Journal of Energy Technologies and Policy
ISSN 2224-3232 (Paper) ISSN 2225-0573 (Online)
Vol.7, No.6, 2017

Assessment of Rural Household Energy Access, Utilization and Sustainability: A Case of Mbuyu Sub-Location of Nyandarua Sub-County, Kenya

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Abstract
According to the ecology-first scenario presented at the World Energy Council held in 1998, the world energy supply in 2100 will be dominated by new and renewable energy sources, incorporating 40% photovoltaic, 30% hydro and 15% biomass. Major energy organizations also forecast greater dependence on new and renewable energy in the future. Development of Sub-Saharan Africa therefore, requires sharp increases in the supply of energy inputs as well as great improvement in the present abysmally low levels of efficiency in the use of energy. Addressing basic energy needs for cooking and lighting is a key element in improving the living standards of people especially those in rural areas. Energy is central to practically all aspects of human welfare including access to water, agricultural productivity, health care and nutrition, education, job creation and environmental sustainability, however, just as energy has the potential to instigate development, it can also act as one of the greatest barriers. While the poor can most benefit from improved access to energy sources, they are also the most likely to suffer from the effects of unsustainable energy use such as climate change, deforestation, adverse health impacts and desertification. This study sought to assess rural household energy access, utilization and sustainability in Mbuyu sub-location of Nyandarua Sub-County of Kenya. A sample of 136 households were selected using systematic random sampling to take part in the study. Study data was collected by use of interview guides and observation. Both quantitative and qualitative data was collected and analyzed. Statistical quantitative data was analyzed using descriptive and inferential statistics. From the study findings, there is evidence that criminal behaviour among students under the age of 18 years has a statistically significant influence on school dropout rates. Conclusions and recommendations are made based on the study findings to guide policy makers and implementers on ways of reducing school dropout rates among individual below the age of 18 years. Study findings revealed that various sources of energy such as firewood, Kerosene, charcoal, LPG, electricity, biogas and solar were used for cooking, space heating and heating water in these rural households. It was also established that adoption and utilization of energy efficient technologies such as improved stoves, solar and biogas were minimal due to lack of information, awareness and financial constraints.
Keywords: Rural, Energy Access, Utilization, Sustainability

1.1 Background

Disparities in household energy access and use exist between rural and urban populations, between high and low-income groups within a country, and among countries. The major factors contributing to these differences are levels of urbanization, economic development, and living standards (UNDP, 2005). In many developing countries, particularly in rural areas, traditional energy sources such as firewood, charcoal and agricultural waste, constitute a major portion of total household energy consumption. Use of these fuels with proper technologies like improved stoves can positively impact on human health and environment. Unfortunately, diffusion of these technologies, especially in developing countries, is slow hence a negative impact on the sustainability of the available sources (Sum Low, 2005). In Africa, energy access base is correspondingly among the lowest in the world. For instance, 80 % of people in sub Saharan Africa have no electricity. Poor people spend up to a third of their income on energy, mostly to cook (Sum Low, 2005). Other studies indicate that in rural Sub-Saharan Africa, women carry 20 kilograms of firewood, an average of five kilometers every day (IEA, 2004). Apparently, access to efficient energy would free the poor, especially women and girls, from the drudgery of collecting fuel wood, thus expanding opportunities for schooling, after-school study and income generation. Use of clean and reliable energy sources would also reduce damage of health from exposure of high levels of indoor air pollution from burning of solid fuels (wood, cow dung etc) for cooking and heating. Similar studies show that sustainability of these energy sources is as critical as the access and consumption. Sustainability could be increased by increasing the productivity of the existing forest resources, establishing new forests and encouraging the alternatives like solar energy by increasing their supply, in addition to improving the technology and raising the efficiency of wood-fuel production and consumption (COMESA, 2008).

In Kenya, biomass energy is the commonest source of energy. It is noted that problems relating to environmental degradation, land clearance, overgrazing, deforestation, drought and desertification are placing

more and more pressure on dwindling biomass energy resources (Mugo & Kituyi, 2002). Household energy is mainly used for cooking, lighting, keeping warm and heating water for other uses. The most common source of energy used by households for cooking and heating in Nyandarua District is firewood and charcoal. Only 9.5% of the households have electricity connection while alternative sources such as solar are yet to be popularized with only 1.5% of the households using it. (Nyandarua District Development Plan, 2002-2008).

1.2 Problem Statement

Though research has been carried out regarding rural household energy such as Karanja (1999), MoE (2004), Yieko (2001), no data however exist on how the rural households access, use efficiently and sustain the available energy sources. In Nyandarua District, at present, there is limited up-to-date data on the access, utilization and sustainability of household energy. While a number of studies have been carried out on rural household energy in this region, most of the studies have relied predominantly on the rural electrification as the solution to rural energy problems. There is little documentation and focus on the energy sources available and affordable, how they are utilized and their sustainability.

According to Miranga (2008), a range of barriers hinders access, utilization and sustainability of energy sources including time, household energy income, the level of education, availability and level of awareness among energy end users about energy conservation practices, options and benefits and insufficient information about energy efficient technologies. This cross-sectional survey sought to address these gaps by assessing the household energy access, utilization and sustainability among the rural households in Mbuyu Sub-location of Nyandarua District.

1.3 Objectives of the Study

i. To identify the types of household energy sources accessed in Mbuyu Sub-location.
ii. To determine the energy efficient technologies utilized in Mbuyu Sub-location.

1.4 Research Questions

i. Which types of household energy sources have been identified in Mbuyu Sub-location?
ii. Which energy efficient technologies utilized have been identified Mbuyu Sub-location?

1.5 Theoretical Framework

1.5.1 Family Resource Management-Family as System

In the Deacon and Firebaugh managerial system model (1988), the family is viewed as a social system that transforms the energy, information, and matter that enter the system into outcomes that the family desires. The model is composed of three major components: input, throughput and output. In the family system, inputs are known as demands and resources. Resources are means capable of meeting demands while demands are either goals or events that require action. The throughput component is further identified as having two sub-systems: the managerial sub-system and the personal sub-system. The managerial sub-system suggests that the family achieves its goals or responds to events through planning the use of its resources and implementing the plans.

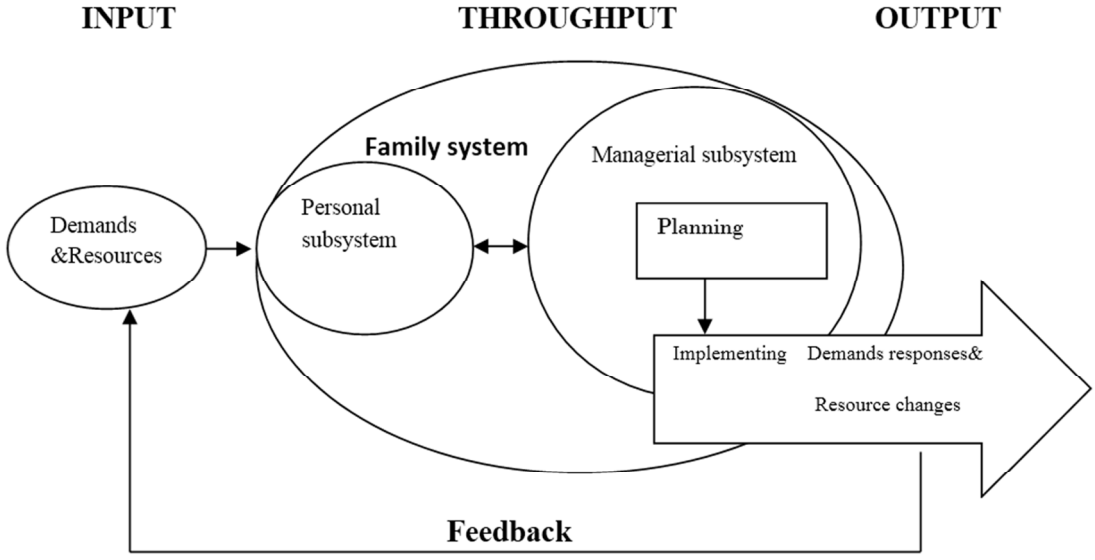

Figure 1: Family system with managerial subsystem emphasis.
Source: Deacon & Firebaugh (1988). Family Resource Management (Principles and Applications)

The role of personal sub-system is to receive input from external forces and clarifying values. It describes an individual's approach to decision making as intuitive or rational. Output is matter, energy or information produced by a system in response to input and from throughput processes.

1.6 Conceptual Framework

From the conceptual framework, sources of energy are the input. During the access and utilization of household energy, family resources are involved. For instance, time, money, physical energy, awareness on energy issues, environmental and human health influences on what energy sources to get and how to use them. This triggers the need to have sustainable energy sources.

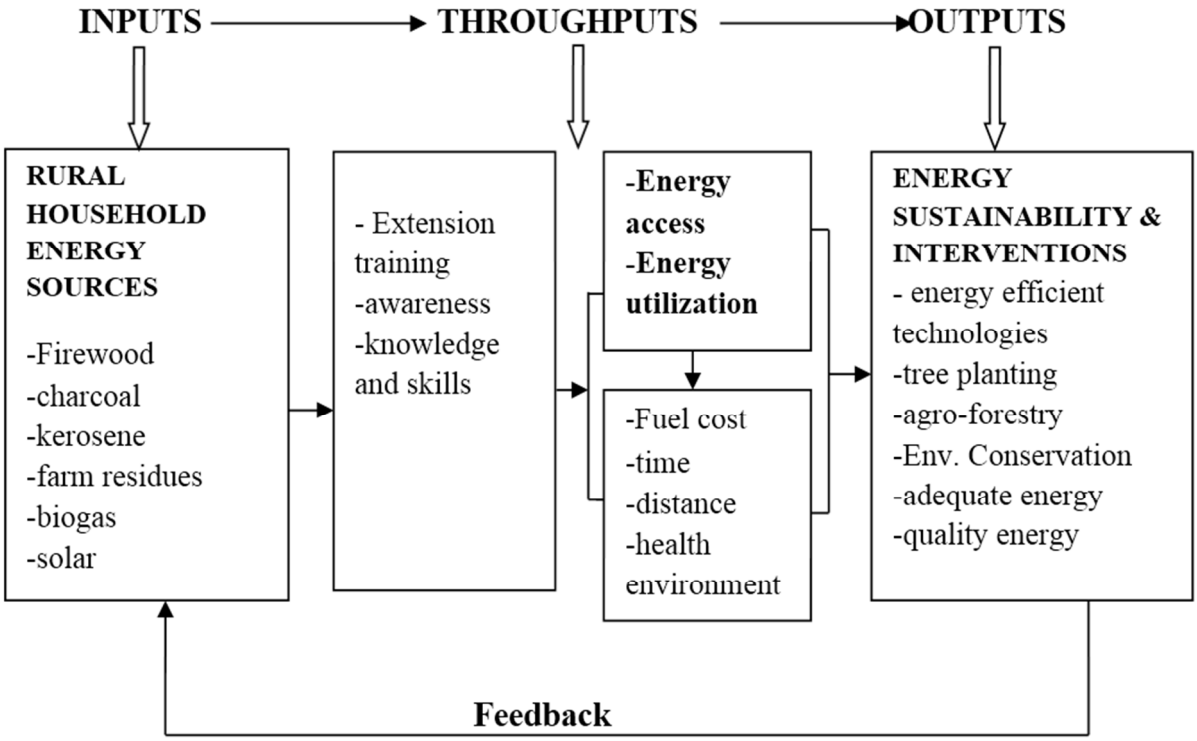

Figure 2: Conceptual framework showing relationships between household energy access, utilization and sustainability

Energy sustainability strategies and interventions are the outcomes or outputs which come about as a result of the decisions or action taken at the throughput level and in return this impacts on the input.

1.7 Literature Review

1.7.1 Household Energy Use and the Rural Poor

Over half of all people relying on biomass for cooking and heating live in India and China, but the proportion of the population depending on biomass is heaviest in Sub-Saharan Africa (IEA, 2004). Extreme poverty and the lack of access to other energy sources mean that 80% of the overall Africa population relies primarily on biomass to meet its residential needs (UNDP, 2005).

For the poor, access to greater quality and quantity of energy services is an essential prerequisite to making the transition from subsistence livelihoods to increased productivity, income generation, and improved living standards. Providing the rural poor with access to clean, efficient, affordable energy services has multiple, synergistic impacts on productivity, education, health and gender equality (UNDP, 2005). Access to efficient energy frees the poor, especially women and girls, from the drudgery of collecting fuel wood, thus expanding opportunities for schooling and after-school study. Use of clean and reliable energy sources also reduces damage of health from exposure to high levels of indoor air pollution from burning of solid fuels (wood, cowdung etc) for cooking and heating (WHO, 2002).

1.7.2 Household Energy Sources

According to the Ministry of Energy (2004), there are three main sources of energy in Kenya. These are wood fuel, petroleum and electricity, accounting for 70 per cent, 21 per cent, and 9 per cent of total energy use respectively. Renewable energy is also becoming important although it remains insignificant in the country's overall energy mix.

Firewood: Close to 89% of rural and 7% of urban households report regular use of firewood, giving a

national average of 67% of all households. The average annual per capita consumption is approximately 741 kg and 691 kg for rural and urban households, respectively. For urban areas, it is the lowest income households who depend on firewood the most. This is in line with previously documented consumption patterns for the country. Firewood comes from agro forestry or on-farm sources (84%), from trust lands (8%) and from gazetted forests (8%). Approximately 76% of households obtain all their firewood free, 17% of households regularly purchase it while 7% supplement their free collection by purchasing some firewood. Firewood is mainly used for cooking and space heating (Mugo & Kituyi, 2002)

Charcoal: Use of charcoal is about 47% at the national level representing 82% and 34% of urban and rural households, respectively. Per capita consumption is 156 kg in urban areas and 152 kg in rural areas. Total charcoal consumption is 2.4 million tonnes (67 million 36-kg bags), representing an annual business of approximately KSh 17 billion at a weighted price of KSh 261 per bag. This is about 53% of the 1998 bill for imported oil. Some 40% of this amount is spent at source in rural areas with the balance being accounted for by transport and marketing at the end-use.

Among the various energy conservation initiatives that have borne fruit in Kenya is the introduction of improved cook stoves (*jikos*) with about 47% of charcoal-using households indicating that they had these units (Muchiri, 2008). The major developmental issue with charcoal is that it is based on wood regarded as a 'free good' and obtained mainly from communal lands. This discourages charcoal production based on grown wood. Production and transportation of the commodity is subject to issuance of movement permits. As most authorities are not willing to issue such movement permits for fear of being associated with environmental destruction, most transportation is done during the nights using very old Lorries.

Petroleum is the second largest energy source in Kenya's economy and the largest sources of energy for modern sector. The fuel is imported into Kenya in the form of crude oil from the Middle East and is refined in the country's only refinery at Mombasa. Kerosene as a cooking and lighting fuel is important for the poor in rural and urban areas and has in some cases served as a substitute for wood fuel. Hence, any efforts to increase kerosene consumption will undoubtedly relieve pressure on wood use. Indeed, the government has often used tax reduction or non-increase for kerosene for this purpose and also as a poverty mitigation measure (Mugo and Kituyi, 2002).

Electricity is the third largest source of energy in Kenya. According to Ministry of Energy (2004), 0.5% of the rural households have access to grid electricity while population growth exceeds the rate of rural connections despite major investments in the rural electrification program.

Farm residues: Overall, about 21% of households use farm residues, but their use is mainly in rural areas with 29% households as compared to 0.5% in urban households. The annual per capita consumption is about 435 kg and 351 kg for rural and urban areas respectively. The continued use of farm residues compromises opportunities to improve soil fertility.

Wood Waste: According to Mugo and Kituyi (2002), only 2.5% of households reported using wood waste, a decline from 5.1% noted in the 1980 Beijer Institute study and attributed to shortages of industrial wood. Use is mainly in urban areas by 3.7% of households as compared to 2.1% in the rural areas. The consumption is about 15,600 tonnes, estimated from industrial by-product production (sawdust, timber rejects, off-cuts etc).

Liquefied Petroleum Gas (LPG): This is not widely used with only 7.8% (23% urban and 1.8% rural) households using it due to various constraints. Average per capita consumption is only 3.6 kg and 9.7 kg for rural and urban areas respectively. LPG is used along with firewood in rural areas while in urban areas; it is used as a supplement for electricity. LPG-based appliances are expensive and regulators are incompatible between different major dealers, making it difficult to interchangeably buy LPG from a variety of companies.

Solar: The main use of solar energy is for lighting and heating water. Most households that use solar energy have a single photovoltaic panel with a power rating of 12-25 watts. A total of 150,000 units have been introduced. The main issue is capital cost as most consumers find the technology expensive. Skilled technicians for backup maintenance are also in short supply.

Biogas: According to the Intermediate Technology Development Group (ITDG), approximately 1,100 biogas units are operational in Kenya. Maintenance technology and the fact that most households do not have piped water are among the constraints to wider adoption of biogas.

Renewable energy resources including solar energy, windmills, power alcohol and biogas have the potential to contribute to social, economic and environmental dimensions of sustainable development.

1.7.3 Household Energy Sustainability

Energy sustainability refers to the availability of energy sources that are diverse, in reliable quantities, affordable, support economic growth, assist in poverty alleviation measures and does not harm the environment. Access to reliable energy is a major factor in human welfare, climate change, health care and environmental sustainability (UNDP, 2002). Moving towards energy sustainability will require changes not only in the way energy is supplied, but in the way it is used, and reducing the amount of energy required to deliver various goods or services is essential. Opportunities for improvement on the demand side of the energy equation are as rich and

diverse as those on the supply side, and often offer significant economic benefits. These include access to renewable sources, human activities such as re-afforestation, agro-forestry and extension training on efficient technologies.

Renewable energy and energy efficiency are sometimes said to be the "twin pillars" of sustainable energy policy. Both resources must be developed in order to stabilize and reduce carbon dioxide emissions. Efficiency slows down energy demand growth so that rising clean energy supplies can make deep cuts in fossil fuel use. If energy use grows too fast, renewable energy development will chase a receding target. Likewise, unless clean energy supplies come online rapidly, slowing demand growth will only begin to reduce total emissions; reducing the carbon content of energy sources is also needed. Any serious vision of a sustainable energy economy thus, requires commitments to both renewable energy and efficiency.

1.7.4 Energy Efficient Technologies in Rural Areas

Out of four billion people in the developing world, about two billion, mostly in rural areas, are still without electricity. Access to safe, affordable energy for heating, lighting and cooking is an immense challenge in many countries. Options are often expensive, inefficient, and can have negative health and environmental impacts. In response, several programmes initiated an Energy Efficient Technologies (EET) portfolio of initiatives that focuses on enhancing the welfare of the poor in developing regions through the development, testing and diffusion of low-cost, energy- related technologies that meet real needs, emphasize energy efficiency and minimize negative environmental impact(Muchiri 2008).

Currently, 99.5 % of rural Kenyan household have no access to electricity. The overall energy demand in the country will continue to grow at a rate of 4.4% per annum. Technologies that could enable Kenya to grow economically while reducing or stabilizing energy use are currently of limited availability (ITDG, 2002). What's more, even when such technologies are economically competitive over the long-term, they tend to require more upfront capital than Kenya can afford unless it receives support from aid agencies or other international funding sources. Solar energy appears to be an ideal solution towards the resolution of Kenya's energy requirement for the 21st century; however, there are few issues and problems that must be ironed out for proper use and acceptance of this energy source. Installation and capital costs have been the main hampering factors to the development of a more generalized and mature solar market, and for equitable distribution of this technology to the most obvious beneficiaries, who are generally people residing in remote rural countryside and low-income earners in urban areas (Karanja, 1999). Benefits expected from renewable energy implementation will include less impact on health and environment since it is basically an indigenous energy source and is available everywhere even within rural areas.

1.7.5 Energy Policy in Kenya

The energy policy in Kenya has tried to address to a certain degree of success the issues of energy access, availability, affordability and sustainability. To address the foregoing biomass energy supply demand imbalance, the government and collaborating organizations have adopted various strategies like expanding the biomass supply through on farm tree planting and biomass substitution and improvement on conversion and end-use efficiencies.

Rural energy focus proposed in sessional Paper No.4 on energy, on dependence on biomass through fuel substitution mainly with LPG, may improve on the management of the family resources resulting to socio-economic development of the rural households. The demand side management strategies pursued in the past and present namely, improved efficiency stoves and energy conservation is not able to keep pace with the depletion rate of the sustainable supply.

The energy policy objectives also spell out measures to be undertaken in resolving energy supply in the country. The policy measures for biomass which is the commonly used energy source in the rural households include enhancing research and development, streamlining the production and marketing of charcoal, increasing the adoption of improved stoves, promoting inter fuel substitution and promoting tree planting for energy production. Policies for energy investments should target increasing access to energy for increased productivity and reducing drudgery for women as failure to invest in low-cost energy supply systems condemns women to continue using low-quality energy sources for cooking and lighting with associated health and environmental problems.

While the strategies may ultimately help, their formulation and implementation are not clearly stipulated. This may inherently constrain the achievement of full benefits envisaged. Therefore in policy making or revisions of the Energy Policy in the future, it is imperative that integration with related sectors be seriously considered.

1.8 Methodology

This study adopted a cross sectional survey design where 136 respondents were identified using systematic random sampling. Both interview and observation methods were used to collect data from the respondents. The data obtained from the field was organized, edited to ensure completeness, comprehensibility and consistency,

classified and coded according to research hypotheses and objectives for analysis. Study data was analyzed by use of both descriptive and inferential statistical procedures by the use of the Statistical Package for the Social Sciences (SPSS) version 20.0 for windows. Each question related to a variable was assigned a score or numerical value by use of likert scale method. The number on a likert scale was ordered such that they indicate the presence or absence of the characteristics being measured. All statistical measurements were performed at 95% confidence level.

1.9 Findings

1.9.1 Energy Sources in Mbuyu Sub-location

In Mbuyu Sub-location, the respondents used a variety of energy sources namely; firewood 95.6%, kerosene 98.5%, electricity 5.9%, gas (LPG) 15.4% solar 23.5%, charcoal 67.6%, agricultural residues 21.3%, biogas 5.9%, and plastics by 1.5%.

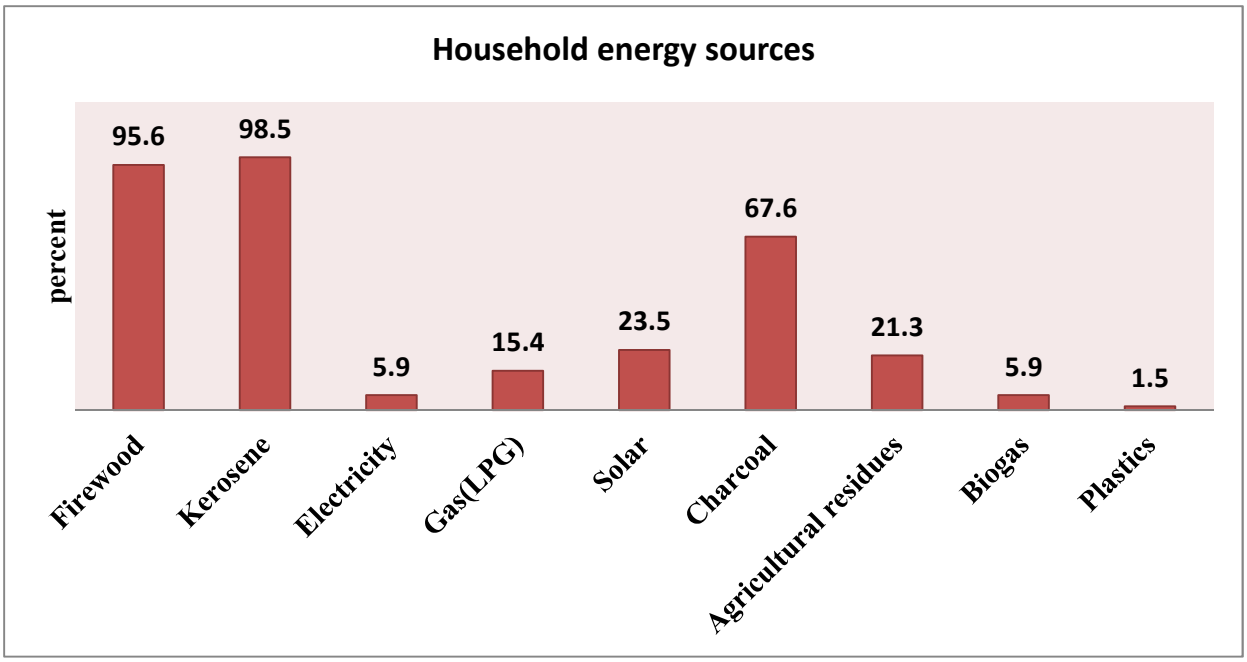

Figure 3: Household energy sources in the study area

Firewood and charcoal were chiefly used as energy sources for cooking and kerosene mostly for lighting. Electricity, though not a common energy source, was used by a few households for lighting. Solar and biogas were used by a minority because of the high costs of installation and the cited cases of cattle rustling therefore, low availability of raw materials (cowdung) for the latter. Plastic materials were used by two households for heating water. These findings concur with observations by Miranga (2008) that biomass energy is the dominant energy form for most African countries.

1.9.2 Factors Considered in Energy Access by Rural Households

While examining types of energy, particular emphasis was put on factors that most likely affected the preference of the type of energy used. These aspects included monthly income, time and distance and others like health and environmental concerns.

Table 1: Household Income and Type of Energy Used

Household income per month (Kshs)	**Energy type (% using)**					
	Firewood	Charcoal	Kerosene	Electricity	LPG	Solar
1500-3000	51.5	54.3	50.0	12.5	5.9	28.1
3500-7000	27.7	19.6	27.6	12.5	55.9	28.1
7500-15000	16.9	19.6	18.7	12.5	29.4	31.3
15500-30000	3.9	6.5	3.7	62.5	8.8	12.5
Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

***Multiple responses allowed**

Income is likely to influence the type of energy used since higher incomes make it affordable to access efficient energy sources. The commonly used energy sources irrespective of the household income were firewood, charcoal and kerosene. The study results concur with observations by Muchiri (2008) that in rural

households of a given area; the types of fuels used were nearly uniform among all income groups. Nevertheless majority of the respondents who used electricity and solar had an income of Kshs. 15500-30000. Those using LPG, the income level was Kshs.3500-7000. Pearson product moment correlation coefficient was performed to establish the relationship between the household income and the expense on energy.

Table 2: Pearson correlations on household income and expense on energy.

		Household income	Expense of energy
Household income	Pearson Correlation	1	.371**
	Sig. (2-tailed)	.	.000
	N	136	136
Expense of energy	Pearson Correlation	.371**	1
	Sig. (2-tailed)	.000	.
	N	136	136

** Correlation is significant at the 0.05

It revealed that there was a positive correlation between household income and the expense of energy as shown on Table 31. This means that as household income increased the energy expenses also increased. This is supported by Yieko (2001) who reported that the higher the income the more expensive the type of energy used. The null hypothesis was therefore rejected.

Table 3: Availability of the household energy

Choice of household energy	Frequency (N)	Per cent (%)
Availability	114	83.8
Availability not considered	22	16.2
Total	**136**	**100.0**

From Table 3 above, about 83.8% of the respondents reported that they considered availability in their choice of household energy. This can be deduced to mean that majority of the respondents used what was readily available to them. For instance the predominance of firewood as the dominant source of energy for cooking despite its inefficiency and harmful impact on human health could be attributed to its availability as a 'free' source of energy. In most cases firewood is collected and not purchased.

Sources of Firewood Collection

This item in the interview schedule required the respondents to indicate whether they gathered the firewood from their farms or other external sources.

Table 4 shows that, 8.1% respondents collected firewood from their own farms, 87.5% collected firewood from external sources while 4.4% respondents did not use firewood.

Table 4: Sources of firewood collection

Response	Frequency (N)	Per cent (%)
Own farms	11	8.1
External sources	119	87.5
Don't use firewood	6	4.4
Total	**136**	**100**

This shows that majority of the respondents set specific time to go to collect firewood elsewhere unlike the few who do it concurrently with other activities in their farms. This can thus be presumed that the area does not suffer fuel wood shortage or the respondents have small farms to support agro forestry. As indicated by Mbuthi (2005) fuel wood scarcity triggers on farm tree planting

Time Spent on Firewood Collection

The average time taken to collect firewood by 50% of the respondents was in the range of 3-4 hours.

Table 5: Time spent on firewood collection

Time in hours per day	Frequency (N)	Per cent (%)
1-2	12	9.2
3-4	65	50
5-6	21	16.2
7-8	32	24.6
Don't use firewood	6	4.4
Total	**136**	**100**

This concurs with the studies carried out by World Resources Institute (2003) which pointed out that in Kenya; the time spent gathering firewood averaged between 3 to 5 hours or about 75 per cent of the household time**.**

Distance Covered to Firewood Collection

Table 6: Distance covered to firewood collection

Distance covered	Frequency (N)	Per cent (%)
Less than 1 km	53	39
1-5 km	35	25.7
6-10km	30	22.1
Over 10 km	12	8.8
No response	6	4.4

The survey results established that 39% of the respondents covered less than one kilometre to gather firewood, 25.7% covered 1-5km, 22.1% covered 6-10km, while 8.8% respondents covered a distance of more than 10 km.

The above findings agree with Muchiri (2008) that due to fuel wood scarcity, many women in fulfillment of their gender roles are forced to travel long distances in search of fuel.

1.9.3 Factors Considered in the Choice of Household Energy

The item required the respondent to highlight the factors they consider in the choice of the household energy used.

Affordability of Energy

Table 7: Cost of energy (affordability)

Cost of energy	Frequency (N)	Per cent (%)
Affordability (low cost)	112	82.4
Cost not considered	24	17.6
Total	**136**	**100.0**

The results from Table 7 show that 82.4% of the respondents considered the price of household energy in the choice of the energy source the household used. Majority of the households were forced to use cheap sources of energy in relation to their household incomes. This finding agrees with a study by Douglas and Willem (1999) that one of the most important determinants of household access and fuel mix is the cost of various energy sources.

1.9.4 Household Energy Sources for Various Tasks

This item sought to establish the different energy sources used for various tasks by the respondents in the households. From the results, firewood was the most commonly used energy type for cooking by 91.9% of the respondents, a typical phenomenon in most rural areas in Kenya. The findings agree with Miranga (2008) who reported that firewood remains the most common fuel for cooking in most African countries.

Household Energy Sources Used for Cooking

Table 8: Energy sources for cooking

Type of energy	Frequency (N)	Per cent (%)
Firewood	125	91.9
Kerosene	5	3.7
Charcoal	6	4.4
Gas (LPG)	16	11.8
Biogas	9	6.6
Solar	5	3.7

***Multiple responses allowed**

Those using gas (LPG) were 11.8% and biogas being used by 6.6% of the respondents. Solar and kerosene were the least used by 3.7% respondents each. Fuel mixing was common in the households in cooking.

Household Energy Sources for Lighting

Table 9 shows that 94.9% of the respondents used kerosene as the most preferred energy source for lighting, 21.3% used solar, 8.1% used electricity and the least was biogas by 0.7%.

Table 9: Energy sources for lighting

Type of energy	Frequency (N)	Per cent (%)
Kerosene	129	94.9
Electricity	11	8.1
Biogas	1	0.7
Solar	29	21.3

These results indicated that the majority of the respondents used kerosene for lighting since it was affordable while biogas was adopted by a few households due to lack of raw materials (cow dung). Only few households had the electricity supply.

This results concur with observations by Karanja (1999) that kerosene is the most widely used modern source for lighting in rural areas; electricity is however not an important option for low income households for

lighting due to its high upfront costs.

Household Energy Sources for space heating

Table 10: Energy sources for space heating

Type of energy	Frequency (N)	Per cent (%)
Firewood	1	0.7
Charcoal	97	71.3
Plastics	2	1.5

From Table 10, 71.3% of the respondents indicated using charcoal to keep warm in their households, 1.5% respondents used plastic materials while 0.7% household used firewood. From the results, charcoal is accessed by majority of households for space heating rather than for cooking or heating water for other purposes because of convenience. Charcoal jikos are portable and can be used in any room unlike sources like firewood which are only used in the kitchen.

Household Energy for Heating Water

From Table 11 below, 22.8% of respondents used firewood to heat water, 17.6% used agricultural residues, 3.7% used kerosene, 2.2% used charcoal and 0.7% of the respondents used gas (LPG).

Table 11: Energy for heating water

Type of energy	Frequency (N)	Per cent (%)
Firewood	31	22.8
Kerosene	5	3.7
Charcoal	3	2.2
Gas (LPG)	1	0.7
Agricultural residues	24	17.6

Firewood and agricultural residues were mostly used for this purpose due to their affordability and accessibility. Charcoal and gas (LPG) were the least used because of their increased cost compared to other energy sources.

1.9.5 Use of Energy Efficient Technologies

Various energy efficient technologies were used in the study area. The distribution was as follows: improved stoves 72.1%, raised hearth 33.1%, solar cookers, 4.4% biogas cookers, 0.7% and 19.9% used energy saving bulbs. Four point four per cent did not use any energy technology. Improved jikos were mostly adopted compared to the traditional metal jikos because they cooked faster and used less charcoal.

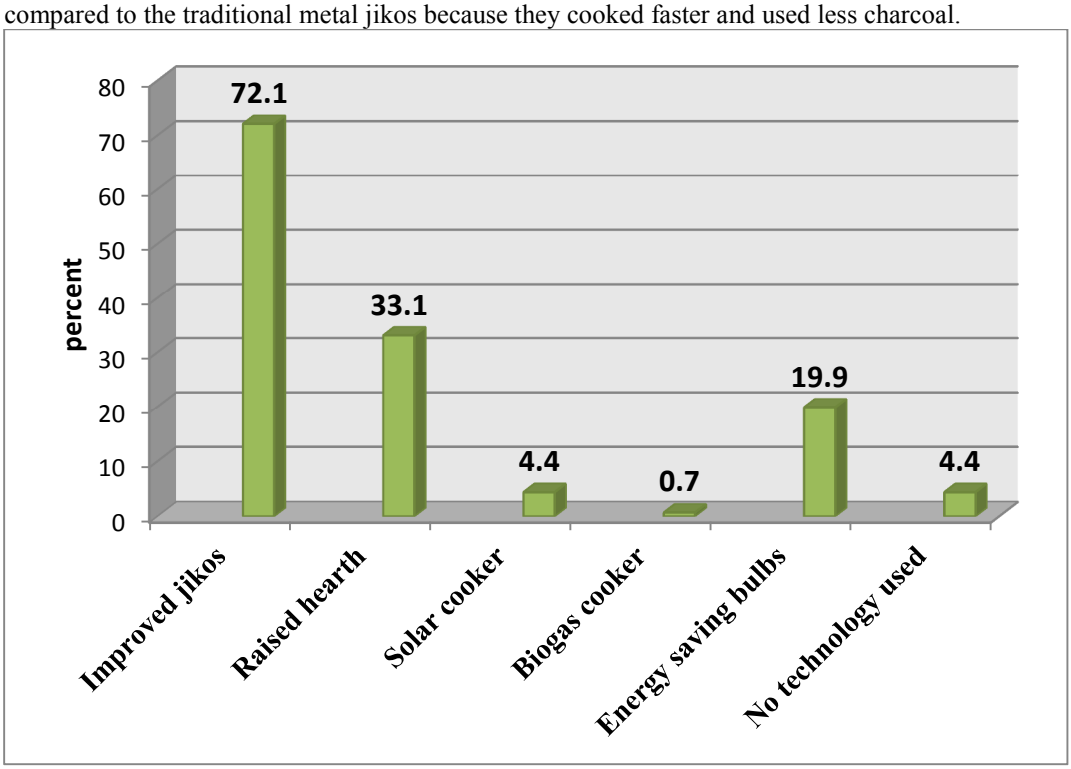

Figure 4: Energy efficient technologies.

Results in Figure 4 indicate that only 33.1% of the respondents who used firewood had adopted the raised hearth technology. This means that majority of the respondents still used the three stone fire which was less efficient and consumed more firewood. Solar and biogas cookers were used to a lesser extent because they were

not fully developed in the study area. This also agrees with observation by Karanja (1999) that installation and capital costs for solar and biogas are a barrier to people in remote rural countryside.

1.9.13 Awareness of Household Energy Efficiency

This item required the respondent to state if they were aware about household energy efficiency.

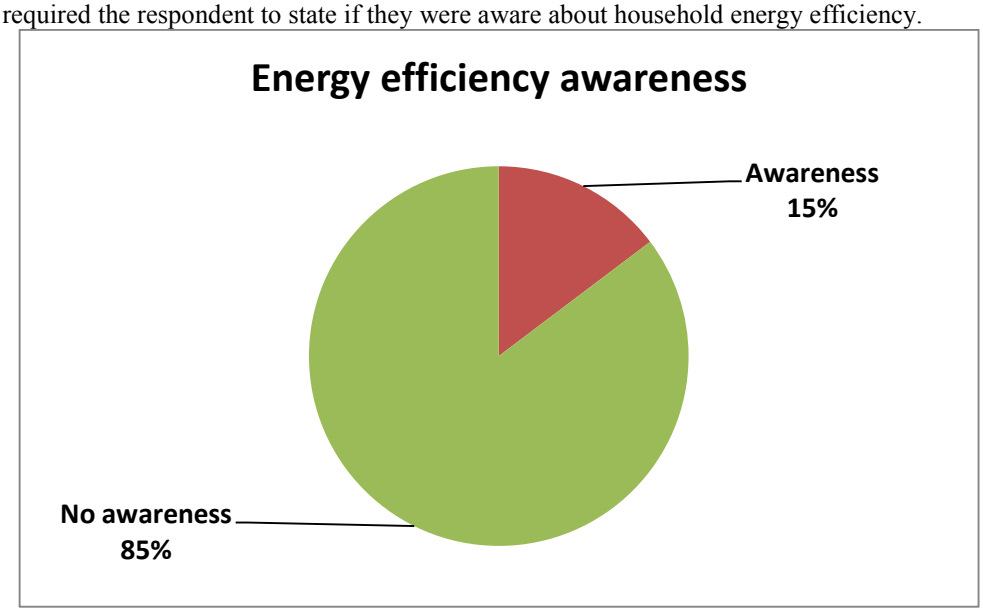

Figure 5: Awareness on energy efficiency

From Figure 5, 15% of the respondents were aware of household energy efficiency while 85% were not aware. This could be an indication that ways of disseminating information in the study area were poor or the respondents were ignorant of energy efficiency. In addition, a chi square test was performed to establish the relationship of energy efficiency awareness among the male and the female respondents.

Table 12: Gender of respondent and Energy efficiency awareness Cross-tabulation

Gender of respondent	Energy efficiency awareness		Total
	Yes	No	
Male	6	13	19
Female	14	103	117
Total	20	116	136

χ^2= 5.013 df=1 p=0.025

From Table 12, a chi-square test performed revealed a statistically significant relationship of energy efficiency awareness and gender of the respondents. Majority of both male and female respondents had no awareness on energy efficiency.

However, a higher number of female respondents (14 out of 20) had awareness on energy efficiency as compared with male respondents (6 out of 20). The findings agree with observations by Mburugu (1994) that women have groups that are a source of knowledge and awareness of development needs for individual women, their families and the larger community.

Impact of Energy Efficiency Awareness in Energy Utilization

This item required the respondent to state the influence of household energy efficiency awareness on household energy use.

Table 13: Impact of awareness programs in energy utilization

Impact	Frequency (N)	Per cent (%)
Less energy used	13	9.6
Install solar/biogas energy unit	6	4.4
No response	117	86.0
Total	**136**	**100.0**

The results in Table 13 showed that 9.6% of those aware reported there was improved energy conservation whereby less energy was used in their households, 4.4% reported that they installed biogas and solar units since it was cheap and clean energy to use in the house and 86% did not respond to the question.

Efforts to Ensure Energy Conservation

The item required the respondents who were not aware of energy efficiency to state what they did to ensure that household energy was saved.

Table 14: Energy conservation methods

Energy saving ways	Frequency (N)	Percent (%)
Cook food for 2 meals at once	74	54.4
Cook several foods in one pot	43	31.6
Use improved jikos	99	72.8
Close kitchen doors when cooking	69	50.7
Did nothing to save energy	56	41.2

On energy conservation methods, results showed that 54.4% of the respondents reported that they cooked food for two meals at once, 31.6% cooked several foods concurrently in one pot, for instance boiling sweet potatoes in a pot cooking githeri while 72.8% indicated that use of improved ceramic jikos saved on energy when in use compared to the traditional metal jikos. Fifty point seven per cent closed kitchen doors to protect the fire from the wind, 41.2% did nothing at all to save on energy when in use. From the results, it was observed that households used more than one way of saving energy.

Promoting Household Energy Efficient Technologies

The respondents were asked to suggest on what the government would do to promote household energy efficient technologies. About 57.4% of the respondents indicated that reduction of taxes to solar and biogas equipments would promote the technology due to low installation and maintenance costs, 36% suggested that government creation of awareness through education would promote energy efficiency in the households, 56.6% reported that extension of electricity supply in the study area would promote the use of household energy efficient technologies and hence improve their living standards.

1.9.6 Strategies for Sustainability of Household Energy.

This section addresses the fourth study objective which set to examine interventions on energy sustainability.

Table 15: Individual strategies for sustainable household energy

Strategies	Frequency (N)	Per cent (%)
Agro-forestry & afforestation	114	83.8
Installation of biogas & solar units	31	22.8
Bulk collection of firewood	3	2.2
Save available energy	2	1.5
Use of efficient technology	9	6.6

*** Multiple responses allowed**

Results in Table 15 showed that, 83.8% of the respondents would practice agro-forestry and afforestation; this would increase the tree cover and also reduce pressure on the dwindling biomass sources of energy. Twenty two point eight percent supported installation of solar and biogas units, 2.2% suggested collecting enough firewood that would last for a year, 1.5% believed in saving on available energy sources while 6.6% reported that the use of energy efficient technology would ensure that energy is saved for one year.

Community Strategies for Sustainability

The item in the schedule sought community strategies for ensuring adequate household energy in the study area.

Table 16: Community strategies for sustainability of household energy

Strategies	Frequency (N)	Per cent (%)
Agroforestry	116	85.3
Install biogas & solar in groups	58	42.6
Seek information on efficient technologies	27	19.9
Electrification through groups	59	43.4
Tree nurseries	43	31.6

*** Multiple responses allowed**

Observations from Table 16 depict that 85.3% of the respondents would plant trees in their farms as a community, 42.6% would form social groups to install solar and biogas units, 31.6% would start tree nurseries, 19.9% would seek information and awareness on energy conservation and energy efficient technologies while 43.4% would avail rural electrification through self-help groups.

Government Intervention towards Energy Sustainability

The question was to establish if the respondent knew of any national or government intervention in the study area that was involved with energy issues in the division. The results are depicted in Figure 7 below.

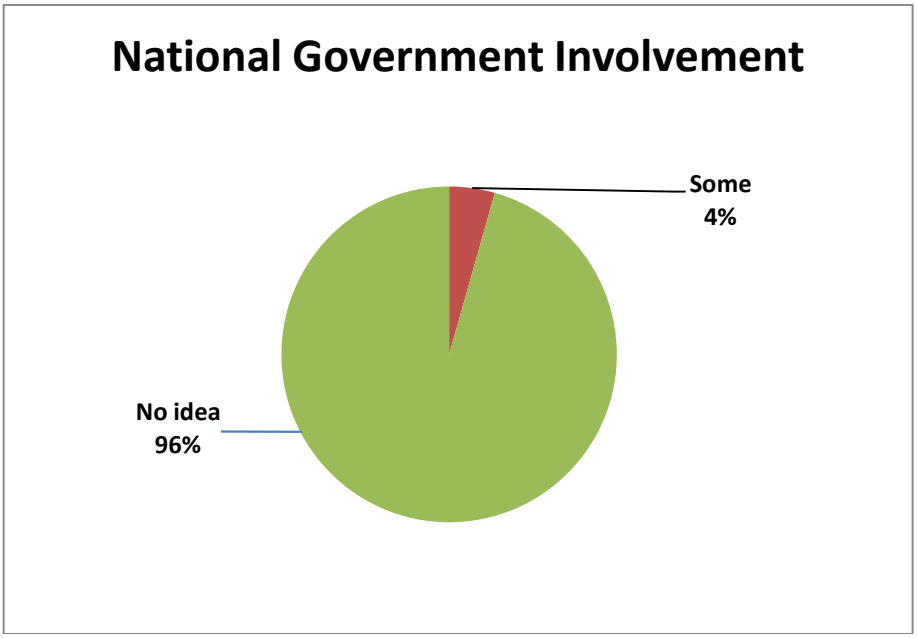

Figure 6: Government involvement in energy issues

From Figure 6, 95.6% of the respondents indicated that they had no idea of any government intervention while 4.4% said there was a government intervention that was in place to deal with energy issues in the division including Ministry of Environment and Natural Resources which advocated on tree planting in their farms and Home Economic Department in the Ministry of Agriculture who trained the communities on biogas formation.

1.9.7 Constraints in Energy Sustainability

Table 17: Constraints in energy sustainability

Challenges	Frequency (N)	Per cent (%)
Inadequate land	64	47.1
High installation cost	65	47.8
Shortage of rains	13	9.6
Lack of information	50	36.8

It can be observed from Table 17 that there were challenges faced by respondents. They cited various challenges; 47.1% reported inadequate land to plant trees, 47.8% stated that the initial cost of installing solar and biogas units was too high for them considering their low incomes, 9.6% feared that the shortage of rains would be a challenge in afforestation while 36.8% stated that lack of information would be a barrier in achieving energy sustainability.

Environmental Changes over the Last 10 Years

The item in the interview schedule required the respondents to state the environmental changes that had occurred in the study area over the last 10 years in relation to household energy access, utilization and sustainability.

Table 18: Environmental changes over the last 10 years

Environmental changes	Frequency (N)	Per cent (%)
Lack of rains	135	99.3
Deforestation	124	91.2
Re-afforestation	32	23.5
Desertification	11	8.1
Frequent floods	12	8.8

From Table 18, 99.3% of the respondents noted that there was no rain in the recent years, 91.2% complained of deforestation, 23.5 % reported there was re-afforestation, 8.1% indicated desertification while 8.8% said there were frequent floods in the study area. The respondents indicated more than one environmental change in the area.

1.9.8 Field Observations

From the observation checklist, it was noted that the respondents used a variety of energy conserving technologies. This included improved jikos, solar cookers and biogas cookers. Few households had adopted raised hearth as majority still used the three stone fire. Majority of the households used firewood for cooking and heating water, charcoal for space heating while kerosene was used for lighting. Few households had electricity connection while solar and biogas cookers were relatively new technologies in the study area and were only used by a few individuals. Agricultural residues used in the area included maize stalks and cobs.

1.9.9 Conclusions

With respect to study findings, the following conclusions are made;

Accessing household energy sources in the rural areas demands valuable time, physical energy and money. Women whom the society has assigned the duties and responsibilities of energy provision and cooking are faced with challenges such as drudgery due to long distances to the source and have little time for leisure and other productive activities at home. Various sources of energy such as firewood, kerosene, charcoal, LPG, electricity, biogas and solar, these were used for cooking, space heating and heating water in these rural households.

Adoption and utilization of energy efficient technologies such as improved stoves, solar and biogas were minimal due to lack of information, awareness and financial constraints.

Household energy sustainability measures suggested included agro-forestry, afforestation and government intervention in reducing the cost of energy.

1.9.10 Recommendations

Regarding study findings and conclusions, the following recommendations are made;

There is need for promotion of agro-forestry and afforestation to provide fuel-wood and to conserve environment and mitigate the effects of global warming by the households and community.

It is necessary to advocate on use of alternative energy sources such as briquettes instead of charcoal.

It is important to enhance provision of credit and loan facilities to assist rural households to install energy efficient technologies like solar and biogas by energy related agencies.

All stakeholders need to create awareness on energy efficient technologies to improve energy saving, time and labour in rural households as well as expand rural electrification programmes.

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