Analysis of Electricity Consumption by Households in Kenya

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KIPPRA in Brief

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Abstract

An estimated 1.3 billion people around the world lack access to electricity, with majority of them living in Sub-Saharan Africa, where two out of every three households stay in darkness after sunset. In Kenya, according to the Draft National Energy Policy 2014, the overall electrification rate is approximated at 28.9 per cent, despite recent government efforts to rapidly increase electrification rates in both urban and rural areas. Similarly, electricity access in rural areas is approximately 5 per cent, and 51 per cent in urban areas. The continued use of solid biomass and kerosene contributes to household air pollution, which leads to respiratory illnesses that are a major health burden.

The main objective of this study is to estimate the amount of electricity consumed by households with a view to determining the factors that explain the differences in the levels of consumption and expenditure on electricity. The study uses cross-sectional data of 3,339 households in Kenya. I an attempt to undertake household expenditure analysis of energy services - mainly biomass and electricity - the study also uses the Tobit model. Data was obtained from the KIPPRA National Energy Survey of 2009 and analyzed using the Tobit and the Probit model. The key findings are that location of household, marital status of the household head, involvement of household head in agriculture, per capita household income, and the tenancy type are significant in explaining the household expenditure on electricity. Also, expenditure on biomass is not significant in explaining the overall household expenditure on electricity. The key policy recommendation is that the government should increase investments in energy and continue to subsidize electricity, especially in terms of pricing.

Abbreviations and Acronyms

GW	Gigawatt
GWh	Gigawatt hour
IEA	International Energy Agency
KIPPRA	Kenya Institute for Public Policy Research and Analysis
KIHBS	Kenya Integrated Household Budget Survey
kWh	kilowatt hour
MW	Megawatt
MWh	Megawatt hour
OECD	Organization of Economic Cooperation and Development

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1. Introduction

1.1 Background

According to the International Energy Agency–IEA (2010), electricity enhances the quality of life in numerous ways as it provides extra hours to work and study, and opens up numerous opportunities to communication, entertainment and productivity in urban and rural areas. For instance, improved cooking, lighting and heating facilities have the potential to significantly reduce the daily exposure of households to noxious cooking fumes.

An estimated 1.3 billion people around the world lack access to electricity, with a majority of them living in Sub-Saharan Africa (IEA, 2013). It is projected that these figures are unlikely to decline given the high cost of investment in electricity supply, thus making it difficult to meet the universal energy access target by 2030. Additionally, global electricity demand is projected to double during the period between 2000 and 2030, with growth in demand being strongest in developing countries (IEA, 2010).

Energy services comprise renewable and non-renewable energy resources. Non-renewable energy sources mainly comprise fossil fuels and nuclear, while renewable energy sources comprise biomass, solar energy, wind power, hydro and geothermal. These primary sources can be transformed into ethanol, electricity and petroleum. The biomass and other material residues can be used directly especially by households, whereas electricity, petroleum products and ethanol must be distributed through a network to the final user. Petroleum fuel accounts for about 28.57 per cent of the total final energy consumption, while electricity and biomass account for about 3.11 per cent and 67.65 per cent of the total final energy consumption, respectively.

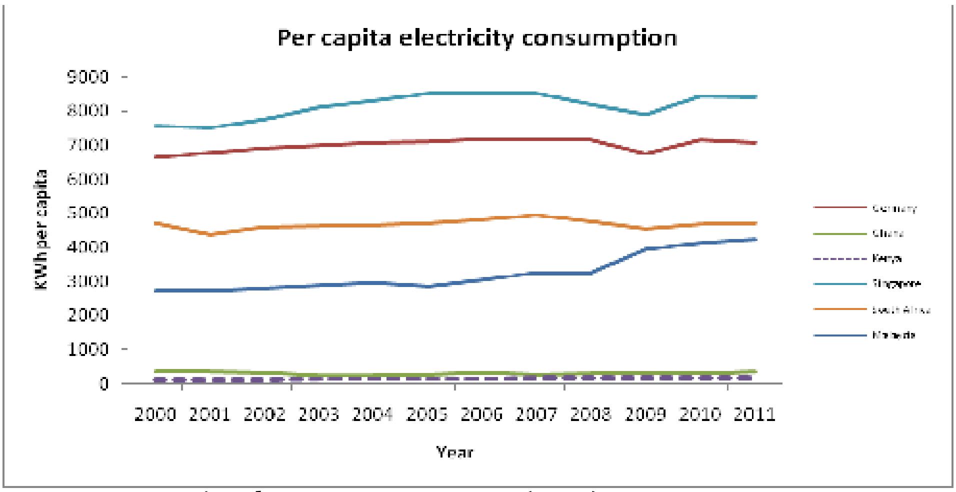
Gradl and Knobloch (2011) suggest that globally, poor households spend up to 30 per cent of their household income on energy as a result of the high cost of traditional energy sources such as biomass and petroleum products. Therefore, access to electricity services is essential in achieving the Millennium Development Goals (MDGs) and also helps in solving the problem of low productivity by increasing the range of options in economic activities and time spent on collecting biomass by households. Electrification along with access to modern cooking fuels and mechanical power is important in improving food security, health and education while reducing poverty levels and gender inequality (GNESD, 2007). This is achieved by reducing the time spent by households in searching for fuel, and the extension of working hours through lighting.

In Sub-Saharan Africa (SSA), it is estimated that a total of 31GW of electricity is generated annually (Eberhard *et al.*, 2008), but fewer than 10 per cent of rural households and institutions such as schools and health centres have access to electricity (Parshall *et al.*, 2009). It is also projected that the number of people without access to electricity will increase if there are no interventions to improve the current energy policies (Yadoo, 2012).

There are strong linkages between the level of energy consumed, especially electricity, and Human Development Index (HDI). Yadoo (2012) reports that countries with low energy per capita experience the least HDIs. However, Aqeel and Sabihuddin (2001) argue that it is not certain for the quantity and type of energy consumed to be influenced by education, income and other socio-economic factors.

Figure 1.1 shows the per capita electricity consumption of six countries, namely Singapore, Germany, South Africa, Malaysia, Ghana and Kenya between year 2000 and 2011. It is evident that the low per capita consumption rates in Kenya and Ghana can closely be linked to the level of economic development. Even though lack of energy access can be attributed to low levels of income, the World Bank (1995) notes that energy access alone would be insufficient in increasing the level of economic growth and development, without other factors such as access to markets, transport and communication infrastructure, access to credit, and literacy levels.

Figure 1.1: Per capita electricity consumption in selected countries



Source: International Energy Agency–IEA (2010)

1.2 Kenya's Energy Situation

Kenya's energy sector faces numerous challenges characterized by insufficient supply and low access to affordable energy, which hinders economic development to majority of poor households. Similarly, a majority of the population rely on traditional biomass and waste, particularly fuel wood, for heating and cooking. Kenya has a number of policies to address energy issues in support of its development challenges. Currently, the energy sector is guided by multiple laws and policies: Sessional Paper No. 4 of 2004; Energy Act No. 12, which was enacted in 2006; Geothermal Resources Act No. 12, enacted in 1982 to control the exploitation and use of geothermal resources; and the Petroleum (Exploration and Production) Act Chapter 308 of the Laws of Kenya, which regulates the negotiation and conclusion by the Government on petroleum. The National Energy Policy 2014 and Energy Bill 2014 seek to consolidate the multiple laws guiding the sector. The focus of these legal frameworks is to facilitate provision of clean, sustainable, affordable, reliable and secure energy services at minimal costs (Government of Kenya, 2014).

Kenya has a number of primary energy sources and is currently undertaking programmes to reduce dependency on biomass, fossil fuels and hydro as key sources of energy. This study will, however, focus on use of electricity by households.

The country has heavily depended on wood fuel and other biomass. Charcoal, firewood, paraffin, and LPG are the main sources of cooking fuel. At the national level, 68.8 per cent of households use firewood as the main cooking fuel and, in rural areas, close to 90.0 per cent of the rural population is dependent on firewood for cooking and heating (KIPPRA, 2009).

As shown in Figure 1.2, electricity is generated from various sources such as hydro, solar and geothermal. There are companies generating electricity through co-generation and fossil fuels. With the discovery of natural gas deposits and coal, there are plans to generate additional 5,000 megawatts of electricity by the year 2016. Most of the electricity produced is normally consumed by households and industries. The number of domestic customers as at June 2013 was reported to be 2,000,790.

Table 1.1 provides an overview of household energy consumption in rural and urban areas in Kenya for cooking and lighting. The 2005/06 KIHBS data distinguishes collected and purchased, for expenditure analysis purposes. Rural households mainly use collected and purchased firewood for cooking, while urban ones use paraffin/kerosene and charcoal for cooking. Only 12 per cent use electricity for cooking, while those using gas are less than one per cent. Lighting has a different consumption pattern; paraffin/kerosene is largely used in rural

Table 1.1: Household energy consumption patterns by location

Cooking			**Lighting**		
	Rural	Urban		Rural	Urban
Collected firewood	74.8	6.3	Collected firewood	5.6	0.4
Purchase firewood	13	3.7	Purchase firewood	0.3	0.2
Grass	0.1	0.2	Grass	0.2	0.1
Paraffin/ Kerosene	2.7	44.7	Paraffin/ Kerosene	86.4	46.3
Electricity	0.2	1.7	Electricity	3.9	51
Gas/LPG	0.7	11.9	Solar	2.0	0.7
Charcoal	7.7	30.2	Gas/LPG	0.2	0.2
Biomass residue[1]	0.4	0.1	Dry cell	1.4	0.1
Biogas	0.0	0.1	Candles	0.1	1.0
Others	0.4	1.1	Others	0.1	0.1
Total	100.0	100	Total	100	100

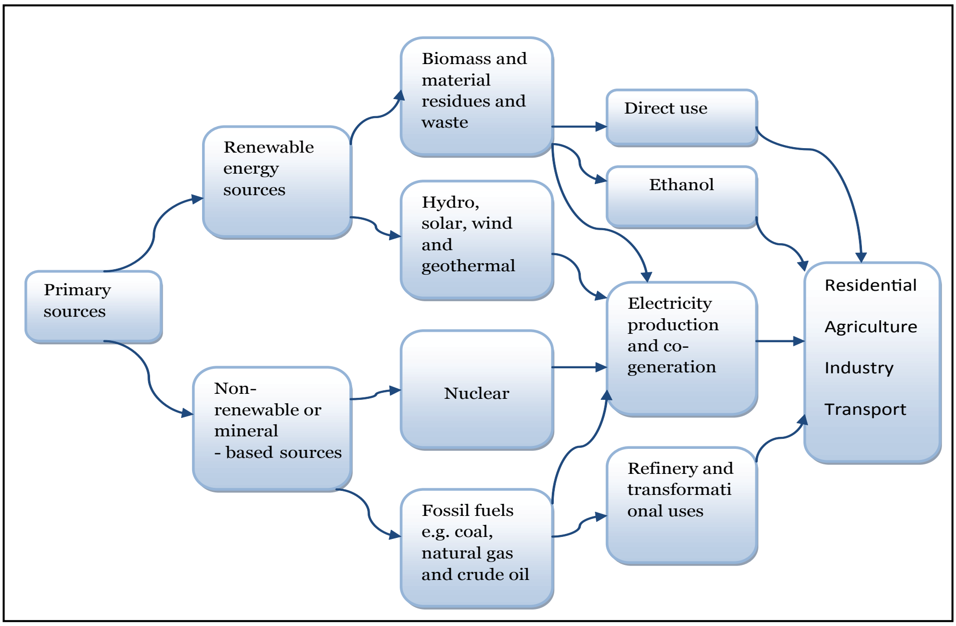
Source: Government of Kenya (2006)

households, while urban households use electricity (51%) and paraffin/kerosene (46%) for lighting.

The household energy consumption profiles are important for establishing the common source of energy for household cooking and lighting. Urban households use paraffin/kerosene and charcoal to cook, while rural households use firewood, either collected or purchased. In terms of lighting, rural households use paraffin/ kerosene, while urban households use electricity.

It is also important to note that whereas 13.3 per cent of households use charcoal for cooking nationally, it is most common in urban areas (44.6%). The survey also indicated that the national average for electricity access was at 29.0 per cent, suggesting the need to reduce the use of biomass energy source in view of increased negative environmental effects. On the other hand, the highest earning income group spend the smallest proportion of their income on energy and contribute most negatively in terms of the environment. It is also argued that charcoal is the single most important source of energy in urban areas for both the poor and non-poor, and both groups expend a similar proportion of their total income on energy (Maliti and Mnenwa, 2011).

Figure 1.2: Energy flow in Kenya



Source: Adapted from the Energy Information Administration (EIA, 2014) and author's illustration

At household level, research shows that about 70 per cent of the consumers use biomass, while 30 per cent use other fuels. Other related studies show that kerosene is mostly used for lighting (52%), while biomass was widely used for cooking (60%) (KIPPRA, 2009). Analysis of fuel types in Kenya by urban and rural areas shows that the most popular fuel types in terms of their various uses are: kerosene (80%), followed by charcoal (60%), fuel wood (55%), electricity (37%) and LPG (21%) in that order. The usage of fuel wood, charcoal and kerosene in rural areas is higher, compared to urban areas. However, the use of LPG and electricity in the rural areas is lower, compared to urban areas. While lower prevalence of electricity use in rural areas can be attributed to lack of connectivity, lower LPG use can be attributed to lack of access and information. Overall, the use of renewable energy from solar, biogas and wind is very low in Kenya, with 3 per cent, 0.2 per cent and 0.1 per cent, respectively (KIPPRA, 2009).

There are numerous study approaches that have attempted to address the energy situation in Kenya, the focus being the trends in rural electrification in Kenya (Yaddo, 2012); energy demand and supply patterns among different consumer categories (KIPPRA, 2009); willingness to pay for energy services by household consumers; and share of energy in the household budgets, among other studies (KIPPRA, 2009).

Importantly, energy demand is anticipated to rise sharply as a result of enhanced energy-intensive activities, population growth, and expected increase in economic growth. However, Kenya's energy profile makes it susceptible to domestic and global economic shocks, hence it is important to understand salient issues that affect expenditure by households.

Based on the foregoing review of the energy sector, this study pursues the following question: to what extent do households' characteristics influence their expenditure on electricity consumption? The primary focus is to provide an analysis of factors affecting energy use amongst households, particularly electricity use in Kenya. Availability of energy sources plays a crucial role to a country's economic growth, and it is important to note that economic and population expansion are key contributing factors to increased demand for energy in all its forms (Inglesi-Lozt and Blignaut, 2011).

1.3 Research Problem

Despite recent government efforts to rapidly increase electrification rates in both urban and rural areas, the overall rate is estimated at 28.9 per cent (Government of Kenya, 2014). Similarly, rural electricity access is approximately 5.0 per cent, while that of urban areas is 51.0 per cent. This has led to continued use of biomass as a source of energy, which is a major health burden to households through indoor air pollution. The Second Medium Term Plan for 2013-2017 targets to connect 2 million new customers to the national grid. However, given the high connection costs and requirements needed to get power supply, it is foreseeable that majority of poor households, especially those in marginalized areas, will be without access to electricity by 2017.

Achieving the Millennium Development Goal of eradicating extreme poverty by 2015 is not achievable without considerable improvement in access to electricity. Lack of access to electricity hinders social and economic development, since it affects productivity of households by reducing the range of options for economic activities. As a result of the high cost of the traditional forms of energy sources, households spend a huge percentage of their income on energy, and these expenditures can be reduced with electrification.

Therefore, the need for appropriate policy intervention has become increasingly urgent to address the factors affecting energy expenditure, especially in electricity. Additionally, it is important to design policies that seek to compensate the poor from adverse effects of higher energy prices.

1.4 Research Objectives

The main research objective of this study is to estimate the determinants of household electricity consumption, with a view to determining the factors that explain the differences in these levels of electricity expenditure.

The specific objective is to determine the factors responsible for the differences in levels of electricity expenditure across households in Kenya.

1.5 Justification and Policy Relevance

The subject of household energy use patterns and expenditure has featured prominently on a large number of studies and policy debates. As a result, recent attention has been given to the possibility of adjusting consumption patterns through price adjustments, with particular emphasis on increasing the level of access throughout the country. The study is significant since it comes at a point when the level of investment in the energy sector has increased, and when the Kenyan government is targeting to generate additional 5,000MW of electricity by 2017 and increase the national electrification rate to 100 per cent by the year 2020. The study, therefore, aims to generate insights that will inform and guide policy implementation in ensuring that access to modern affordable forms of energy is achieved, and per capita electricity consumption by households is increased.

2. Literature Review

There are several theoretical and empirical explanations for understanding household expenditure decisions and resource allocation patterns. This section presents an overview of studies undertaken to model household energy expenditure. It attempts to explain the theoretical framework that underpins energy studies, and it uses a survey of econometric methodologies by previous studies.

2.1 Theoretical Literature

Household energy consumption is influenced by a wide variety of highly inter-related economic and social factors, such as household preferences, budget constraints, and household characteristics (Michaelis and Lorek, 2004). However, energy demand is derived from the demand for services that individuals in a household use on a daily basis.

The adoption of the production household model makes it possible to incorporate the economics of production theory into household consumption decisions. This implies that commodities are in general produced at a minimum cost, or the household is on the frontier of a multiple-output multiple-input relationship, where energy is both produced and consumed by households (Dzioubinski and Chipman, 1999). Therefore, the demand for energy is essentially demand-derived. Muth (1966) suggests that commodities purchased by consumers in the market are inputs for households used in production of other goods and services. Therefore, energy in itself does not create utility, but is used as an input into the household production process, which in turn creates utility.

Two-stage budgeting model

Another important theory that has informed household expenditure analysis is the two-stage budgeting approach. It assumes that households engage in a two-stage process in their consumption decisions. First, they allocate income to various broad categories of goods such as food, clothing, fuel and light, among others. In the second stage, given their expenditure constraints in the first stage, they maximize utility within each sub-category of good.

The two stage budget model specifies that economic agents allocate total expenditure to a group of goods based on a price index, after which they apportion expenditure within the group based on individual prices (Gorman, 1959). This allows for a simplification of the households' decision process by looking only at one category at a time. For example, at the first stage, only information on the households' total budget and prices for the broad categories of goods is required.

At the second stage, only information on the amount of household expenditure on energy (for example) and prices for the different types of energy within that group is required (Molina, 1997).

Consumer choice theory

Consumer choice theory has been used to model utility derived from consuming certain commodities. It is therefore important to understand that consumption is an activity in which goods, either as a combination or singularly, are viewed as inputs and outputs (Lancaster, 1966). The theory closely relates to the revealed preference theory, which states that if a consumer purchases good one when he should have purchased good two, then he has revealed his preferences (Ritcher, 1966).

Based on the aforementioned arguments, examining household energy consumption behaviour can be understood on the basis of the preferences, and the quantities they consume. The principles of consumer theory as stated by Gowdy and Mayumi (2001) are useful assumptions in this study. The principles include invariance of the preferences, non-satiation, complementarity and the hierarchical nature of wants.

2.2 Empirical Literature

This section summarizes some recent studies on household energy demand and electricity consumption. The focus is on the methodologies adopted and the key findings from the analyses, including discrete choice models (the Probit and the Logit models), limited dependent variable models (Tobit, Craggs Double Hurdle, Heckman) and two-part selection models. Additionally, there have been count data models and single equation estimation that have been used to analyze energy, transport and household consumption of durable goods. A number of studies, especially on energy consumption patterns, have been conducted with specific reference to Kenya and other parts of the world.

There are studies that have also considered the price elasticity of the various energy components such as gas, biomass and electricity. The key focus is on households' behaviour when making decisions on the energy services to use, based on their budget and preferences. For instance, Malla and Timilsina (2014) indicate that urban households do not abandon biomass use altogether because of the cost, reliability, cultural preference and cooking practices. The study also indicates that the share of expenditure devoted to modern energy use in rural areas in Kenya and other selected developing countries is around two per cent.

At the same time, urban households spent nearly twice as their rural counterparts on petroleum products. In studying the United Kingdom energy market. (1989) established that energy demand rises with increased income but stabilizes over time. The studies used a two-stage budgeting framework of the allocation of household expenditures and estimation done using single equation model. Eakins (2013), using Tobit and the Cragg double hurdle models, concludes that increased income increases the likelihood of positive expenditure on energy by households.

Other methods of estimation in household electricity demand, such as the General Method of Moments, have been applied by Reiss and White (2002). The study states that electricity is not consumed directly by households, but is derived from the flow of services provided for by appliances, concluding that modelling the demand behaviour for multi-part prices requires a linearization of the non-linear budget constraint.

Using descriptive analysis in studying the methods of payment for energy services in the United Kingdom, Advani, *et al.* (2013) establish that how households pay for energy services will influence their consumption. For instance, poorer households using prepayment for energy services face higher prices than those using direct debit payments from their banks. This can be explained by the fact that in the United Kingdom, there are cheaper packages for those using direct debits than prepayments.

It is also established that improvement in income leads to increased demand for electricity and petroleum products (Shittu, Idowu, Otunaiya and Ismail, 2004). The study involved the use of linear logit model and cross sectional data of 90 households in Nigeria. It is important to note that low-income households are more likely to be affected by both price and income changes than higher-income households (Guertin, Kumbhakar and Durainppah, 2003). This is because a greater percentage of the household budget will be spent on supporting food budget items such as cooking, of which energy services are important.

Using a combination of Ordinary Least Squares (OLS) method, Cragg Double Hurdle and Tobit models, Eakins (2013) notes that the stocks of appliances, type of heating system and other household characteristics have significant effects on the levels of energy expenditure. This can be attributed to the fact that energy use and the level of use of appliances increases with the number of household members. Fletcher and Terza (1986) also shows that using cross-sectional data and two stage probit models, household incomes and the type of occupancy have effects on consumption.

In the study of Kenya households using of Contingent Valuation Method (CVM) and the Willingness to Pay (WTP), Abdullah and Markandya (2012) indicate that most households in the rural areas face the challenges of limited access to modern energy sources, and high expenditures on traditional fuel sources. This situation makes household fuels unaffordable, hence the need for energy subsidy reforms, and establishment of financial schemes.

3. Methodology

3.1 Research Methods and Data Sources

The study uses cross-sectional data comprising of 3,339 households in Kenya to analyze household expenditure on energy services, mainly biomass and electricity. The study uses the Tobit model. Data was obtained from the KIPPRA National Energy Survey of 2009.

3.2 Analytical Framework

Based on literature review and the theory of choice, the main objective of the consumer is to maximize utility subject to the prices of the goods and services consumed, such that:

Max U (x,y)

s.t. PxX + PyY < 1 .... (1)

The utility theory also assumes that consumers will always try to maximize their satisfaction from consuming extra units of goods and services.

$$\frac{MU(X_1)}{p(X_1)} > \frac{MU(X_2)}{p(X_2)} \quad \text{.. (2)}$$

Where *MU* (X_i) denotes the marginal utility of consuming good *X*, given price *P* (X_i). Given the nature of consumers, household's preferences are largely determined by the extra utility obtained by consuming extra units at price *P*.

It is important to note that the preferences for the bundle of goods that most households choose largely depends on a set of constraints and the utility function, such that they may spend the entire budget on selected goods and services, while consuming zero quantities of other commodities. In this study, the dependent variable is the expenditure on electricity, which is continuous but the range is constrained. However, there is a possibility of a proportion of the households not having access to energy services, thus reporting zero expenditure and the rest having positive values of consumption with different outcomes.

Therefore, the presence of a significant number of zero expenditure reported across households requires special attention, as inappropriate treatment leads to unbiased and inconsistent estimates. Using Ordinary Least Squares would result in biased estimates, since the estimated regression line fits the scatter of points and does not take into account the fact that the data is limited on one end.

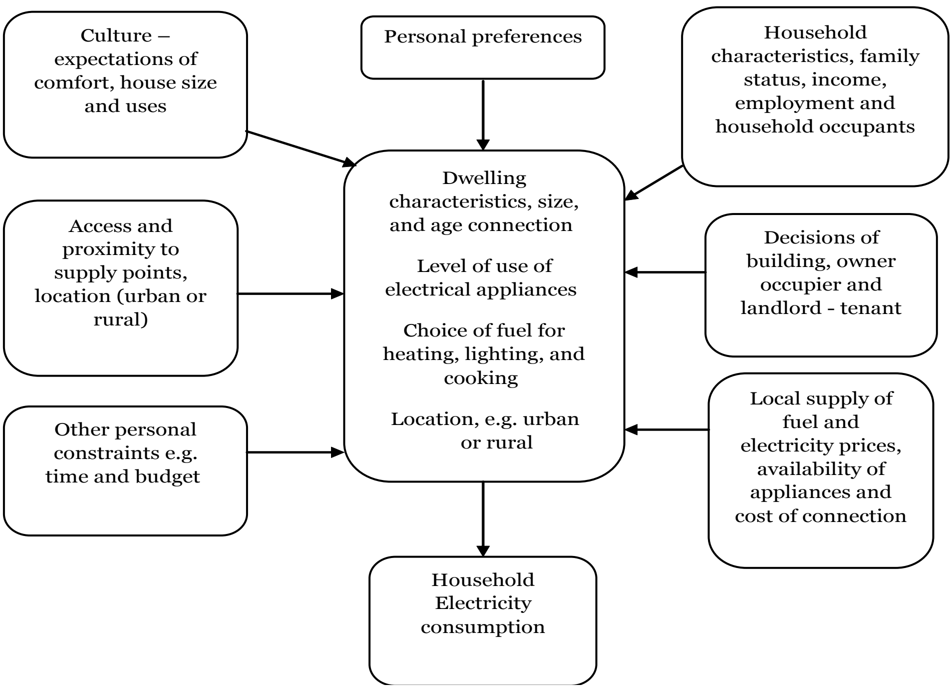
Econometric models, where the dependent variable of interest has zero observations, use a latent variable representation where each household has an unobserved or latent expenditure. For some households, this is known and is given by the actual expenditures and for some is unknown or unobserved and is denoted by zero.

3.3 Conceptual Framework

The study is modelled on the premise that observed demand and expenditure of energy services in most Kenyan households is influenced by the individual household characteristics, preferences and budget constraints they face. However, the individuals must choose to participate in the market for that commodity before deciding on how much to spend.

Figure 3.1 indicates the various factors that would affect household electricity consumption, such as dwelling characteristics, the level of use of appliances, fuel type choice, and the location of the household. In Kenya, these factors are broadly affected by personal preferences, cultural aspects, household characteristics such as family status, proximity to the supply points and other personal constraints.

Figure 3.1: Factors affecting household electricity consumption



Source: Adapted from Michaelis and Lorek (2004) and author's illustration

Households are assumed to maximize their utilities from consuming units of electricity based on the factors mentioned in Figure 3.1. These factors will be analyzed in the study using econometric methods.

3.4 Data Sources and Variables

The study uses national household energy survey of 2009. However, for the purposes of this study, the total number of observations used for the analysis is 3,339 households. A total of 326 households were not considered in the analysis due to missing information on the variables of interest.

3.5 Data Analysis

This study uses the Tobit model, which assumes there are households with zero levels of expenditure, but would like to purchase goods and services, but cannot due to the current prices and income. This implies that these are the same variables affecting the probability of non-zero observations to determine the level of a positive observation.

The Tobit model originally formulated by Tobin (1958) to analyze household expenditure on durable goods postulates that individuals with zero consumption levels do so because they are restrained by the relative prices and income. Therefore, if a sufficiently large change in income or relative prices occurred, then positive expenditures would be observed. Following Tobin (1958), the specification of the Tobit model can be written as:

(i) Consumption equation

$y^*_i = x_i\beta + \varepsilon_i$ with $\varepsilon_i \sim N(0, \sigma^2)$ ....(3)

and I = 1 ..... n.

$y_i^* = \begin{matrix} y_1^* \; if \; y^*i > 0 \\ 0 \;\; if \; y^*i \leq 0 \end{matrix}$ .... (4)

where:

y_i is actual observed level of expenditure;

y^*_i is a latent endogenous variable representing an individual or households expenditure level;

x_i is a set of individual vector of variables explaining the expenditure decision;

β_i corresponding vector of parameters to be estimated; and

ε_i respective error terms are independent and identically distributed as they are assumed to be homoskedastic, normally distributed error term.

The independent Tobit model is estimated using the maximum likelihood

$$LL_{Tobit} = \sum_{0} In\left[1-\phi\left(\frac{Xi\beta}{\sigma i}\right)\right] + \sum_{+} 1n\left[\frac{1}{\sigma i}\Phi\left(\frac{Yi - Xi\beta}{\sigma i}\right)\right]$$

technique with the log-likelihood given as follows:

where:

0 indicates the summation over the zero observations in the sample (y_i=0);

+ indicates the summation over the positive observations (y_i>0);

Φ and φ indicates the cumulative distribution function for a standard normal random variable and a standard normal cumulative distribution function (cdf) and probability density function (pdf), respectively; and

The Tobit model has been used in analysis of petroleum expenditures (Nolan, 2003).

However, Eakins (2013) argues that since the Tobit model assumes the non-consumption observations are as a result of budget constraints, it could be restrictive in certain analyses. For instance, some consumers may deliberately refrain from consuming a commodity due to personal reasons.

The other model used in the analysis is the probit model proposed by Bliss (1934) and further refined by Finney (1952). The original model suggested the use of units or probit(s) obtained from the normal probability function to represent the probability that an event would occur given some observed characteristics. The use of binary choice models is based on an underlying behavioural assumption of the dependent variable called a latent variable (White, 2008; Sibuya, 1961). The formulation of the latent variable implies that the focus of analysis is in the effect of χ_i on the Y*.

Latent variable model can be determined from the following equations:

$$Y_{i2}^{*} = x_i\beta + \varepsilon_i \quad \text{.......(5)}$$

$$d = \begin{cases} \dfrac{1 if y_{i1}* > 0}{0 if otherwise} \end{cases} \quad \text{.......(6)}$$

where

Y_{i2}* is the latent endogenous variable representing an individuals' or households' consumption decision;

χ_i is a vector of variables explaining the expenditure decision;

ε_i is respective error terms distributed as U_i ~ N(0,1); and

d is an unobserved or the latent variable.

The independent probit model is estimated using the Maximum Likelihood technique. The technique looks at every different possible value of β and chooses the most likely estimate to produce the distribution of the dependent variable and is given as follows:

$$LL = \sum{}_0 \ln\left[1 - F(X_i\beta\right] + \sum \ln\left[F(X_i\beta\right] \quad \text{...(7)}$$

where

$$F(Xi\beta) = \Phi(Xi\beta) = \int_{-\infty}^{Xi\beta} \frac{1}{\sqrt{2\Pi}} \exp\left\{-\frac{1}{2}e^2\right\} dt \quad \text{...(8)}$$

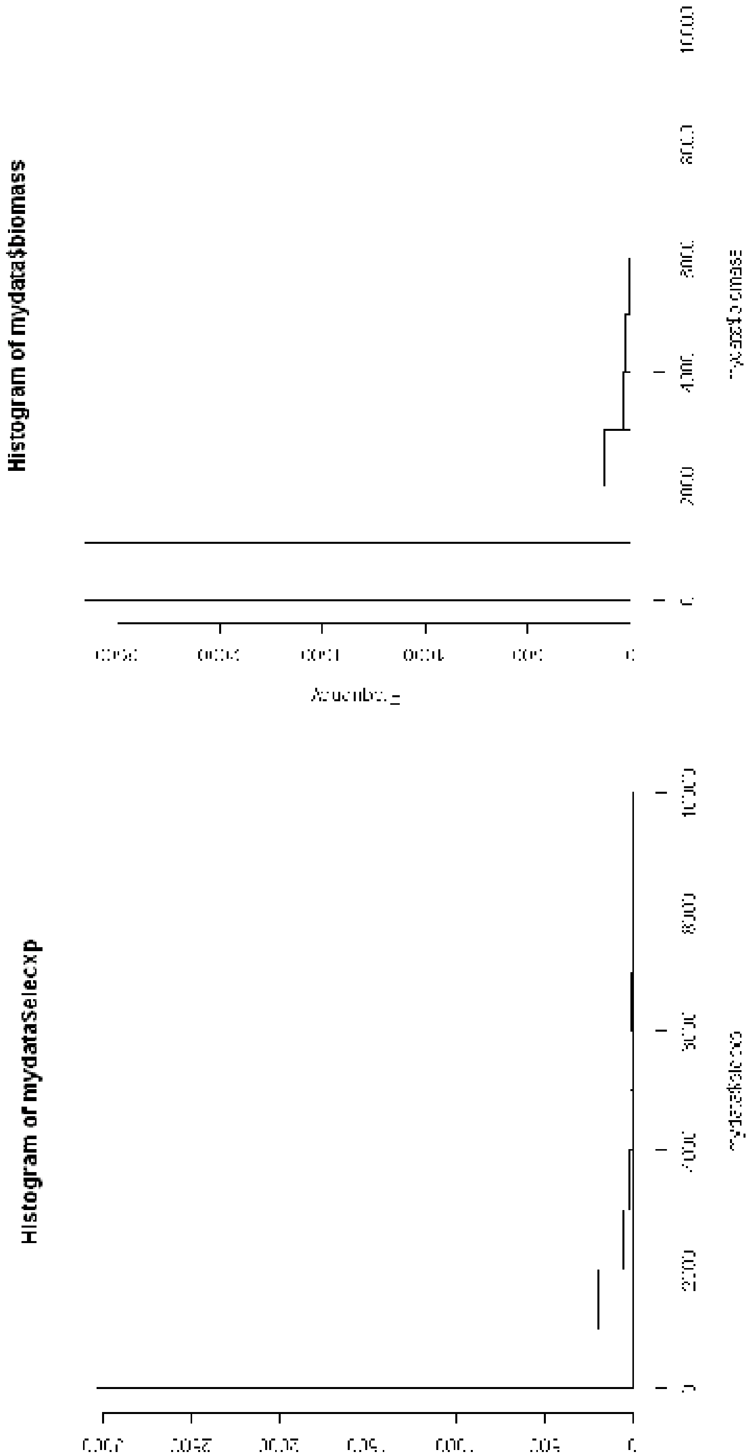
The probit model was therefore used in addition to the Tobit model, and the data analysis was carried out using R-statistical software and STATA.

3.6 Descriptive Statistics

The data had 66.3 per cent of households recording zero expenditure in electricity. The significant number of zero observations indicates the level of access to electricity at around 33.0 per cent. Figure 3.2 indicates the expenditure used by the households on both biomass and electricity in Kenya shillings, where "mydata$elecxp" is the expenditure on electricity, whereas "mydata$biomass" is the expenditure on material residues, biomass and charcoal.

Figure 3.2 shows that a large number of households spend less than Ksh 1,000 on both electricity and biomass per month. However, it is important to note that the households that recorded zero expenditure in electricity were 66.3 per cent compared to 27.0 per cent in biomass. Similarly, the average expenditure on electricity is Ksh 337.6, which is lower than the average monthly expenditure on biomass of Ksh 666.0 according to the data set. The mean household size is five members, with an average monthly household expenditure of Ksh 14,538. The statistics indicate that, on average, Kenyan households spend less on electricity compared to biomass. The data used also had 65.0 per cent of the households surveyed living in rural areas.

Figure 3.2: Histogram on expenditure levels on electricity and biomass



4. Analysis and Discussion

4.1 Selection of Variables

Available literature suggests that the location, tenancy, occupation, household size and type of house, whether semi-permanent, permanent or temporary, influence the level of monthly expenditure on energy services (Eakins, 2013). Table 4.1 indicates the variables used and the expected signs.

In the analysis, household expenditure is considered as the proxy for household income. The main assumption is that households spend all their income and make no savings. The dependent variable is the expenditure on electricity, which is influenced by location, tenancy, marital status, employment, expenditure on biomass, household income and the type of house (dwelling).

4.2 Model Specification

The following equation has been estimated using the maximum likelihood estimation method.

$Y=\alpha+\beta(area)+\beta(tenancy)+\beta(marit)+\beta(agric)+\beta(biomass)+\beta log(hh\_cum)+\beta log(hh\_cum))2+\beta(hse\_type)+\varepsilon$

where:

Table 4.1: Explanation of variables

Variable	Acronym	Explanation/measure	Expected sign
Electricity consumption	Y	Expenditure on electricity	
Location	Area	0 if urban, 1 if rural	+
Tenancy	Tenancy	0 if rented, 1 if otherwise	+
Marital status	Marit	0 for married, 1 if otherwise	+
Employment	Agric	0 if household head is involved in agriculture	-
Biomass	Biomass	Amounts spent on biomass fuel sources	+
Income	Hh_cum	Per capital household income	+
House type	Hse_type	1 for permanent, 2 semi-permanent, and 3 temporary	+

Source: Author's illustration

Y is expenditure on electricity;

Area is location 0 for urban, 1 otherwise;

Tenancy is 0 for rented, 1 owner occupier;

Marit–0 for married, 1 else;

Agric–0 household head involved in agriculture, 1 if otherwise;

Biomass–expenditure on biomass;

Hh_cum–scaled per capita household income obtained by log (Mean(hhincome/ hhsize)); and

Hse_type–0 for permanent; 1, semi-permanent; and 2, temporary.

4.3 Specification Tests

Lin and Schmidt (1984) suggest the use of Lagrange Multiplier (LM) test for Tobit model, where the same parameters determine the probability of limit observation and also the level of positive observations. However, the authors suggest that test for equal parametization of Cragg model be done using likelihood ratio (LR) test. The following estimations were carried out to determine the model that best explains the data and the analysis.

Table 4.2 indicates that most of the variables selected are significant at 95 per cent level. The likelihood ratio test was conducted to determine the variables for the two models, and the results indicate that at two degrees of freedom, the χ_2 is 9.010 and the p-value is 0.0115. The study concludes that there is no significant difference between the two models, and either model can be used in the analysis.

Goodness of fit measure

The goodness of fit measure indicates that the model better explains the data set than a model with the intercept only. In this case, the pseudo R-squared shows that the explanatory variables in the model only explain 6.5 per cent of the variations in the dependent variable in electricity expenditure. However, using the likelihood ratio test, the model explains the data but it will have to be tested against other models that can be used in such.

Hypothesis testing for goodness of fit

H_0=the model does not explain the data; and

H_1=the model explains the data and is better that the model is with the intercept only.

Table 4.2: Tobit estimation results

Model 1				Model 2		
Parameter	**Estimate**	**Marginal Effect**	**Significance**	**Estimate**	**Marginal Effect**	**Significance**
Area	-735.259 (97.944)	-178.770 (19.257)	***	-756.741 (76.452)	-184.943 (19.198)	***
Tenancy	-319.014 (76.712)	-77.565 (18.27)	***	-349.022 (75.248)	-85.299 (18.182)	***
marit	277.774 (80.845)	67.538 (19.72)	***	285.298 (80.481)	69.725 (19.635)	***
biomass	-0.115 (0.039)	-0.280 (0.009)	**	--	--	
agric	-381.432 (84.476)	-92.741 (20.429)	***	-394.454 (84.510)	-96.402 (20.488)	***
hhsize	216.071 (18.415)	52.535 (4.567)	***	202.657 (17.842)	49.529 (4.422)	***
log(hh_cum)	1299.006 (52.306)	315.840 (13.188)	***	1274.58 (50.685)	311.501	***
I(log(hh_cum)^2)	-37.303 (37.517)	-9.070 (9.018)		--	--	
logSigma	7.197	--		7.198	--	

Source: Author calculations

Using the results from the LM test:

Model 2

Y=α+β(area)+β(tenancy)+β(marit)+β(agric)+β(biomass)+βlog(hh_cum)+β log(hh_cum))^2*+β(hse_type)+ε*

Model 3

$Certified=\beta_0+U_1$

Since the calculated LM χ2 (1,457.7) and a significantly low p-value, the study fails to reject the null hypothesis and concludes that the model does not explain the data.

Table 4.3: Probit estimation results

Variable	Estimate	Marginal effect	Std.Error	z-value	Pr(>|z|)	Significance
Intercept	-0.2771	-0.097	0.029	-3.35	0.0009	***
area	-0.8351	-0.292	0.022	-13.388	< 2e-16	***
Tenancy	-0.4388	-0.153	0.021	-7.257	0.0000	***
marit	-0.3027	0.106	0.023	4.632	0.0000	***
biomass	0.0001	0.000	0.000	0.479	0.6321	
agric	-0.3225	-0.109	0.021	-5.230	0.0000	***
hh_cum	0.4347	0.152	0.013	11.848	< 2e-16	***

Source: Author's calculation

4.4 Diagnostic Tests

To compute for a goodness of fit measure, the Pseudo R-squared was obtained to be 27.4 per cent, which is higher than the value obtained for the Tobit model.

Secondly, the per cent correctly predicted is obtained to be 57.44 per cent. This is the percentage of times that the expected value of the dependent variable is equal to the observed value, such that $\hat{y}_i=y_i$. This, therefore, implies that the model correctly predicts 57.44 of the outcomes in the results table. A likelihood ratio test was done to select the probit model for analysis, to test whether there exists a significance difference between the probit model and the Tobit model. The results indicate that there are significant differences between the two models. The χ2 =17,739; df=1; p-value<2.2e-16, and a lower p-value, hence reject the null hypothesis that there is no significant difference between the probit model and the Tobit model.

Hypothesis testing for heteroskedasticity

Wooldridge (2009) suggests that in the presence of heteroskedasticity, the standard errors that are used to calculate test statistics are biased and not valid in making conclusions of whether a particular variable is significant. Guided by this fact, it is informative to test for heteroskedasticity before proceeding with our analysis.

H_0=the variance of the error term is constant across all population segments (homoscedasticity exists); and

H_1=the variance of the error term is not constant across all population segments (heteroskedasticity exists).

The Breusch-Pagan test for heteroskedasticity

Wooldridge (2009) states that the rejection rule for homoskedasticity is that if the p-value is smaller than the chosen significance level, the null hypothesis of homoskedasticity is rejected. Using the results from the Breusch-Pagan test indicated as $\chi 2=272.3063$, df=6, p-value<2.2e-16, the results show that the p-value is lower than the 5 per cent and 10 per cent significance level, hence heteroskedasticity. The problem of heteroskedasticity was solved using the Heteroskedastic Corrected Covariance Matrix (HCCM) to make inference as suggested by Long and Ervin (1998). The results are as shown in Table 4.4.

4.5 Key Findings

The results indicate that location of household, household head marital status, household head involvement in agriculture, per capita household income, and the tenancy type are significant in explaining household expenditure on electricity. It is also important to note that the expenditure on biomass is not significant in explaining the overall household expenditure on electricity.

4.6 Discussion

The results from the study indicate that expenditure on electricity for households located in rural areas decreases by 0.29 units compared to households located in urban areas. This can be explained by the fact that in urban areas, the possibility of staying in houses connected to electricity is higher compared to rural areas due to numerous commercial and business activities. However, the presence of slums in major cities might reduce the possibility of staying in houses connected to the grid, hence reduced expenditure on electricity. The second most visible finding

Table 4.4: Estimates of Heteroskedastic Corrected Covariance Matrix (HCCM)

Variable	Estimate	Marginal Effect	Std.Error	z-value	Pr(>|z|)	Significance
Intercept	-0.2771	-0.097	0.1624	-1.7069	0.0009	.
area	-0.8351	-0.292	0.0983	-8.4877	< 2e-16	***
Tenancy	-0.4388	-0.153	0.0878	-4.9423	0.0000	***
marit	-0.3027	0.106	0.0958	3.1576	0.0000	**
biomass	0.0001	0.000	0.0000	0.3197	0.6321	
agric	-0.3225	-0.109	0.0894	-3.6045	0.0000	***
hh_cum	0.4347	0.152	0.0100	4.3401	< 2e-16	***

Source: Author's calculation

from the study results is that the married are likely to spend additional 0.10 units in electricity consumption compared to the single and the unmarried. The additional units can be explained by the fact that households have at least other individuals that they are staying with, hence consuming more units.

At the same time, it can be observed that involvement of household head in agriculture reduces electricity consumption by 0.10 units, compared to those involved in other kinds of employment. We can infer that despite a growing trend towards agribusiness initiatives, a large population of those involved in agriculture are likely to use biomass sources for their energy needs as opposed to electricity. It is also important to note that increased per capita household income increases the consumption of electricity by 0.15 units. This can be explained by the fact that the households can afford a stock of electric appliances such as refrigerators, television sets, iron boxes and water heaters compared to households with low per capita income.

Lastly, it can be observed that the tenancy type influences the amount of electricity consumption. Those living in owner occupier houses are most likely to increase their consumption levels by 0.15 units. It is important to point out that there are also numerous challenges to increasing the electrification rate. For instance, inadequate incentives to poor households in getting connected to electricity, high connection costs, and focus on grid connection has led to low public awareness on the various attempts to increase electrification rates in Kenya. These include alternative technologies such as installation of solar panels and off grid solutions.

5. Conclusion and Policy Recommendations

5.1 Conclusion

It is worth noting that since electricity is important in our day to day life, access is an indicator of the quality of life within a society. This is despite the numerous challenges facing the energy sector, such as low connection rates to electricity, insufficient capacity, poor reliability and high tariff rates. It is, therefore, important to obtain accurate information on the factors that influence households decision on the amount spent on electricity.

The study is motivated by the increased level of investment in the energy sector, which seeks to raise an additional 5,000MW in the country's generation capacity by the year 2017. Similarly, increased attention has been placed on improving the level of electricity access in the country. This has resulted into increased attention on influencing the household electricity consumption patterns by adjusting the prices paid for connection and tariffs.

The results from the regression indicate that location of household, household head, marital status, household head's involvement in agriculture, per capita household income, and house type are significant in explaining household expenditure on electricity. However, the tenancy type and the expenditure on biomass is not significant in explaining overall household expenditure on electricity. In summary, efforts to expand electricity access are likely to be more successful when the above issues are taken into consideration.

5.2 Policy Recommendations

The study findings have the following policy implications:

1. Households located in rural areas are less likely to spend more compared to their urban counterparts. Therefore, to increase the likelihood of rural households being connected to electricity, the Rural Electrification Authority, Kenya Power and Lighting Company, and the county governments should initiate basic electricity provision to poor rural households. This can be implemented through the establishment of county electricity distribution units as provided for in the Constitution 2010. To increase access in rural areas, there is need to review the fixed charge tariff for low income consumers and lower the connection fee.
2. The results indicate that the tenancy type and per capita household income significantly affect the expenditure on electricity. Therefore, there should be some subsidization of the rural electrification programme. For instance,

provision of basic electricity by the rural electrification authority and the counties can help poor households in accessing electricity at affordable rates.

3. With plans underway to establish an energy efficiency and conservation agency, there is need to develop a national strategy that would compel counties to implement education and training of landlords and tenants on energy saving efforts. This should include additional funding to schools and low income areas.

5.3 Limitations of the Study and Suggestions for Future Research

The scope of this study was limited to estimating the determinants or factors that influence household electricity consumption. However, it will be valuable to conduct research on the energy access index so as to provide an understanding of how the country is fairing in terms of energy access.

Secondly, in the absence of many distribution companies in the country, estimating the efficiency of electricity distribution has been somewhat difficult, hence it would be important to determine the efficiency scores once the county electricity companies are established.

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