Marketing and training of Envirofit stove are perceived important by 2% of the households who have heard of promotion activities

(Figure 4.25). It was reported that being aware of the stove alone is not important if a household cannot afford to purchase the stove.

- **Rocket stove**

As shown in Figure 4.15, Rocket stove (Plate 4.3) is adopted by 12% of the rural households and 6% of the urban households; adoption is still very low on this stove. Findings in Table 4.21 indicate that Kenya Women Finance Trust (KWFT) and catholic diocese are the only promoters of Rocket stove. According the study findings catholic diocese provides the construction materials that is, red oxide and cement and the households are required to pay 800 KES for labour, prepare/buy bricks and sand. During key interview discussions it was noted that initially the catholic diocese project was thought by many households to be targeting Catholics and thus the non-Catholics did not show any interest of adoption. However, through educational campaigns they have managed to attract all households in the area to gain interest in adopting the stove.

KWFT on the other hand has a scheme that provides loan to clients who then pay it in installments. The operational terms of the scheme are for a loan of 10,000 KES for a two pot holder rocket stove it should be repaid at an installment of 1,000 KES for 10 months and 5,000 KES with an installment of 500 KES per month for one pot holder rocket stove. Despite this promotion, the scheme is not widely known.

Provision of construction materials is perceived to be highly supportive by 61% of the households who have heard of promotion activities because of the money a households is able to save when constructing the stove (Figure 4.25). However, some households have difficulties in raising labour charges, getting sand and bricks for the construction of the catholic diocese rocket stove hence not in a position to adopt; currently, only 18 % of the households have adopted a rocket stove. 4% of the households who have heard of promotion activities rated the financial support from KWFT as highly supportive due to the high cost of the stove.

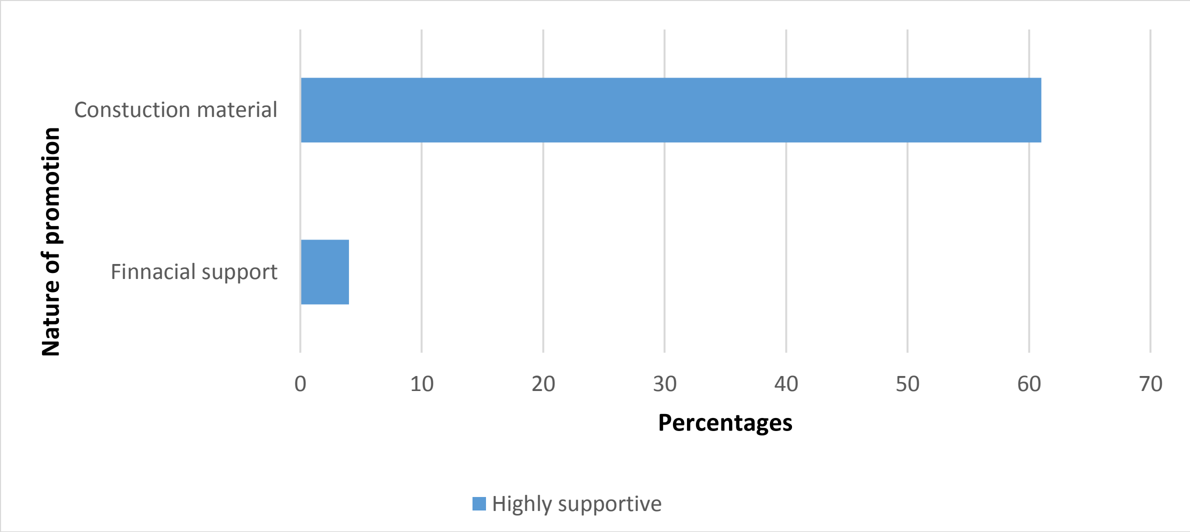

Figure 4.25: Nature and level of support of rocket stove promotion

(Field Data, 2014)

- **Maendeleo stove**

Maendeleo stove is adopted by 22% of the rural households and 2% of the urban households (Figure 4.15). As shown in Table 4.21, Maendeleo stove (plate 4.4) is being promoted by KWFT, Kitui Renewable Energy Centre, women groups and Musekavo CFA in the study area.

Kitui Renewable Energy Centre and Musekavo CFA are involved in marketing the stove and training women groups on how to make Maendeleo stove and install maendeleo liners. The trained women groups in return train the community on how to make the stove and install the liners. During key informant's discussions, it was noted that sustaining women groups is a challenge because of group dynamics which cause wrangles leading to changing the group from community enterprise to individual enterprise or breaking up of the groups all together.

Interestingly, KWFT has introduced a multipurpose stove a modification of maendeleo stoves which allows a household to use either charcoal or firewood for cooking. KWFT has a scheme that provides loan to clients to purchase the multipurpose stove at KES 2, 250 which is repaid in installments. The operational terms of the scheme are for a loan of KES 2,250 for a multipurpose stove which should be repaid at an installment of KES 250 for 10 months.

Only 9% of the households who have heard of promotion considered training highly supportive while 52% reported that training is supportive (Figure 4.26). Training on how to make the stoves and install maendeleo liners is necessary to minimize the breakage on the liners. After acquiring this knowledge, some have used it to gain some money by installing liners to households at a fee. Women groups also sell the maendeleo stoves and liners which helps them to develop in other activities. Marketing is rated as being moderately supportive by 13% of the households who have heard of promotion activities. The households reported that through marketing they were able to know about the stove and its advantages, hence adoption. Maendeleo stove is perceived not expensive and thus more marketing can increase its adoption.

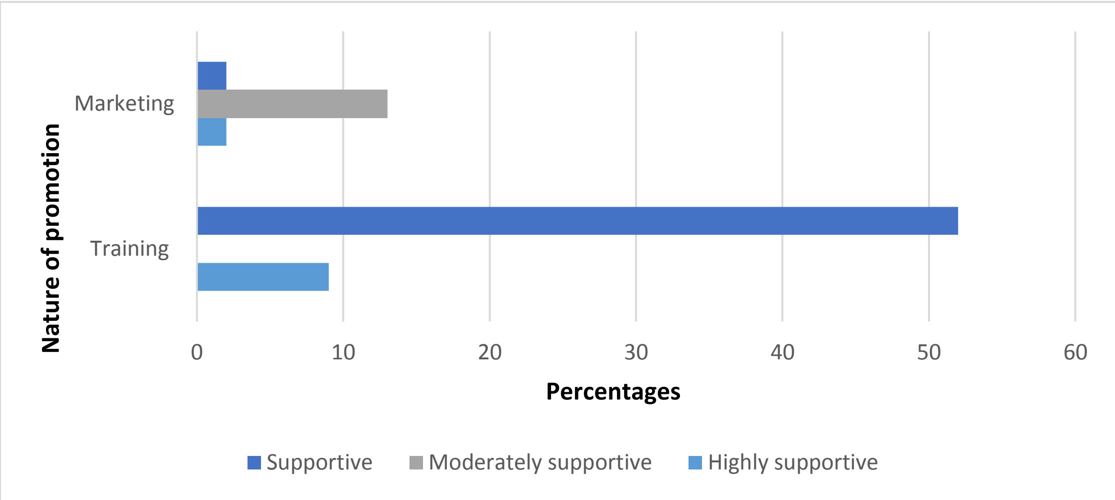

Figure 4.26: Nature and level of support of maendeleo stove promotion

(Field Data, 2014)

- **Kenya ceramic jiko**

Figure 4.15 shows that KCJ is adopted by 70% of the rural households and 92% of the urban households; a very high adoption. Findings in Table 4.21 indicate promoters of KCJ (Plate 4.6) are traders, Kitui Renewable Energy Center, women groups and Musekavo CFA with Kitui Renewable Energy Center being the widely known promoter.

Kitui Renewable Energy Center, women groups and Musekavo CFA are involved in training the community on the process of making KCJ while the traders engage in marketing the stove. The three promoters also make KCJ and sell to the community but Kitui renewable center was reported to make more durable KCJ stoves. During key informant’s discussions, it was noted that the presence of less durable stoves in the market is a factor of lack of standards in making KCJ, failure to fire liners and use of light gauge metal sheet this was also asserted during FGDs. During key informant’s discussions, it was also revealed that some traders purchase KCJ from Kitui renewable center at a cheap price and sell them to buyers at a high price.

Some households (9%) perceive marketing as supportive and 15% of the households who have heard of promotion activities perceive training as supportive (Figure 4.27). During the study it was noted that training the community on the process of making KCJ is not highly valued because what matters to them is the quality of a ready-made KCJ and not how to make one. The 2% of the households who have heard of promotion activities rated training highly supportive because they are part of a women group which make KCJ after training and from this they make some money out of it (Figure 4.27).

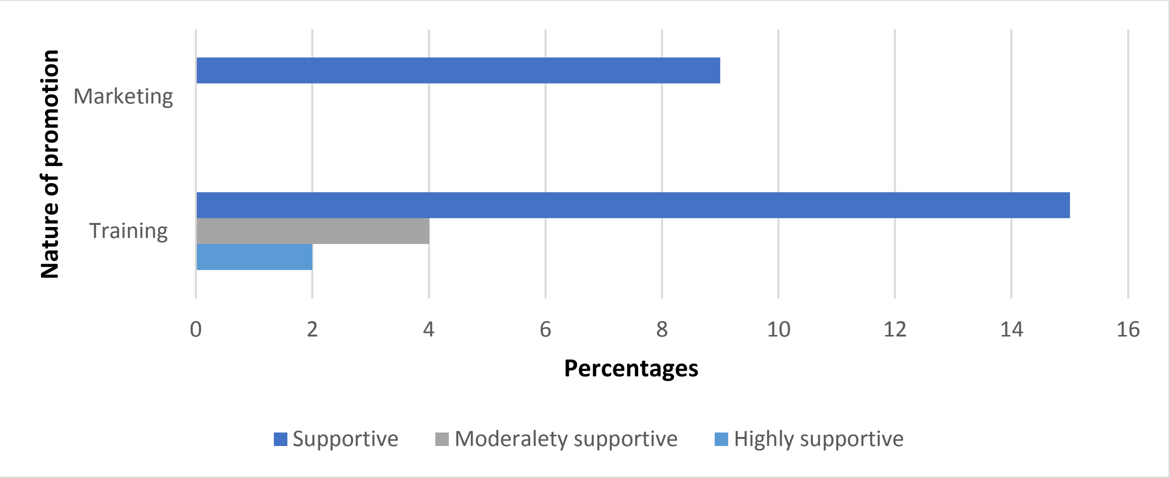

Figure 4.27: Nature and level of support of KCJ promotion

(Field Data, 2014)

- **Liquid biofuel stove, biogas and briquette stoves**

Liquid biofuel stove and briquette stoves have not been adopted at all in the study area while single cooking burner is adopted by only 6% of the households (Figure 4.15). As shown in Table 4.21, Green Africa Foundation is the only promoter of both briquette stove and Liquid biofuel stove. The study revealed that Green Africa Foundation has a project on Liquid biofuel where they train the community on how to plant Jatropha. During the trainings, they demonstrate how to press the oil and use it for cooking. This has given the community a chance to see how a Liquid biofuel stove looks like and how it works. Unfortunately, Green Africa Foundation did not proceed with the plans at the time despite the community willingness to plant Jatropha due to lack of infrastructure but it is on the process of reviving the project after putting in place the infrastructure. Musekavo CFA promotes biogas technology which includes provision of the single biogas cooking burner to the adopters.

Findings in Figure 4.28 indicate that 15% of the households who have heard of promotion activities reported financial support to be highly supportive and training being moderately supportive for all stoves. Basically, the three stoves are perceived expensive and thus any financial support is perceived very important. Training on how to use these stoves is perceived a moderate type of support since it helps them be aware of how to use them but not adequate enough since they cannot purchase the stove.

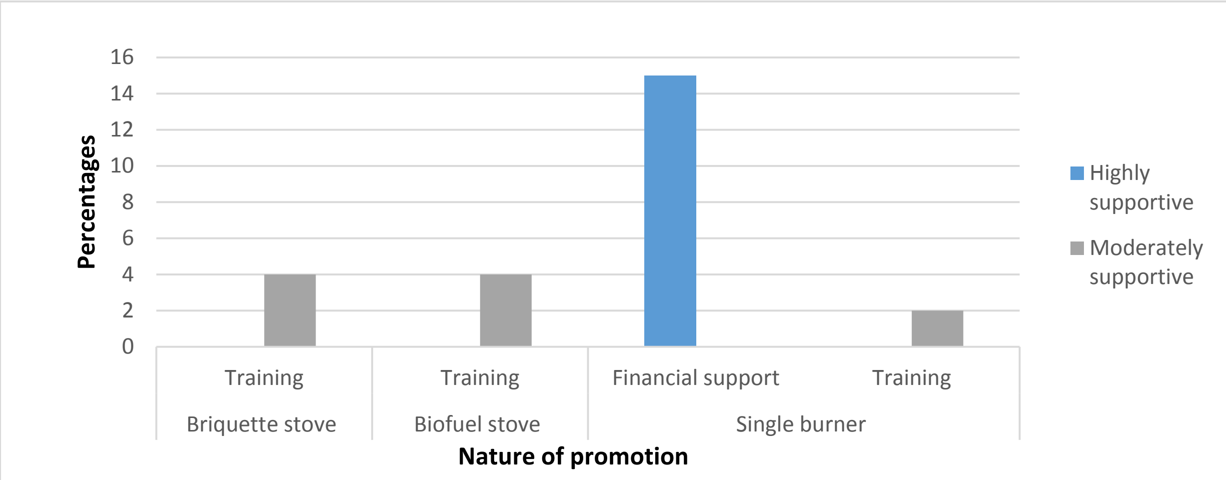

Figure 4.28: Nature and level of support of briquette stove, liquid biofuel stove and single burner promotion (Field Data, 2014)

4.5.5 Analysis of the variables

The fourth null hypothesis was: The promotion of improved biomass energy technologies does not significantly influence adoption of improved biomass energy technologies. The independent variable is awareness of promotion activities for improved biomass technologies while the dependent variable is adoption of improved biomass energy technologies. Values of measurement for independent and dependent variables are aware or not-aware of promotional activities and adoption or non-adoption of improved biomass energy technologies respectively (Table 4.21). Both variables are categorical in nature. The hypothesis is tested by use of Pearson's Chi square and Phi test to test the significance of the relationship.

Table 4.21: Awareness of Promotional Activities and Adoption of Improved Biomass Technologies Cross Tabulation

		HH that have Adopted improved biomass energy technologies		Total
		Yes	No	
Awareness on Promotion of various technologies for cooking	Yes	45	9	54
	No	41	5	46
Total		86	14	100

(Field Data, 2014)

As shown in Table 4.22, the calculated chi square value (0.693) is less than the critical (3.84) while the p value which is 0.405 is greater than 0.05. Thus, the null hypothesis is adopted since there is no enough evidence to reject it. This is attributed to lack of access to promotional activities. Additionally, promoters offer partial support to the households leaving the households to contribute the other part. Most often the households cannot implement their own part due to lack of ability especially financial ability hence not in a position to adopt.

Table 4.22: Chi-Square Tests for Hypothesis 3

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.693[a]	1	.405		
Continuity Correction[b]	.295	1	.587		
N of Valid Cases	100				

(Field Data, 2014)

Further test indicate that there is no statistically significant correlation between awareness and adoption of improved biomass energy technologies by rural and urban households with 0.405 approximate significant value (Table 4.23). This is attributed by perceptions towards improved biomass energy technology which plays a role in decision making process of whether to adopt or not to adopt improved biomass energy technologies.

Table 4.23: Phi Test

		Value	Approx. Sig.
Nominal by Nominal	Phi	-.083	.405
	Cramer's V	.083	.405
N of Valid Cases		100	

(Field Data, 2014)

4.6 Acceptance of alternative biomass energy with a view to possible future development

In the following sections, results are presented that address objective five of the study and describes the households' acceptance and willingness to change fuels and cooking practices. This finding is important because it provides information which will help future scaling out of biomass fuels and improved biomass energy technologies for cooking. It also gives insights for future development in this field. Acceptance in this context refers to the action or process of biomass fuels and improved biomass technologies for cooking being received as adequate or suitable for households' cooking needs. The different levels of acceptance are defined in the following way and same levels of acceptance apply for the improved biomass energy technologies.

- In this context a decision by a household to **highly accept** an improved biomass energy technology or biomass fuel means that the households is ready to fully adopt it, either because they are fully knowledgeable about it or have seen it being used. Non-adoption maybe due to lack of their capability to adopt it such as financial ability.
- A decision by a household to **accept** an improved biomass energy technology or biomass fuel means that the household has either heard of it or seen it and have liked it but lack crucial information on its availability and cost.
- A decision by a household to **moderately accept** an improved biomass energy technology or biomass fuel means that the household has heard of technologies but due to the mixed information they have not yet decided whether to adopt it or not. These households can be swayed to either adopt or not to adopt.
- A decision by a household to **least accept** an improved biomass energy technology or biomass fuel means that the household is aware or heard of the negative features of an improved biomass energy technology or biomass fuel that outweigh its positive features.
- A decision by a households to **not accept** an improved biomass energy technology or biomass fuel means that the household is not ready to adopt it mainly due to strong perceptions or misinformation.

4.6.1 Acceptance of the 5 biomass fuels by rural and urban households

- **Level of acceptance of firewood**

Firewood production has a relatively high degree of informality and poor development and so often it does not receive proper management inputs since it is generally collected for free in rural areas. In urban areas limiting factors of trading firewood include its bulky shape and expensive transportation costs. When traded, firewood prices exhibit high fluctuation as they are influenced by accessibility, transportation costs and availability but a cheaper fuel compared to charcoal in urban areas. It is very common for rural households to use firewood as their main cooking energy in many developing countries especially in Sub-Saharan Africa. The use of firewood in rural areas is still predominant since it is often the only available, accessible and affordable fuel in the study area.

Quite a few (84%) of the rural households highly accept firewood compared to only 10% of the urban households (Figure 4.29). Acceptability of firewood is very high in rural areas because it has been used since ancient times and has shaped the rural household’s cooking habits accordingly. Additionally, it is accessible and affordable even among the poorest in the rural area. Rural households reported that more often they collect firewood for free in their farms, at the forests or pay a very affordable fee of KES 100 per month to collect firewood from the forest.

Accessibility of firewood is a crucial factor for households using firewood for cooking purpose, especially in rural areas where alternative fuels such as LPG are not affordable. Households can collect firewood close to their homesteads at all times its availability all year-round and not susceptible to heavy seasonal fluctuations. Nonetheless, due to steadily decreasing availability, people are faced with ever-increasing distances and must therefore expend more labor and time to collect firewood.

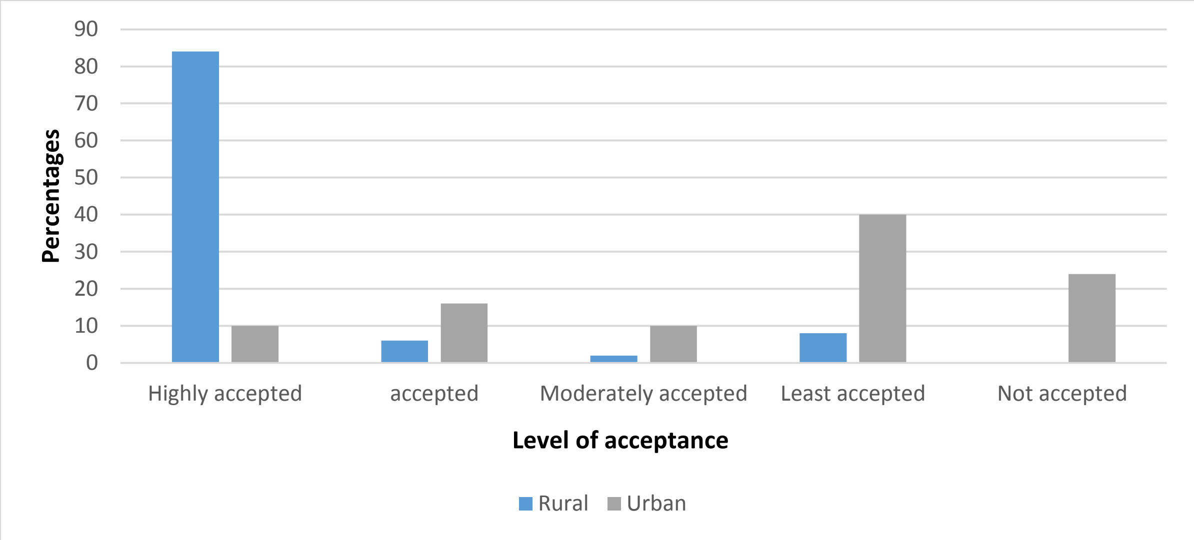

Figure 4.29: Level of acceptance of firewood by rural and urban households

(Field Data, 2014)

Findings in Figure 4.29 also indicate that firewood is least accepted by 40% of the urban households and 8% of the rural household. Moreover, 24% of the urban households do not accept firewood for cooking at all (Figure 4.29). This is a reflection of the decreased dependency of urban households on firewood due to availability and access to other biomass and modern fuels.

- **Level of acceptance of charcoal**

Charcoal is a highly commercialized commodity and valued among households, especially in urban settings. Its affordability is still a decisive factor in fuel decisions made by households.

As shown on Figure 4.30, charcoal is accepted by 72% of the urban households and 36% of the rural households. Moreover, charcoal is highly accepted by 46% of the rural households and 10% of the urban households. Charcoal is preferred by both rural and urban households considering that it is cheaper than kerosene, Liquid Petroleum Gas (LPG) and electricity. Furthermore, as in the case of firewood, charcoal can also be purchased in small quantities for very little money on a daily basis. However, respondent mentioned that charcoal is still more expensive compared to firewood. Convenience is another advantage reported of using charcoal compared to cooking with firewood. Users do not need to be as attentive with the fire when using charcoal and it produces less or no smoke when burnt. Consequently, cooking pots stay cleaner for a longer time. Charcoal is also considered as a good secondary fuel by rural households for specific cooking tasks such as cooking chapattis, cooking in the evening and during the rainy season where it becomes hard to get dry firewood. Another reason why charcoal is preferred is because it is easy to transport and store due to its lightweight physical property and can even be stored for a long period of time without the risk of insect or fungal intrusions.

Despite this high preference of charcoal, 4% of the urban households least accept charcoal and 2% do not accept it at all because it is perceived to be tedious to light and dirty to handle. 16% of the rural households and 12% of the urban households moderately accept charcoal because of its price fluctuations especially during rainy seasons (Figure 4.30).

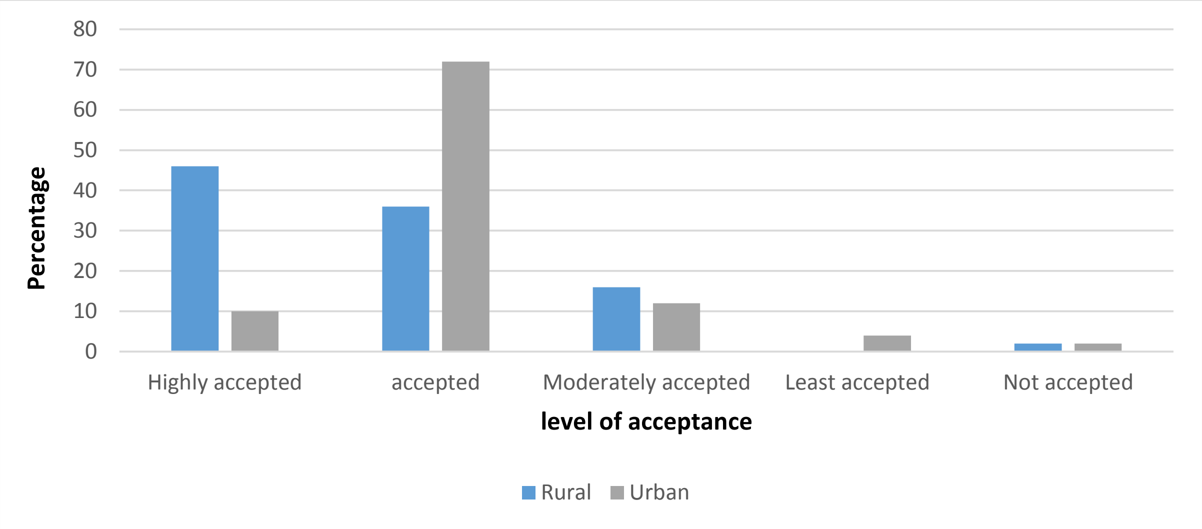

Figure 4.30: Level of acceptance of charcoal by rural and urban households

(Field Data, 2014)

- **Level of acceptance of briquette**

Briquettes offer a viable and low-cost alternative to firewood and charcoal. Briquettes can be produced at a household level by use of a manual machine or through locally modified ways where the machine is not affordable.

Briquettes are accepted by 76% of the urban households and 22% of the rural households for cooking. Of the urban (16%) and rural (14%) households respectively highly accept briquette (Figure 4.31). Briquettes are perceived clean compared to charcoal thus accepted as a substitute for charcoal. The urban households reported that materials for making briquette such as sawdust, soil, cartoons and charcoal dust are readily available and free / affordable. Thus, they only need to learn the skills on how to make briquette. The study revealed that shared experiences from households who have used briquette before has a great influence on the acceptability of briquettes. Similar findings were reported by Barnes et al (2012a) in their study in Karnataka, India where neighbors' experiences influenced adoption of improved technologies for cooking. These findings agree with the diffusion of innovation by Rogers (2003) as well as theory of planned behavior by Ajzen (1985).

Briquettes are moderately accepted by 58% of the rural households mainly because they lack the skills to produce briquettes and some raw materials such as saw dust are not available. As shown in Figure 4.31, 2% of the urban households do not accept briquette for cooking. These are the households that have fully switched to LPG and no longer use biomass fuels.

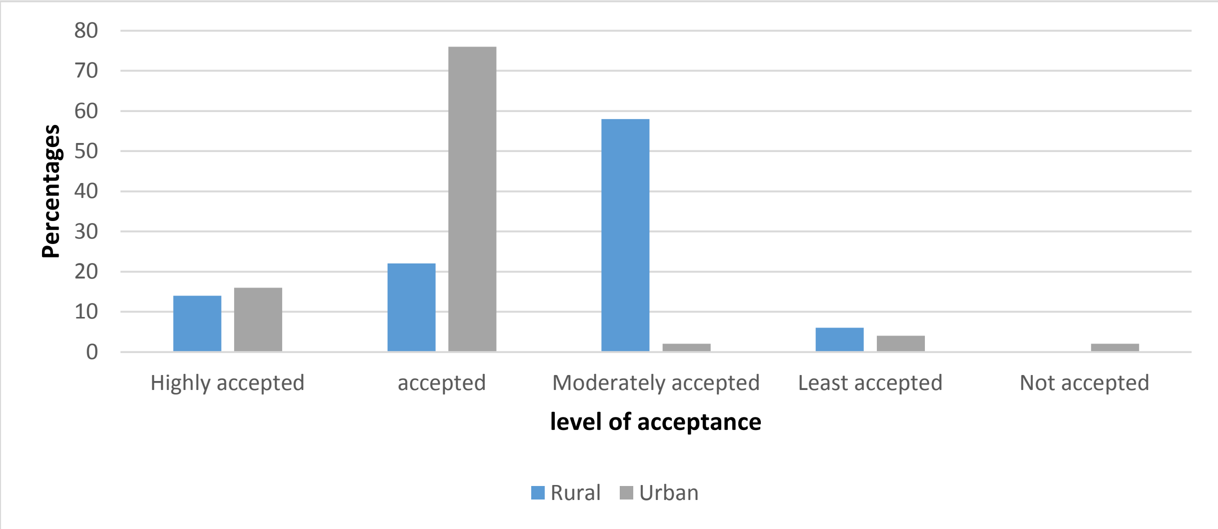

Figure 4.31: Level of acceptance of briquette by rural and urban households

(Field Data, 2014)

- **Level of acceptance of biogas**

Biogas has the potential to provide energy to households, especially those experiencing domestic energy crisis due to scarcity of fuel for cooking. Biogas requires adoption of the technology at the household level since biogas is not yet packaged and cannot be transported in Kenya. Thus, a household's capability to adopt the technology has a high influence in biogas acceptability.

Findings in Figure 4.32 indicate that biogas technology is least accepted by 18% of the rural households and 38% of the urban households. The low acceptability levels are due to the fact that biogas technology is expensive to install, time consuming and requires a lot of commitment for its success. This was confirmed during key informants' and focused groups' discussions. Secondly, the technology requires a lot of water which is a problem in the area and requires some technical skills which are lacking. Thirdly, difficulty in understanding the fact that the slurry, which comes out after producing gas is good manure and its 'strength' is not lost by yielding gas, which is combustible has reduced the acceptability of biogas. This aspect can only be proved through demonstration. 2% of the rural households do not accept the technology at all because they have not fully settled in their homes to take care of the plant which needs constant attention and maintenance. The 6% of the urban households that do not accept the technology reported that they are already comfortable with LPG.

Few (6%) urban households highly accept biogas technology as they reported to have the necessary inputs required to run the biogas plant. Around a quarter (22%) of the urban households accept biogas technology but on condition that it is already processed just like LPG. More (44%) of the rural households highly accept biogas majorly because it is a clean fuel compared to firewood and charcoal. Secondly, availability of feed-stocks for a greater proportion of the rural households increases its levels of acceptance. Biogas technology is accepted by 28% of the rural households who perceive it to provide comfort while cooking just like LPG (Figure 4.32).

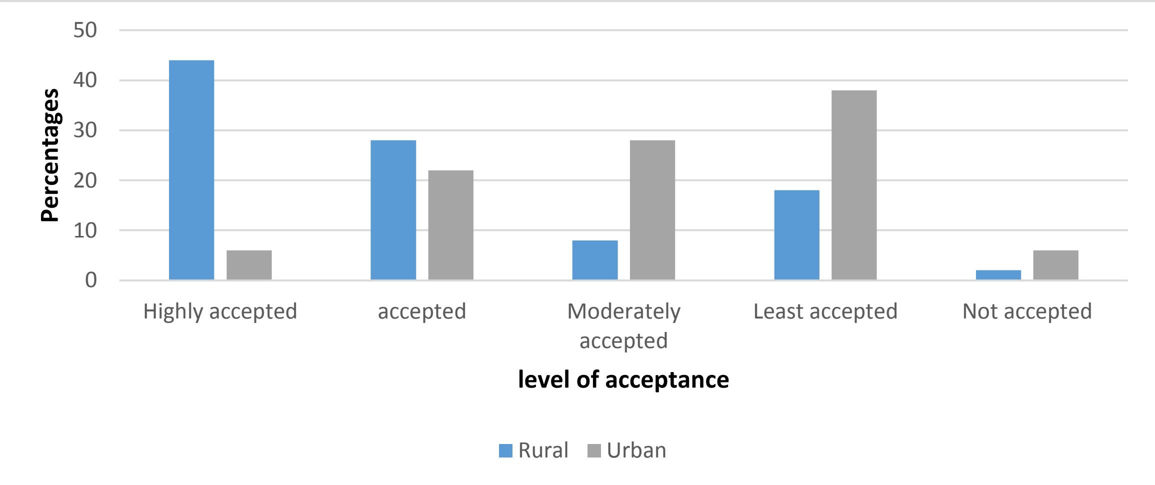

Figure 4.32: Level of acceptance of biogas by rural and urban households

(Field Data, 2014)

- **Level of acceptance of liquid biofuel**

As liquid biofuel possesses various potential uses, it is regarded as the best option compared to petroleum oil. In Kitui Central where energy need is majorly fulfilled by biomass i.e. fuelwood, Jatropha plant can be an additional source of biomass energy. Thus, its acceptance in the area could be highly beneficial.

Findings in Figure 4.33 indicate that liquid biofuel is highly accepted by 2% of the urban households and 38 % of the urban households reported to least accept liquid biofuel. The study reviewed that majority of the households have little or no knowledge and awareness on this type of biofuel and this has greatly affected its level of acceptance.

Liquid biofuel is accepted by 44% of the rural households and 24% of the urban households as an alternative source of cooking energy (Figure 4.33). Of the rural households (48%) and 36% of the urban households reported to moderately accept liquid biofuel (Figure 4.33). The acceptance by rural households is higher compared to urban household mainly because the rural households face fuel shortage especially firewood and need to diversify their source of fuels. Urban households on the other hand are enthusiastic to substitute kerosene with Liquid biofuel for comparison purposes.

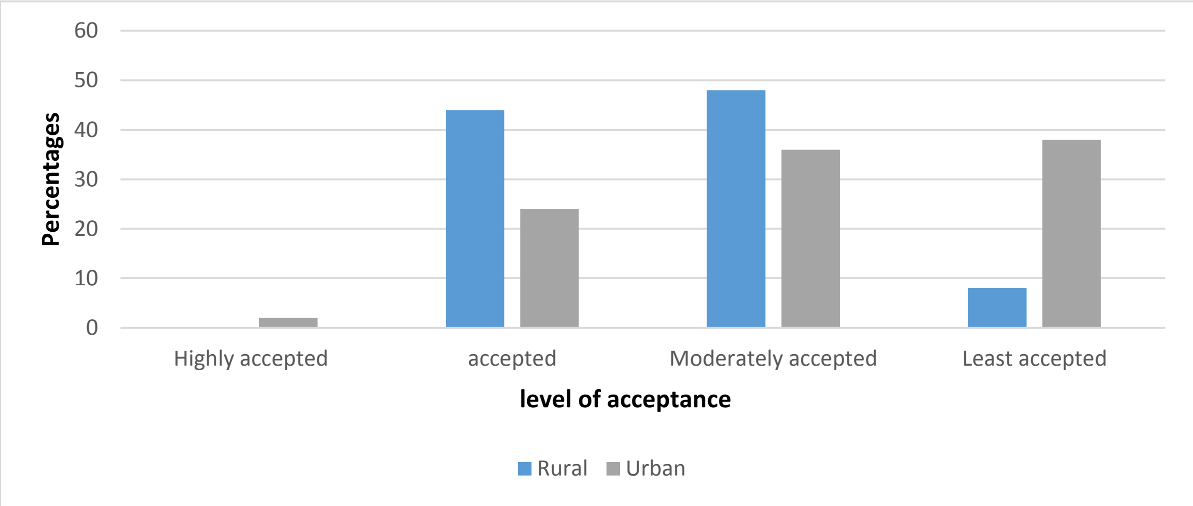

Figure 4.33: Level of acceptance of liquid biofuel by rural and urban households

(Field Data, 2014)

4.6.2 Acceptance of improved biomass energy technologies for cooking by rural and urban households

Acceptance of improved biomass energy technologies for cooking can ensure efficiency in the use of biomass fuels. Moreover, they reduce smoke emission and health hazards while cooking, reduce cooking time, there is less blackening of the cooking utensils, saving fuel, and some are portable stoves an advantage during rainy season.

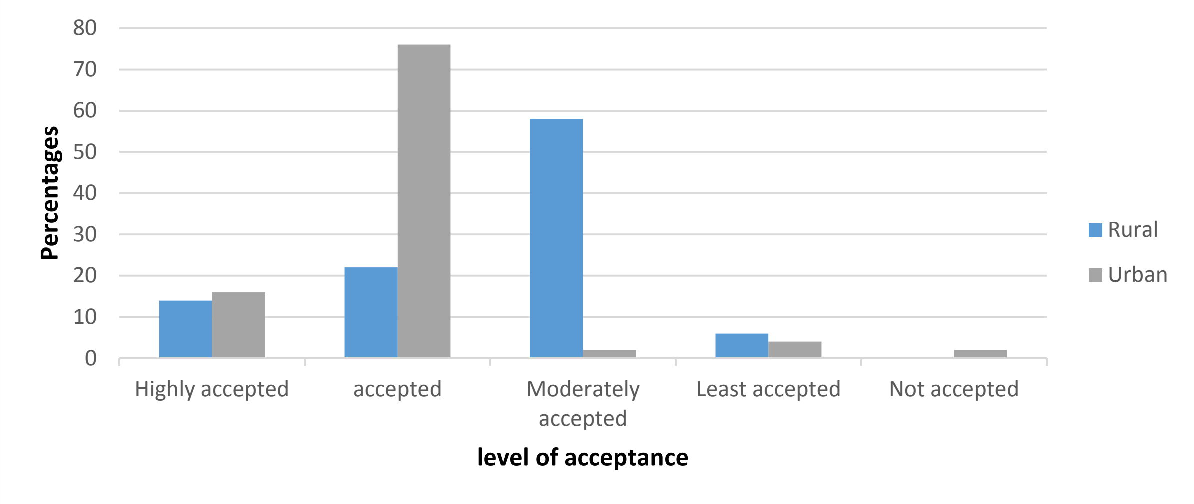

Figure 4.34: Level of acceptance of Envirofit stove by rural and urban households

(Field Data, 2014)

As shown in Figure 4.34, 2% of the urban households do not accept Envirofit stove at all. 6% of the rural households and 4% of the urban households reported to least accept Envirofit stove. Quite a high number (58%) of the rural households moderately accepts Envirofit stove. This low acceptance of Envirofit stove was reported because it cannot accommodate large pots, the combustion chamber is small and thus it cooks slowly. Additionally, there is need to frequently feed and adjust the fuel because of the small grate.

Envirofit stove is accepted by 76% of the urban households and 22% of the rural household (Figure 4.34). These households prefer the stove because it is portable, uses less fuel, smoke production is minimal and its appearance is appealing. Similar findings on Envirofit were reported in Bangladesh by USAID in 2013.

- **Rocket stove**

Rocket stove is least accepted by 62% of the urban households and not accepted by 8% of the urban households (Figure 4.35). Urban households reported that rocket stove is not portable and it requires a permanent kitchen. This prevents them from adopting the stove in the urban setup due to lack of house ownership. However, since urban households have rural homes they reported to like Rocket stove for their rural homes because it has two pot holders, it is permanent and thus requires minimal maintenance.

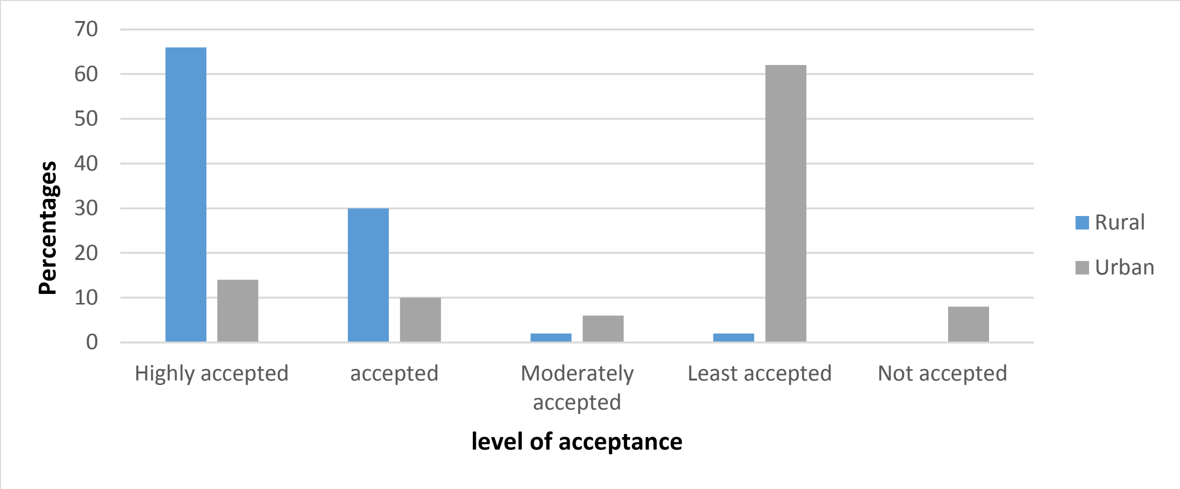

Figure 4.35: Level of acceptance of rocket stove by rural and urban households

(Field Data, 2014)

Sixty six percent (66%) of the rural households and 14% of the urban households highly accept Rocket stove (Figure 4.35). Rocket is mainly accepted due to its ability to accommodate two pots while cooking and retaining heat. For instance, adopters of rocket stove reported that after cooking dinner, they usually leave a pot of water on the stove which they would use for bathing in the morning when the water is still warm. The stove also uses less fuel, produces less smoke and it is durable. The rural households have greater awareness of the stove from the promoters and neighbors compared to other stoves. Person et al. (2012) in rural Kenya, reported similar findings that the decision to purchase ICS by households was significantly influenced by the experiences of neighbors and relatives who had adopted the stove.

- **Maendeleo stove**

Maendeleo stove is moderately accepted by 10% of the rural households and 8% of the urban households and 2% of both rural and urban households do not accept the stove at all (Figure 4.36). This can be explained by the fact that urban households rarely use firewood as a fuel in their domestic activities and for the rural households they less preferred it because it is not durable.

Of the rural households, 44% highly accept Maendeleo stove as well as 18% of the urban households (Figure 4.36). Quite a lot of the urban households (70%) accept the portable model of Maendeleo stove while 46% of the rural households accept both models. Maendeleo stove is liked because it cooks faster, uses less firewood and produces less smoke leading to improved indoor air condition and thus better health for the woman and children as well as saving on fuel expenditure and time spent in search of wood fuel.

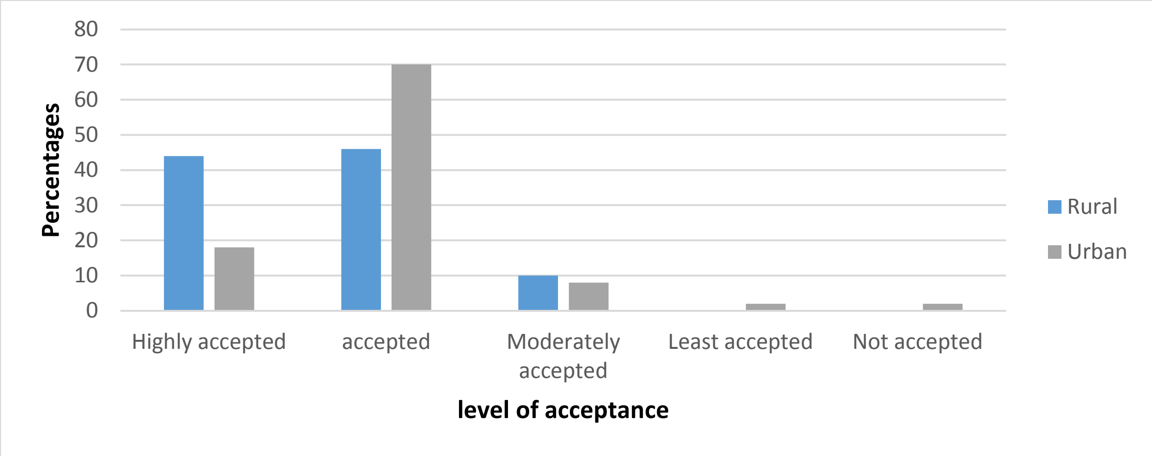

Figure 4.36: Level of acceptance of maendeleo stove by rural and urban households

(Field Data, 2014)

- **Three chamber stove**

Findings in Figure 4.37 indicate that only 4% of the rural households highly accepts Three chamber stove (Plate 4.5). Three chamber is accepted by 2% of the rural households and 8% of the urban households. The stove is not accepted at all by 2% of the rural households and 8% of the urban households (Figure 4.37). This is because of its high cost of installation and low levels of awareness.

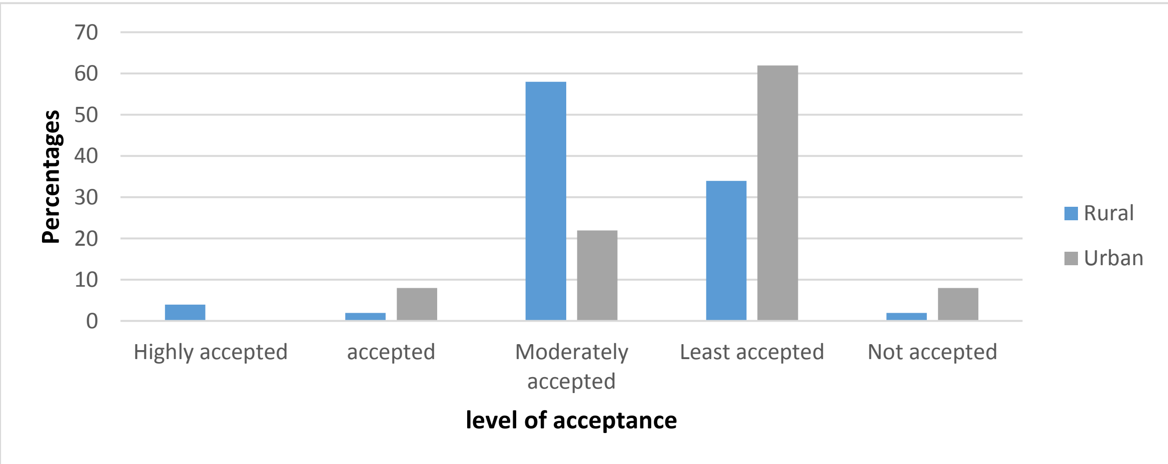

Figure 4.37: Level of acceptance of three chamber stove by rural and urban households

(Field Data, 2014)

Fifty eight percent (58%) and 22% of the rural and urban households respectively moderately accepted the stove. The stove is least accepted by 34% of the rural households compared to 62% of the urban households (Figure 4.37). The difference in the level of acceptance by urban and rural households is contributed by the fact that rural households are constantly looking for improved firewood technologies that use less fuel but urban households are mainly interested in improved charcoal technologies.

- **Kenya ceramic jiko (KCJ)**

KCJ is moderately accepted by 4% of the urban households mainly because it is not durable (Figure 4.38). The households reported that KCJ liners are not fired by some producers and the metal gauge used is very light hence short lifespan. Despite these features of KCJ its acceptability is quite high. 50% of the rural households and 34% of the urban households reported to highly accept KCJ stove. Moreover, 50% of the rural households and 62% of the urban households reported to accept KCJ stove (Figure 4.38). The acceptability of the charcoal stove is a factor of high knowledge and awareness of KCJ by households. KCJ uses less charcoal, it is portable and affordable by these households. Additionally, lack of any other widely known improved charcoal stove makes KCJ the best choice for the households in the study area.

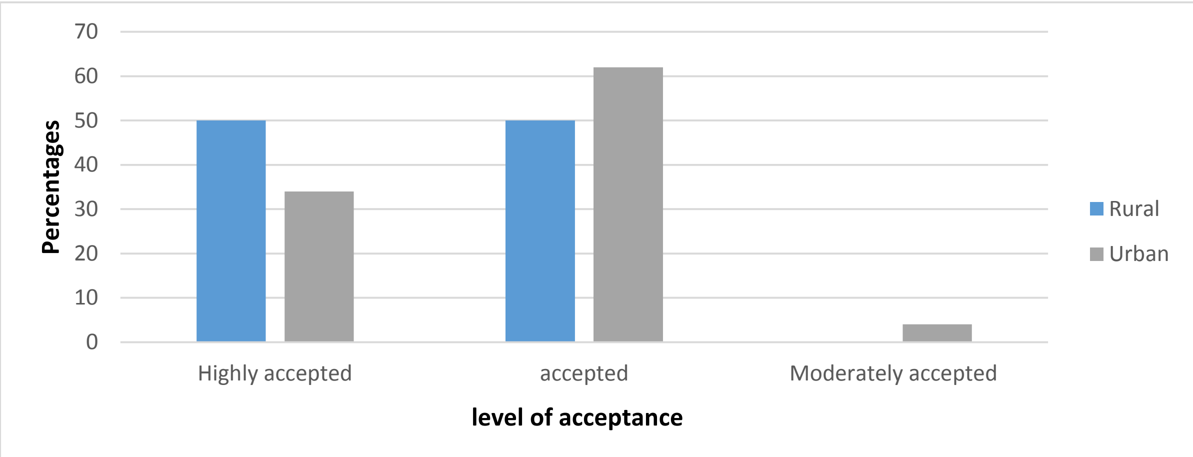

Figure 4.38: Level of acceptance of KCJ by rural and urban households

(Field Data, 2014)

- **Briquette stove**

As shown in Figure 4.39, Briquette stove is least accepted by 10% of the rural households and 6% of the urban households. Additionally, 40% of the rural households and 10% of the urban households reported to moderately accept the stove. Due to availability of a substitute stove (KCJ) using briquettes, households do not see the need to buy briquette stove. 2% of the rural households however, reported to highly accept the stove just to do try it out and judge its performance with KCJ.

Over half (82%) of the urban households accept briquette stove compared to 38% of the rural household (Figure 4.39). The study revealed that the acceptability of the stove is influenced by the durability of KCJ meaning if the available KCJ stoves are more durable than they are now, households can prefer it to buying a briquette stove.

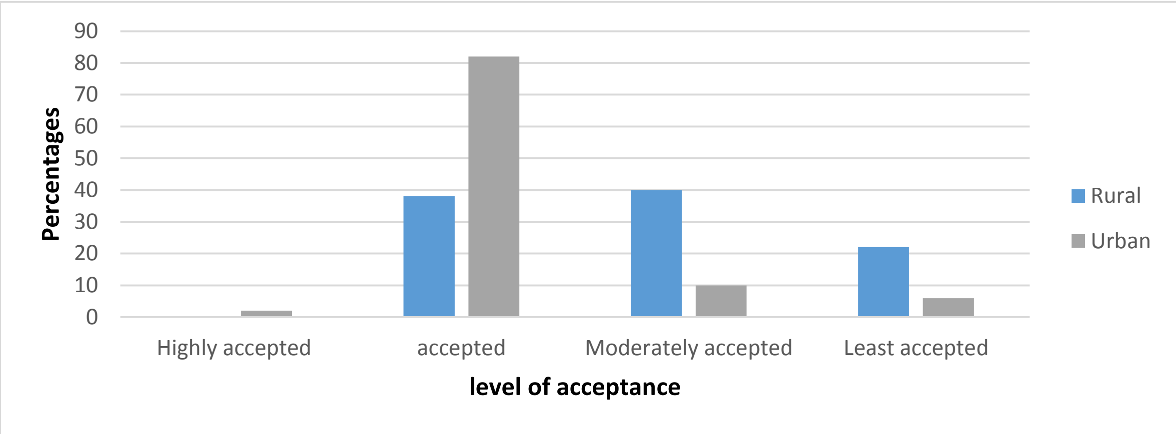

Figure 4.39: Level of acceptance of briquette stove by rural and urban households

(Field Data, 2014)

- **Liquid biofuel stove**

Due to its high viscosity, Liquid biofuel has difficulty in cooking. Also, presence of other component forming coke and higher ignition temperature of Liquid biofuel compared to petroleum make it difficult to ignite the fuel. Thus, special stoves for Liquid biofuel have been innovated whose adoption however depends on the availability of Liquid biofuel.

Findings in Figure 4.40 indicate that 8% of the rural households and 30% of the urban households reported to least accept the stove. This acceptability level is contributed by inadequate knowledge and low levels of awareness of Liquid biofuel (Liquid biofuel) which in return affects the stove's acceptability. It is however worth noting that households are interested in learning more about the fuel which is assumed will increase the acceptability level of the stove.

Findings in Figure 4.40 6further indicates that 68% of the rural households have moderate acceptance of the stove compared to 38% of the urban households. The stove is accepted by 24% of the urban households and 18% of the rural households. The study reviewed that rural households' acceptability of new biomass fuels is high compared to the urban counterparts because of fuel shortage in the rural areas and the need to diversify to solve this problem. The urban households and some rural households who accept the stove use kerosene more often and thus, are interested in trying Liquid biofuel of cooking for comparison purposes. This need has led to acceptance of Jatropha stove.

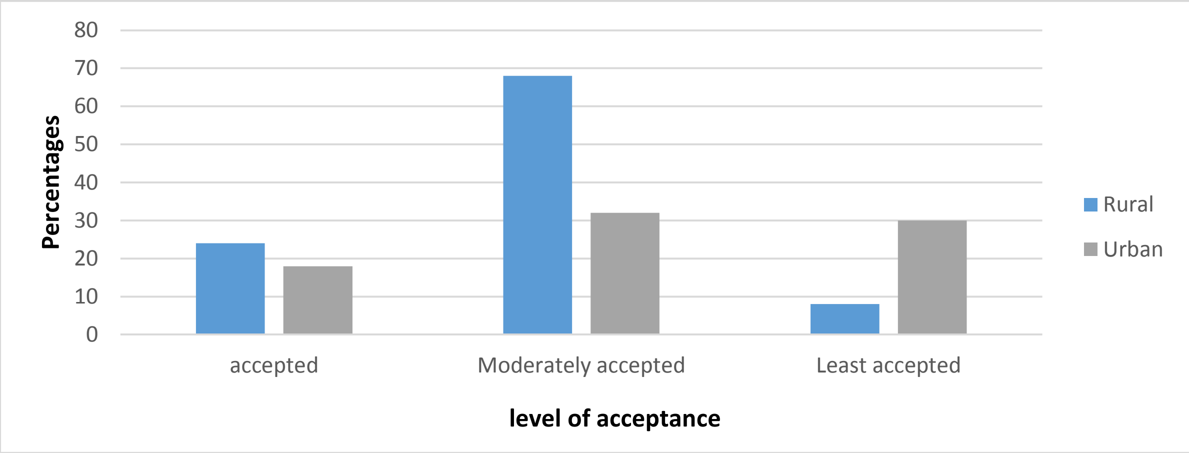

Figure 4.40: Level of acceptance of liquid biofuel stove by rural and urban households

(Field Data, 2014)

- **Biogas cooking burners**

Acceptability of biogas cooking burners is largely dependent on the availability of biogas which in return depends on the household ability to adopt biogas technology.

Single burner cooking stove

As shown in Figure 4.41, 30 % of the urban households and 10% of the rural households reported to least accept the single burner. Only, 2% of the urban households do not accept the single burner. It was reported that single burners do not allow cooking of two dishes at the same time and it is small to accommodate large pots. Experiences sharing by single burner adopters has led to low acceptance. The study reviewed that adopters of single burner experience gas leaking due to loosening of the valve.

Half of the urban households reported moderate acceptance of single burner compared to 12% of the urban households. The moderate acceptance mainly by the urban households is contributed by the fact that they do not know how they can process biogas in the urban setting due to lack of space and other required resource such as feedstock.

Seventy eight percent (78%) of the rural households accept single burner compared to 18% of the urban households (Figure 4.41). This is because the rural households are more familiar with the single burners especially through the shared experiences by the adopters. The single burner is perceived easy to operate and affordable in case it needed replacement.

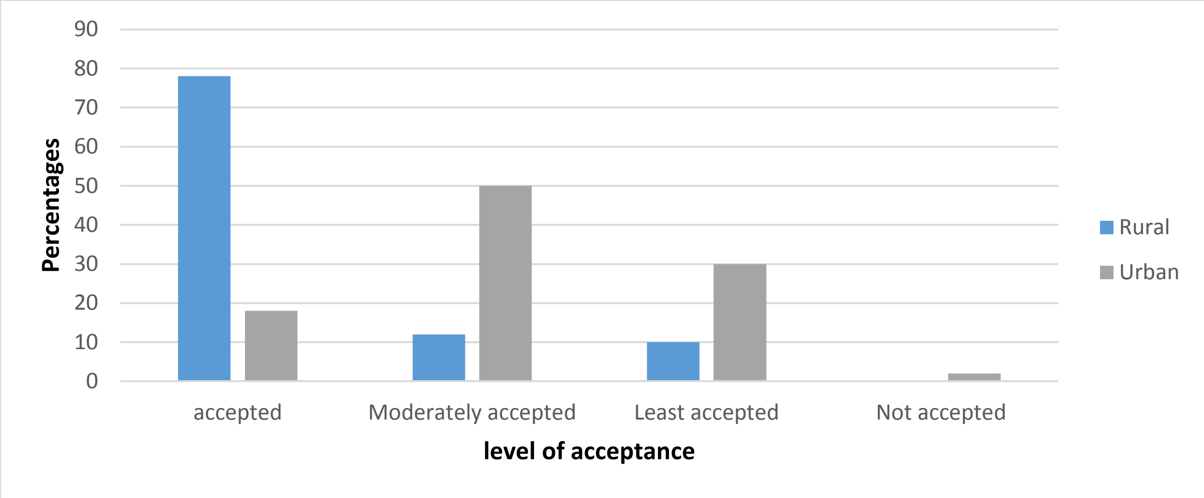

Figure 4.41: Level of acceptance of biogas single burner by rural and urban households

(Field Data, 2014)

Double burner cooking stove

Double burner is not accepted at all by 2% of the urban households. These households reported that they are comfortable with the fuel they are currently using especially for the LPG users. Double burner is least accepted by 28% of the urban households and 8% of the rural households who are concerned with its affordability and availability since they have not seen it before (Figure 4.42).

As shown in Figure 4.42, 44% of the urban households reported moderate acceptance of the double burner because it is perceived easy to use since they are used to similar burners. However they are still not sure of how to get already processed biogas to use with the double burner.

Fifty two percent (52%) of the rural households and 6% of the urban households have a high acceptance of the double burner. It is accepted by 30% of the rural households and 20% of the urban households (Figure 4.42). Urban households acceptability levels are affected by the perception that biogas can never be processed in the urban areas and thus, no need to even consider having the burner. The study reviewed that for the urban households double burner can be their highly accepted biogas burner if biogas is readily available and already processed.

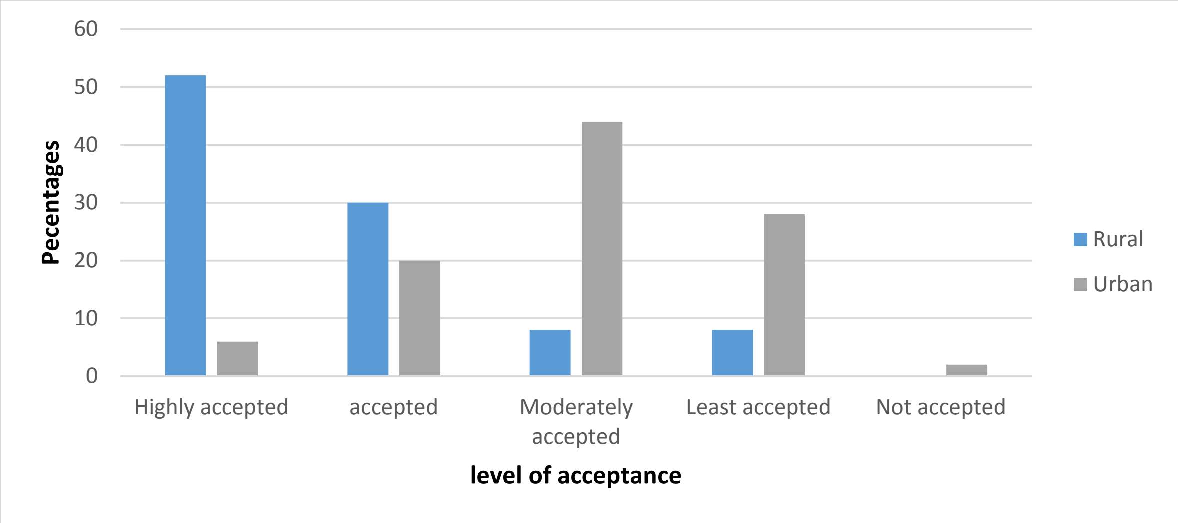

Figure 4.42: Level of acceptance of double burner by rural and urban households

(Field Data, 2014)

4.6.3 Summary: Distinct patterns of acceptance comparing rural and urban households

4.6.3.1 Rural and urban level of acceptance of biomass fuels

Overall, the study reveals that rural and urban households show quite a distinctive pattern of acceptance with regard to the five biomass fuels due to the different availability of the various biomass fuels, but also due to current knowledge about the fuels and different socio-economic situations of the households. Rural households have a high acceptance of firewood because they perceive it as affordable, available and economical to use. However, firewood is not a preferred fuel for urban households mainly because it is perceived as a rural fuel and more costly in urban areas. Similar findings were reported in Bangladesh by USAID WASHplus project in 2013.

Charcoal is generally accepted more by urban households because they perceive it to be affordable and available compared to any other biomass fuel. Rural households highly accept charcoal as a subsidiary fuel to perform specific tasks such as cooking chapattis. 2% of urban households do not accept charcoal because it is dirty when handling and tedious to light (Figure 4.43). Briquettes are generally accepted by rural and urban households. They are perceived easy to use and clean compared to charcoal. Biogas is highly accepted by rural households but least accepted by 38% of the urban households (Figure 4.43). This is because for a household to use biogas they have to produce it which is a bit impossible for urban households due to lack of the necessary resources and raw materials. Liquid biofuel is moderately accepted by most rural and urban households. This is because it is perceived to be unavailable.

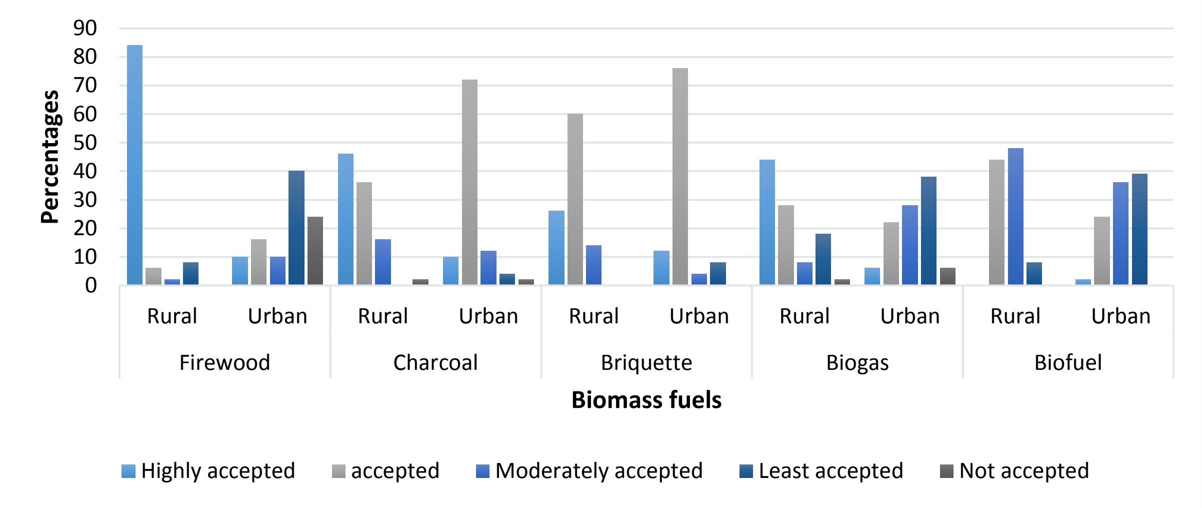

Figure 4.43: Level of acceptance of biomass fuels by rural and urban households

(Field Data, 2014)

4.6.3.2 Rural and urban level of acceptance of Improved Biomass energy Technologies

By and large, rural households have a high acceptance of improved firewood technologies as well as alternative technologies for alternative fuels while urban households highly accept improved charcoal technologies. Additionally, acceptance of improved biomass energy technologies reflects also the availability and preference related to the biomass fuel.

Rural households highly accept Rocket stove because it has two pot holders and a permanent stove requiring minimal maintenance. Maendeleo stove too is a preferred choice by rural households thanks to its availability in two models, both portable and the liners. It is preferred because it is perceived affordable and its ability to use less fuel and to cook faster. KCJ is also accepted by rural households as a subsidiary stove to be used during rainy seasons and to cook specific dishes. Double burner is highly accepted by rural households because it has two pot holders (Figure 4.44).

Urban households generally accept portable stoves due to their frequent mobility from one rental house to another. Thus, Envirofit and portable maendeleo stove are the most preferred firewood stoves by urban households. These findings conform to findings in Bangladesh by USAID (2013) where they found out that because of the lack of space in urban areas, users welcomed portable models that can be used inside the apartment. KCJ stove on the other hand is accepted by urban households because it uses less fuel and cooks faster. However, they do not highly accept it because of it short lifespan. This has resulted to acceptance of briquette stove by urban households as they search for more durable charcoal stoves (Figure 4.44).

Urban households have low acceptance of biogas stoves because of their concern on the availability of Biogas. However, they prefer the double burner to single burners. Liquid biofuel stove is moderately accepted by both rural and urban household because of their uncertainty of the availability of Liquid biofuel and the cost of the stove.

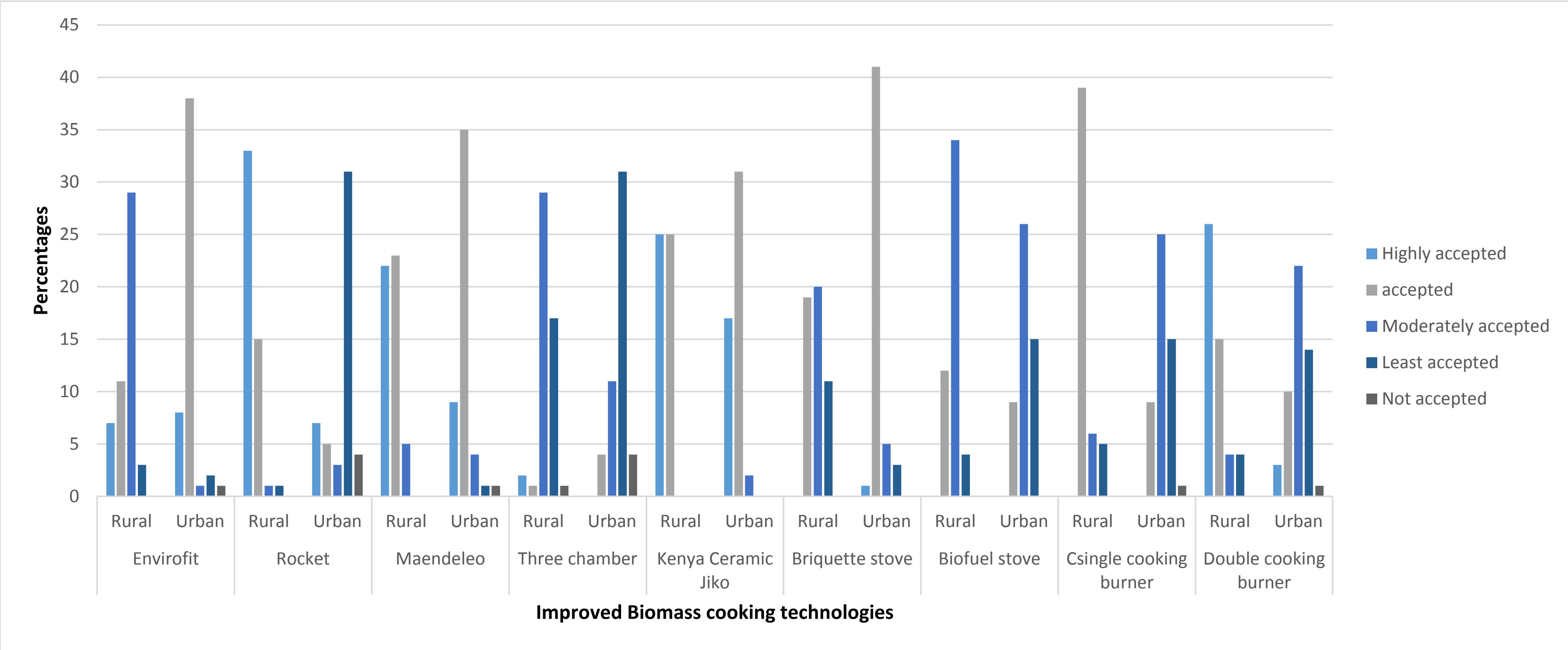

Figure 4.44: Level of acceptance of improved biomass energy technologies by rural and urban households

(Field Data, 2014)

4.7 Willingness to switch to various biomass fuel and improved technologies

Willingness in this context refers to the state of being ready to change currently used biomass fuels and cooking technologies. Recognition of a problem to be solved by a new technology is a factor influencing the willingness to adopt of a technology. Households being rational have their own priority of problems they want to solve for their development and they may not be ready to invest their time and resources to what they do not perceive to be a problem. The public perception is also a determinant factor on their willingness or resistance toward improved biomass energy technologies for cooking. So, it is normally assumed that people's perceptions and willingness to change toward other energy technologies need to change in order to better implement improved biomass energy technologies especially Liquid biofuels, and it is important to know what the main factors shaping their perceptions and willingness to change are (Devine-Wright, 2007).

4.7.1 Willingness to switch to other biomass fuel

Findings show that 8% of the households in the study area are not willing to change their current fuels. Some of these households use LPG and others perceive other biomass fuels such as biogas expensive to install and laborious, thus prefer sticking to the current fuels. 92% of the households in the study area are willing to change from their current biomass fuel to another. Households reported that they are facing problems with their current fuels especially firewood because it is becoming scarce and therefore they are willing to diversify to other biomass fuels.

As shown in Figure 4.45, 62% of the rural households and 78% of the urban households are willing to switch to briquette. They perceived it to be a clean fuel compared to charcoal, easy to use and it burns longer than charcoal. Households also believe that they have the necessary materials to make briquette on their own. About 14% of the urban households are willing to switch from kerosene to Liquid biofuel as an alternative biomass fuels but on condition Liquid biofuel is affordable and readily available. Six percent (6%) of the rural households who only use firewood for cooking are willing to switch to charcoal because it is more comfortable to cook using charcoal than it is when using firewood (Figure 4.45).

Thirty percent (30%) of the rural households and 28% of the urban households are willing to switch to biogas because it is perceived to be a clean fuel and easy to use (Figure 4.45). The influencing factor regarding adoption of biogas by rural households concerns scarcity of firewood leading to longer distances in search for firewood. Thus, rural households are more in need of alternative energy source to help them solve the fuelwood problem. Urban households are interested in comparing the performances of LPG to that of biogas. Rural and urban households also appreciate the fact that biogas is more secure to use in the house than LPG which is highly flammable.

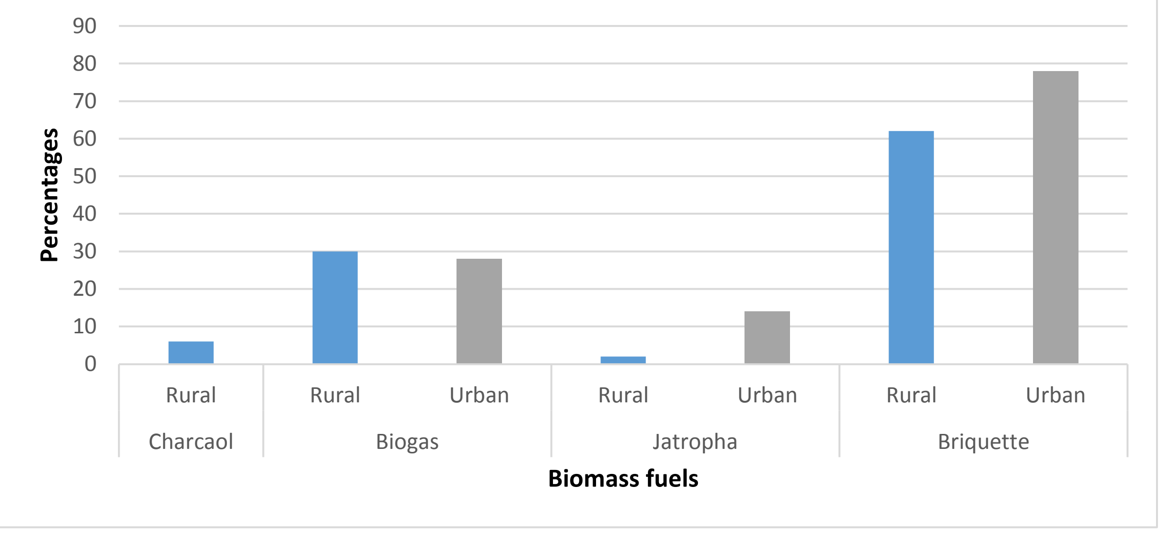

Figure 4.45:Willingness by rural and urban households to change from their current fuels to another biomass fuel (Field Data, 2014)

4.7.2 Willingness to switch to various improved technologies

Majority of the households (85%) in the study area are willing to switch from their current cooking technologies to other technologies they perceived to have more benefits. About 14% of the households who reported lack of willingness to change from their current technologies argued to be okay with their current technology and others reported not to have money to purchase the stove or buy the construction materials. In the study area, 1% of the households do not use biomass fuel and thus there willingness was based on the willingness to switch from non-biomass technologies.

Findings in Figure 4.46 indicate that rural households are more willing to switch to improved technologies than the urban households. The study revealed that rural households use traditional cookstoves which consumes a lot of fuel and produces a lot of smoke while cooking which necessitates the need to adopt improved technologies to save on fuel. On the other hand, urban households use KCJ which is preferred for using less fuel but short lifespan and majority reported to know of no other improved charcoal technology in the market. 2% of the urban households use LPG for cooking and are comfortable with it (Figure 4.46).

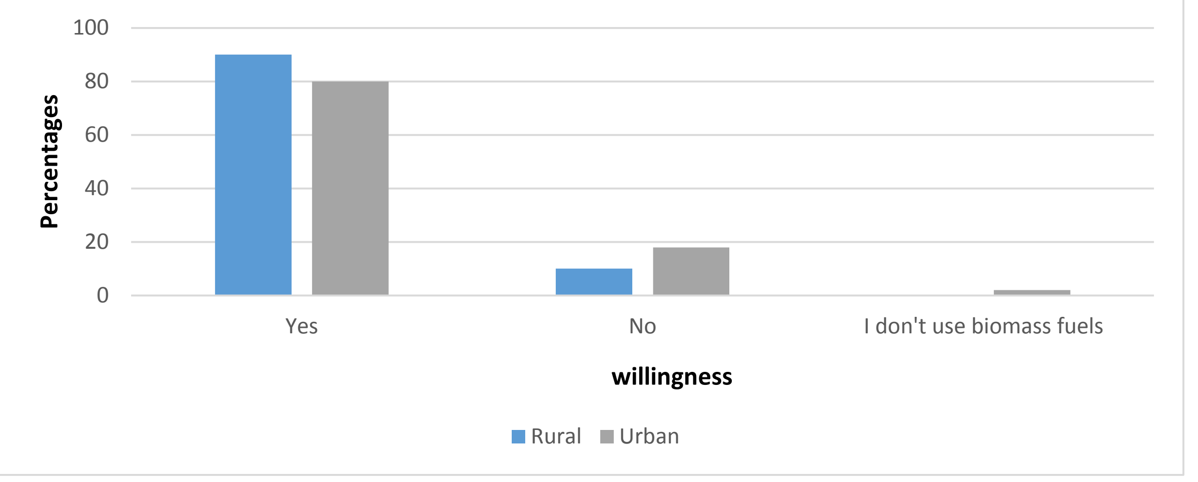

Figure 4.46: Willingness by rural and urban households to change cooking technologies (Field Data, 2014)

Finding in Figure 4.57 indicate that majority of the rural households (92%) are willing to switch to rocket stove because it has two pot holders, comfortable, produces less smoke and it is a permanent stove that requires minimal maintenance. Of the urban households (8%) willing to switch to Rocket stoves have their permanent homes in the urban area and thus are willing to invest in a more permanent stove.

Over half (52%) of rural households are willing to use Maendeleo stove compared 4% of the urban households (Figure 4.47). Maendeleo stove is perceived to be affordable compared to Rocket stove. Other preferred features of Maendeleo stove is cooking faster, using less fuel and production of less smoke. Additionally, availability of a portable model increases it chances of adoption in the urban areas.

Further, 52% of the urban households are willing to adopt Envirofit stove compared to 28% of the rural households. The study discovered that urban households are willing to use Envirofit stove because of its appearance, its portability, comfort and it produces less smoke. Urban households are more aware of Envirofit stove because it is being promoted in urban areas and some of them have seen it unlike the rural households who are less knowledgeable about the stove. These findings conform to findings by El Tayeb Muneer and Mohamed (2003) who found that the adoption rate of ICS is very slow mainly due to lack of knowledge in Khartoum, Sudan. Rural households are less willing to adopt the stove because they perceive it to be expensive for them to afford. Moreover, according to rural households Envirofit stove cannot accommodate large pots.

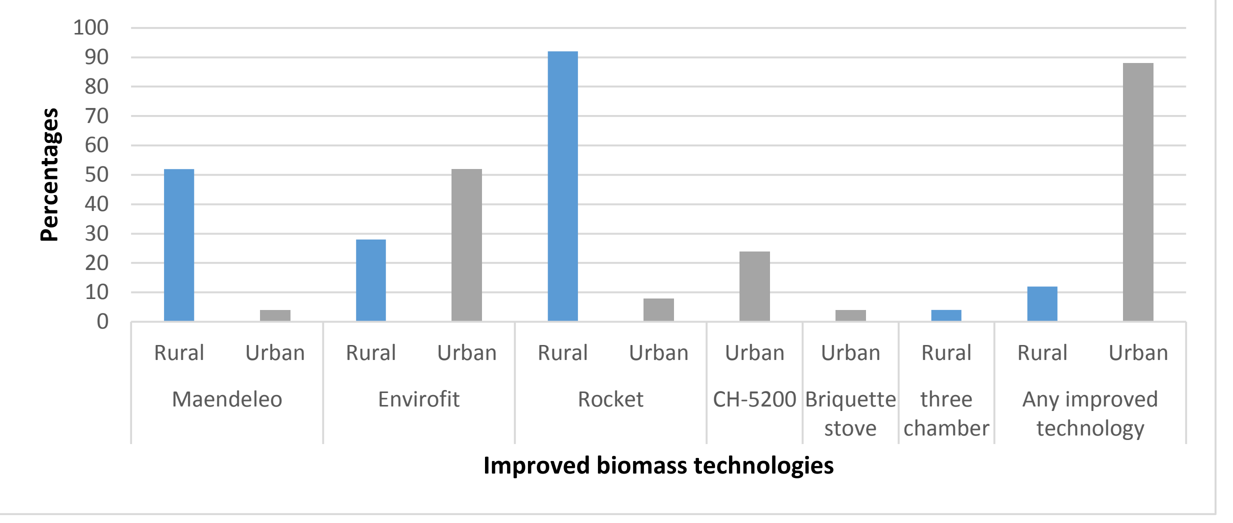

Figure 4.47: Willingness to switch to various technologies

(Field Data, 2014)

As shown in Figure 4.47, 88% of the urban households and 12% of the rural households are willing to try any other improved technology to compare it with the currently adopted technology. The technology in question here is KCJ which seems to be the only improved charcoal technology known by majority of the households. It was reported that KCJ is not durable due to breaking of the liner and light gauge metal sheet. Additionally, 24% of the urban households are willing to adopt Envirofit CH-5200 (appendix IV) charcoal stove but it is perceived expensive. The rural households seems to be comfortable with KCJ because it is used as a subsidiary stove meaning it is not used more often to notice how easily the liners can break.

4.7.3 Analysis of the variables

The fifth null hypothesis was: There is no significant difference in the willingness by rural and urban households to change biomass fuels and cooking biomass energy technologies. For the first part of the hypothesis, the independent variable is rural and urban households and the dependent variable is willingness to switch to alternative biomass fuels. Values of measurement for independent and dependent variables are rural/urban households and willing or not-willing to switch to alternative biomass fuels respectively (Table 4.24). Both variables are categorical in nature. The hypothesis is tested by use of Pearson's Chi square and Phi test to test the significance of the relationship.

Table 4.24: Willingness to switch to alternative biomass fuels by rural and urban households cross tabulation

		Willingness to switch to other biomass-based fuel		Total
		Yes (%)	No (%)	
Location	Rural	46 (92)	4 (8)	50 (100)
	Urban	46 (92)	4 (8)	50 (100)
Total		92 (92)	8 (8)	100 (100)

(Field Data, 2014)

As shown in Table 4.25, the analysis on the willingness by rural and urban households to change cooking biomass energy technologies indicates that the calculated chi square value (0.000) is smaller than the critical value (3.84) while the p value which is 1.000 is more than 0.05. The null hypothesis is thus adopted since there is no enough evidence to reject it. Thus, there is no significant difference in the willingness by rural and urban households to change biomass fuels. This is attributed to the acceptance of alternative biomass fuels by rural and urban households.

Table 4.25: Hypothesis testing

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.000[a]	1	1.000		
Continuity Correction	0.000	1	1.000		
N of Valid Cases	100				

(Field Data, 2014)

Phi test analysis further indicates that there is no statistically significant correlation between the willingness to switch to alternative biomass fuels by rural and urban households with 1.00 approximate significant value (Table 4.26). This attributed to independent decisions by rural households and urban households to switch to alternative biomass fuels.

Table 4.26 Phi test

		Value	Approx. Sig.
Nominal by Nominal	Phi	0.000	1.000
	Cramer's V	0.000	1.000
N of Valid Cases		100	

(Field Data, 2014)

For the second part of the hypothesis, the independent variable is rural and urban households while the dependent variable is willingness to switch cooking technologies. Values of measurement for independent and dependent variables are rural/urban households and willing or not-willing to switch to improved biomass energy technologies for cooking respectively (Table 4.27). Both variables are categorical in nature. The hypothesis is tested by use of Pearson's Chi square and Phi test to test the strength of the relationship.

Table 4.27: Willingness to switch to improved biomass energy technologies by rural and urban households cross tabulation

		Willingness to switch to improved biomass energy technologies		Total
		Yes (%)	No (%)	
Location	Rural	45 (90)	5 (10)	50
	Urban	40 (80)	10 (20)	50
Total		85 (85)	15 (15)	100

(Field Data, 2014)

As shown in Table 4.28, the analysis on the willingness by rural and urban households to switch to improved biomass energy technologies indicates that the calculated chi square value (1.961) is smaller than the critical value (3.84) while the p value which is 0.161 is more than 0.05. The null hypothesis is thus adopted since there is no enough evidence to reject it. Thus, there is no significant difference in the willingness by rural and urban households to switch to improved biomass energy technologies. This is attributed to the acceptance of to improved biomass energy technologies by rural and urban households.

Table 4.28: Hypothesis testing

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	1.961[a]	1	.161		
Continuity Correction[b]	1.255	1	.263		
N of Valid Cases	100				

(Field Data, 2014)

Further analysis indicate that there is no statistically significant correlation between the willingness by rural and urban households to switch to improved biomass energy technologies with 0.161 approximate significant value (Table 4.29). The study revealed that shared experiences by both rural and urban households regarding use of improved biomass energy technologies have an influence on their willingness to switch to these technologies.

Table 4.29: Phi test

		Value	Approx. Sig.
Nominal by Nominal	Phi	.140	.161
	Cramer's V	.140	.161
N of Valid Cases		100	

(Field Data, 2014)

CHAPTER 5: SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

The chapter is subdivided into three sections, section one makes a summary of the study findings in relation to the objectives of the study. Section two presents conclusion on the study findings while section three recommends on some possible measures to increase the future scaling up of improved biomass energy technologies and alternative biomass fuels adoption.

5.2 Summary

The study revealed that socio-economic characteristics of a household such as average household income, type of the house, water availability and fuel availability has an influence on the adoption of improved biomass energy technologies for cooking. For instance, although households with higher income are more likely to use modern fuels or afford the increasing prices of biomass fuels, their decision for cooking fuel choice and adoption of improved biomass energy technologies are quite complex and multi-dimensional; deep understanding of the interaction of these factors is necessary for designing government plans, policies and strategies to improve access to alternative biomass fuels and adoption of improved biomass energy technologies.

Firewood and charcoal are the widely used biomass fuels primarily because they are perceived readily available, easy to use and affordable. Alternative biomass fuels such as liquid biofuel are not highly adopted in the study area. Biogas technology is perceived to be an expensive investment that is not affordable by households and the perceived lack of technical knowhow. Additionally, inadequate resources such as feedstock has an influence on the low adoption. Liquid biofuel on the other hand is not available for purchase and the awareness of this alternative fuel is very low hence non-adoption. Briquettes are gaining popularity especially in the urban areas although the adoption is still very low. This is due to lack of adequate skills to process briquette and inadequacy of raw materials.

Improved biomass energy technologies are generally perceived more superior than traditional biomass energy technologies for cooking with less constraints. However, the adoption of improved technologies is rather low compared to the vast use of traditional technologies. The reasons behind this low adoption is the perception that improved technologies are expensive and not readily available. Rural households have adopted more improved firewood energy technologies compared to other improved biomass energy technologies because these households heavily rely on firewood for cooking. It was revealed that adoption of improved biomass energy technologies is greatly influenced by the availability of the biomass fuel.

In the study area, various stakeholders including governments, non-governmental organizations, and development agencies are focusing on improving access to affordable and reliable alternative biomass fuels and improved biomass energy technologies for cooking. However, their efforts have not significantly led to adoption of improved biomass energy technologies as well as alternative biomass fuels. This is firstly because of levels of income of the households in the study area and negative perceptions on alternative biomass energy and improved biomass energy technologies. Secondly, projects involved with promotion of improved biomass energy technologies are still on progress meaning they have not yet achieved their 100% targets. Thus, there is a possibility of increased adoption in the near future.

Rural and urban household's level of acceptance of alternative biomass fuels and improved biomass energy technologies is high although it differs depending on the fuel and the technology but also on the context of the households. Rural households' acceptance of alternative fuels such as biogas is higher than in urban areas due to availability of space and feedstock. Rural households' acceptability of fixed improved biomass energy technologies is more compared to urban households which prefer portable stoves. Willingness to change cooking fuels and technologies is high in the study area. The study findings show that more rural household are willing to adopt Maendeleo and Rocket stoves. Urban households are willing to adopt improved charcoal technologies apart from KCJ because it is not durable.

5.3 Conclusion

Household's wealth has a great influence on the adoption of improved biomass energy technologies due to the resources that are needed for initial installation and maintenance. A large proportion of rural households in the study area still rely heavily on firewood for cooking using traditional stoves. Households are aware of the many constraints in the use of traditional technologies which creates an opportunity for the adoption of improved biomass energy technologies. Charcoal is also a major fuel for cooking by both urban and rural household. Positive perceptions on firewood and charcoal has an influence on the continued use of firewood and charcoal. Unless major policy interventions are introduced, firewood and charcoal are expected to remain the main sources of biomass energy for cooking for years to come.

Different types of promotions in the study area are relevant, however, financial support is the most valued support by the households mainly due to their low income levels. Additionally, the government has not yet given much attention to promoting alternative biomass fuels and their improved technologies which are geared towards reducing the high dependence on firewood and charcoal. This is only left to non-governmental organizations.

Acceptability of biomass fuels and improved biomass energy technologies is also dependent on the household's level of awareness, their affordability and availability. To increase the level of acceptance of improved biomass technologies for biogas, Jatropha and Briquette, there is need to make these fuels available, affordable and to create awareness. This will change household's perceptions towards these fuels leading to high acceptance. It is evident that households are willing to change their cooking fuels and practices. This is a positive feedback from the study area which if backed up with effective policies will result to high adoption of improved biomass energy technologies and alternative biomass fuels.

5.4 Recommendations

The high level of acceptance and willingness to switch from current biomass fuels and cooking technologies offers a good potential to foster a wider adoption of alternative biomass fuels and improved biomass energy technologies. Below are some of the recommendations to make this possible and to accelerate the rate of adoption.

5.4.1 Government and development agencies

1. Creation of awareness on the available improved biomass energy technologies and alternative biomass fuels and training households on their effectiveness is essential as well as making them attainable and affordable for them.
2. Subsidies and incentives are the main financial mechanisms to promote use of alternative biomass fuels and improved biomass energy technologies. Household's ability to adopt improved biomass energy technologies and alternative biomass fuels is rather low and that a subsidy program need to run alongside with the dissemination of stoves as households cannot afford their initial costs.
3. There is need to train briquette producers on how to carbonate briquettes to reduce smoke production because there is a high interest in briquettes as an alternative fuel.
4. Additionally, production of briquettes from alternative raw materials such as bagasse, coffee and maize residues or saw dust can provide a more sustainable alternative to firewood and charcoal. This will ensure their sustainability.
5. Extension services should be made available for maintenance of adopted technologies and for follow up activities. This will ensure there is continued functioning of the technologies.

6. There is need to educate the households and conduct demonstrations to show that the slurry, which comes out after producing gas is good manure and its ‘strength’ is not lost by yielding gas, which is combustible. Introduction of packaged biogas is very essential to encourage its use in the households not capable of producing their own biogas especially urban households. Additionally, encouraging households to practice zero grazing for ease in accumulating feedstock and ensuring sustainable water supply in the areas can aid in the adoption of biogas technology.
7. There is need to use other entry points for the dissemination of improved biomass energy technologies in the community instead of from women groups to ensure sustainability. Women groups are more often than not faced with wrangles which makes them unsustainable.

5.4.2 Households

1. Knowledge sharing by the adopters should also be encouraged in the area. This will help in creating awareness of the benefits of using alternative biomass fuels and improved biomass energy technologies for cooking leading to increased adoption.
2. Households should be encouraged to form groups so that they can access credit and bargain for prices of improved biomass energy technologies.
3. Households should be sensitized on socio cultural aspects that hinder adoption of technologies in the County.

5.4.3 Manufacturers

1. Improved biomass technologies for cooking with two burners should gain more importance during model design. As the findings of the study highlights the need for improved biomass energy technologies models with two burners especially in rural areas, government, and development agencies should proactively consider supporting the development of these models. This must also entail the development of related quality and performance standards by government and regulatory bodies to ensure quality product development. For instance, there is need to focus on the durability of the stoves through streamlining the production process in order to increase efficiency and reduce breakages especially for KCJ and Maendeleo stoves. In Kenya standards exist for biomass cookstoves, at Kenya Bureau of Standards (KEBS) which can be used as a benchmark for entrepreneurs to obtain, and to guide entrepreneurs on materials to be used in production and stove dimensions.

5.4.4 Distributors

1. Selection of improved biomass energy technologies for cooking should incorporate user preferences and be based on the local context. The study suggests that the sustained adoption of improved biomass technologies for cooking will depend largely on user acceptance and the selection of appropriate technologies. Any intervention aimed at creating sustained adoption should include a pilot to identify improved biomass technologies for cooking that are suitable to fuel uses, cooking practices and user preferences. These pilots must provide an option for users to provide feedback on different technologies and designs that are being considered for dissemination. For instance, Envirofit stove does not suit most households' preferences due to small combustion chamber and grate.

5.4.5 Recommendations for further research

1. More data on stove efficiency and emissions under field conditions are required. This study is based entirely on adoption and user acceptability of improved biomass energy technologies for cooking and can therefore not make any reliable statements on actual smoke emissions and efficiency. There is an urgent need to measure cooking performance of stoves such as stove efficiency and emissions under actual-use conditions, to complement the user-focused findings of this study.
2. Household awareness and understanding of the health impacts of biomass fuels and cooking technologies should be further investigated.

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APPENDICES

Appendix I: Household Questionnaire

This research is aimed at investigating the socio-economic factors that influence the acceptability of improved biomass energy technologies for cooking, adoption and households' ability to switch from one biomass fuels to another in rural-urban Kitui Central.

This can be used for future policy improvements in the area. The research is a non-profit assignment. All the answers provided are confidential and will not be used to disclose any person's identity without their knowledge.

Site details

County		Division			
Location					
Sub-location		Village			
GPS Co-ordinates					
Interviewer(s)					
Interview date		Start time:		End time:	
Q, Number					

Respondent's details

1. Position in the household
   1. Household head ( )
   2. Spouse ( )
   3. Son ( )
   4. Daughter ( )
   5. Parent ( )
2. Gender of the respondent
   (1) Male ( )
   (2) Female ( )
3. What is your age in years?
   (1) 18-25 ( ) (5) 50-57 ( )
   (2) 26-33 ( ) (6) 58-65 ( )

(3) 34-41 ( ) (7) 66 and above ( )

(4) 42-49

4. Marital status
   (1) Married ( )
   (2) Single ( )
   (3) Separated/divorced ( )
5. What is your highest level of education?
   (1) None ( )
   (2) Primary ( )
   (3) Secondary ( )
   (4) College ( )
   (5) University ( )
6. What is your main occupation?
   (1) Farming-crops ( )
   (2) Livestock keeping ( )
   (3) Business ( )
   (4) Salaried ( )
   (5) Casual work ( )
   (6) Others (specify)…………………………………………………..

<u>Household characteristics and Demographics</u>

7. What is the type of this household headship?
   (1) Male headed ( )
   (2) Female headed ( )
   (3) Child headed ( )
8. How many members are there in this household?
   Males…..…Females……..Total……....
   (1) 1-3
   (2) 4-6
   (3) 7-10
   (4) 10 and above
9. What is the source of the household income?

   ***Income source**
   (1) Farming-crops
   (2) Livestock keeping
   (3) Business
   (4) Salaried employment
   (5) Pension

(6) Casual work

(7) Remittances

(8) Social networks

****Income range (monthly)**

(1) <5,000

(2) 5,000-15,000

(3) 15,000-25,000

(4) 25,000-35,000

(5) 35,000-45,000

(6) 45,000-55,000

(7) >55,000

No.	**Income source**	**Monthly Income range**
1		
2		
3		
4		
5		
6		

<u>Nutrition and health</u>

10. What are the common foods cooked in the household and what are their sources?

***Sources of food**

(1) From farm

(2) Purchasing

No.	**Type of food**	**Source***
1		
2		
3		
4		
5		
5		

Welfare Indicators

11. What is the type of fencing? Household: …………………… Farm: …………………………

12. House construction materials

No.	Section of house	Construction materials
1	Walls	
2	Roof	
3	Floor	
4	Doors	
5	Windows	

13. What are the sources of your domestic water?

(1) Piped (municipal) ( )

(2) Piped (water project) ( )

(3) Wells ( )

(4) River ( )

(5) Other (specify)……………………………

14. What water storage facilities do you have?

No.	Storage facility	Capacity (litres)
1		
2		
3		
4		

15. Do you ever face water shortages?

(1) Yes ( )

(2) No ( )

16. If yes, when (months)? ....

17. What are the alternative sources of water during the shortage season?

(1) ……………………………..

(2) ……………………………..

(3) ……………………………..

18. What type of fuel do you use and what are the sources?

***Sources**

(1) Forest (2) Vendors (3) Farm (4) Others Specify

No.	Type of fuel	Source	Cost (in kshs)
1	Firewood		
2	Charcoal		
3	Biogas		
4	LPG gas		
5	Kerosene		
6	Farm residue		

19. Do you ever face fuel shortages?
    1. Yes ( )
    2. No ( )
20. If yes, for which fuel types?
    1.
    2.
21. What do you do in times of this shortage?
    Explain………………………………………………………………………………..
22. Why do you like using the cook stove?
    1) Readily available ( )
    2) Cheap ( )
    3) Easy to use ( )
    4) No other alternative ( )
    5) Others (specify) ………………………………………………..
23. Do you know of other biomass fuels? (1) Yes (2) No
24. If yes, which ones?
    1. ……………………………………………….
    2. ……………………………………………….

25. Why don't you currently use them?

....

....

Land tenure and farming systems

26. What is the size of your land? ……………….acres

27. How was your land acquired?
    (1) Inherited ( )
    (2) Hired/rented ( )
    (3) Purchased ( )
    (4) Other (specify) ……………………….

28. What land ownership document do you have?
    (1) Title deed ( )
    (2) Allotment letter ( )
    (3) Self-allocation ( )
    (4) Verbal agreement ( )
    (5) Written document ( )
    (6) No legal document ( )

29. What are the main uses of your land?

No.	Use	Estimated size of land (acres)
1	Housing structures	
2	Crop farming	
3	Livestock keeping	
4	Forest/woodlot	
5	Other (specify)	

30. What types of livestock do you keep and what are your modes of grazing?

***mode of grazing**

(1) Zero grazing
(2) Paddocking
(3) Transhumant
(4) Nomadic
(5) Free range
(6) Caging system
(7) Deep litter system

No.	Livestock type	Number	Mode of grazing*
1	Cattle		
2	Sheep		
3	Goats		
4	Chicken		
5	Camel		
6	Donkey		
7	Other (specify)		

PART B: PROMOTION AND LEVEL OF SUPPORT

31. Have you ever heard of the following improved biomass energy technologies?

STOVES	YES	NO
(1) Envirofit stove		
(2) Rocket stove		
(3) Maendeleo stove		
(4) Three chamber stove		
(5) Kenya ceramic jiko		
(6) Briquetting stove		
(7) Cooking single burners		
(8) Cooking double burner		

32. **If YES**, from whom did you get the information from?

1) Government extension workers ( )
2) NGOs ( )
3) Traders ( )
4) Women groups ( )

5) Friends/neighbours/relatives ( )

6) Others (specify) ( )

33. Do you know of any promoters of improved biomass energy stoves in this area?

(1) Yes ( ) (2) No ( )

34. **If YES**, name one promoter, type of promotion and the level of support using the scale below;

(1)Highly supportive, (2) moderately supportive, (3) Supportive (4) Least supportive (5) Not supportive

IMPROVED STOVES	PROMOTER	TYPE OF PROMOTION	LEVEL OF SUPPORT
(1) Envirofit stove			
(2) Rocket stove			
(3) Maendeleo stove			
(4) Three chamber cookstove			
(5) Kenya ceramic jiko			
(6) Briquetting stove			

(7) Biogas cooking single burners			
(8) Biogas cooking double burners			

PART C: PERCEPTIONS AND CONSTRAINS

For firewood users answer 35-40

35. Which firewood stove do you use for cooking?

Firewood stove	Tick	Cost (Kshs)		Source of stove	Lifetime	Limitations if any of the stove
		Buying	Maintenance			
(1).Envirofit stove						
(2).Rocket stove						
(3).Maendeleo stove						
(4).Three chamber stove						
(5).3Stones stove						

36. Why do you like using the cook stove?

(1) Readily available ( )

(2) Affordable ( )

(3) Easy to use ( )

(4) No other alternative ( )

(5) Others (specify) ( )

37. Is this the only stove available for firewood? (1) Yes (2) No

38. **If No,** which one (s) are available?

………………………………………………………………………………………

………………………………………………………………………………………

39. Why don't you use them?

………………………………………………………………………………………

………………………………………………………………………………………

40. What are the current limitations associated with firewood?

………………………………………………………………………………………

………………………………………………………………………………………

For charcoal users answer Qn. 41-46

41. Which charcoal stove do you use for cooking?

Charcoal stove	**Tick**	**Cost (Kshs)**		**Source of stove**	**Lifetime**	**Limitations if any of the stove**
		Buying	**Maintenance**			
(1).Kenya ceramic jiko						
(2).Mettalic traditional stove						

42. Why do you like using the cook stove?

(1)Readily available ( )

(2) Affordable ( )

(3) Easy to use ( )

(4) No other alternative ( )

(5) Others (specify) ( )

43. Is this the only stove available for charcoal? (1) Yes (2) No

44. **If No,** which one (s) are available?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

45. Why don’t you use them?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

46. What are the current limitations associated with charcoal?

………………………………………………………………………………………………

…………………………………………………………………………………………………

<u>**For biogas users answer Qn. 47-61**</u>

47. Which technology do you use for production?

(1) Plastic Biogas Model ( )

(2) Fixed Dome Biogas ( )

(3) Floating drum Biogas digester ( )

48. Where did you get cash for biogas Installation and maintenance?

1) Own savings ( )
2) Credit /Loan ( )
3) Fully Sponsored by Biogas project ( )
4) Own contribution and subsidy from Biogas project ( )
5) Own contribution and subsidy from the Government ( )
6) Other sources (Specify) …………………………………………..

49. Is your biogas plant functioning? (1) Yes ( ) (2) No ( )

50. **If No**, for how long? ……….…………… (months)

51. What are the reasons for none functioning of your biogas plant?

1) Technical problems ( )
2) Feeding related problems ( )
3) I don’t know ( )
4) Others (specify)…..

52. Are technical services available when needed?

1) Easily available ( )
2) Available but not frequent ( )
3) Not available ( )

53. Is your household labor able to accomplish the activities required to run biogas Related activities? (1) Yes ( ) (2) No ( )

54. **If No**, what do you do to solve the problem of shortage of labor?

1) Use hired labor (Fulltime) ( )
2) Use hired labor (part time ( )
3) Use of own off-work hours ( )
4) Others (specify) ( )

55. What are weaknesses/ limitations of biogas technology?

1) High costs of installation ( )
2) Difficult to operate ( )
3) Unavailability of feed stocks ( )
4) High maintenance costs ( )
5) Difficult in getting maintenance services ( )
6) Not producing enough energy for cooking ( )
7) Others (Specify) …………………………………………………....................

56. Which cooking burner do you use for cooking?

Cooking burner	**Tick**	**Cost (Kshs)**		**Source of stove**	**Lifetime**	**Limitations if any of the burner**
		Buying	**Maintenance**			
(1).Single burner						
(2).Double burner						

57. Why do you like using the burner for cooking?

(1)Readily available ( )

(2) Affordable ( )

(3) Easy to use ( )

(4) No other alternative ( )

(5) Others (specify) ( )

58. Is this the only burner available for biogas? (1) Yes (2) No

59. **If No,** which one (s) are available?

…………………………………………………………………………………………

…………………………………………………………………………………………

60. Why don't you use them?

…………………………………………………………………………………………

…………………………………………………………………………………………

61. What are the current limitations associated with biogas?

…………………………………………………………………………………………

<u>For Briquette users answer Qn. 62-75</u>

62. Which technology do you use for production?

(1) Manual machine ( )

(2) Electrical ( )

(3) Others (specify) ( )

63. Do you own it? (1) Yes (2) No **(If No, go to Qn. 69)**

64. **If Yes,** Where did you get cash to buy the machine?

(1) Own savings ( )

(2) Credit /Loan ( )

(3) Fully Sponsored by briquette project ( )

(4) Own contribution and subsidy from briquette project ( )

(5) Own contribution and subsidy from the Government ( )

(6) Other sources (Specify) …………………………………………..

65. Is your machine functioning? (1) Yes ( ) (2) No ( )

66. **If No**, for how long? ………….………….. (months)

67. What are the reasons for none functioning of your briquette machine?

(1) Technical problems ( )

(2) Feeding related problems ( )

(3) I don't know ( )

(4) Others (specify)…..

68. What are the weakness of the machine?

…………………………………………………………………………………………

…………………………………………………………………………………………

69. **If No,** who owns the machine and how much do you pay for briquette?

Briquette machine	**Tick**	**Owner**	**Cost of briquette per unit in Kshs**
1.Manual Machine			
2.Electric machine			

70. Which cook stove do you use for cooking?

Cook stove	**Tick**	**Cost (Kshs)**		**Source of stove**	**Lifetime**	**Limitations if any of the stove**
		Buying	**Maintenance**			
(1).Briquette stove						
(2).Others (Specify)						

71. Why do you like using the stove for cooking?

(1)Readily available ( )

(2) Affordable ( )

(3) Easy to use ( )

(4) No other alternative ( )

(5) Others (specify) ( )

72. Is this the only briquette stove available for cooking? (1) Yes (2) No

73. **If No,** which one (s) are available?

……………………………………………………………………………………………

……………………………………………………………………………………………

74. Why don't you use them?

……………………………………………………………………………………………

……………………………………………………………………………………………

75. What are the current limitations associated with briquette?

……………………………………………………………………………………………

……………………………………………………………………………………………

<u>For Jatropha users answer Qn. 76-89</u>

76. Which technology do you use for production?
    (1) Manual machine ( )
    (2) Electrical ( )
    (3) Others (specify) ( )

77. Do you own it? (1) Yes (2) No **(If No, go to Qn. 83)**

78. **If Yes,** Where did you get cash to buy the machine?
    (1) Own savings ( )
    (2) Credit /Loan ( )
    (3) Fully Sponsored by Jatropha project ( )
    (4) Own contribution and subsidy from Jatropha project ( )
    (5) Own contribution and subsidy from the Government ( )
    (6) Other sources (Specify) …………………………………………..

79. Is your machine functioning? (1) Yes ( ) (2) No ( )

80. **If No**, for how long? ………..…………… (months)

81. What are the reasons for none functioning of your Jatropha machine?
    (1) Technical problems ( )
    (2) Feeding related problems ( )
    (3) I don't know ( )
    (4) Others (specify)…..

82. What are the weakness of the machine?

……………………………………………………………………………………………

……………………………………………………………………………………………

83. **If No,** who owns the machine and how much do you pay for Liquid biofuel?

Jatropha machine	**Tick**	**Owner**	**Cost of Jatropha per Litre in Kshs**
1.Manual Machine			
2.Electric machine			
3.Others			

84. Which cook stove do you use for cooking?

Liquid biofuel stove	**Tick**	**Cost (Kshs)**		**Source of stove**	**Lifetime**	**Limitations if any of the stove**
		Buying	**Maintenance**			
(1).Liquid biofuel stove						
(2).Others (Specify)						

85. Why do you like using the stove for cooking?

(1)Readily available ( )

(2) Affordable ( )

(3) Easy to use ( )

(4) No other alternative ( )

(5) Others (specify) ( )

86. Is this the only Jatropha/Liquid biofuel stove available for cooking? (1) Yes (2) No

87. **If No,** which one (s) are available?

…………………………………………………………………………………………

88. Why don’t you use them?

…………………………………………………………………………………………

…………………………………………………………………………………………

89. What are the current limitations associated with Liquid biofuel?

…………………………………………………………………………………………

<u>All respondents using the cooking devices for the 5 carriers answer Qn. 90-113</u>

90. What do you consider while adopting / deciding which biomassfuel to use for cooking?

Possible answers: Affordability, Availability, Smoke production/cleanliness, Social status, Cooking time, sustainability, efficiency, cooking practices.

(1)Very important, (2) important, (3) Somewhat importance, (4) Least important, (5) Not important

....

....

....

....

91. What do you consider while adopting / deciding which technology to use for cooking?

Possible answers: Affordability, Availability, Smoke production/cleanliness, Social status, Cooking time, durability, maintenance, efficiency, cooking practices, portability

(1)Very important, (2) important, (3) Somewhat importance, (4) Least important, (5) Not important

....

....

....

....

PART D: LEVEL OF ACCEPTANCE AND WILLINGNESS TO SWITCH..

92. Please indicate the level of acceptance of the following improved biomass energy technologies and biomass fuel for cooking.

(1)Highly accepted (2) accepted (3) moderately accepted (4) least accepted (5) not accepted

FUEL	Level of acceptance		STOVES	Level of acceptance
(a)Firewood			(1) Envirofit stove	
			(2) Rocket stove	
			(3) Maendeleo stove	
			(4) Three chamber stove	
(b) Charcoal			(5) Kenya ceramic jiko	
(c) Briquette/Farm residue			(6) Briquetting stove	
(d) Liquid biofuel/Liquid biofuel			(7) Liquid biofuel stove	
(e) Biogas			(8) Cooking single burners	
			(9) Cooking double burner	

93. Would you be willing to switch from the current technology using the same biomass-based fuel to another?

(1) Yes ( ) (2) No ( )

94. **If yes,** to which technology

....

Give reasons

....

....

....

95. **If No** to question 107, give reasons

....

....

....

96. Would you be willing to switch from the current biomass fuel to another?

(1) Yes ( ) (2) No ( )

97. **If yes**, to which biomass fuel

....

Give reasons

....

....

....

98. **If No** to question 110, give reasons

....

....

....

99. What modifications can you recommend for any of the stove if any? Do you have any other remarks that you wish to tell us?

Recommendations	Remarks

THANK YOU!!!!!

Appendix II: Key Informants Interview guide

1. Name of Organization ………………………………………..………………
2. When did the organization start disseminating improved biomass technologies? ………………. (year)
3. Is there any other organization in this Region dealing with technology? Yes / No
   If yes, mention them;
4. What motivated your organization to engage into biomass technology?
5. What were the Project's main objectives? At what level (%) are the objectives met?
6. What was the targeted group of people to be reached by biomass technologies as per your initial plans? …………………………..……………………………
7. At what extent have you met the targeted group.
   If not met as Expected, what do you think are the reasons?
8. How many villages in this region have you reached for biomass technology?
9. Do you think many people are aware of biomass technologies in this area?
   What percentage of population? ……………………………………………..……..
10. How many households in a region have adopted the technologies?
    (i) Kitui Urban ………………………………………………..
    (ii) Kitui Rural…………………………………………………….
11. How many biogas plants have been installed in this Region? ....
12. How much does the biogas plant (family size) cost Kshs…………………….
13. Apart from animal dung what other materials can be used as feed-stocks for biogas plants?
    (i) …………………………………….
    (ii) ……………………………………..
    (iii) ……….………………………….
14. What is the percentage of adopters of biomass technologies as per population of the area? ……………
15. If the adopters' percentage is small compared to the expected, what do you think are the factors for people not adopting biomass technology?
16. Are people willing to switch to other biomass fuels? Reasons for No and Yes
17. Are people able to switch to other biomass fuels? Reasons for No and Yes
18. Are people willing to switch to improved stoves using same biomass fuel? Reasons for No and Yes

19. Are people able to switch to improved stoves using same biomass fuel? Reasons for No and Yes
20. What are the major complains received from biomass technology users on the technologies?
21. What technical problems affecting functioning of biogas plants?
22. What have you done or you suggest as remedy to the problems you mentioned in your response to qn 18 and 19 above?
23. Did your organisation give any support/ contribution to people who adopted or who intend to adopt biomass technologies? ……………………………..………

24. If yes what kind of support and at what level?

Kind of support	**Level of contribution (%)**
1.	
2.	
3.	

25. Are the technical assistance/services available when needed by biogas adopters? How frequent do your technicians visit people who adopted the technology? ………………………………………..……………………….
26. What are the strategies your organization use to disseminate biomass technologies?
27. What are the problems facing your organization in disseminating the technologies?
28. What is your opinion on Governments' involvement in biomass technologies Dissemination? ....
29. What support does your organization receive from the Government in technology dissemination efforts?
30. What have you leant as organization about; and your suggestion to the Government on:
    (1) Promotion of technology ………..…………………………………………
    (2) Affordability of the technology …..……………………………………
    (3) Sustainability of the technology…………..……………………………
    (4) Plant types and sizes …………………………………………………
31. Any comment on sustainability of your project as far as biomass technologies dissemination is concerned? ……………………………………………………………………

Appendix III: Focused Group Questions

FUELS & STOVES

1. What do you think about cooking with charcoal, firewood, biogas, Liquid biofuel, farm residue? Advantages & disadvantage?
2. What do you think about cooking with other fuel e.g LPG? Advantages & disadvantages
3. Are you looking for an alternative for the current fuel you are using?
4. What is the biggest barrier for buying an improved biomass stove?
   (1) High investment cost of stove
   (2) Lump-sum payment of technology.
5. Why do you think people would use improved biomass cookstoves if money weren't an issue?
6. Why are you using more than one fuel at the same time? Why don't you fully switch?
7. Are there any cultural reasons behind that? What foods do you always cook using charcoal, firewood, biogas, Liquid biofuel, farm residue? Why?
8. Are there any foods that cannot be cooked using charcoal/firewood/biogas/Liquid biofuel/farm residue?
9. Are people willing to switch to other biomass fuels? Reasons for No and Yes
10. Are people able to switch to other biomass fuels? Reasons for No and Yes
11. Are people willing to switch to improved stoves using same biomass fuel? Reasons for No and Yes
12. Are people able to switch to improved stoves using same biomass fuel? Reasons for No and Yes

ICS

13. Why would you be interested in ICS?
14. Which ICS are being promoted in this area? By who?

HH INFO

15. If an alternative would arise (ICS) would we have to target women or men? Who makes the financial decisions?
16. Are modern stoves considered 'status symbols?
17. Do you have any other comments, questions, ideas you want to add before we finish the interview?

Appendix IV: Envirofit CH-5200 stove

Appendix V

Average HH income per month in Kshs * HH that have acquires at least one improved technology Cross tabulation

		HH that have acquires at least one improved technology		Total
		Yes	No	
Average HH income per month in Kshs	less than 5000	14	7	21
	5,001-15,000	40	4	44
	15,001-25,000	15	3	18
	25,001-35,000	9	0	9
	35,001-45,000	2	0	2
	Over 45,000	6	0	6
Total		86	14	100