TECHNOLOGICAL AND SOCIAL BASIS FOR A SUSTAINABLE ENERGY SYSTEM IN ENHANCING THE POTENTIAL BENEFITS OF ENERGY EFFICIENCY: CASE STUDY IN KILIFI COUNTY

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Abstract

Low energy costs have not induced industry and households to adopt energy efficiency measures and the growing GHG emissions are a source of growing concern and promoting energy efficiency standards. Demand-side management can be used to limit residential demand growth or mitigate the impacts through the provision of incentives for industry and commerce to move load out of the peak periods. Benefits of this include avoiding high price increases through the deferment or avoidance of certain generation capacity construction. This paper explores how electrification connection to poor households (where Biomas, wood, paraffin and liquid petroleum gas were the primary household energy sources), promotes the use of clean, versatile and convenient form of energy that connects them to the modern economy. This can raise the proportion of energy sales, leading to a rise in peak demand, with the residential sector contributing more than 30% because of the peaky nature of the load (Africa, 2003). The researcher used stratified sampling technique to select the male and female respondents for this study. The researcher established that Beta coefficients are highest for energy characteristics clean (beta = 0.220) and no smoke (beta = 0.101). To determine the relative importance of the significant predictors, the researcher looked at the standardized than the unstandardized coefficients. Therefore people prefer clean energy and therefore it contributes more to the model because it has a larger absolute standardized coefficient (beta = 0.175). The results of multiple coefficients indicate that all the five variables do not have equal explanatory power of the dependent variable. However, the choice of energy influenced mostly by the variance in cost according to the un-standardized beta coefficients (beta = 0.106, t = 1.109) which was found to be statistically significant at 5 percent level. The second most important characteristic clean energy means (beta = 0.220, t = 1.186) also found to be statistically significant at 5 percent level. The results indicate that with a positive beta, the two variables must be adjusted positively in order to reduce dependence on other forms of unhealthy energy. The paper provides a useful insight into technological and social basis for a sustainable energy system in enhancing the potential benefits of energy efficiency. The choice of energy influenced mostly by the variance in cost according to the un-standardized beta coefficients (beta=0.106, t=1.109) which was found to be statistically significant at 5 percent level. The second most important characteristic clean energy means (beta = 0.220, t=1.186) also found to be statistically significant at 5 percent level. Quality of energy can be ensured by seizing the momentum and global spotlight on clean household energy.

Key words: Electrification, GHG emissions, low energy, residential demand growth and sustainable energy system

1.0   Introduction

It is estimated that in Kenya 77% people do not have electricity or direct access to clean energy mechanisms. Over 85 % of the population rely on traditional fuels such as wood, charcoal, dung, and agricultural residues for cooking and heating (Karekezi and Kimani, 2001). Many urban and rural poor are not reached by grid-based electrical power nor is there adequate distribution of gas or other cooking and heating fuels. (DFID report, 2000).

Firewood remains the predominant fuel for cooking. Nationally 68.3% of all households use firewood as their main sources of cooking fuel. Over 80% of households in the rural areas rely on firewood for cooking compared to 10% of urban households. Charcoal is the second most popular type of cooking fuel used by 13.3% of households. Kerosene is ranked the third predominant cooking fuel, but is the most common type of fuel for cooking among 44.6% of urban dwellers. (Karekezi and Kimani, 2001).

As UNDP, 2005 and Wamukonya, 2001 reports on World Energy Council (WEC) puts it, the lack of access to affordable energy has a number of implications for poor households, and for women in particular including: Women and children disproportionately suffer from health problems related to gathering and using traditional fuel and cooking in poorly ventilated indoor conditions. These include respiratory infections, cancer, and eye diseases. High opportunity costs related to time spent gathering fuel and water which limits their ability to engage in educational and income-generating activities resulting in dramatically different literacy rates and school enrolment levels between men and women; Lack of access to clean energy and electricity in rural areas is an added hindrance to access to useful media information such as market for their produce, health information and civic education.

Clearly, energy infrastructure interventions can be expected to have significant impacts on people's livelihoods. The nature and magnitude of these are some of the questions the case study seeks to address. What emerges in the first instance is that the provision of energy infrastructure and energy services will not automatically lead to the enterprise creation and income generation that project plans might predict. In the language of the sustainable livelihood approach, an increase in physical assets may not increase financial assets, at least not in the expected way. The enhancement of natural assets, however, does not follow directly and demands complimentary programs. Lack of electricity is however viewed as an indicator of extreme poverty. A general view is that the major impact of electricity on livelihoods arises from its capacity to reduce general workloads and lengthen the working day, thereby increasing the possibilities for diversification of activities. Electricity is used for smaller domestic equipment and viewed mainly as a consumption item. Its importance lies in its less tangible benefits, allowing women to do tasks in the evening, allowing children to do their homework and read after dark, and providing access to television.

Energy projects have emerged as one of the critical pathways for linking poverty interventions to the Millennium Development goals. Yet, despite many efforts, energy poverty is widespread, and gender inequality exits at every level of the energy sector. At the same time, most poverty assessments and research exclude energy.

The poor quality fuels many people use contribute to their time poverty, ill health, and level of drudgery. Despite these negative impacts, energy policy remains blind. This can be attributed to the invisibility of people's needs to energy planners, stemming from a lack of appropriate gender-analysis tools to meet the particular data requirements of the energy sector.

The study is expected to generate interest among researchers on energy, poverty and gender policy, and asks what approaches to policy research could help make the linkages among gender, energy and poverty more understandable and more convincing to policy makers and practitioners, both in the energy sector itself, and in the gender and development community. Most past poverty and energy research has seen its primary audience as the energy community and has sought to respond to energy imperatives and frameworks.

A mention of "Household Energy" finds most researchers and organizations equating the term with cooking and stoves, issues strongly identified with women. Clancy (2002), in her briefing paper Household Energy and Gender, takes in a more broad definition used in earlier works to define household energy to encompass all the activities that take place within a household and the linkages to a much wider system of energy supply and demand.

Lack of adequate energy sources (both fuel and labour) is seen as contributing to a "vicious circle" of poverty, while provision of energy could reverse this into a "virtuous circle" "Energy poverty" is defined as: "The inability to buy improved energy supplies or equipment resulting in low productivity, low quality of outputs and an inability to release reproductive labour for economic activity leading to low returns to investment and labour inputs, again limiting possibilities for energy investments." Cecelski and Elizabeth. 1992a.

In addition, there are significant linkages between household energy and other sectors, for example, agriculture (agricultural residues as fuel source), health (lung and eye diseases, nutrition), education (children's opportunity for after-school study) and income generation (cottage industries). These linkages also demonstrate that it is not

sufficient to consider only women when addressing household energy issues but men also play a significant role in decision making on household energy.

In Kenya, biomass is the largest single source of energy, providing over 75% of final energy demand and over 93% of rural household energy needs. Energy use patterns vary significantly between rural and urban areas and also among different economic levels. The preferred forms of energy continue to be electricity and Liquefied Petroleum Gas (LPG), but these are inaccessible to the majority of Kenyans. A 1994 welfare survey showed that only 3% of Kenyans use LPG for cooking (Karekezi et al 2002).

The national electricity grid is mainly hydro powered and supplies less than 40% of urban households, and less than 2% of rural households. The electricity is primarily used for lighting. Poor urban households use biomass in the form of charcoal for cooking and heating, while in the rural areas, fuel wood and Agricultural wastes are the predominant fuels for cooking and heating. Approximately 85% of rural and 50% urban households use kerosene for lighting. Like in many other developing countries, women and children in Kenya suffer the most from over-reliance on limited biomass energy resources in rural areas. They are the main procurers and consumers of wood fuel for domestic use and generally have very limited access to modern, clean and efficient energy technologies. Consequently, they spend considerable amounts of time and energy involved in the drudgery of gathering fuel and performing basic daily tasks, and exposed to high levels of air pollution and associated illnesses related to smoke from fuel wood fires. (Khamati, B.2001)

1.1 Biomass Energy
Following the oil crisis in 1973, energy policy and research suddenly became a separate discipline in both industrial and developing countries. Attention gradually turned not only to oil and electricity supply, but also to questions of energy pricing, fuel substitution, energy conservation, and alternative energy sources. Demand management and energy efficiency were identified as sources of energy savings, and energy balances were prepared to determine where in the economy energy was being consumed, (Eric Eckholm, 1975).

In developing countries, it gradually became obvious that much of the national energy balance consisted not of fossil fuels but rather of what became known as "non-commercial energy" or "traditional fuels" – wood, charcoal, animal dung, and crop residues freely collected and used by rural households for cooking and heating. In 1975, an influential pamphlet by Eric Eckholm of the World Watch Institute described fuel wood as "the other energy crisis." Traditional biomass fuel use in developing countries was blamed for the massive tropical deforestation beginning to be identified by the nascent environmental movement.

Figure 1: Tour of rural image at Rabai, 3-stone cooking stove using firewood

Over the next decade, some energy analysts sought to bring a better understanding of biomass energy into energy sector thinking. It soon became apparent that basic data was severely lacking and could only be obtained through household surveys, which would always be location-specific and presented a number of measurement problems - not least the invisibility of biomass energy in the economy. By the 1980s, data had clarified this picture to some

extent, to show that (Cecelski *et al.* 1979; Barnett, 1982): About half of the world's population cooked with biomass for all or some of their meals; For the poorest developing countries in Africa and Asia, as much as 90% of total energy consumption was by households and consisted of traditional biomass fuels; Most fuel collection by households was done by unpaid household labour of women and children; Biomass fuels were burned in open fires and primitive stoves, with low efficiencies; Biomass fuels were part of complex, inter-related agricultural, forestry, and even industrial production and use systems; Biomass consumption was not only by rural households, but also by urban households and small industries, and in many cases entered commercial markets. (Peskin and Barnes, 1992).

2.0   Research Methodology
2.1   Introduction
This section is focused on the methodology that the researcher adopted to achieve the research objectives. The path to finding answers to the research questions constitutes the research methodology. A research design selected that best achieve the objectives of the study. Sample size and sampling technique were also carefully selected to as much as possible obtain data that is representative of the population of the study. Data collection instruments were prepared to obtain as much information as possible on the independent variables hypothesised in the conceptual framework for the study.

2.2   Research Design
This is a descriptive study. According to Kothari (1990) a descriptive research attempts to describe systematically a situation, problem, phenomenon, or provides information about say, living condition of a community, or describes attitudes towards an issue. The researcher used this design to capture the technological and social basis for a sustainable energy system in enhancing the potential benefits of energy efficiency in Kilifi County. Kilifi County case was investigated as amongst the poorest counties in Kenya. The researcher collected both qualitative and quantitative data to exhaustively obtain all the pertinent information and draw valid conclusions and offer recommendations.

2.3   Population for the study
The target population for the study were selected energy users in the urban, peri-urban and rural communities of the Kilifi County. This included the male and female residents to capture their opinions on the effects of energy infrastructure projects for sustainable livelihoods in Kilifi County by looking at their daily energy requirements and constraints associated with them. The research was expected to take three months to be completed.

Table 1: Study population

Towns	Population	Sample Size	%
- Malindi	118,265	7	0.0024
- Kilifi	48,826	6	0.0021
- Mtwapa	48,625	10	0.0035
- Mariakani	24,055	9	0.0031
- Watamu	10,030	5	0.0017
- Majengo	7,788	8	0.0028
- Mazeras	6,886	6	0.0021
- Magarini	6,051	5	0.0017
- Njabini	6,042	5	0.0017
- Marereni	5,949	7	0.0024
- Kaloleni	5,573	7	0.0024
	288090	**75**	**0.026**

Source: KIPPRA report to ERC 2010

2.4   Sampling Frame

The following eleven towns were selected for the study; Malindi, Kilifi, Mtwapa, Mariakani, Watamu, Majengo, Mazeras, Magarini, Njabini, Marereni and Kaloleni. All the town centres were crucial in establishing the effects of energy infrastructure projects on poverty reduction for sustainable livelihoods in Kilifi County. Each and every resident in the population had an equal chance of inclusion in the sample and each one of the possible samples, in case of finite universe, had the same probability of being selected. This was a good sample size since statistically a sample size should not be less than thirty for a large population (Anthony & Michael, 1999). These provided adequate findings on the effects of the energy projects on poverty reduction.

2.5   Sample and Sampling Technique

The researcher used stratified sampling technique to select the male and female respondents in each of the towns selected for the study. This gave a total of seventy five people. This was a good sample size since statistically a sample size should not be less than thirty for a large population (Anthony & Michael, 1999).

2.6   Data Collection Instruments

The study used primary data obtained by use of structured and semi structured questionnaires with the selected male and female residents of the towns. Both closed and open ended questions were used and a four point assigned number questionnaires. The four point scale was an improvisation of likert scales (Oppenheim, 1982). Part I identified the general information about the respondent. Part II featured the effects of energy infrastructure projects for sustainable livelihoods in Kilifi County. The questionnaires were self-administered. Secondary data was also collected from the relevant government departments to capture their energy needs and consumption trends.

2.7   Data Collection Procedure

Primary data was collected through survey. The questionnaires were distributed by a field assistant to the respondents in the selected towns, namely Malindi, Kilifi, Mtwapa, Mariakani, Watamu, Majengo, Mazeras, Magarini, Njabini, Marereni and Kaloleni. The questionnaires were issued to the respondents and collected later. Secondary data were also collected from the relevant government departments. Data was also collected by way of researchers' own observation, without interviewing the respondents. The researcher also followed a rigid procedure and sought answers to a set of pre-conceived questions through personal interviews.

2.8   Data processing and Analysis

After the data had been collected, the researcher turned to the task of analysing them. The analysis of data required a number of closely related operations such as establishment of categories, the application of these categories to raw data through coding, tabulation and then drawing statistical inferences. The unwieldy data were condensed into a few manageable   groups   and   tables   for   further   analysis.   The researcher   coded   the   data   through   which   the categories of data were transformed into symbols that may be tabulated and counted. The researcher also edited the data to improve the quality of the data for coding. Classified data were put in the form of tables, graphs and charts for easier comprehension. Statistical package for social sciences (SPSS) was used to analyse the data and obtain statistical parameters such as mean, variances, standard deviation, coefficients and other frequencies.

Regression was carried out after scatter plots suggested linear relationships exists to establish the strength of the relationship by determining the Karl Pearson's product moment coefficient of correlation (r) and the coefficient of determination (R^2) to explain the extent of the influence on technological and social basis for a sustainable energy system in enhancing the potential benefits of energy efficiency. A regression model was obtained for the linear, exponential and logarithmic relationships between the independent variable and the dependent variables after which curve fitting estimation was carried out and tested for significance in order to determine which type of relationship, linear, exponential or logarithmic was predominant. The standardized residual plots were used to test the stability of variance hence plausibility of a linear relationship followed by a log transformation if a linear fit is found wanting for both exponential and logarithmic tests.

Typically, the test method involved a test statistic and a sampling distribution. Computed from sample data, the test statistic were a mean score, proportion, difference between means, difference between proportions, z-score,

t-score, chi-square, etc. Given a test statistic and its sampling distribution, a researcher assessed probabilities associated with the test statistic.

3.0   Research Findings and Discussion
This section summarized the approach used in the collection of data that provided the information for this report. It also provides information on the demographic characteristics of the people interviewed in the survey followed by a brief discussion of the findings. The data collected in this research was analyzed by use of descriptive statistics and regression analysis which is also presented in this chapter.

3.1   Response Rate
The researcher served respondents with 75 questionnaires and received 50 of them back. This gave a total response rate of 67%. The response rate was as tabulated below:

Table 2: Response rate

No. of questionnaires distributed	No. of questionnaires received	Percentage
75	50	67

3.2   Household's Energy Sources
The researcher sought to investigate the household energy sources. The researcher observed that the availability of multiple fuels enables fuel switching, e.g. from charcoal and biomass to electricity in both urban and rural areas. While lack of access to electricity and use of traditional unimproved cooking methods are predominantly rural phenomena, it was discovered that there are many urban households who cannot obtain reliable electricity and who spend large fractions of their budgets on cooking fuel. The energy distribution is as shown in the chart below:
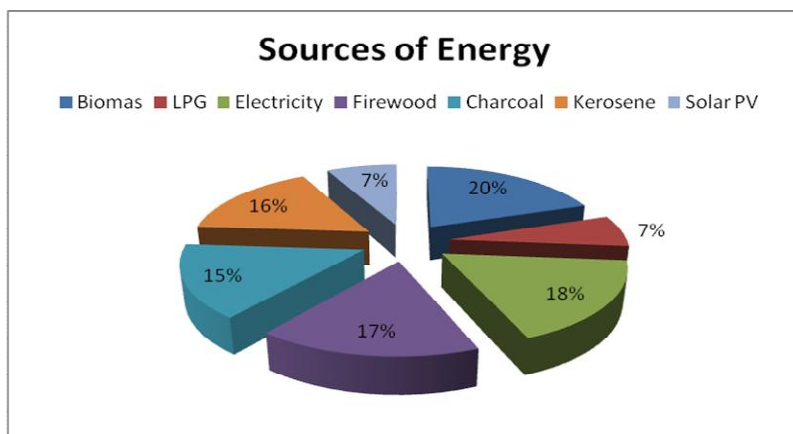

Figure 2: Energy Sources

The findings of the research indicated that 18% of the respondents make use of grid based electricity and 16% use biomas fuels including crop residues and animal wastes for various purposes. A large population at 17% also use of firewood for their energy services.

3.3   Connectivity to Grid Based Electricity
The researcher investigated the rate of connection to the grid based electricity. The energy distribution amongst households was compared to number of households connected to the grid. This is presented using the histogram below:
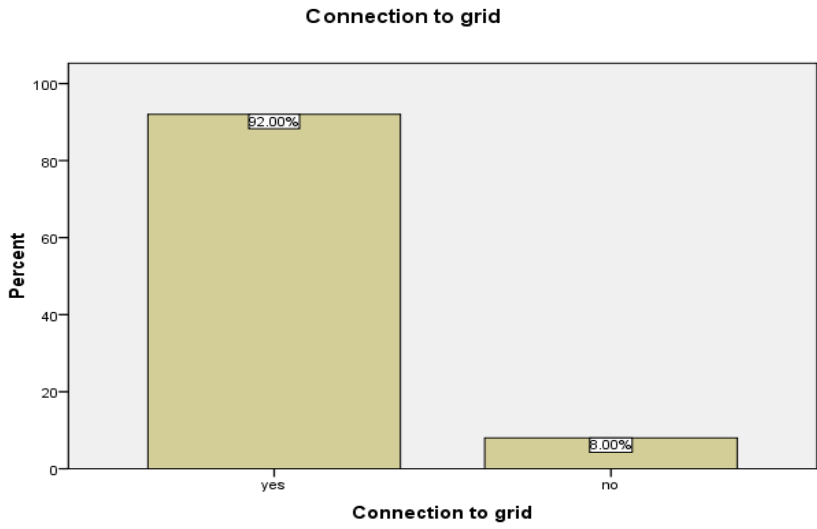
Figure 3: Connectivity to grid based electricity

The researcher established that of the total number of respondents 92% are connected to the grid. The researcher observed that grid extends to virtually all urban areas, so that urban people without electricity tend to be relatively poor. Since few houses in urban areas do not have electricity, the unobserved characteristics of those without electricity in the city likely differ more substantially from those that have electricity than they do in rural areas. Mariakani town had the largest share of connection to main grid at 16% followed by Malindi town at 10%. A relatively small proportion, 20% is dedicated to projects that promote adoption of improved and advanced biomass stoves (which are often more efficient and generate less indoor air pollution), and fuel switching to cleaner fuels such as LPG. However, 84% of the respondents acknowledge that the energy sources in place are inadequate in meeting population demands.
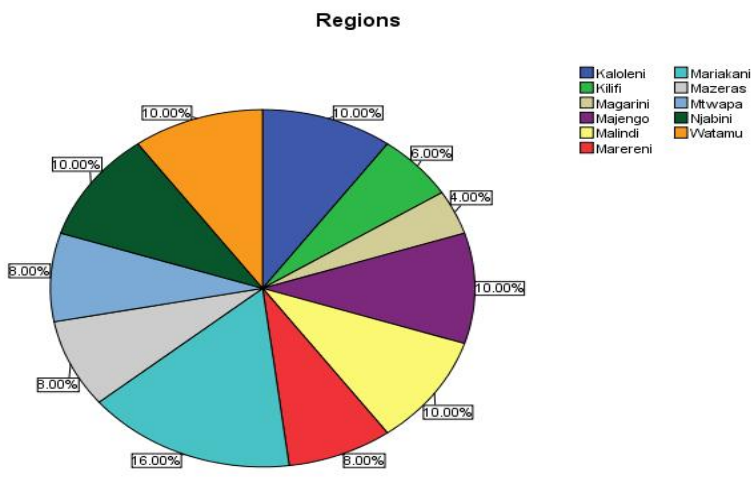

Figure 4: Connectivity to grid across towns

3.4   Energy Uses

The researcher identified that the first and strongest effects of electricity therefore via lighting and TV. Further, Electricity displaces more expensive candles and kerosene lamps, thereby reducing indoor air pollution and fire

and burn risk, and providing higher quality light. Lighting and television help improve access to information, the ability to study, and extend the effective working day. Lighting also improves the productivity of many household activities, and has potential benefits for public safety and expanded income-generating opportunities. The energy uses are as tabulated below:

Table 3: Energy uses

Energy Source	Uses	Frequency	%
Biomass	Heating, Lighting,	45	18
LPG	Production, Lighting, Heating	23	9
Electricity	Production, Lighting, Heating	41	17
Firewood	Heating	45	18
Charcoal	Heating	37	15
Kerosene	Lighting, Heating	39	16
Solar PV	Lighting	17	7

It was observed that most households make use of more than one energy type at any time. The availability of many energy sources allows for easier fuel switching to more convenient fuels. Biomass finds application in heating and lighting and is preferred by 18% of the population, grid electricity is majorly used for lighting and preference rate is at 17%. Kerosene also finds wide application, 16%, in lighting and heating mostly in rural and peri-urban areas. The results of the energy uses were presented in a pie chart as shown below:
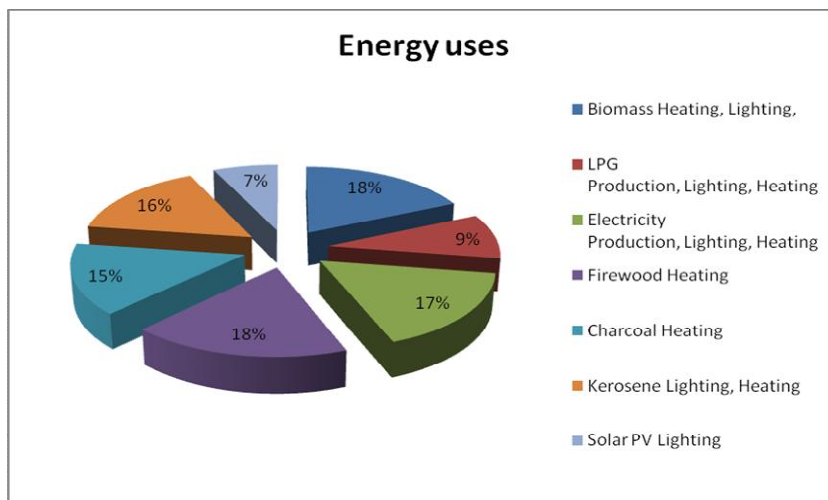

Figure 5: Energy uses

3.5   Characteristics Associated with Household Fuels
The researcher investigated effects of interventions designed to promote energy access depending on household decision-making, and, in particular, how household's preferences, opportunity cost of time, and welfare are reflected in those decisions. The research of cooking interventions covered a broad spectrum of improved fuels and stoves designed to improve energy efficiency, remove smoke from the indoor living space, and raise the productivity of cooking. The results were as tabulated:

Table 4: Characteristics associated with household fuels

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.262[a]	.069	-.037	.74207

a. Predictors: (Constant), Safe, Clean, Expensive, Fast, Nosmoke

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.791	5	.358	.650	.663[a]
	Residual	24.229	44	.551		
	Total	26.020	49			

a. Predictors: (Constant), Safe, Clean, Expensive, Fast, Nosmoke

b. Dependent Variable: Sufficiency of capacity

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.702	1.677		.418	.678
	Expensive	.106	.096	.169	1.109	.273
	Clean	.220	.186	.175	1.186	.242
	Nosmoke	-.101	.176	-.089	-.574	.569
	Fast	.040	.168	.036	.237	.814
	Safe	.045	.110	.066	.413	.682

a. Dependent Variable: Sufficiency of capacity

In a multiple linear regression model, adjusted R square measures the proportion of the variation in the dependent variable accounted for by the explanatory variables. Unlike R square, adjusted R square allows for the degrees of freedom associated with the sums of the squares. Adjusted R square is generally considered to be a more accurate goodness-of-fit measure than R square. Thus, approximately 6.9 per cent of the variation in terms characteristics associated with household fuels is explained by the independent variables in the model.

The anova table tests the acceptability of the model from a statistical perspective. The Regression row displays information about the variation accounted for by our model. The Residual row displays information about the

variation that is not accounted for by our model. The significance value of the F statistic is less than 0.05 (or 0.01 which is the significance level we have set due to the sampling imperfections.

Standardized coefficients or beta coefficients are the estimates resulting from an analysis performed on variables that have been standardized so that they have variances of 1. From the table 4.15 we can see that the Beta coefficients are highest for energy characteristics clean (beta=0.220) and no smoke (beta=0.101). To determine the relative importance of the significant predictors, the researcher looked at the standardized than the unstandardized coefficients. Therefore people prefer clean energy and therefore it contributes more to the model because it has a larger absolute standardized coefficient (beta=0.175).

The results of multiple coefficients indicate that all the five variables do not have equal explanatory power of the dependent variable, Table 4.15 However, the choice of energy influenced mostly by the variance in cost according to the un-standardized beta coefficients (beta=0.106, t=1.109) which was found to be statistically significant at 5 percent level. The second most important characteristic clean energy means (beta = 0.220, t=1.186) also found to be statistically significant at 5 percent level. The results indicate that with a positive beta, the two variables must be adjusted positively in order to reduce dependence on other forms of unhealthy energy.

3.6 Sufficiency of the Energy Capacity
The researcher investigated whether the energy supplied is of sufficient capacity to their demands. The findings were tabulated as shown in Table 5.

Table 5: Sufficiency of the energy capacity

Sufficiency of capacity		Frequency	Percent
Valid	0	2	4.0
	less than needed	11	22.0
	sufficient	29	58.0
	capable of meeting higher demand	8	16.0
	Total	50	100.0

The findings shown that 22% of the respondents say that the energy capacity is still less than needed. However, 58% of the respondents feel that the energy supply is sufficient to meet their demands. 8% of the respondents even noted that the energy supplied to them is even capable of meeting higher demands.

3.7 Mode of Payment
The researcher investigated how the respondents pay their electricity bills. The findings were tabulated as shown in Table 6.

Table 6: Mode of Payment

	Mode of Payment	Frequency	Percent
Valid	0	3	6.0
	capacity	3	6.0
	meter	37	74.0
	fixed fee	6	12.0
	other	1	2.0
	Total	50	100.0

The results show that majority at 74% pay their bills as per the meter readings installed by the energy supplying authority. A few who own small industries either pay by capacity of energy bought, 6% or by a fixed fee 12% fixed by the authorities. Failure to pay the bills leads to disconnection from the supply.

3.8   Ownership of Household Devices

The researcher investigated the rates of ownership of household devices. The rates were as presented in the histogram (Figure 6).

Household devices
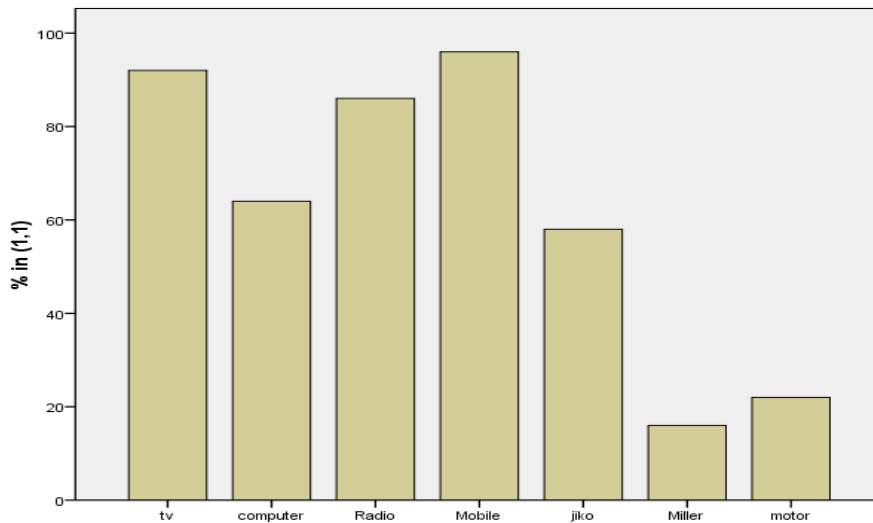
Figure 6: Ownership of Household devices

From the results, 96% of the respondents own mobile phones and a greater number of 94% do own television sets. Further, 90% of the respondents own radios and 64% do own computers. Only a few 18% own millers. The ownership of the gadgets has been enhanced by improved grid electricity connection.

4.0   Conclusions

According to the research findings 84% of the population relies on traditional use of biomass (crop residues) for cooking (i.e., 3-stone fires and unimproved stoves), and 38% of the population do not have access to electricity. A relatively small proportion, 20% is dedicated to projects that promote adoption of improved and advanced biomass stoves (which are often more efficient and generate less indoor air pollution), and fuel switching to cleaner fuels such as LPG However, 84% of the respondents acknowledge that the energy sources in place are inadequate in meeting population demands. The choice of energy influenced mostly by the variance in cost according to the un-standardized beta coefficients (beta=0.106, t=1.109) which was found to be statistically significant at 5 percent level. The second most important characteristic clean energy means (beta = 0.220, t=1.186) also found to be statistically significant at 5 percent level. In order to ensure that time use is reduced the government should develop infrastructure to design and test energy appliances to satisfy performance standards on safety, energy efficiency and durability. Quality of energy can be ensured by seizing the momentum and global spotlight on clean household energy.

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