Discussion Paper Series

The KENYA INSTITUTE for PUBLIC
POLICY RESEARCH and ANALYSIS

Intensity of Energy Consumption among Kenya's Households

Charity Kageni Mbaka

DP/209/2018

THE KENYA INSTITUTE FOR PUBLIC
POLICY RESEARCH AND ANALYSIS
(KIPPRA)

YOUNG PROFESSIONALS (YPs) TRAINING
PROGRAMME

Intensity of Energy Consumption among Kenya's Households

Charity Kageni Mbaka

Kenya Institute for Public Policy Research and Analysis

KIPPRA Discussion Paper No. 209
2018

KIPPRA in Brief

The Kenya Institute for Public Policy Research and Analysis (KIPPRA) is an autonomous institute whose primary mission is to conduct public policy research leading to policy advice. KIPPRA's mission is to produce consistently high-quality analysis of key issues of public policy and to contribute to the achievement of national long-term development objectives by positively influencing the decision-making process. These goals are met through effective dissemination of recommendations resulting from analysis and by training policy analysts in the public sector. KIPPRA therefore produces a body of well-researched and documented information on public policy, and in the process assists in formulating long-term strategic perspectives. KIPPRA serves as a centralized source from which the Government and the private sector may obtain information and advice on public policy issues.

Published 2018

Bishops Garden Towers, Bishops Road
PO Box 56445-00200 Nairobi, Kenya
tel: +254 20 2719933/4; fax: +254 20 2719951
email: admin@kippra.or.ke
website: http://www.kippra.org

ISBN 978 9966 058 96 6

The Discussion Paper Series disseminates results and reflections from ongoing research activities of the Institute's programmes. The papers are internally refereed and are disseminated to inform and invoke debate on policy issues. Opinions expressed in the papers are entirely those of the authors and do not necessarily reflect the views of the Institute.

This paper is produced under the KIPPRA Young Professionals (YPs) programme. The programme targets young scholars from the public and private sector, who undertake an intensive one-year course on public policy research and analysis, and during which they write a research paper on a selected public policy issue, with supervision from senior researchers at the Institute.

KIPPRA acknowledges generous support from the Government of Kenya, African Capacity Building Foundation (ACBF), and the Think Tank Initiative of IDRC.

Abstract

The primary objective of this paper is to examine the effect of households' socio-economic characteristics presumed to affect consumption intensity on various energy sources, and establish variations in energy consumption intensity for cooking and lighting among rural and urban areas in Kenya. The study used a micro level data set, the KIPPRA National Energy Survey, to analyze themes under study. The study also used robust analysis by conducting diagnostic and specification tests to identify the most suitable estimation technique. Estimation of energy consumption equations and analysis of the associated discrete marginal effects was conducted using Tobit, double-hurdle model and One way Anova. The discrete unconditional marginal effects indicated that average monthly household income, gender, education level, location (rural or urban), and household dwelling unit significantly affect the consumption intensity on clean and non-clean energy sources. On urban/rural variations in energy consumption intensity, the study found that there was a significant difference in the kerosene consumption intensity for lighting and also significant differences on the consumption intensity for cooking using LPG, wood fuel and charcoal. From the study findings, this study recommends that for optimal and sustainable consumption of clean energy sources, there is need to create awareness among household heads with low literacy levels on the importance of consuming clean energy sources. Embedment of energy consumption strategies such as provision of incentives in acquiring household energy devices such as water pumps in rural areas can boost consumption and productivity, whose benefits are twofold; for households and the power utility.

Abbreviations and Acronyms

ANOVA	Analysis of Variance
CM	Condition Moment
GHGs	Green House Gases
HH	Household
HHH	Household Head
IEA	International Energy Agency
IEE	Intelligent Energy Europe
KIPPRA	Kenya Institute for Public Policy Research and Analysis
KNBS	Kenya National Bureau of Statistics
LM	Lagrange Multiplier
LPG	Liquefied Petroleum Gas
LR	Likelihood Ratio
OECD	Organization for Economic Cooperation and Development
SDG's	Sustainable Development Goals
SSA	Sub-Saharan Africa

Table of Contents

1. Introduction

1.1 Background

Access to, and adequate consumption of, clean and affordable energy sources is essential for a nation's overall socio-economic and human development (World Bank, 2013). Consumption of clean energy sources among households is associated with provision of the most basic facilities required for the sustenance of human life, including food, shelter, clothing, health services and also for productive gains. Therefore, the pursuit for sustainable socio-economic development at the household level is directly linked with the quality of energy consumed and the consumption intensity (AGECCU, 2010). At micro-level, energy consumption intensity refers to the proportion of energy consumed from a particular source compared to the total household energy consumption (Behera and Ali, 2016).

The global totals indicate that about 2.7 billion people consume solid biomass for cooking and lighting needs. However, energy consumption patterns vary distinctively across and within regions. For instance, transition economies and countries belonging to the Organization for Economic Cooperation and Development (OECD) have virtually universal (99%) consumption level on clean energy sources (International Energy Agency - IEA, 2016) (Table 1.1). About 66 per cent of the population in Southeast Asia relies on clean energy sources. On the contrary, energy consumption patterns in Sub-Saharan Africa (SSA) are of global concern as they dominate the global totals, with roughly 80 per cent of the population consuming solid biomass as opposed to barely 35 per cent consuming electricity, which is one of the primary clean energy sources. North Africa region stands out with about 99 per cent of the populace consuming clean energy sources (IEA, 2016). It is projected that if the current scenario persists, nearly 880 million people in SSA will be consuming non-clean energy for domestic use in the year 2020 (Lambe et al., 2015). High consumption intensity on non-clean energy compromises opportunities at household level and is a major setback in fostering a nation's pathway to transitioning to clean energy sources (Nababan, 2015). The energy sector in Sub-Saharan Africa (SSA) is yet to meet the energy needs and aspirations of its citizens (IEA, 2014). The primary concern is on how to ensure sustainable access and consumption of adequate and affordable clean energy sources to the vast deprived population.

Table 1.1: Inter-regional disparities in consumption of clean and non-clean energy sources

Region	Population consuming non-clean energy sources (%)	Population consuming clean energy sources - electricity (%)
Global	25	84
OECD	0.01	100
Latin America	14	95
North Africa	4	99
Middle East	3.7	92
South East Asia	44	64
Sub-Saharan Africa	80	35
East Africa Region	72	36
Kenya	69	46

Source: International Energy Agency (2016)

Kenya's current energy scenario is not different from that of other developing countries. Biomass is the largest primary energy source in Kenya, accounting for about 69 per cent of total primary energy consumed. Projections indicate that it is likely to remain a dominant energy source in Kenya (Intelligent Energy Europe, 2016). Other major energy sources accounting for total energy consumed include petroleum products and electricity at 22 per cent and 9 per cent, respectively (Institute of Economic Affairs, 2015). Roughly, 80 per cent of the population in Kenya relies on biomass sources to meet their cooking and heating needs (Africa Progress Panel, 2015). Other sectors relying on biomass include industries and small and micro-enterprises (Mapako and Mbewe, 2013). Non-clean energy sources considered for this study include material residue, wood fuel charcoal, and kerosene, which are primarily used for cooking and lighting purposes in urban and rural areas.

Kenya's progress in access to electricity has increased, with an additional 38.2 per cent of households having been connected through the rural electrification programme in 2016 (KNBS, 2017). In spite of the considerable increase in the number of customers having access to electricity, intensified and maximal consumption of clean energy at the household level has remained minimal, with many households consuming non-clean energy sources for various functions. It is projected that consumption of non-clean energy for cooking, heating and lighting is expected to rise significantly among emerging economies (Harvey and Pilgrim, 2011). Productive energy needs are likely to remain unmet for hundreds of millions of households, unless there is significant progress in ensuring access to and optimal utilization of efficient, reliable and affordable energy sources.

In view of the adverse effects caused by dependency on non-clean energy sources to the environment and sustainable development, a comprehensive understanding of households' energy consumption portfolio is crucial. Therefore, this study examines households' socio-economic factors influencing consumption intensity on various energy sources and variations in energy consumption intensity for cooking and lighting across rural and urban areas. This study is anticipated to be an imperative baseline in design of appropriate evidence-based energy policies with the potential to spur sustainable energy consumption in the country.

1.2 Problem Statement

Access to and consumption of clean and efficient energy sources is one of the fundamental pillars of Kenya's development agenda and Sustainable Development Goals (SDGs). The country targets that by 2030, all Kenyans should have access to clean energy sources. Plans to accelerate uptake of clean energy sources in Kenya have gained momentum in the recent past. Energy access projects such as rural electrification programmes, and the last mile connectivity programme have significantly improved access to clean energy sources among households.

Despite the considerable gains in reforming the energy sector in Kenya, hurdles in the household clean energy consumption are evident. Households account for the highest proportion of the total energy consumption in the country, yet the consumption is mainly from non-clean energy sources. This scenario is more evident among households with multiple energy use where consumption intensity on clean energy sources is constantly low rated when compared to non-clean energy sources.

High consumption intensity on non-clean sources has implications to the overall growth of the economy. It hinders growth in demand for productive activities such as small home enterprises and also the overall welfare benefits at the household level (World Bank, 2013). Additionally, indoor pollution from exposure to biomass smoke impacts negatively on human health. Close to 15,000 lives are lost annually in Kenya and the implications are severe among women and girls, who are typically responsible for these chores (Lambe et al., 2015). If action is not taken, by year 2030, projections indicate that 42,000 people will die annually from acute lower respiratory infections and chronic obstructive pulmonary disease linked to solid fuel cooking in Kenya (Bruce et al., 2015).

Apparently, there is limited information focusing on how household socio-economic factors affect consumption intensity on various energy sources with the aim of informing policy. Numerous studies focus on the decision to choose different sources that do not assess household's consumption intensity on various energy sources. In light of this, there is need to examine household's factors affecting consumption intensity on various energy sources and establish variations in energy consumption intensity for cooking and lighting.

1.3 Research Objectives

This study broadly seeks to evaluate the intensity of energy consumption among Kenya's households.

1.4 Specific Objectives

Specifically this study seeks to:

(i) Determine the factors affecting households' consumption intensity on various energy sources in Kenya.

(ii) Establish variations in household energy consumption intensity for cooking and lighting in urban and rural areas in Kenya.

1.5 Research Questions

(i) How does household's socio-economic factors affect the consumption intensity on various energy sources in Kenya?

(i) How do consumption intensity of various energy sources for cooking and lighting vary across rural and urban areas in Kenya?

1.6 Justification and Policy Relevance

One of the strategic development agenda in the 21st century is on promoting the use of clean energy sources among different sectors. The Kenya Vision 2030 and the Second Medium Term Plan (2013-2017) are in line with the Sustainable Development Goal (SDG) 7, which envisages access to and consumption of affordable, reliable and sustainable energy for all by the year 2030. In the recent past, a lot of attention has been on accelerating energy distribution networks and access while the consumption component has been mildly contemplated. This study is important as it unveils the major factors affecting consumption intensity at a household level, aimed at serving as a basis for promoting programmes geared towards intensification in consumption of clean energy sources among households in Kenya.

1.8 Scope and Limitation of the Study

The study was conducted in Kenya, mainly focusing on consumption intensity on various energy sources in the country. Analysis was on the main energy sources utilized by the households, including material residue, wood fuel, charcoal kerosene, Liquefied Petroleum Gas (LPG) and electricity. The definition of clean energy sources is confined to efficient and low-carbon energy sources that emit less GHGs during their use. LPG and electricity are considered as clean energy sources.

2. Literature Review

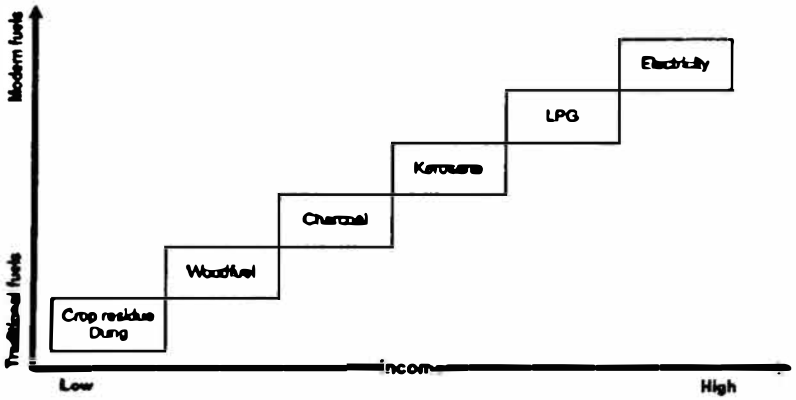
2.1 Theoretical Literature

2.1.1 Theoretical approaches to households' energy consumption intensity

Household energy consumption intensity is influenced by a variety of highly inter-related economic and social factors, such as household preferences, budget constraints and household characteristics (Puzzolo et al., 2013). The main theoretical literature related to energy consumption intensity at household level is based on energy transition ladder and fuel stacking theories. Application of these theories to this study is conferred by Wooldridge (2015), whereby the size and nature of the factors affecting energy choice and consumption at household level are not different.

The energy ladder hypothesis is a prominent model of explaining household energy use and consumption in developing countries (Lee, 2013). The energy ladder describes a pattern of fuel substitution as a household's economic situation changes. The energy preference ladder ranks electricity and LPG as modern sources considered superior fuels due to their high efficiency, cleanliness and convenience of storage and usage (Figure 2.1). Modern energy sources are located higher up the ladder than biomass and transitional sources such as kerosene. This model postulates that, in response to higher income households transitions from traditional sources to modern and efficient energy sources such as LPG and electricity, quantity and quality of energy consumed is based on household income.

Figure 2.1: The energy ladder theory



Source: Leach (1992)

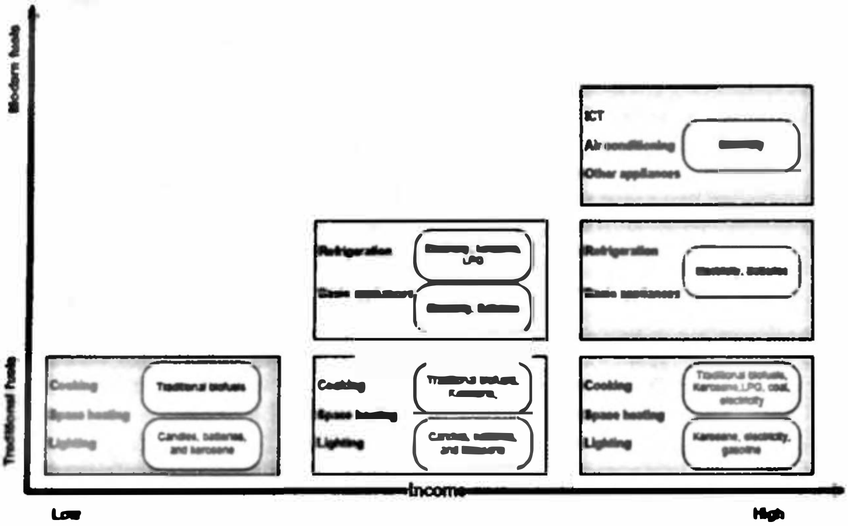
2.1.2 Fuel stacking theory

The energy ladder model explains the income dependency of energy source choices. This theory has been criticized as being insufficient to represent actual energy choice and consumption dynamics (Kowsari and Zerriffi, 2011). Complexities of switching process as economic aspects are linked with social and cultural issues, therefore giving rise to the fuel mix or stacking model. This model postulates that household fuel switching is not unidirectional and people may switch back to non-clean energy sources even after adopting modern energy carriers. Fuel stacking indicates that fuels are imperfect substitutes and, often, specific fuels are preferred for specific tasks. Instead of simply switching between fuels, households choose to use a combination of fuels and conversion technologies depending on budget, preferences, and needs (Foell et al., 2011). A study of Mexican households by Masera et al. (2000) confirms this model by showing that as households welfare improves, there is also a change in energy which is characterized by accumulation of various energy sources rather than as a linear switching between fuels in a process known as fuel stacking.

Fuel stacking framework exemplifies that households will always allocate their disposable income among the different goods or combination of goods that will maximize utility (an assumption of neoclassical economic theory). A household expenditure may consist of three main categories, namely: food expenditure, clothing expenditure and energy expenditure. The energy expenditure is further broken into expenditures associated with the different forms of energy: wood fuel, charcoal, kerosene, LPG and electricity (Figure 2.2).

The characteristics of the energy ladder model and the energy mix model provide us with basis by which we conceptualize our framework for household energy consumption in Kenya. The energy staking model is used as an appropriate framework to analyze the consumption intensity on various energy sources in Kenya. The model allows inclusion of alternative variables to the widely used econometric modeling rooted in the neoclassical tradition by considering variables, such as the urbanization spectrum. Urbanization is a major contributor to the differences in energy consumption. According to O'Neil et al. (2012), urbanization influences economic growth and leads to a rapid transition from biomass use in developing countries.

Figure 2.2: The illustration of energy stacking



Source: Barnes and Floor (1996)

2.2 Empirical Literature

2.2.1 Factors affecting household energy consumption intensity

Empirical literature on factors influencing consumption intensity on various energy sources is limited. Most studies focus on factors influencing household energy choice. This study uses the available empirical literature that closely links to consumption intensity at household level. Therefore, this study will focus on energy consumption studies, methodologies adopted, key findings and analyses. The determinants of energy consumption in developing countries have been explored extensively in literature by applying a range of empirical methods, which focus on take up and usage of various energy sources at the household level. A study by Africa et al. (2008) on domestic energy use of low income households reported on the domestic energy preferences and six years trends for low income households in Grahamstown, Eastern Cape (South Africa). Using descriptive statistics and non-parametric tests, the findings revealed pertinent constraints in shifting to clean energy by low income earners, including poor service delivery by the local authority and financial constraints on electricity generation.

Household energy consumption is influenced by a wide variety of social, economic and behavioural technological aspects of energy use. Rahut et al. (2017) analyzed the factors influencing consumption intensity on various energy sources at household level. Using household level panel data, the author applied the Tobit model to estimate the factors influencing consumption intensity. According to the findings, household energy consumption intensity for cleaner energy sources such as LPG and electricity increases with increase in household income, wealth, access to electricity and proximity to markets, and education.

Daioglou et al. (2012) investigated the factors influencing household energy consumption. The study findings indicate that income influences household's consumption on various energy sources. With increased income, the opportunity cost of time also increases along with purchasing power, and consequently the household's willingness to pay for better quality fuel and greater convenience of use increases. Therefore, with an increase in income, a household is more likely to move from using non-clean energy sources such as firewood to clean energy sources such as LPG and electricity (Daioglou et.al., 2012).

Different tools of econometric analysis have been applied in various energy consumption studies. For instance Lee (2013) and Svoboda (2013) used Ordinary Least Square (OLS) regression to assess the determinants of household electricity consumption. Variables, including number of household members, total family income, municipality of residence, expenditure per capita, and age of household head were significant and positively related to electricity consumption at household level. Factors such as household perception of wood consumption, time when the dwelling was built, level of education of the household head, and fire wood price were significant and negatively influenced electricity consumption. However, this study's focus was on only electricity consumption, thereby neglecting other aspects such as consumption of fuel wood, material and kerosene and liquefied natural gas.

Koshala et al. (1999) also used the same OLS model to examine the determinants of kerosene consumption in Indonesia. Conversely, Osiolo (2009) used the same OLS method to examine the determinants of fuel wood expenditure in Kenya. Only age of the household head and the level of education of household head were found to have a positive significant relationship with household fuel wood expenditure. However, the major limitation is that OLS is incapable of estimating limited dependent variables.

Nlom and Karimov (2014), Eakins (2013) and Mensah and Adu (2013) applied ordered logit/probit models to examine the factors that influence household energy choice to more clean energy sources. The results indicate that income, firewood price, education level of household head, share of dwelling with other people, urban household and access to LPG were found to have a positive relationship with the probability of adopting cleaner energy. While other variables such as electricity price, price of kerosene, age of the household head, household size, gender (male) of the household head, and access to fire wood had negative effects on the probability of the use of clean and efficient fuels.

On the other hand, multinominal logit model is used to analyze household energy choice decision (Song and Tan, 2012; Couture et al., 2012). The energy categories often used by such studies as the dependent variables include biomass, kerosene, electricity and liquefied petroleum gas. Household income, age of the household head, level of education of the head of the household, household size, the dwelling ownership, occupation of the household head, number of rooms, number of years the house was built, size of the resident, and ratio of female in the household were found to have a positive relationship with the household decision to use fire wood instead of kerosene or electricity or gas (Song and Tan, 2012). Other studies found these variables to have a negative relationship with fire wood use, thereby encouraging adoption or use of electricity and gas (Couture et al., 2012). Different conclusions were arrived at by these studies because they were carried out in different locations' data sets. This signifies that energy consumption behaviour among households varies from one region to another and not all factors are equally important in determining energy consumption in different areas and regions.

Studies have also documented that gender and the size of the household significantly influence the degree of dependency on various energy sources. For instance, a study by Behera (2015) indicated that education is a strong determinant of fuel switching as increasing levels of education are associated with higher probability of using modern energy sources and lower incidence of solid fuels. Further, as the education level of the household head and spouse increases, consumption of fuel wood and other conventional fuels reduces because education prejudices households in favour of modern fuels, and improves decision-makers' understanding of the costs and benefits of modern energy sources, and in particular their health benefits.

The size of the household has a negative impact on the probability of dependency on clean energy sources, although the relationship can be non-linear (Rao and Reddy, 2007). The number of members in the household positively affects the use of fire wood and self-collected fuels, because these do not have a monetary cost; their collection and use is guided by opportunity costs that depend on the productivity of labour in fuel wood collection vis-à-vis the opportunity cost of time spent in alternative employment (Heltberg, 2005). Moreover, affordability of an energy source is determined by its price, which is an important factor in household energy use in terms of the extent of consumption (Wuyuan et al., 2008). Access to markets for modern energy sources is also recognized as a major factor affecting the degree of dependence on clean energy at the household level. The effect can be observed particularly in the pattern of energy use based on distance from major trading routes and large cities (ESMAP, 2005).

2.2.2 Variations in household energy use for cooking and lighting

The main use of energy in households in developing countries is for cooking and lighting. This study concentrates on fuel sources for cooking and lighting in addressing locational variations in energy consumption. Households generally use a combination of energy sources for cooking that can be categorized as traditional (such as dung, agricultural residues and fuel wood), intermediate (such as charcoal and kerosene) and modern (such as LPG, biogas, and electricity) (Malla and Timilsina, 2014). A study by Alem et al. (2016) used three rounds of a rich panel data set to investigate the determinants of household cooking fuel choice in urban Ethiopia. Regression results from a random effects multinomial logit model suggest that households' economic status, price of alternative energy sources, and education are important determinants of fuel choice in urban Ethiopia.

A multinomial probit model was used to estimate the factors influencing use of various energy sources for cooking using firewood, charcoal and modern energy (cleaner energy including electricity, kerosene and LPG (Jumbe and Angelsen, 2011). The factors that influenced household energy choices were observed as consumption expenditure, residence (urban and rural), household size, and achievement of education levels beyond primary level, and regional location of a household.

Multinomial logit selection model as applied for household's choice of cleaner fuels for lighting, cooking and heating indicated that households with a better-educated, female head, higher level of income and in urban areas and proximity of access to clean energy have a higher probability of switching to clean energy (Rahut et al., 2017).

An ordered probit model was used to determine the factors that influence a household's choice of energy sources for lighting (Behera, 2015). The results revealed that older households are less likely to adopt electricity, solar and batteries and are more likely to adopt candles, kerosene and solid fuels as their source of energy for lighting, which suggests that younger members prefer to use cleaner energy sources than their elder counterparts. The variables for the number of adult males and females are positively and significantly associated with the use of electricity and batteries while they were negatively associated with candles, kerosene, and solid fuels.

2.6 Overview of Literature

In a nutshell, from the existing literature, many studies were conducted in both developed and developing countries on household energy consumption. However, these studies have specific limitations based on the scope covered, model used, the variables included, among others. For instance, some study findings are limited to descriptive statistics and biased samples covering either urban or rural areas. Moreover, most studies on household energy consumption focus on decision and probability to use various energy sources. Such studies treat consumption on various sources as same regardless of the quantities consumed. This study understands these limitations and uses appropriate methodological approach to cover major research gaps.

This study uses tobit model and double hurdle model due to the limited nature of the dependent variable. The independent variables considered in this study include age of household head, location, type of dwelling unit, marital status, gender, income, and level of education. A new variable introduced is the decision maker on energy consumption. The contributions of this paper to the existing body of knowledge are: first, no such energy study has been carried out using large nationally-representative household data sets to examine the factors affecting household consumption intensity in Kenya. Secondly, the study looks keenly into the consumption intensities for the most important energy source used in a household by establishing locational variations for cooking and lighting.

3. Methodology

3.1 Theoretical Framework

The theory underpinning this study is the discrete random utility theory, whereby individual consumers choose what they prefer and non-choice is associated with random factors. Following Pudney (1989) theory derived by use of discrete random preferences regimes, consumers are hypothesized to have a different preference structure than non-consumers whereby, regardless of the price and income levels, some individuals will not consume certain commodities. This indicates that zero observations are not only as a result of economic non-consumption (standard corner solution) but also determined by other socio-economic factors apart from prices and income.

3.2 Analytical Framework

According to Pudney (1989), energy consumers are hypothesized to have a different preference structure than non-consumers. The observed zero consumption reflects either the decision not to use a certain energy source or a standard corner solution and hence only potential consumers determine the parameters of energy Engle curve.

Given this background, household's utility function is as follows:

$$U = U(d_{c1}, c_2 \ldots\ldots c_n; w) \qquad 3.1$$

Where c_1 is the quantity of energy consumed (with price p_1), $c_2,\ldots,c_n$ represents other goods consumed in household, d is a binary variable equal to 1 if a household is an actual or potential consumer of a certain energy source and 0 otherwise. If d is equal to 1, every household is assumed to be a potential consumer of a particular source of energy and observed 0 is a standard corner solution. w is a vector of socio-economic factors representing the qualitative characteristic of energy consumption. Therefore, the Tobit model is applicable in this scenario.

From equation 2, we further derive the second equation separating consumers and non-consumers as:

$$U = dU^s((c_1, c_{2,\ldots\ldots,} c_n; w) + (1-d)U^{ns}(\ c_{2,\ldots\ldots} c_n; w) \qquad 3.2$$

U^s is the utility function of energy consumers (actual and potential) and U^{ns} for non-consumers. For non-consumer of certain energy sources, given that c_1 does not enter a $U^{ns}(c_2,\ldots\ldots c_n; w)$ and when $p1$ is in any case positive, the optimal energy consumption level is $c_1^* = 0$.

For actual and potential consumers of various energy sources, the optimal level of consumption is determined by solving the following constrained utility maximization equation:

$$\frac{max}{c_{1,\dots,}c_n}\{U^s(c_1,c_{2,\dots,}c_{n;}w)\}s.tp'c=m \qquad 3.3$$

Where p ` is a vector of prices (including p_1) and m is individual's (or households) budget.

Assuming the utility $U^s(c_1,c_2\dots,c_n; w)$ to be continuous, increasing quasi-concave, then the hypothetical demand for an energy source can be expressed as a demand function $f(p,m;w)$ and the corresponding consumption equation can be indicated as $g(m;w)$. The hypothetical demand and expenditure are derived from utility maximization, with only the budget constraint given household's socio-economic characteristics. However, the quantity and expenditure are also subject to a non-negativity constrain, the optimal level of consumption (e_{ci}^*) can be either an interior solution or a corner solution (that is $e_{ci}^*=max\{0,g(m;w)\}$), justifying the use of double hurdle model specification for modeling energy consumption, since it jointly accounts for both non-economic and corner solution consumption.

3.3 Econometric Specification

3.3.1 Standard Tobit model for corner solution

The Tobit model is listed among the limited dependent variable models; these models are used when there is a limit or boundary on the dependent variable. The Tobit model is applicable for censored regression and corner solution. Tobit model for corner solution is applied when the dependent variable is zero for a part of the population, but positive (and with different outcomes) for the rest of the population.

The dependent variable in this study is the intensity of consumption on various energy sources, which is a continuous proportionate variable comprised of zeros and positive (0 and +n...) observations.

The assumption for the Tobit model is that not all households consume positive amounts of particular energy sources, and that the participation decision influences the consumption levels. Therefore, households that do not use particular energy sources report zero consumption levels. With these underlying assumptions, the dependent variable is expected to comprise lots of zero values concentrated on the lower limit of the data.

According to Wooldridge (2015), presence of zero observations in the dependent variable poses difficulties when analyzing micro-data and, therefore, there is need to choose the right model for concrete results. For instance, with the aforementioned nature of the dependent variable, Ordinary Least Squares regression leads to biased results of the parameter estimates. This is because the estimated regression line simply fits the scatter of points and does not take into account the fact that the dependent variable is zero for a substantial proportion of the population and accumulation of observation at the limit of the range of the variable. The Tobit model uses a latent variable representation of the dependent variable of interest, which has zero observations.

OLS estimates are not used in this study as they are based on a sub-sample of positive expenditures, while the Tobit estimates are based on the full sample, including the zero expenditure. Secondly, even if the OLS estimates were based on the full sample, a direct comparison would still not be appropriate. In Tobit model, β_j measures the effect of x_j on E[yi* | x], where y* is the latent unobserved variable. This is obviously not directly comparable with *E[yi | x] = xβ*, from an OLS model where y_i represents observed values (Wooldridge, 2015).

The standard Tobit specification is defined as:

$$y_i^{*} = x_i\,\beta + \varepsilon_i \quad \text{with} \quad \varepsilon_i \sim N\left(0,\partial^2\right)$$
$$\text{and} \quad i = 1,\ldots n. \qquad 3.4$$

y_i* is a latent endogenous variable representing household's level of consumption (consumption intensity) for various energy sources. x_i represents households' socio-economic characteristics weighty in explaining households' consumption intensity. The set of variables include age, education level, marital status, and location of the household, monthly income, decision maker on energy expenditure and type of dwelling unit, β is a corresponding vector of parameters to be estimated, ε_i is assumed to be homoscedastic, and normally distributed error term.

Where y is a latent variable in that it is observed for values greater than τ and censored otherwise.

The observed *y* is defined by the following measurement equation:

$$y_i = \begin{cases} y^{*} \; if \; y^{*} > \tau \\ \tau_y \; if \; y^{*} \le \tau \end{cases} \qquad 3.5$$

In the typical Tobit model *τ=0*; that is, the dependent variable is censored at 0. This also occurs when we have limited dependent variable and a lot of zeros and positive values from the sample:

$$y_i = \begin{cases} y_i^* \ if \ y_i^* > 0 \\ 0 \ if \ y_i^* \le 0 \end{cases} \qquad 3.6$$

Where *y(i)* is actual observed level of consumption.

The standard Tobit model is estimated using maximum likelihood technique with log likelihood function as follows:

$$LL_{Tobit} = \sum_0 \ln\left[1-\phi\left(\frac{X_I\beta}{\beta}\right)\right] + \sum_+ \ln\left[\frac{1}{\sigma}\phi\left(\frac{y_i - x_i\beta}{\sigma_i}\right)\right] \qquad 3.7$$

Whereby zero (0) indicates summation over the zero observations for energy consumption on material residue, wood fuel, charcoal, kerosene LPG and electricity *(yi = 0)* and + indicates summation over energy consumption intensity on various energy sources that are greater than zero *(yi > 0)*. *Φ* and *φ* are the cumulative distribution function (cdf) for a standard normal random variable and standard normal probability density functions (pdf). However, for corner solution models, ***y**** has no meaningful interpretation. Unlike most maximum likelihood commands, Tobit defaults to no log as it suppresses the iteration log. Maximum likelihood function for Tobit model is used to derive the log-likelihood estimates used for diagnostic tests, as indicated on Appendix 1.

However, Cragg (1971) contends that zero observations not solely arise from non-participation but also from participation but non-consumption. This assumption gives rise to the double hurdle model, which is indicated as a better representation of household consumption behaviour. It is worth noting that the standard Tobit model is a nested version of double hurdle model (the log likelihood of the tobit model equals that of the Cragg model when there is no participation equation).

Double hurdle model is specified as follows:

(i) Participation decision

$$y_{il}^* = w_i a + u_i$$

$$d = \begin{cases} 1 \ if \ y_{il}^* > 0 \\ 0 \ otherwise \end{cases} \qquad 3.8$$

(ii) Consumption decision

$$y_{i2}^* = x_i\beta + v_i$$

$$y_i = x_i\beta + u_1 \quad \text{If} \quad y^{\bullet}_{il} > \text{o and} \quad y^{\bullet}_{i2} > 0 \qquad 3.9$$

$$y_i = 0 \qquad \text{otherwise}$$

In the participation equation, the dependent variable y^*_{i1} is a latent variable representing household's participation decision to use an energy source. w_i is a vector of variables explaining the participation decision. w_i is a set of individual characteristics explaining the participation decision, u_i is the error term distributed as $u_i \sim N(0,1)$. *d* is an unobserved latent variable $y_{il}^{\bullet}$ is a binary indicator equaling one if household *i* consumes the particular energy item under consideration and zero otherwise.

In the consumption equation, the dependent variable (y^*_{i2}) is the amount of energy consumed by household *i* on a particular energy source. y^*_{i2} is a vector of variables explaining the consumption decision. v_i is the error term distributed as $v_i \sim N(0,\sigma^2)$. y_i is the observed dependent variable (household consumption intensity on a particular energy source. y^*_{i2} is a latent endogenous variable representing households consumption decision. A positive level of consumption y_i is the dependent variable (household energy consumption intensity on various energy sources) observed only if the household participates in the market for the energy source ($y_{il}^{\bullet} > 0$) and also consumes energy ($y^*_{i2} > 0$). In light of the above, the study equation 3.2 forms the focus of this study, which is the decision on consumption intensity for various energy sources.

The double hurdle model is estimated using maximum likelihood technique with log likelihood as follows:

Double hurdle Maximum likelihood estimation

$$LL_{DoubleHurdle} = \sum_{0} \ln\left[1 - \phi(w_i a)\phi\left(\frac{x_i\beta}{\sigma}\right)\right] + \sum_{+} \ln\left[\phi(w\ a)\frac{1}{\sigma_1}\phi\left(\frac{y_{i-}x_i\beta}{\sigma}\right)\right]$$

3.10

The first term corresponds to the contribution of all the observations with an observed zero. It indicates that the zero observations are coming not only from the participation decision but also from the level of consumption decision. The second term in accounts for the contribution of all the observations with non-zero consumption intensity. Log likelihood estimation is followed by deriving the unconditional marginal effects represented as:

$$E[y \mid x_i] = p(y_i > 0 \mid x)E(y_i \mid y_i > 0, x)$$

$p(y_i > 0 \mid x)$ is the probability of a positive value of y_i for values of the explanatory variables, x

$E(y_i \mid y_i > 0, x)$ is the expected value of y_i for values of the explanatory variables, x, condition of $y > 0$

The equation estimated is specified as:

Yi=a+β1(Age)+β2(Education)β3(location)+β4(gender)+β5(dwellingunit)+β6(household income)+β7(marital status)+β8(Decision maker) + ε 3.11

The double hurdle model is estimated for the following energy sources: electricity, LPG, kerosene, charcoal, wood fuel and material residue. Thus, if we take electricity as an example, the dependent variable in the participation equation represents whether a household consumes electricity or not (i.e. 0 and 1) and the dependent variable in the consumption equation represents a households level of electricity consumption (including zeros). The same logic applies for the other fuels.

3.3.2 One way analysis of variance

In establishing variations in household's energy consumption intensity for cooking and lighting across the rural and urban areas in Kenya, One Way Analysis of Variance (ANOVA) estimation was used. ANOVA tests the equality of population means when classification is by one variable, hence considered in addressing the second objective. The study considered consumption intensities for households' most important energy source for cooking and lighting. For ANOVA, the dependent variable differentiates individuals on some quantitative continuous dimension, and independent variable is a categorical variable that divides individuals into two or more groups or levels. In this case, the dependent variable is the consumption intensity for the primary energy sources used for cooking and lighting. The independent variable represents locational divide: urban and rural areas, important in understanding variations in energy consumption.

The ANOVA F test evaluates whether the group means on the dependent variable differ significantly among the groups. This study has used a random-factor or effect ANOVA, indicating that the treatment levels were randomly selected and results can be generalized to the population levels from which the levels of the independent variable were randomly selected.

Hypothesis testing for ANOVA

The null hypothesis (H_0) tested in ANOVA is that the population means from which the *K* samples are selected are equal. Population means are the consumption intensities for most important energy sources used for cooking and lighting.

$Ho: \mu_1 = \mu_2 = \ldots = \mu_K$ Where *K* is the number of levels of the independent variable and represents urban/rural divide.

The null hypothesis is stated as:

$Ho: \mu_1 = \mu_2$

3.4 Data Source and Variables

Based on the research gap identified, the study used nationally-representative household data set from the KIPPRA National Energy Survey, 2009. This is the most current reliable dataset on household energy use in the country. The cross-sectional data comprises of 3,663 households, which are used to analyse household's consumption intensity on use of various energy sources in Kenya.

The dependent variable (energy consumption intensity) in this case is the ratio of expenses in a particular energy source to total expenses on energy in a household. The computed variable is in ratio form (implying degree of intensity). The independent variables are identified as household's socio-economic characteristics substantial in explaining dynamics in energy consumption (Table 3.1).

Table 3.1: Description of variables used in the Tobit and double hurdle model

Variables	**Description of the variable**	**Measurement of the variable**	**Apriori expectation**
Dependent variables y Consumption intensity	Proportion of energy consumed from a particular source compared to the total household energy consumption in a household	Continuous Consumption intensity of material residue, wood fuel, charcoal, kerosene, LPG and electricity	
Explanatory variables x			
Age	Age of the household head in years	Categorical below 30 years=1 31 - 35 years=2 36 - 40 years=3 41 - 45 years=4 46 - 50 years=5 51 - 60 years=6 Over 60 years=7	-/+
Location	The location of the household	Dummy 0= urban, 1 rural	-/+
Gender	Gender of the household head	Dummy 0= male, 1=female	-/+
Education level	Education level of the household head	Categorical 1=No formal education 2=Primary school 3=Secondary school 4=Vocational/ diploma 5=Bachelor's degree 6=Postgraduate	-/+
Decision maker on energy choice	The person in the households who makes the decision on energy consumption	Categorical 1=Household head 2=Spouse 3=Child	-/+
Dwelling unit	Household dwelling unit type	Categorical 1=permanent, 2=semi-permanent 3= Temporary	-/+

Household income	Average monthly income (Ksh)	Categorical below 2500=1 2501 - 5000=2 5001 - 10000=3 10001 - 15000=4 15001 - 20000=5 20001 - 50000=6 50001 - 100000=7 Above 100000	-/+
Marital status	Marital status of household head	Categorical 1=single 2=married 3=widowed 4=divorced	-/+

4. Results and Discussions

4.1 Overview

This section highlights the socio-economic factors affecting households' energy consumption in Kenya. The discussion covers descriptive statistics and model estimation results. Results of the socio-economic factors affecting households' consumption intensity of various energy sources and variations in consumption intensity for cooking and lighting among households are presented.

4.1.1 Households socio-economic characteristics

The findings presented in Table 4.1 indicate that at national level (sample), 66 per cent of household heads (hhh) were male while 34 per cent were female. This shows that most households are headed by males. However, 47.9 per cent of spouses who are considered to be female are the key decision makers on the type of energy sources utilized by households compared to 46.1 per cent of household heads who are mainly male. Results on years of the household heads indicate that 21.5 per cent were 30 years and below. About 18.8 per cent and about 16.8 per cent were household heads aged 31-35 and 36-40, respectively. Also, the proportion of hhh aged 46-50 was slightly over 11 per cent. About 12.7 per cent of the hhh attained age 51-60 and 6.1 per cent were over 60 years. For a better and clear psychological and sociological explanation of the role of men and women in consumption of clean energy sources, marital status provides valuable information (Walton et al., 2009). The findings show that 12.8 per cent of hhh were single, 77.9 per cent married, 0.5 per cent divorced, 8.6 per cent widowed and 0.2 per cent were separated. Results shows that 6.9, 29.1, 31.8, 21.2, 8.9, 1.8, and 2.1 per cent of households had no formal education, primary secondary, vocational, diploma, bachelor's, master's and doctorate degree, respectively.

Table 4.1 also presents the tabulations between household socio-economic characteristics and energy sources consumed by households. The major observation is that majority of households in rural areas consume non-clean energy sources, including: material residue, wood fuel and charcoal compared to urban areas. Electricity and LPG are mainly consumed by urban households. Household heads with higher education level rely on energy sources compared to households with lower levels of education. Based on the decision maker on energy use, spouses who are women are reported to depend more on clean energy sources compared to their male counterparts. The proportion of households relying on clean energy sources increases with increase in mean monthly income.

Table 4.1: Household socio-economic characteristics and energy sources consumed by households (%)

Variables	National (sample)	Material residue	Fuel wood	Charcoal	Kerosene	LPG	Electricity
Location							
Urban=0	66.04	5.01	8.94	40.5	28.25	70.48	67.53
Rural =1	33.96	94.98	91.06	59.5	71.75	29.52	32.47
Gender of the household head							
Male=0	65.79	71.76	29.43	32.71	33.65	34.07	36.52
Female=1	34.21	28.24	70.57	67.29	66.35	65.93	[illegible]
Decision maker on energy use							
Household head=1	46.10	32.94	46.04	43.59	45.69	47.31	46.35
Spouse=2	47.90	56.47	46.04	49.88	48.26	47.59	47.77
Child=3	6.00	10.59	7.93	6.52	6.05	5.1	5.97
Household dwelling unit							
Permanent=1	50.40	5.88	18.85	57.39	44.56	88.14	82.02
Semi-permanent=2	37.40	64.71	31.15	34.07	42.51	9.24	14.25
Temporary=3	12.00	29.41	50	8.54	12.93	2.62	3.72
Household head: Average monthly income (Ksh)							
Below 2500=1	4.40	32.54	4.49	2.72	4.75	0.69	0.57
2501 - 5000=2	12.60	12.7	11.86	8.68	14.16	0.83	3.08
5001 - 10000=3	21.80	15.08	16.35	20.65	24.59	6.21	10.93
10001 - 15000=4	17.50	11.11	16.42	18.96	18.54	11.45	15.87
15001 - 20000=5	15.00	10.32	13.25	16.94	15.6	14.48	17.73
20001 - 50000=6	20.70	9.52	29.68	23.09	17.44	37.79	33.52
50001 - 100000=7	6.30	5.56	3.61	6.95	4.31	21.66	14.09
Above 100000	1.80	3.17	1.35	2.01	0.62	6.9	4.21
Household head: Education level							
No formal education=1	6.90	15.29	10.71	4.13	7.05	0.55	1.94
Primary school=2	29.10	38.82	36.93	26.79	32.97	4.41	11.01
Secondary school=3	31.80	27.06	32.21	34.54	34.06	21.79	27.77
Vocational / diploma=4	21.20	14.12	16.44	23.42	19.32	36.69	33.36
Bachelor's degree=5	8.90	4.71	2.95	9.1	5.54	29.1	20.73
Postgraduate=6	2.10	0	0.76	2.02	1.06	7.45	5.18

Household head age in years							
Below 30 years=1	21.50	11.76	13.59	20.37	21.07	21.1	23.24
31 - 35 years=2	18.80	20	13.76	18.4	18.5	23.86	22.43
36 - 40 years=3	16.80	14.12	16.54	17.97	17.24	17.38	17.25
41 - 45 years=4	12.30	10.59	13.16	12.95	12.38	12.14	13.04
46 - 50 years=5	11.60	10.59	14.85	11.59	11.8	10.48	9.8
51 - 60 years=6	12.70	17.65	18.57	13.28	12.65	10.9	10.12
Above 60 =7	6.10	15.3	9.53	5.44	6.36	4.14	4.13
Household head: Marital status							
Single=1	12.80	3.53	12.8	10.61	11.25	17.66	16.84
Married=2	77.90	84.71	77.86	81.37	78.66	77.79	77.89
Widowed=3	8.60	11.76	8.6	7.23	9.34	3.72	4.37
Divorced=4	0.50	0.74	0.8	0.75	0.83	0.89	0.74
Proportion of households using a particular energy source	0.20	2.32	32.38	58.18	79.83	19.79	33.72

n=3,663

Source: Authors calculations

The study further assessed the most important energy source used by households. Findings indicate that 37.6 per cent of households used kerosene as the primary energy source. This exemplifies that kerosene is an important energy source for households in Kenya as it can be used in major functional roles of energy, such as cooking and lighting. This was followed by charcoal (24.2%), fuel wood (19.6%), electricity (7.9%), LPG (9.5%), and materials residues (1.4%) as primary energy sources.

4.2 Household Energy Consumption

The energy sources included in the study area were material residue, firewood, charcoal, kerosene, LPG and electricity. The findings presented in Appendix II reveal 38 combinations of energy sources consumed by households. Majority of households combined charcoal and kerosene (676), followed closely by those using firewood charcoal and kerosene (478). This reveals multiple energy use (fuel stacking behaviour) among households. The study also revealed a combination of clean and non-clean energy sources. Findings concur with the energy stacking theory that households' tend to consume a combination of fuels rather than switching from one inferior fuel to a superior fuel but rather consume both sets of fuels (Davis, 1998). The results further indicate that a handful (149) of households used clean energy sources for their energy needs. The study also indicates that only a small proportion of households consumed a single energy sources as indicated on the second column of Appendix II.

4.3 Variations in Household Energy Consumption Intensity for Cooking and Lighting in Urban and Rural Areas in Kenya

Considering that households consume different energy sources for same activities, it was important to reveal the most important energy source used by households for cooking and lighting. Kerosene (53%) was reported as the most important energy source for lighting, charcoal (31%) is mostly used for cooking, while electricity (26%) is mainly used for lighting) (Table 4.2).

Table 4.2: Households' most important energy source for cooking and lighting

Energy sources	Cooking (%)	Lighting (%)
Material residue	3	2
Wood fuel	28	10
Charcoal	31	5
Kerosene	22	53
LPG	12	4
Electricity	4	26

Source: Author's calculation

The study further segregated urban and rural areas based on the most important energy source for cooking and lighting. Results revealead a striking deference between rural and urban households. Majority of rural households use kerosene for lighting while urban areas mainly depend on electricity (Table 4.3). Households in rural areas mainly use wood fuel while majority of urban households use charcoal and LPG for cooking. LPG is the dominant clean energy source for cooking in urban areas, partially attributed to availability and accessibility in urban market centres.

Table 4.3: Household most important energy sources for cooking and lighting in rural and urban areas

Energy sources	Cooking		Lighting	
	Rural (%)	Urban (%)	Rural (%)	Urban (%)
Material residue	67	33	97	3
Wood fuel	71	29	76	24
Charcoal	45	55	80	20
Kerosene	64	34	80	20
LPG	36	64	25	75
Electricity	25	75	25	75

Source: Author calculation

A proportion of 36 per cent rural households are using LPG for cooking, implying a prospect of LPG diffusion for cooking in rural areas if the right infrastructure for supply model are put in place.

In relation to clean energy sources, households in urban areas use electricity for lighting compared to minority of rural households depending on non-clean sources. In conclusion, non-clean energy sources including fuel wood, charcoal and material residue constitute the energy mix in rural areas, while kerosene, electricity and LPG dominate in urban areas.

Further, the study established consumption intensities for various energy sources across urban and rural areas (Table 4.4). The intensities from various energy sources for either cooking or lighting are computed and averaged. Kerosene and electricity indicated the highest consumption intensity for lighting in rural and urban areas, respectively. LPG had the highest consumption intensity for cooking in urban areas, while wood fuel had the highest consumption intensity in rural areas.

Table 4.4: Mean intensity for primary energy sources cooking and lighting consumption intensity

	Cooking Intensity		Lighting Intensity	
Energy sources	Rural	Urban	Rural	Urban
Material residue	0.1209	0.065	0.2384	0.2483
Wood fuel	0.6925	0.36	0.541	0.4249
Charcoal	0.03	0.05	0.4946	0.4125
Kerosene	0.4907	0.4283	0.5861	0.5425

LPG	0.4219	0.4513	0.5067	0.437
Electricity	0.4089	0.4302	0.5733	0.7671

Source: Author's calculation

The results exemplify a high dependency level on non-clean energy sources by households for lighting need. Additionally, consumption intensity on various energy sources for cooking indicates high consumption of wood fuel and LPG as the most important energy source for cooking. Results indicate that non-clean energy sources still play various functional roles among households.

In establishing variations in energy consumption intensity for cooking and lighting in urban and rural areas, further analysis was conducted using one way ANOVA. The first step was to test the assumption of homogeneity of variance. The Levene's F-Test for equality of variances was used to test the assumption of homogeneity of variance. Levene's test uses the level of significance set a priori for the ANOVA, whereby it was tested at a=0.05. Homogeneity of variance tests carried out on variables indicated a significant level greater than alpha 0.05 (p> .05). Therefore, results were interpreted as the assumption of homogeneity of variance was met. As shown in Table 4.5, variations in household energy consumption intensity for various energy sources for cooking exist between rural and urban populations. There was a significant difference in consumption intensity for wood charcoal and LPG between rural and urban areas.

Table 4.5: One way ANOVA results energy consumption intensity for cooking in urban and rural areas

Energy sources	**F test**	**Sig.**
Material residue	0.022	0.88
Wood fuel	16.057	0.02**
Charcoal	39.394	0.54
Kerosene	1.201	0.27
LPG	8.985	0.00***
Electricity	0.939	0.35

**significance at 0.05 ***significant at 0.01

Source: Author's calculation

Anova results presented in Table 4.6 show a significant difference in kerosene consumption intensity for lighting between rural and urban areas. The results could be as a result of high dependency levels of kerosene for lighting in the rural areas. Further, results showed a significant difference on the consumption intensity of electricity in rural and urban areas.

Table 4.6: One Way Anova results on consumption intensity for lighting in urban and rural areas

Energy sources	F test	Sig.
Material residue	0.256	0.432
Wood fuel	0.346	0.568
Charcoal	2.624	0.144
Kerosene	0.328	0.575
LPG	9.257	0.002***
Electricity	2.594	0.108**

**significance at 0.05, ***significant at 0.01

Source: Author's calculation

4.4 Effects of Household Socio-economic Characteristics on Energy Consumption Intensity

4.4.1 Statistical tests and estimation results

To correctly estimate factors affecting households' consumption intensity on various energy sources, the first task was to assess violation assumptions and choice of most appropriate model. Distributional assumptions assume crucial relevance in limited dependent variable models, since maximum-likelihood estimation will lead to inconsistent parameter estimates when normality and homoscedasticity are not fulfilled (Arabmazar and Schmidt, 1982). For these reasons, preliminary tests for the validity of distribution assumption are necessary.

4.4.2 Diagnostics tests

The Lagrange Multiplier (LM test) tests for homoscedasticity (Wooldridge, 2015) and Conditional Moment (CM) base tests (Pagan and Vella, 1989) for normality were conducted on each of the equations of the Tobit model. According to Table 4.7, the LM test values are below the relevant critical values, hence heteroskedasticity. We reject the null hypothesis, and therefore Tobit specification is unsuitable. Non-constant variance across observations (heteroskedasticity) results in the maximum likelihood estimators of Tobit parameters being inconsistent. The CM test for testing the null hypothesis that the disturbances in a Tobit model have a normal distribution is also rejected.

Table 4.7: Lagrange Multiplier (LM) and Conditional Moment (CM) test values

Tobit Model	The Lagrange Multiplier Test Value	Conditional moment test Value
Electricity	720.76 (40) [0.000]	29.196 (40) [0.000]
LPG	754.18 (40) [0.000]	11.603 (40)[0.000]
Kerosene	176.46 (40) [0.000]	188.26(40)[0.000]
Charcoal	576.68 (40) [0.000]	117.39(40)[0.000]
Wood fuel	1003.7 (40) [0.000]	323.89(40)[0.000]
Material residue	50.721 (40) [0.000]	45.872(40)[0.000]

Author's calculation

As the results indicate, the normality and homoscedastic assumptions are violated. The two assumptions do not hold, and therefore we conclude that the Tobit model is not valid and will likely give misleading results. Therefore, there is need to choose an appropriate model for analysis.

4.4.3 Specification test

Once the diagnostics of the model have been analyzed, the specifications test was conducted for the choice of the most appropriate model for this study. The adequacy of Tobit model is compared to a nested version which is an alternative model to the Tobit corner-solution model known as the double hurdle model by estimating using a Tobittest (superiority test).This test serves as the primary comparison between the two models.

The likelihood ratio test (Tobittest) statistic is computed as follows:

$LR = -2{*}x_{y}^{2}(lnLDH-lnLT)x^{2k}$

where:

$lnLDH$ = log likelihood of the double hurdle model (the unrestricted model)

$lnLT$ = log likelihood of the Tobit model (the restricted model)

x^{2k} = chi-squared distribution with k degrees of freedom, k = the number of variables in the participation equation, i.e. the number of coefficients that are assumed to be zero under the restricted model. The likelihood ratio test can be defined as Tobittest = 2* (llprobit + lltrncreg - lltobit) or (-2*(Double hurdle - Tobit). The null hypothesis is that there is no significant difference between the double hurdle model and the Tobit model, which implies that the Tobit model fits the data better. Rejection of the null implies that the double hurdle model fits the data better.

Likelihood Ratio (LR) values of the two models (Appendix 2 and 3) were estimated and the Tobittest for each equation was compared to the critical values for the chi square distribution with the specified degrees of freedom (Table 4.8). Results indicate that LR test values were above the critical value; that is, the test statistic Γ = exceeds the critical value of the χ2 distribution. This leads to the rejection of the Tobit model and adoption of the double hurdle model.

Table 4.8: Likelihood Ratio (LR) tests for Tobit model versus Double Hurdle model Ho: Tobit; H1: Double hurdle

Model	Test type	Test value	Decision
Double hurdle model vs Tobit	LR	Tobittest	
Electricity	LR	111.1473 (40) [0.000]	Reject H_0
LPG	LR	662.2951 (40) [0.000]	Reject H_0
Kerosene	LR	1016.7036 (40) [0.000]	Reject H_0
Charcoal	LR	2053.3678(40) [0.000]	Reject H_0
Wood fuel	LR	692.01038 (40) [0.000]	Reject H_0
Material residue	LR	823.84511 (33) [0.000]	Reject H_0

Source: Author's calculation

In conclusion, LR test of the double-hurdle model against the Tobit model strongly rejects the latter specification. This is an indication for the existence of two separate decision making stages in which individuals make independent decisions regarding the participation and consumption decision on various energy sources. Tobit model is restrictive as it does not make any distinction between the two stages of decision making. The rejection of the Tobit model further indicates that the observations of zero consumption intensities for various energy sources can no longer be considered as deliberate choices made by individuals. This implies that a zero observation could be due to either non-participation or participation but non-consumption. Therefore, the double-hurdle model is the best specification to assess the effects of various factors on consumption intensity decision.

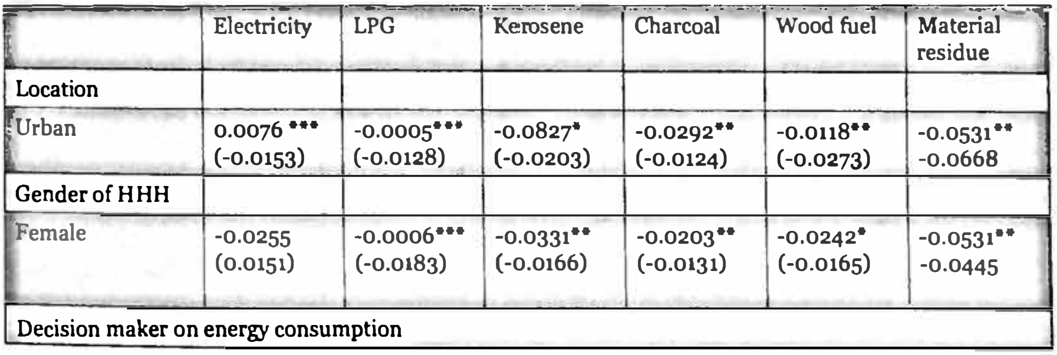
4.3.4 Marginal effects

The first step was generating the maximum likelihood estimates for Tobit and Double Hurdle model (Appendix II and III). The Double Hurdle model maximum likelihood estimates for electricity, LPG, kerosene, charcoal, wood fuel and material residue were estimated. Thus, if we take electricity, as an example, the dependent variable in the participation equation represents whether a household consumes electricity or not (i.e. 0 and 1) and the dependent variable in the consumption equation represents a households electricity's consumption intensity (including zeros). The same logic applies for the other fuels.

To assess the effect of the explanatory variables on the dependent variable, marginal effects are calculated and used to generate estimates for discrete changes in the categorical variable. The marginal effect of interest for this study is the overall effect on the dependent variable; that is, the expected value of y_i for values of the explanatory variables, x also known as the unconditional expectation of y_iE[yi | x]. Unconditional marginal effects refer to the total effect on intensity of energy consumption. This refers to all households under examination; therefore, a positive value would suggest an increase in the consumption of the energy item across all households, including those who do not currently consume it. The significant marginal unconditional effects are interpreted in this study.

The unconditional effects showed that the consumption intensity on various energy sources was either positively or negatively significantly affected by various discrete categories of household's income, level of education, occupation, dwelling unit, age, marital status and decision maker on energy consumption (Table 4.3).

Table 4.3: Unconditional marginal effects for household's energy consumption intensity



	Electricity	LPG	Kerosene	Charcoal	Wood fuel	Material residue
Location						
Urban	0.0076 *** (-0.0153)	-0.0005*** (-0.0128)	-0.0827* (-0.0203)	-0.0292** (-0.0124)	-0.0118** (-0.0273)	-0.0531** -0.0668
Gender of HHH						
Female	-0.0255 (0.0151)	-0.0006*** (-0.0183)	-0.0331** (-0.0166)	-0.0203** (-0.0131)	-0.0242* (-0.0165)	-0.0531** -0.0445
Decision maker on energy consumption						

Spouse	-0.0092 *** (-0.0163)	0.0133** (-0.0190)	0.0108** (-0.0172)	0.0291** (-0.0125)	0.0104** (-0.0159)	-0.0263** -0.0467
Child	0.01278 (-0.0299)	0.0161 (-0.0389)	-0.0074 (-0.0338)	0.0045 (-0.0239)	-0.0570** (-0.0283)	-0.0762 -0.0693
Dwelling unit						
Semi-permanent	-0.0270** (-0.0207)	-0.0101*** (-0.0389)	0.0356** (-0.0179)	0.0162** (-0.0129)	0.0780* (-0.0168)	0.1333 -0.0407
Temporary	-0.0327*** (-0.0364)	0.0260** (-0.0488)	0.1139 (-0.0269)	0.0251 (-0.020)	0.1110147 (-0.0257)	0.1190 (0.1040)
Average monthly income (Ksh)						
2,501 – 5,000	0.1170 (-0.0971)	0.0078*** (-0.1291)	0.0206** (-0.0412)	0.0053 *** (-0.0375)	0.0387** (-0.0364)	-0.1513 (-0.1124)
5,001 – 10,000	0.0941* (-0.0918)	0.1130 (-0.0991)	-0.0600*** (-0.0396)	-0.0250 ** (-0.0351)	0.0263** (-0.0344)	-0.2177*** (-0.1084)
10,001 – 15,000	0.0809* (-0.0910)	0.1189 (-0.0959)	-0.0948*** (-0.0418)	-0.0814*** (-0.0359)	0.0483* (-0.0362)	-0.0903 (-0.1222)
15,001 – 20,000	0.0652* (-0.0905)	0.0688* (-0.0952)	-0.0904*** (-0.0428)	-0.0851*** (-0.0363)	0.0172* (-0.0370)	-0.2007 (0.1104)
20,001 – 50,000	0.1052 (-0.0898)	0.0643* (-0.0935)	-0.1687*** (-0.0435)	-0.1119*** (-0.0367)	0.0517** -0.0384	-0.1677 (-0.1320)
50,001 - 100000	0.1106 -0.0910	0.0389** -0.0943	-0.3347*** -0.0406	-0.2152*** -0.0423	-0.0306*** (-0.0511)	0.1612 (-0.1892)
100, 001 and above	0.0230** (-0.1033)	0.0122** (-0.1077)	-0.0358*** (-0.0443)	-0.2855*** (-0.0793)	-0.1224*** (-0.1435)	0.0890 (-0.1663)
Education level						
Primary school	-0.0245** (-0.0536)	0.0263** (-0.1165)	0.0053 *** (-0.0314)	-0.0451** (-0.0296)	-0.1460*** (-0.0254)	0.0844* (-0.0709)
Secondary school	-0.0244** (-0.0519)	0.0230** (-0.1124)	-0.0247** (-0.0328)	-0.0451 ** (-0.0298)	-0.1594*** (-0.0271)	0.02027** (-0.0735)
Vocational/ diploma	-0.0058*** (-0.0519)	0.0191*** (0.1121)	-0.0256*** (0.0377)	-0.0785*** (-0.0315)	-0.1696*** (-0.0316)	0.0153 (-0.0804)
Bachelor's degree	0.0474** (-0.0547)	0.0441 ** (-0.1133)	-0.0811 * (-0.0566)	-0.1070*** (-0.0380)	-0.3337*** (-0.0561)	-0.0985* (0.0637)
Post graduate level	0.2367** (-0.1192)	0.2071 (0.1591)	-0.1763 (0.1000)	-0.1602*** (0.0595)	-0.0130** (-0.1711)	
Age of HHH (years)						
31 - 35	-0.0416** (0.0211)	0.0477** (0.0251)	-0.0585*** (-0.0250)	0.0383** (-0.0177)	-0.0087*** (-0.0275)	0.063652* (-0.0491)
36 - 40	-0.0355 ** (-0.0231)	-0.0297** (-0.0276)	-0.0606** (-0.0261)	-0.0005*** (-0.0182)	-0.0008*** (-0.0267)	0.0393** (-0.0473)
41 - 45	-0.0126** (-0.0256)	-0.0286** (-0.0318)	-0.0440 ** (-0.0293)	-0.0086*** (-0.0204)	0.0077*** (-0.0284)	0.1851** (-0.0872)
46 - 50	-0.0057*** (-0.0282)	-0.0002*** (-0.0338)	-0.0445 ** (-0.0301)	-0.0288** (-0.0214)	0.0108** (-0.0279)	0.2562*** (-0.1070)

51 - 60	0.0032*** (-0.0291)	-0.0367** (-0.0348)	-0.0748** (-0.0296)	-0.0008** (-0.0519)	-0.0141** (-0.0272)	0.1483* (-0.0837)
61 and above	-0.0228** (-0.0425)	-0.0148 ** (-0.0504)	-0.0968*** (0.0387)	-0.0604** (-0.0318)	0.0158** (-0.0345)	0.2013*** (0.0711)
Marital status of HHH						
Married	-0.0876*** (0.0210)	-0.0634*** (-0.0246)	-0.0520** (-0.0280)	-0.0081*** (-0.0196)	-0.0066*** (-0.0312)	-0.0030*** -0.1221
Widowed	-0.0940*** (-0.0389)	-0.0691 * (-0.0481)	-0.0427 ** (-0.0367)	-0.0326** (-0.0279)	-0.0209 ** (-0.0365)	0.0022*** -0.1370
Divorced	-0.0356 ** (-0.0838)	-0.0079 (0.1167)	-0.0265 ** (0.0829)	-0.0265** (0.0829)	0.1668 (0.1087)	
Lower limit	0.0000	.0000	0.0000	0.0000	0.0000	0.0000
Upper limit	+inf	+inf	+inf	+inf	+inf	+inf
Number of observations	1235.	725.	2131	2924	1184.	83

Standard errors in parentheses; *** p-value < 0.01, **p-value < 0.05, *p-value <0.10. Excluded reference categories: Rural, Male Household head, Permanent, Below 2500, No formal education, Below 30 year, Single

Source: Author's calculation

In the electricity model, the average monthly income is one of the significant variables. Specifically, household heads with an average monthly income of Ksh above 100,000 (0.02295856) are significant and positive, indicating that consumption intensity for electricity increases with increase in the level of income. When compared to male-headed households, female-headed (-0.0255477) households consumption intensity on electricity is indicated as lower. Married (-0.0875548) and widowed (-0.0940326) consumption on electricity decreases compared to single headed households. Household heads aged between 31-35 years (-0.0415804) consume much less electricity than household heads below 30 years. Finally, in the electricity model, the largest significant unconditional discrete effect is the household heads with the highest level of education, which is a postgraduate (0.236692). This implies that household heads in possession of a doctorate degree consume higher proportions of electricity compared to households with no formal education.

Kerosene estimates indicate that location significantly affects consumption intensity, whereby households in urban areas consume (0.0827319) more units compared to households in rural areas. Unconditional effects for female-headed households indicate low consumption (-0.0330867) on kerosene compared to their male counterparts. The significant average monthly income level effects indicate that households with an average monthly income of 10,000-15,000 (0.0948209), 15,001-20,000 (-0.0903929), 20001-50,000 (-0.1687489), 50,001-100,000 (-0.3346774) and above 100,000 (-0.03583833) consume lower proportions of kerosene compared to lower income earners. However, households in income bracket 2,500-5,000 consumption on kerosene increases. Household heads that have attained postgraduate degrees have low consumption intensity on kerosene when compared to those with no formal education. However, households with primary level education consumption intensity on kerosene increases. Age of the household head is a key variable determining the unconditional levels of consumption. Significant marginal effects for age of the household head indicate that household heads in age bracket 31-35 (-0.0585138), 36-40 (-0.0606526), 41-45 (0.0439037), 51-60 (-0.0748048) above 60 (-0.0968082) consume lesser proportions of kerosene. Married household heads are less likely (-0.0520642) to consume higher proportions of kerosene.

Charcoal model estimates indicate that urban household's consumption intensity (-0.0292092) for charcoal decreases as compared to the rural households. When the key decision maker on energy consumption is the spouse, consumption intensity for charcoal (-0.0292092) decreases. Households with monthly income of: 10001-15000 (-0.0814455), 15001-20000 (-0.0851023), 20001-50000 (-0.1118514) 50001-100000 (-0.2151528), 100,001-200000 (-0.3034367) 50,001 -100,000(-0.2151528). Above 100,000 (-0.2855028) consume lower proportion of charcoal as compared to low income earners.

Marginal effects for education level indicate that households with higher level of education consume low proportion of charcoal; vocational/diploma (-0.078435), bachelor's degree (-0.01069678) and postgraduate (-0.01602673). For the significant household age effect, household heads aged 31-35 (0.0383573) consume more charcoal compared to older household head aged above 60 (-0.0604579), over 70 (-0.13388) whose consumption intensity for charcoal is low.

The wood fuel model reveals a number of significant unconditional discrete effects in the various variables. For instance, the wood fuel model significant location effect indicate that consumption intensity in urban areas is lower (-0.1178102) compared to rural areas. Households with their children make decision on energy consumption consume lower proportions of wood fuel (-0.0569754). Consumption intensity on wood fuel increases in semi-permanent (0.077977) and temporary (0.1110147) households. The effects on dwelling unit may be representing households in the lower income groups. Relating to the location effect, households with semi-permanent dwelling units are mainly in rural areas. Household level of education significant effects indicate that consumption intensity for household heads with primary school (-0.1460102) secondary school (-0.01593993) vocational/diploma (-0.01696429) and bachelor's degree (-0.03337176) and postgraduate (-0.0129748**) is lower compared to households with formal education.

The final equation on material residues model, the significant unconditional discrete effects on household with semi-permanent dwelling unit indicate that household's consumption intensity on material residue increases. Additionally, households with an average monthly income of 5,001–10,000 (-0.2176554) and 15,001-20,000 (-0.2006785) consume smaller amounts of material residue energy. Household heads within the age limit of 46-50 (0.256249), 51-60 (0.1482886) and 60-70 (0.2013238) consume higher proportions of material residue.

In summing up the results from the models, it is revealed that location, particularly the urban and rural divide, average monthly income, age of household head and education level of the household head are some key variables affecting consumption intensity. Firstly, the average monthly income is important across model, particularly for electricity, LPG, kerosene, charcoal, wood fuel and material residue. The location of the household is another important variable affecting energy consumption intensity. The discrete effects estimate indicate that those in rural areas tend to use non- clean energy sources such as kerosene, wood fuel and charcoal while those in urban areas tend to consume high quantities of electricity and kerosene. Relating to the location effect are households living in semi-permanent households. More educated household heads consume more of electricity and LPG compared to those in lower education level.

5. Conclusion, Policy Recommendations and Further Research

5.1 Conclusion

It is worth noting that access to affordable clean energy is important in our day to day life, a critical indicator of the quality of life within a society. This is despite the numerous challenges facing the energy sector, such as low consumption intensity of energy from clean sources at a household level. It is, therefore, important to obtain accurate information on the factors that influence households' consumption intensity on energy sources. The study is motivated by the reportedly high level of biomass consumption and the aggravating socio-economic effects. Similarly, increased attention has been placed on accelerating of grid and off-grid solution, which has been accompanied by low consumption.

The results from the analysis showed that monthly household income, gender of the household head, education level of the household head, location (rural or urban area), occupation and household dwelling unit significantly affect consumption intensity on various energy sources. Results indicate a significant difference in energy consumption intensity for cooking using wood fuel, charcoal and LPG between rural and urban areas. Further, there was significant difference in the energy used for lighting using kerosene between rural and urban areas. In summary, efforts to expand clean energy consumption are likely to be more successful when the above issues are taken into consideration.

5.2 Policy Recommendations

Households' socio-economic factors significantly affect consumption intensity on clean and non-clean energy sources. In promoting intensified consumption of clean energy sources, energy access programmes such as the rural electrification, last mile connectivity and off-grid projects have considered reduction of upfront cost considering that majority of households in rural areas are low income earners. However, to achieve the optimal consumption levels, the programmes should also focus on creating awareness among household heads with no formal education on the importance of consuming clean energy sources as opposed to over-reliance on non-clean sources.

Cooking being one of primary energy use is dominated by the use of non-clean energy sources in rural and urban areas. Considering the socio-economic disparities in rural and urban areas, identification of cost effective energy sources would be viable in solving over dependency on non-clean sources; for instance, promoting and sensitizing on clean energy alternatives and substitutes for sustainable clean energy sources in rural and urban areas such as biogas digesters and solar cookers.

The embedment of strategies in the local energy development plans that focus on the productive use of electricity will boost electricity consumption at the household level.

5.3 Areas for Further Research

Despite the large number of studies on household energy in general, most studies focus on household energy choice with a limited set of household's energy consumption intensity studies among households in developing countries. Therefore, there is need for a study to address behavioural, cultural, energy appliances and physical environmental characteristics influencing household energy consumption intensity.

References

Africa Progress Panel (2015), Power, people, planet: Seizing Africa's energy and climate opportunities: Africa Progress Report 2015. Geneva.

Arabmazar, A. and Schmidt, P. (1982), "An investigation of the robustness of the Tobit estimator to non-normality". *Journal of the Econometric Society*, 1055-1063.

Africa, L., Blore, M., Dwight, R., Reichhardt, C., Retief, D. and Mpando, T. (2008), Domestic energy use of low income households in Grahamstown East. State of the Environment Report (SoER) for Grahamstown, Eastern Cape, 1-29.

AGECCU (2010), Energy for a sustainable future: Summary report and recommendations. New York: United Nations.

Ajzen, I. and Fishbein, M. (1980), Understanding attitudes and predicting social behaviour.

Alem, Y., Beyene, A. D., Köhlin, G. and Mekonnen, A. (2016), "Modeling household cooking fuel choice: A panel multinomial logit approach". *Energy Economics*, 59: 129-137.

Barnes, D. F. and Floor, W. M. (1996), "Rural energy in developing countries: A challenge for economic development". *Annual Review of Energy and the Environment*, 21.

Behera, B. and Ali, A. (2016), "Household energy choice and consumption intensity: Empirical evidence from Bhutan". *Renewable and Sustainable Energy Reviews*, 53, 993-1009.

Behera, B. and Ali, A. (2017), "Factors determining household use of clean and renewable energy sources for lighting in Sub-Saharan Africa". *Renewable and Sustainable Energy Reviews*, 72: 661-672.

Bergasse, E., Paczynski, W., Dabrowski, M. and De Wulf, L. (2013), The relationship between energy and socio-economic development in the Southern and Eastern Mediterranean. CASE Network Reports, (412).

Bruce, N., Pope, D., Rehfuess, E., Balakrishnan, K., Adair-Rohani, H. and Dora, C. (2015), "WHO indoor air quality guidelines on household fuel combustion: Strategy implications of new evidence on interventions and exposure–risk functions". *Atmospheric Environment*, 106: 451-457.

Christensen, T. H. and Jensen, J. O. (2010), "Information and communication technologies: A new round of household electrification". *Energy Policy*, 38(4): 1764-1773.

Couture, S., Garcia, S. and Reynaud, A. (2012), "Household energy choices and fuelwood consumption: An econometric approach using French data". Energy Economics, 34(6): 1972-1981.

Connolly, D., Lund, H., Mathiesen, B. V. and Leahy, M. (2010), "A review of computer tools for analysing the integration of renewable energy into various energy systems". *Applied Energy*, 87(4): 1059-1082.

Cragg. J. (1971), "Some statistical models for limited dependent variables with

application to the demand for durable goods". Econometrica, 39(5): 829-844, https://ideas.repec.org/a/ecm/emetrp/v39y1971i5p829-44.html

Davis, M. (1998), "Rural household energy consumption: The effects of access to electricity Evidence from South Africa". *Energy Policy*, 26(3): 207-217.

Daioglou, V., Van Ruijven, B. J. and Van Vuuren, D. P. (2012), "Model projections for household energy use in developing countries". *Energy*, 37(1): 601-615.

Ericson, P. and Hansen, J. (1999), "A note on the performance of simple specification tests for the Tobit model". *Oxford Bulletin of Economics and Statistics*, 61(1): 121-127.

Eakins, J. (2013), An analysis of the determinants of household energy expenditures: Empirical evidence from the Irish household budget survey.University of Surrey. Surrey Energy Economics Centre.

ESMAP (2007), Technical and economic assessment of off-grid, mini-grid and grid electrification technologies. Technical Paper. Washington, DC: Energy Sector Management Assistance Programme, World Bank.

Foell, W., Pachauri, S., Spreng, D. and Zerriffi, H. (2011), "Household cooking fuels and technologies in developing economies". *Energy Policy*, 39(12): 7487-7496.

Farhar, B. C. (1998), "Gender and renewable energy: Policy, analysis, and market implications". *Renewable Energy*, 15(1): 230-239.

Harvey, M. and Pilgrim, S. (2011), "The new competition for land: Food, energy, and climate change". *Food Policy*, 36: S40-S51.

Heltberg, R. (2005), "Factors determining household fuel choice in Guatemala". *Environment and Development Economics*, 10(3): 337-361.

International Energy Agency(2014), *Sustainable Energy for All 2013-2014: Global Tracking Framework Report*. Washington DC: World Bank.

Institute of Economic Affairs (2015), Situational analysis of energy industry policy and strategy for Kenya.

International Energy Agency - IEA (2016), *World Energy Outlook: Energy statistics*. Paris.

International Energy Agency - IEA (2011), Energy for all, financing access for the poor. Special Excerpt of the World Energy Outlook. Paris.

Intelligent Energy Europe (2016), Assessment of sustainable lignocellulosic biomass potentials from Kenya for export to the European Union 2015 to 2030.

International Energy Agency (2012), World Energy Outlook 2012: Measuring progress towards energy for all: Power to the people. Paris, International Energy Agency.

Kenya National Bureau of Statistics (2017), *Statistical Abstract 2017*. Nairobi: Kenya National Bureau of Statistics.

Khandker, S. R., Barnes, D. F., Minh, N. H. and Samad, H. (2009), Welfare impacts of rural electrification: Evidence from Vietnam. Washington DC, World Bank.

Kowsari, R. and Zerriffi, H. (2011), "Three dimensional energy profile: A conceptual framework for assessing household energy use". *Energy Policy*, 39(12): 7505-7517.

Koshala, R. K., Koshal, M., Boyd, R. G. and Rachmany, H. (1999), "Demand for kerosene in developing countries: A case of Indonesia". *Journal of Asian Economics*, 10(2): 329-336.

Jumbe, C. B. and Angelsen, A. (2011), "Modeling choice of fuelwood source among rural households in Malawi: A multinomial probit analysis". *Energy Economics*, 33(5): 732-738.

Lambe, F., Jürisoo, M., Wanjiru, H. and Senyagwa, J. (2015), Bringing clean, safe, affordable cooking energy to households across Africa: An agenda for action. Prepared by the Stockholm Environment Institute, Stockholm and Nairobi, for the New Climate Economy.

Lee, L. Y. T. (2013), "Household energy mix in Uganda". *Energy Economics*, 39: 252-261.

Lutzenhiser, L., Moezzi, M., Hungerford, D. and Friedmann, R. (2010), Sticky points in modeling household energy consumption. ACEEE Summer Study on Energy

Efficiency in Buildings, 167-182.

Malla, S. and Timilsina, G. R. (2014), Household cooking fuel choice and adoption of improved cookstoves in developing countries: A review.

Mapako, M. and Mbewe, A. (2013). *Renewables and energy for rural development in Sub-Saharan Africa*. Zed Books.

Masera, Omar R., Saatkamp, Barbara D., Kammen and Daniel M. (2000), "From linear fuel switching to multiple cooking strategies: A critique and alternative to the energy ladder model". *World Development*, 28 (12): 2083-2103.

Mensah, J.T. and G. Adu (2013), An empirical analysis of household energy choice in Ghana.Swedish University of Agricultural Sciences, Department of Economics, Working Paper Series Uppsala 2013.

Michaelis L. and S. Lorek (2004), Consumption and the environment in Europe: Trends and futures. Danish Environmental Protection Agency, Environmental Project No. 904 2004, Copenhagen, Denmark.

Nababan, T. S. (2015), The factors affecting the household energy consumption, energy elasticity, and energy intensity in Indonesia. In International Conference on Entrepreneurship, Business, and Social Sciences.

Nansaior, A., Patanothai, A., Rambo, A. T. and Simaraks, S. (2011), "Climbing the energy ladder or diversifying energy sources? The continuing importance of household use of biomass energy in urbanizing communities in Northeast Thailand". *Biomass and Bioenergy*, 35(10): 4180-4188.

Nlom, J. H. and Karimov, A. A. (2015), "Modeling fuel choice among households in northern Cameroon". *Sustainability*, 7(8): 9989-9999.

Nlom, J. H. and Karimov, A. A. (2015), "Modeling fuel choice among households in northern Cameroon". *Sustainability*, 7(8): 9989-9999.

O'Neill, B. C., Ren, X., Jiang, L. and Dalton, M. (2012), "The effect of urbanization on energy use in India and China in the iPETS model". *Energy Economics*, 34: S339-S345.

Pagan, A. and Vella, F. (1989), "Diagnostic tests for models based on individual data: A survey". *Journal of Applied Econometrics* 4 (S), S29-S59.

Osiolo, H. (2009), *Enhancing household fuel choice and substitution in Kenya*. KIPPRA Discussion Paper No. 102. Nairobi: Kenya Institute for Public Policy Research and Analysis.

Puzzolo, E., Stanistreet, D., Pope, D., Bruce, N. and Rehfuess, E. (2013), Factors influencing the large-scale uptake by households of cleaner and more efficient household energy technologies. London: EPPI Centre.

Pudney, S. (1989), *Modelling individual choice. The econometrics of corners, kinks and holes*. London: Basil Blackwell.

Pukšec, T., Mathiesen, B. V. and Duic, N. (2013), "Potentials for energy savings and long term energy demand of Croatian households sector". *Applied Energy*, 101: 15-25.

Rao, M. N. and Reddy, B. S. (2007), Variations in energy use by Indian households: An analysis of micro level data. Energy, 32(2), 143-153.

Rahut, D. B., Mottaleb, K. A. and Ali, A. (2017), "Household energy consumption and its determinants in Timor-Leste". Asian Development Review, 34(1), 167-197.

Ren, Z., Foliente, G., Chan, W.-Y., Chen, D., Ambrose, M. and Paevere, P. (2013), "A model for predicting household end-use energy consumption and greenhouse gas emissions in Australia". *International Journal of Sustainable Building Technology and Urban Development*, 4(3): 210-228.

SEI (2011), Long-range energy alternatives planning system user guide for version 2011: First Draft.Retrieved March 2014, from www.energycommunity.org.

Shove, E. (2003), "Converging conventions of comfort, cleanliness and convenience". *Journal of Consumer Policy*, 26(4): 395-418.

Song, J. and Tan, Y. K. (2012), Energy consumption analysis of ZigBee-based energy harvesting wireless sensor networks. In Communication Systems (ICCS), 2012 IEEE International Conference.

Svoboda, P. and Brcak, J. (2013), "Electricity consumption demand model in Czech households". *International Advances in Economic Research*, 19(1): 63-65.

United Nations (2016), Report on Actions on Air Quality.

Walton, E., Takeuchi, D. T., Herting, J. R. and Alegría, M. (2009), "Does place of education matter? Contextualizing the education and health status association among Asian Americans". *Biodemography and Social Biology*, 55: 30-51.

Wooldridge, J. M. (2015), Introductory econometrics: A modern approach. Nelson Education.

World Bank (2013), Toward a sustainable energy future for all: Directions for the World Bank Groups energy sector. Washington DC: World Bank.

World Health Organization (2015), WHO guidelines for indoor air quality: Household fuel combustion. World Health Organization.

Wuyuan, Peng, Hisham Zerriffi and Pan Jihua (2008), Household level fuel switching in Rural Hubei.

Appendices

Appendix I: Household multiple energy consumption

Energy use combination	M	W	C	K	L	E
		21	23	550	12	31
M	-	5	2	6	-	27
W	-	-	36	369	3	98
C	-	-	-	676	22	131
K	-	-	-	-	19	95
L	-	-	-	-	-	149
E	-	-	-	-	-	-
MW	-	-	5	25	1	2
CL	-	-	-		-	178
CK	5		-		63	259
WC	-	-	-	478	6	49
KE	2		-	-	-	-
WK	25	-	-	-	7	41
LE	-	5	-	97	7	-
[illegible]	3		-	-	178	
CKE	-	-	-	-	-	119
WCE	-	-		-	9	-
WKE	2	-	-	-	4	-
WCK	21	-	-	-	23	28
WCKE	2	-	-	-	11	-
LWCKE	2	-	-	-	-	-

Key: M-material residue, W-wood fuel, C-charcoal, K -kerosene, L-Liquefied Petroleum Gas and E-electricity

Source: Authors calculations

Appendix II: Log Likelihood estimates for the determinants of houshold energy consumption intensity for tobit model

	0.0197 ***	0.0291 ***	0.0734*	-0.5737	-0.1075	-0.1443
	(-0.3157)	(-0.2563)	(0.0174)	(-0.0362)	(-0.0152)	(0.0712)
	-0.0161***	0.0350	0.0233	0.0761*	-0.0140***	0.0821 *
	(-0.0193)	(0.0291)	(0.0163)	(-0.0278)	(-0.0138)	(-0.0526)
	-0.0302	-0.0314 ***	0.0307**	0.0524*	0.0010***	-0.1431***
	(0.0203)	(-0.0303)	(-0.0168)	(-0.0277)	(-0.0142)	(0.0529)
	-0.0404	-0.1450**	0.0504**	0.0511**	0.0167 ***	0.0425 *
	(0.0386)	(-0.0597)	(0.0320)	(-0.0510)	(-0.0274)	(-0.0834)
	-0.2468***	-0.2852***	-0.0506***	0.2445***	0.0641*	0.1277
	(0.0223)	(-0.0362)	(-0.0177)	(0.0291)	(-0.0149)	(-0.0551)
	-0.2435***	-0.2161***	-0.1031***	0.1081	0.0845*	-0.1957
	(0.0385)	(-0.0649)	(-0.0270)	(-0.0432)	(-0.0220)	(-0.0530)

Monthly Income						
Ksh 2501 - 5000	0.1364 (0.0840)	-0.2164 (0.1410)	0.0140 ** -0.0435	0.0210** -0.0637	0.0307** (0.0337)	-0.0972 *** -0.0996
Ksh 5001 - 10000	0.2277*** (0.0796)	0.0289 ** -0.1194	0.1016** -0.0414	0.0727 * -0.0613	-0.0280 *** -0.0338	-0.2133** (0.0992)
Ksh 10001 - 15000	0.3163*** (0.0798)	0.1500 (0.1185)	0.0958** (0.0428196)	0.1167* (0.0643)	-0.0766** (0.034795)	-0.2341** (0.1075)
Ksh 15001 - 20000	0.3631 -0.0802	0.2103* -0.1188	0.1152 -0.0438	0.1067 (0.0643)	-0.0927 *** (0.0348)	-0.1775* -0.1060
Ksh 20001 - 50000	0.4239 (-0.0799)	0.3447 (-0.1177)	0.0833* (-0.0438)	0.1150 (-0.0676)	-0.1729*** (0.0352)	-0.2099*** -0.1095
Ksh 50001 - 100000	0.4855 (-0.0842)	0.5347 (-0.1223)	0.0321 (-0.0523)	0.1007 (0.0868)	-0.2713*** (0.0437)	-0.0994*** -0.1403
Above 100000	0.4728 (-0.1052)	0.5837 (-0.1451)	0.0166** (-0.0827)	-0.1470 *** (-0.1747)	-0.3522*** (0.0788)	-2.3850*** (-0.0789)
Education level of HHH						
Primary	0.0707 * (-0.0521)	0.18364 (0.1117)	0.1579 (-0.0346)	-0.1351*** (0.0475)	0.0620 ** (0.0268)	-0.0750 *** -0.0784
Secondary school	0.1633 (-0.0514)	0.4430 (-0.0346)	0.1740 (-0.0354)	-0.1596*** (0.0499)	0.0339** (0.0278)	-0.1212 (0.0864)
Vocational / diploma	0.2537 (-0.0530)	0.5761 (-0.1085)	0.0978* (-0.0382)	-0.2302*** (0.0568)	-0.0007*** (-0.0307)	-0.0980 * (-0.0983)
Bachelor's degree	0.0590** (-0.0591)	0.6745*** (0.1145)	0.0141** -0.0472	-0.4813*** (0.0847)	-0.1003** -0.0399	-0.0504 ** (-0.1464
Master's degree	0.3737*** (-0.0770)	0.5647*** (0.1303)	0.0092 *** (-0.0710)	-0.3347** (0.1493)	-0.1316** (0.0655)	-2.0529 (-0.2779)
Doctorate	0.0273** (-0.1606)	0.0620* (-0.2234)	-0.0315 *** (-0.1561)	-0.2009 (0.2644)	-0.0656 (0.1355)	-2.1203 -0.2010
Age of HHH (years)						
31 - 35	-0.0131** (-0.0275)	0.0476 * (0.0404)	0.0131 ** (0.0237)	0.0025 *** (0.0437)	-0.0255*** (0.02017)	0.1157 (0.0823)
36 - 40	-0.0424 -0.0299	-0.0617 (0.0446783	0.0312 -0.0249	0.0951** (0.0440)	-0.0168 (0.0212)	0.0411 (0.0874)
41 - 45	-0.0192 (-0.0326)	-0.1067 (0.0497)	0.02348 (0.0275)	0.1462*** (0.0474)	-0.0013 (0.0233)	0.0096 (0.0972)
46 - 50	-0.0592* (-0.0351)	-0.0833 (-0.0528)	0.0055 (0.0287)	0.1904*** (0.0479)	-0.0090 (0.0242)	0.04564 (0.0952)
51 - 60	-0.0183 (-0.0356)	-0.0268 (-0.0535)	0.0345** (0.0288)	0.2127*** (0.0475)		0.0726 (0.0908)
Above 60	0.0386 (-0.0505)	0.0807* (0.0768)	-0.0181 (0.0412)	0.2523*** (0.0625)	-0.0361 (0.0339)	0.2103** (0.1019)
Marital status of HHH						
Married	-0.0812*** (-0.0281)	-0.0923** (-0.0410)	0.0789 * (-0.0370)	0.1721 (-0.0483)	0.0226 (0.0369)	0.2110 -0.0235
Widowed	-0.0626* (-0.0459)	-0.0488** (0.0723)	0.0122 ** (-0.0418)	0.1359 (0.0606)	0.0277** (0.0698)	0.1144 (-0.0235)
Divorced	-0.0551 (0.1173936)	-0.2646 (0.1815)	-0.0979 (0.0791)	0.2685 (0.1757)	0.0712 (0.1310)	0.2103 -0.0677
Separated	-0.2223 (0.1882)	-0.0439 (0.2600)	-0.2161 (0.1512)	0.0091*** (0.2851)	0.1063 -0.0547	0.1927 -0.2850
Left censored	2428.0000	2938.0000	1532.0000	2479.0000	739.0000	3580.0000
Uncensored	1235.0000	725.0000	2131.0000	1184.0000	2924.0000	83.0000
Number of observations	3663.0000	3663.0000	3663.0000	36663.0000	3663.0000	3663.0000
LR chi2(40)	1774.9800	-0.9071	281.0200	914.5900	864.6600	90.5100
[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Prob> chi^2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Pseudo R^2	0.3756	0.0579	0.0579	0.1785	0.1948	0.1161
Log likelihood	-1475.5	-2284.9	-2286.9	-2104.4	-1787.4	-344.5

Standard errors in parentheses; *** p-value < 0.01, **p-value < 0.05, *p-value <0.10

Excluded reference categories: Rural, Male Household head, Permanent, Below 2500, No formal education, below 30 year, single

Source: Author calculation

Appendix III: Log-likelihood estimates for the double hurdle model

	HURDLE ONE					
Variables	**Electricity**	**LPG**	**Charcoal**	**Kerosene**	**Wood fuel**	**Material residue**
Location						
Urban	0.9868	0.6482	0.3172	-0.3389	-0.9884	-0.3489
	(0.0572)	(0.0659)	(0.0535)	(0.0591)	(0.0639)	(0.1546)
Decision maker on Energy consumption						
Spouse	-0.0919***	-0.0935***	0.0577**	0.0156**	-0.1208***	-0.3196***
	(0.0616)	(0.0715)	(0.0499)	(0.0601)	(0.0534)	(0.1138)
Child	-0.1266***	-0.3642***	0.1718	0.1049	0.1174	0.1133
	(0.1196)	(0.1397)	(0.0969)	(0.1145)	(0.1001)	(0.1839)
Gender of HHH						
Female	-0.0042***	0.1271	0.1195	0.0495**	0.1719	0.2038
	(0.0588)	(0.0687)	(0.0483)	(0.0577)	(0.0533)	(0.1158)
Dwelling unit						
Semi-permanent	-0.6512	-0.5854	-0.2073	0.3335	0.4193	0.2501
	(0.0618)	(-0.0799)	(0.0527)	(0.0651)	(0.0556)	(0.1193)
Temporary	-0.6361	-0.4512	-0.3441	0.0383**	0.1028)	-0.4341
	(-0.1098)	(0.1493)	(0.0780)	(0.0956)	(0.0830)	(0.2196)
Ave monthly income Ksh						
2501 - 5000	0.2916	-0.4386	0.0045***	0.1098	-0.0057**	-0.1211***
	(0.2343)	(0.3155)	(0.1210)	(0.1550)	(0.1228)	(0.2279)
6001 - 10000	0.5063	-0.0030***	0.2692	0.1978	0.1066	-0.3667**
	(0.2215)	(0.2693)	(0.11580	(0.149)	(0.1186)	(0.2241)
10001 - 15000	0.7673	0.2217	0.0350**	0.0004***	0.1789	0.1062
	(-0.2219)	(-0.2673)	(-0.1210)	(0.1523)	0.1247	-0.9033
15001 - 20000	0.9220	0.3757	0.4343	0.0279**	0.1826	-0.2927***
	(-0.2233)	(-0.2678)	(-0.1244)	(0.1556)	(0.1284)	(0.2399)
20001 - 50000	1.0700	0.6800	0.3851	-0.3291***	0.1691	-0.3581
	(-0.2227)	(-0.2653)	(-0.1254)	(-0.1541)	(0.1307)	(0.2466)
60001 - 100000	1.3944	1.3634	0.4022	-0.4322***	0.2165	-0.1652 ***
	(-0.2438)	(-0.2 794)	(-0.1514)	(0.1750)	(0.1665)	(0.3197)
100001-200000	1.1119	1.6132	0.5235	-1.0358***	-0.2922***	0.3571
	(0.3329)	(0.3645)	(-0.2498)	(0.2700)	(0.3268)	(0.1152)
over 200,000	2.1731	1.4973	0.1750	-1.5903***	0.1186	0.3546
	(0.5206)	(-0.4054)	(-0.3000)	(0.3553)	(0.3624)	(0.1152)
Education level of HHH						
Primary school	0.2064	0.3693	0.4882	0.0357**	-0.0790***	-0.1482**
	(-0.1481)	(-0.2473)	(-0.0977)	(-0.1152)	(-0.0951)	(0.1766)
Secondary school	0.4322	0.8946	0.5384	0.2982	-0.1117***	-0.2261***
	(0.1464)	(-0.2390)	(-0.1006)	(0.1176)	(0.0994)	(0.1928)
Vocational / diploma	0.7038	1.2065	0.3563	0.0843*	-0.2414***	-0.1786***
	(-0.1519)	(-0.2413)	(-0.1097)	(-0.1256)	(0.1121)	(-0.2193)
Bachelor's degree	0.0933*	0.0470*	0.1000	-0.0370***	-0.6215***	-0.0280***
	(-0.1779)	(-0.255)	(-0.1374)	(-0.1374)	(-0.1597)	(-0.3211)
Master's degree	1.1133	1.3253	0.1238	-0.2665***	-0.1334***	0.0986*
	(-0.2825)	(0.3084)	(-0.2060)	(0.2174)	(-0.2107)	(0.0856)
Doctorate	0.2105	0.8145	-0.2111***	0.3739	-0.3531***	0.4882
	(-0.5987)	(-0.5292)	(-0.4267)	(0.5041)	(0.4993)	(-0.0977)
Age_HH						
31 - 35 years	0.0549**	-0.0925***	0.1160	0.1416	0.1806	0.0523**
	(-0.0848)	(-0.1052)	(-0.0748)	(0.0897)	(-0.0836)	(-0.1908)
36 - 40 years	-0.0482***	-0.0254***	0.1113	0.1530	0.2730	-0.0547***
	(-0.0918)	(-0.0823)	(-0.0823)	(0.0977)	(-0.0902)	(-0.2159)
41 - 45 years	-0.0431***	-0.1917***	0.0986**	0.1148	0.37206	0.0061 ***
	(-0.0993)	(0.1245)	(-0.0856)	(0.1022)	(0.0922)	(0.2115)

46 - 50 years	-0.1899*** (-0.1063)	-0.0355*** (0.1251)	0.1966 (-0.0862)	0.0305** (0.1023)	0.4596 (0.0916)	0.1093 (0.1989)
51 - 60 years	-0.0656*** (-0.1072)	0.1479 (0.1774)	0.0499** (-0.1198)	0.1587 (0.1470)	0.3182 (0.1231)	0.4122 (0.2227)
60 - 70 years	0.0891* (-0.1486)	0.5034 (0.2897)	0.3896 (-0.1865)	-0.3180*** (0.2077)	0.2324 (0.1886)	-0.3130*** (-0.4512)
Over 70 years	0.0982** (-0.2568)					
Marital_status_HH						

[illegible]

Variables	Electricity	LPG	Charcoal	Kerosene	Wood fuel	Material residue
Urban	0.0080*** (-0.0161)	-0.0006*** (-0.0090)	-0.0316*** (-0.0133)	-0.1395*** (-0.0347)	-0.1209*** (-0.0281)	0.0001*** (0.0016)
Gender of HHH						
Female	-0.0267*** (-0.0158)	0.0006*** (-0.0993)	-0.0003*** (-0.0415)	-0.0558*** (-0.0281)	-0.0248*** (-0.0169)	-0.0009*** (0.0014)
Spouse	-0.0097*** (-0.0171)	0.0136*** (0.0195)	0.0314** (0.0135)	0.0181*** (0.0290)	0.0107*** (-0.0163)	-0.0038*** (0.0015)
Child	0.0133*** (0.0312)	0.0165*** (0.0399)	0.0049*** (0.0259)	-0.0127*** (0.0584)	0.0589** (0.0295)	-0.0005*** (0.0028)
Dwelling unit						
Semi-permanent	-0.0283*** (-0.0218)	-0.0104*** (-0.0289)	0.0174*** (-0.0138)	0.0613* (0.0309)	0.0801* (0.0173)	0.0048*** (0.0016)
Temporary	-0.0344*** (0.0387)	0.0266** (0.0497)	0.0270** (0.0221)	0.1824 (0.0418)	0.1137 (0.0262)	-0.0046*** (0.0023)
Average Monthly Income						
2501 - 5000	0.1250 (0.1070)	0.0082*** (0.1346)	0.0055*** (-0.0386)	0.0286** (0.0575)	0.0398** (0.0376)	-0.0100*** (0.0036)
5001 - 10000	0.1012 (0.1019)	0.1157 (0.1031)	-0.0257*** (0.0361)	-0.0881*** (0.0565)	0.0271** (0.0355)	-0.0143*** (0.0034)
10001 - 15000	0.0873 (0.1011)	0.1217 (0.1000)	-0.0850*** (0.0370)	-0.1438*** (0.0180)	0.0496** (0.0373)	-0.0135*** (0.0036)
15001 - 20000	0.0707* (0.1006)	0.0709* (0.0993)	-0.0888*** (0.0376)	-0.2050*** (-0.0645)	0.0178*** (0.0382)	-0.0131*** (0.0037)
20001 - 50000	0.1128 (0.0999)	0.0663* (-0.0975)	-0.1175*** (-0.0380)	-0.2776*** (-0.0683)	0.0531 (0.0396)	-0.0150 (0.0037)
50001 - 100000	0.1184 (0.1010)	0.0403** (0.0984)	-0.2344*** (-0.0461)	-0.8545*** (-0.1355)	-0.0317*** (0.0531)	-0.0112*** (0.0045)
100001- 200000	0.1936 (0.1096)	0.0491** (0.1053)	-0.3495*** (-0.0829)	-0.2779*** (0.2425)	-0.0468*** (0.1258)	-0.0158*** (-0.0073)
over 200,000	0.2400 (0.1123)	-0.1330*** (0.1159)	-0.3243*** (-0.1044)	-1.2401*** (0.9557)	-0.1299*** (0.1258)	-0.0144*** (0.0089)
Education level of HHH						
Primary school	-0.0258*** (0.0562)	0.0270** (0.1203)	-0.0475*** (0.0309)	0.0086*** (0.0510)	-0.1477*** (0.0256)	0.0015*** (0.0042)
Secondary school	-0.0257*** (0.0542)	0.0307** (0.1161)	-0.0476*** (0.0312)	-0.0412*** (0.0538)	-0.1614*** (-0.0273)	0.0057*** (0.0043)
Vocational / diploma	-0.0061*** (0.0546)	0.0197*** (0.1157)	-0.0833*** (0.0330)	-0.0427*** (0.0624)	-0.1719*** (-0.0321)	0.0017*** (0.0049)
Bachelor's degree	0.0491** (0.0570)	0.0453** (0.1170)	-0.1146*** (0.0407)	-0.1446*** (0.1058)	-0.3464*** (0.0616)	0.0040*** (0.0052)
Master's degree	0.0853* (0.0647)	-0.0331*** (0.1216)	-0.1751*** (-0.0676)	-0.3693*** (0.2831)	-0.0880*** (0.1121)	-0.0017*** (0.0044)
Doctorate	0.2406 (0.1204)	0.2097 (0.1620)	-0.0516*** (-0.1502)	-0.5661*** (0.4078)	-0.0130*** (0.1720)	0.0064*** (0.0067)
Age of HHH						
31 - 35	-0.0010 (0.0012)	0.0485** (0.0255)	0.0407** (-0.0188)	-0.0955*** (-0.0410)	-0.0090*** (0.0282)	0.0026*** (0.0021)
36 - 40	-0.0372*** (0.0242)	-0.0305*** (0.0284)	-0.0006*** (0.0195)	-0.0992* (-0.0430)	-0.0009*** (0.0274)	0.0018*** (0.0022)
41 - 45	-0.0130*** (0.0266)	-0.0294*** (0.0327)	-0.0092*** (0.0219)	-0.0706*** (0.0476)	0.0079*** (0.0291)	0.0025*** (0.0024)
46 - 50	-0.0060*** (0.0293)	-0.0002*** (0.0346)	-0.0311*** (0.0232)	-0.0715*** (0.0490)	0.0111*** (0.0286)	0.0041*** (0.0025)
51 - 60	0.0032*** (0.0301)	-0.0377*** (0.0358)	-0.0428*** (-0.0231)	-0.1241*** (0.0501)	-0.0145*** (0.0279)	0.0030*** (0.0025)
60 - 70	-0.0238*** (0.0445)	-0.0152*** (0.0517)	0.0661* (-0.0353)	-0.1646*** (-0.0702)	0.0162*** (0.0353)	0.0101*** (-0.0035)
over 70	0.0123*** (0.0859)	0.0097*** (0.0895)	-0.1512*** (0.0550)	0.0154*** (0.1022)	-0.1396*** (0.0559)	-0.0046*** (0.0056)
Marital status of HHH						
Married	-0.0906*** (0.0215)	-0.0646*** (0.0250)	-0.0087*** (0.0210)	-0.0846*** (0.0440)	-0.0067*** (0.0320)	0.0025*** (0.0038)

[illegible]-70	-0.0238***	-0.0152***	0.0661*	-0.1646***	0.0162***	0.0101***
	(0.0445)	(0.0517)	(-0.0353)	(-0.0702)	(0.0353)	(-0.0035)
over 70	0.0123***	0.0097***	-0.1512***	0.0154***	-0.1396***	-0.0046***
	(0.0859)	(0.0895)	(0.0550)	(0.1022)	(0.0559)	(0.0056)
Marital status of HHH						
Married	-0.0906***	-0.0646***	-0.0087***	-0.0846***	-0.0067***	0.0025***
	(0.0215)	(0.0250)	(0.0210)	(0.0440)	(0.0320)	(0.0038)
Widowed	-0.0974***	-0.0705***	-0.0353***	-0.0689***	-0.0216***	-0.0005***
	(0.0407)	(0.0494)	(0.0303)	(0.0592)	(0.0375)	(0.0073)
Divorced	-0.0365***	-0.0695***	-0.0287***	-0.0876***	0.1689	-0.0037**
	(0.0863)	(0.1200)	(0.0902)	(0.2032)	(0.1094)	(0.0136)
Separated	-0.2618***	0.0644*	0.1006	-0.4175***	-0.0866***	0.0023***
	(0.1615	(0.1480)	(0.1003)	(0.3490)	(0.2006)	(0.0013)
Lower limit	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Upper limit	+inf	+inf	+inf	+inf	+inf	+inf
Number of observations	1235.0000	725.0000	2131.0000	2924.0000	1184.0000	83.0000
Wald chi^{2}40	136.5500	72.8900	281.7800	261.2600	202.8500	202.8500
Prob> chi^{2}	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Log likelihood	246.7734	192.9536	377.7989	-86.7727	122.6400	122.6378

Appendix II: Log likelihood estimates for the determinants of household energy consumption intensity for tobit model

Standard errors in parentheses; *** p-value < 0.01, **p-value < 0.05, *p-value <0.10

Excluded categories: Excluded reference categories: Rural, Male Household head, Permanent, Below 2500, No formal education, below 30 year, single

Source: Author calculation