MODELLING OF HOUSEHOLD ENERGY UTILIZATION, CHANGING BEHAVIOURS AND DIVERSIFICATION IN WESTERN KENYA: MEDIATION AND MODERATION ANALYSIS

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DEDICATION

This research is dedicated to:

My parents

and

My family

Whose love and support have seen me this far.

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Many individuals and institutions have contributed either directly or indirectly to the accomplishment of this study. Due to constraints of space, I will only mention a few by name.

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ABSTRACT

Clean, diversified and sustainable household energy sources for cooking is essential in order to maintain worthy health for women and children and also improvi~~ng~~ the energy security of people in the developing countries. Yet, the understanding of household energy dynamics and information remains unclear. This necessitates investigation of transition pathways towards diversification, sustainable and modern household energies. The main objective of this research was to model household energy utilization, changing behaviours and diversification using Structural Equation Modelling (SEM). The specific objectives included: determinants of household energy utilization and changing behaviours; the effects of renewable energy and accessibility on energy utilization, changing behaviour and household diversification of energy sources and finally modeling of the effects of moderators and mediators on the household energy sources diversification. The research was carried out in the counties of Bungoma and Uasin Gishu. Random sampling technique was used to select 640 households from a target household of 663,739 and data was collected using a structured questionnaire. The data was analyzed using AMOS version 23 to achieve the first three objectives. Bootstrapping method was utilized to validate mediation and moderation models. The results showed that firewood is still the most common energy resource used for cooking in both rural and peri urban areas as evidenced by responses of 87.5% and 72.4%, respectively. The use of LPG (26 to 42%), charcoal (39.4% to 53.8%) and kerosene (14.3% to 17.3%) for cooking was found to increase as one moves from rural to peri-urban and vice versa for agricultural residues (12.3% to 5.3%). Biogas uptake still represents a small fraction (11.4 to 14.6%) of the energy mix at local level. The use of solar for lighting showed reduction as one move from rural to peri urban (44.8% to 39.6%) and vice versa for kerosene and electricity. SEM analysis found that factors such as education level, income, residential status, peri urbanization, house size, house composition, age and gender of the household head influence the changing behaviours and diversification among households both for cooking and lighting. Biogas users realized time saving of 1hour 36 minutes on average per household daily with financial saving of KES 2,557 per month as compared to firewood users. In addition, biogas indicated negative association with the use of conventional household energy sources for cooking fuels. Consequently, accessibility increased household fuel utilization and diversification. Interestingly, LPG (Path coefficient (β) = 0.461, critical ratio (C.R) = 15.204) followed by biogas (β = 0.333, C.R = 11.738) revealed to be the most important contributor to household diversification. The mediating effects of peri urbanization improved the household utilization of charcoal (β = 0.01, C.R = 6.72) kerosene (β = 0.04), LPG (β = 0.01), and conversely for firewood (β = - 0.013, C.R = 8.72) and agricultural residues (β = - 0.01). With income as an independent variable and education as a moderator; number of cars (β = 0.21), peri urbanization (β = 0.01), household size (β = 0.0397), residential status (β = - 0.0396), and gender (β = - 0.104) revealed mediating effects on the household energy diversification. According to bootstrapping reliability test, the limit for Bollen-Stine bootstrap is < 0. 12. In conclusion, household attributes have direct, moderating and mediating effects on the household energy utilization, changing behaviour and diversification. This study showed that household energy changing behaviour and diversification in Kenya are affected by moderating and mediating factors such as peri urbanization, cars among others. This study puts forward the need for policymakers and energy planners in Kenya and other developing countries to improve accessibility (supply and distance) of sustainable fuels and create awareness about the harmful effect of using dirty fuel at early stage through education curriculum, seminars and workshops.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS, ABBREVIATIONS AND NOTATIONS

AGFI	Adjusted Goodness-of-Fit Index
AMOS	Analysis of a moment structures
ANOVA	Analysis of variance
ASALI	A sustainable approach to livelihood improvement
ρ	Bollen-Stine bootstrap
C.R	Critical ratio
CFA	Confirmatory Factor Analysis
CFA	Confirmatory Factor Analysis
CMIN	Chi-Square Value Minimum
DF	Degrees of Freedom
ECA	Economic Commission for Africa
ECB	Energy Consumption Behavior
EFA	Exploratory Factor Analysis
GFI	Goodness-of-Fit Index
GHG	Greenhouse gases,
HCE	Household Carbon Emission
HED	Household energy diversification
HH	Household head
KNBS	Kenya National Bureau of Statistics
Kshs	Kenyan Shillings

LPG	Liquefied Petroleum Gas
M	Mediator variable
m^2	Square metre
MR	Multilevel regression
N	Population size
NFI	Normed Fit Index
P	Population
PCFI	Parsimony-Adjusted Comparative Fit Index
PNFI	Parsimony-Adjusted Normed Fit Index
R^2	Squared Multiple Correlations
RE	Renewable Energy
RMSEA	Root Mean Square Error of Approximation
S. E	Standard error
SDGs	Sustainable Development Goals
SEM	Structural Equation Modelling
SPSS	Statistical Package for Social Sciences
SPSS	Statistical Program for Social Sciences
TLI	Tucker-Lewis's index
UK	United Kingdom
UN	United Nations
X	Independent variable,

Y	Dependent variable,
Z	Moderator variable
$\chi 2$	chi-square

DEFINITION OF TERMS

Accessibility	The quality of being easy to obtain or use
Changing	Take or use another instead of
Diversification	Varying its range of products or field of operation/ the action of diversifying something or the fact of becoming more diverse
Effects	A change which is a result or consequence of an action or other cause
Energy	Power derived from the utilization of physical or chemical resources, especially to provide light and heat or to work machines
Energy Ladder	The change in energy-use and demand patterns in accordance to the variations in economic status of the household
Energy stacking	Spreading your use of energy/ multiple use of household energy
Household	A house and its occupants regarded as a unit
Latent variables	Variable that are not directly observed but are rather inferred from other variables that are observed (as opposed to observable variables)
Mediator	Explains how or why two variables are related
Moderator	Affects the strength or direction of the relationship
Peri urban	landscape interface between town and country/ transition zone where urban and rural uses mix
P-value	The probability of obtaining results as extreme as the observed results of a statistical hypothesis test
Significance	The quality of being worthy of attention; importance
Utilization	The action of making practical and effective use of something
Variable	An element, feature, or factor that is liable to vary or change

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Africa is experiencing the fastest growth in population world-wide: with a projected rise of 2.2% per year on average. According to (Conti et al., 2016), its population will increase from 1.2 billion in 2016 to 2.0 billion in 2040. Sub-Saharan Africa population is also expected to show average annual growth rates of 2% and result in an increase by one million people between 2015 and 2050, doubling the current population within the next 35 years (United, 2015) and to increase from 1.14 billion (current 2021) to 1.52 billion by 2050 (Ezeh et al., 2020). The economy of Africa has grown as well, at an average rate of 5% between 2000 and 2014. Growth at such scale will have major implications for household energy utilization and changing behaviour (Karekezi et al., 2008) and is likely to outpace the rate of household energy utilization across different parts of the continent.

The predictions shows that, by 2030, around 600 million people in Sub-Saharan Africa will still remain without access to electricity and continue to depend on conventional energy from biomass (e.g., wood, straw and manure), coal, or kerosene for cooking (Conti et al., 2016). It is also projected that the number of people relying on the traditional use of biomass in Sub-Saharan Africa will rise from 2.7 billion today to 2.8 billion in 2030 (Kaygusuz, 2012). The continued dependence on conventional energy sources will have a serious impact on human health from indoor air pollution (Carvalho et al., 2019; de la Sota et al., 2018; Duflo et al., 2008; Kandeler et al., 2000; Liu et al., 2018; Rehfuess & Organization, 2006; Zuo et al., 2018). This, likewise will affect the environment by forest degradation and enhanced carbon emissions in the atmosphere resulting from wood-fuel consumption (Pearson et al., 2017; Rahut et al., 2016).

Moreover, deforestation associated with timber cutting, agriculture and other forms of resource exploitation reduces the availability of biomass-based energy sources (Petursson et al., 2013; Sulaiman et al., 2017), forcing people to increase their efforts in securing wood fuel and travelling longer distance between home and fuel source (Rahut et al., 2017; Rahut et al., 2016). Furthermore, this will limit their fuel consumption (e.g., lower frequency or intensity of fuel use) and in view of the reduction of adverse health effects (Baland et al., 2010), diversify their fuel use (Treiber et al., 2015) and moreover, look out for renewable and cleaner alternatives such as wind, solar and biogas (Kelebe et al., 2017).

The SEM (structural equation modelling) approach intends to describe household energy transition pathways for sustainable energy. The structural equation model will help to explore future transitions and what might enable or inhibit them; to design, asses and evaluate transition pathways towards modern/clean household energy sources and infrastructure for sustainable energy: and to understand where appropriate, the roles of independent variables, moderator and mediating variables and also, opportunities of large and small 'actors' in the dynamics of transitions.

A crucial challenge for policy makers in Kenya and Sub-Saharan Africa is to resolve the persistent lack of access to modern and clean cooking such as electricity and LPG, which have served as brakes on the continent's growth. The study of household fuel choice for cooking in peri urban and rural areas of Bungoma and Uasin Gishu counties in Kenya is of particular interest because of different socio-economic changes. Analyzing the change in household energy utilization pattern and diversification is important, as findings of such analysis have vital policy implications. Most importantly, it can help in predicting the household energy of the peri urban and rural areas to enable the governments to make wise decisions on production sectors accordingly. A study of household energy utilization, changing behaviour and diversification among households using SEM model was conducted in Kenya, as an example of a developing country where households change their energy sources with interactions of many interdependent variables to the extent of even diversifying their portfolio.

1.1.1 The role of peri urbanization

Peri-urbanization refers to a process of dynamic change in land-use and livelihoods affecting the perimeter of growing or stable urban areas (Simon, 2020). An increasing share of Africa’s population is expected to live in cities and towns by 2030. Whereas urban areas comprise 472 million people at present, it is expected that this number will double over the next 25 years as more people will be pushed out of rural areas (Lall, 2017b). The rate of urbanization is projected to increase from 41% in 2016 to 51% in 2040 (Lall, 2017a; Van Noorloos & Kloosterboer, 2018). It is likely to be accompanied by a rise in appliance and vehicle use and increased demand for modern household energy use, including energy-intensive products such as LPG and electricity (Hove et al., 2013; Madlener & Sunak, 2011; Zhao & Zhang, 2018). However, lack of access to electricity may form a major barrier to urban development and Africa’s economic development in general. Electricity access is the lowest in Sub-Saharan Africa, both in urban and rural areas, with rates at 58% and 12% respectively (Freire, 2017; Goebel, 2007; Hove et al., 2013; Rahut et al., 2017).

Households in cities and surrounding rural areas differ in energy use and supply needs.
Whereas urban dwellers use relatively less firewood compared to their rural neighbors,

they typically employ more charcoal which is usually cheap and readily available. Various energy studies on Sub-Saharan Africa confirm an increase in charcoal consumption with rising urbanization levels (Arnold & Persson, 2003; Hanif, 2018; Mwampamba, 2007; Wang & Dong, 2019).

According to the theoretical explorations, urbanization exert impact on energy problems in two main ways: first, the construction and use of abundant infrastructures, buildings, and security during urbanization increase energy consumption and have a negative impact on climate change. Second, the economies of scale for energy supply and concentrated use of energy consumption caused by population agglomeration and urbanization, as well as industrial structure optimization, technological innovation, and updating of consumption brought by industrialization, increase energy utilization, thus affecting the energy utilization and changing behaviour (Li et al., 2019).

It is believed that housing development in most peri urban is mostly characterized by a high level of informal development, poor quality housing and confronted with a multi-dimensional environmental and socio-cultural challenges (Luo et al., 2020; Puttal & Ravadi, 2014). Furthermore, grid electricity is usually available in cities, yet, it is not accessible to all particularly the urban poor (i.e., slums) who mostly live at neglected localities deprived of basic infrastructure (Karekezi et al., 2008). In rural areas, homesteads are often dispersed and consequently, not connected to grid electricity because of high transmission and distribution costs associated with grid extension (Fobi et al., 2018). The latter is particularly evident in Eastern and Southern Africa where the majority of the rural population resides in dispersed homesteads (Karekezi & Kithyoma, 2002). As a consequence, rural households resort to conventional energy sources, yet at the same time, rural areas are perceived as the ideal place for deployment of new and innovative electrification technologies such as those based on solar energy (Karekezi & Kithyoma, 2002).

So far, literature on the impact of peri urbanization on household energy utilization and changing behaviour is still scarce. Many scholars have paid special attentions to the relationship between socio economic factors such as income and energy consumption, hence there is need to understand the role and mediating effects of peri urbanization on household energy utilization changing behaviour and diversification.

Peri urbanization is an important factor that affects the pattern of energy consumed in developing countries especially Kenya. As a given area becomes urbanized or per urbanized, the level of household energy utilization also increases. This level may be accompanied by increases in income that comes together with urbanization. There is also a shift from traditional to modern/clean fuels in peri urban areas but the use of traditional fuels in many urban areas of developing countries is still high especially among low-income groups. Furthermore, instead of shifting to modern fuels, people are consuming diverse types of energy sources that constitute both traditional and modern fuels. The purpose of this part is to explain the mediation effects of peri urbanization on household energy utilization and diversification.

1.1.2 Kenya as a case study country

Like elsewhere on the African continent, the energy demand in Kenya is expected to rise at a fast pace in the coming decade. Kenya was in the year 2017 characterized by a population growth of 2.6% and an economic growth of 6% (UN ECA 2017) as shown in Figure 1.1.

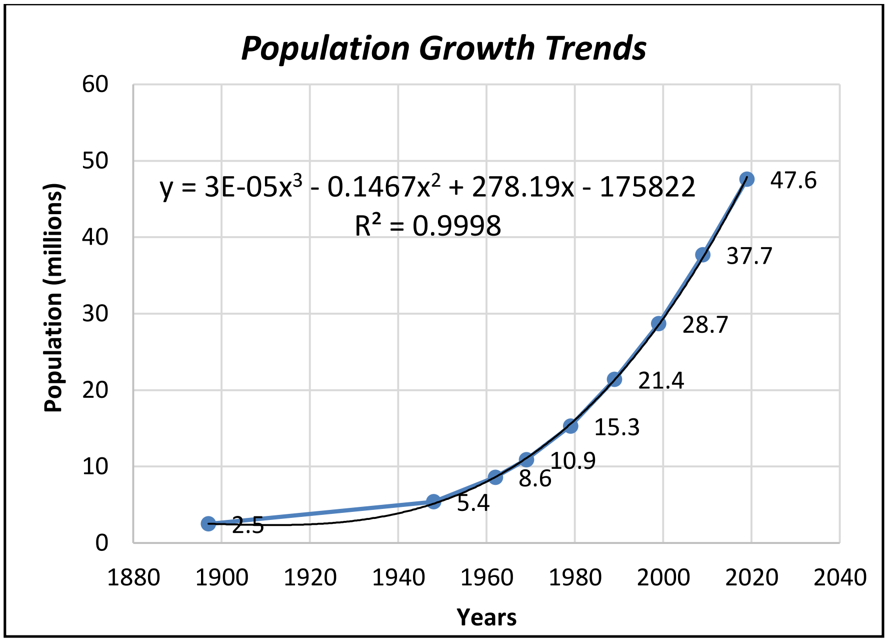

Figure 1. 1: Population growth trends in Kenya

(KNBS, 2019)

While Kenya's current urbanization rate of 27.8 % is well below those reported for SSA and Africa (37% and 40% respectively) (Lall, 2017a), it is estimated that nearly half (44%) of the entire population of Kenya will be urban by the year 2050 (Desa, 2014). However, most parts of the country still rely on conventional sources of energy, with firewood being the first-choice cooking fuel for the majority of households as shown by various studies (Kimutai et al., 2019; Pundo & Fraser, 2006; van der Kroon, 2016; Van der Kroon et al., 2013; Yonemitsu et al., 2015).

Even though there are several initiatives promoting the use of renewable energy sources, analysis of its effects on the use as alternative energy sources and accessibility of household energy sources are limited especially in Kenya (Sarkodie & Adom, 2018). Access to clean energy for cooking in Kenya is about 15-23% which is low as compared with India and China, that have reached 49% and 71% respectively (Michoud & Hafner, 2021). Most of the existing literature on household energy use focus mainly on economic, social, and demographic factors (Azam et al., 2016; Martínez-Espiñeira et al., 2014) disregarding the potential effects of renewable energy (Sugiawan & Managi, 2016) and accessibility on household energy utilization and changing behaviours. In developing countries like Kenya, the accessibility of household energy use continues to pose a formidable challenge, especially with the high cost of cooking gas and kerosene and the environmental problems associated with firewood (Afrane & Ntiamoah, 2012; Gioda et al., 2019; Pode, 2010).

This research was carried out in the counties of Bungoma and Uasin Gishu, both located in Kenya's semi-humid region, with the selection of both counties under the guidance of the ASALI project and experts at the Kenya Forestry Research Institute (KEFRI) (Ondiba & Matsui, 2020).

1.2 STATEMENT OF THE PROBLEM

In the world, about 3 billion people depend on biomass fuels resulting to about 4,000,000 , 739,000 in Africa and 21,500 Kenyans annual deaths respectively (Abera et al., 2021). Rising populations, increasing urbanization, and resource-intensive activities have made Kenyan cities a significant source of pollution. African urban growth rates are and will likely continue to be the highest in the world at 3.1–3.8% annually (Abera et al., 2021). Further, in Sub-Saharan Africa approximately 600 million people have no access to electricity and 890 million still use traditional fuels such as agricultural residues, twigs, fire wood to cook. Also, globally, about 20 – 30% of total energy demand is for household energy use. Yet, our understanding of transition towards clean, sustainable and modern household energy sources remains unclear (Bayer et al., 2020; Estiri, 2014; Leal Filho et al., 2019). Therefore, there is a need to shift toward more sustainable energy which reduces the health, environmental consequences and household energy security, and to understand the transition pathways towards sustainable and modern household energies.

Analyzing household energy utilization, changing behaviour and diversification with the help of Structural Equation Modelling (SEM) is useful, as it describes simultaneous examination of the effects which are relevant and allows for the investigation of more varied and complex research. The research was conducted in the counties of Bungoma and Uasin Gishu, both located in the semi-humid region of Kenya, with the selection of both counties guided by ASALI project and experts at the Kenya Forestry Research Institute (KEFRI).

1.3 PURPOSE OF THE STUDY

With the increased exposure to the smoke and particulate matter due to biomass fuels which causes health problems (Edwards & Langpap, 2012; Fullerton et al., 2008; Schilmann et al., 2019) to the household members, like coughing, irritating and painful eyes and more severe health issues like pneumonia, stroke and lung cancer, there is a need to shift toward more sustainable and clean energy. Also, environmental degradation and erosion occur due to the dependency on biomass resulting to the loss of forests cover, the burning of biomass and more greenhouse gasses are emitted into the atmosphere (Ziming Liu et al., 2020; Schilmann et al., 2019). Worldwide, 3 billion people still use biomass as an energy source and this is associated with 1.2 million premature deaths per year, a number comparable with the consequences of malaria (Bailis et al., 2005). Household indoor air pollution is estimated to cause 9.8 million premature deaths by the year 2030 further estimated that GHG emissions will be 6.7 billion tons of carbon by 2050, which is 5.6% of Africa's total emissions and also it is believed that with current charcoal-intensive use, emissions will increase by 140 to 190% (Bailis et al., 2005).

Household energy changing behaviour has been considered by numerous researchers and is now recognized as a vital tragedy for human society owing to its growing prevalence. Most studies have been done on the household energy utilization patterns and factors affecting the fuel choices using correlations (Akpalu et al., 2011; Arnold & Persson, 2003; Burger et al., 2015; Choumert-Nkolo et al., 2019; Louw et al., 2008; Masera et al., 2000; Musango, 2014; Mutua et al., 2012; Rahut et al., 2017; Rahut et al., 2019; Rahut et al., 2016; Ruiz-Mercado & Masera, 2015; van der Kroon, 2016; Van der Kroon et al., 2013).

Analyzing household energy utilization, changing behaviour and diversification with the help of Structural Equation Modelling (SEM) may be useful, as it describes simultaneous examination of the effects which are relevant and allows for the investigation of more varied and complex research (Fairchild & MacKinnon, 2009; Tóth-Király et al., 2018).

The model approach intends to describe household energy transition pathways for sustainable energy. The structural equation model will help to explore future transitions and what might enable or inhibit them; to design and evaluate transition pathways towards modern energy sources and infrastructure for sustainable energy: and to understand where appropriate, the roles of independent variables and opportunities of large and small ‘actors’ in the dynamics of transitions. The new model suggested illustrates the overall impacts of explanatory variables (income, education, household size, and distance to household energy suppliers, age and renewable energy sources) that lead to predicting the outcome (diversification of house energy) utilized. Therefore, it is a single model capable of helping researchers to better understand the relations and provide an overall evaluation of the constructs (latent or measurement variables) by utilizing a combination of seven characteristics (income, education, household size, gender, age, residence status and peri urbanization). Moreover, the model proposed in the present study seeks to estimate the independent (income) and mediator variables (household size, accessibility, peri urbanization, wealth measured by cars, age, gender, dwelling characteristics and renewable energy) moderated by education based on definitions of the latent variables.

1.4. RESEARCH OBJECTIVES

1.4.1 Main Objective

The main objective of this study was to model household energy utilization, changing behaviours and diversification in Uasin Gishu and Bungoma counties, Kenya using structural equation modelling approach.

1.4.2 Specific Objectives

Specifically, the study aims at achieving the following objectives:

(i) To investigate household energy utilization and examine factors that influence the changing behaviours and diversification among households.

(ii) To analyze the effects of renewable energy and accessibility on energy utilization, changing behaviour and household energy sources diversification**.**

(iii) To develop a model to assess the effects of moderators and mediators on the household energy sources diversification, and

(iv) To validate the SEM model parameters.

1.5 JUSTIFICATION OF THE STUDY

The increased exposure to the smoke and particulate matter due to biomass fuels causes health problems to the household members, like coughing, irritating and painful eyes and more severe health issues like pneumonia, stroke and lung cancer. It is projected that household indoor air pollution will cause an estimated 9.8 million premature deaths by the year 2030 and further, estimated that GHG emissions will be 6.7 billion tons of carbon by 2050 with current charcoal-intensive use, increase emissions will increase by 140 to 190% (Bailis et al., 2005). Hence, there is need to understand the transition pathways towards sustainable and modern household energies.

Also, regardless of the importance of renewable energy technologies in the daily lives of people, very few empirical studies of the effects of renewable energy consumption and accessibility exist (Lusambo, 2016). Furthermore, no attempts have been made to quantify the association between renewable energy consumption and other factors that influence the number of energy sources used in household. Also, little or no attention has been paid to model the complex interrelationships that exist among the various variables involved, especially on the effects of diversification of household energy sources (Choumert-Nkolo et al., 2019; Estiri, 2014).

The relevance of the SEM model for solving the household energy related problems of today have been emphasized by many researchers (Belaïd, 2017; Gim, 2019; Sharaai et al., 2015; Singh & Sharma, 2016). First, the strength of the approach adopted here is that it develops a structural relationship between model variables. In the household sector, such relationships are grounded in physical laws and defined by economic relationships. For example, households with a large household size will consume more energy while households occupied by people with higher incomes will be more likely to have higher energy expenditure and diversity. For this reason, the structural relationships estimated from historical data are still relevant for understanding the consumption patterns of today and in the future. This is because; the structural relationship between variables remains relatively constant over time. By use of SEM it is possible to decompose the relative magnitude of these effects and therefore increase deeper understanding of variables that have the most impact when attempting to understand household energy utilization, changing behaviours and diversification.

This research will present the first known application of Structural Equation Modelling (SEM) for the explanation of household energy utilization and changing behaviours in Kenya including diversification of energy sources. This powerful statistical technique allows estimation of the magnitude and significance of both direct and indirect effects that explain household energy utilization and diversification. Household income is directly correlated with energy utilization and diversification but is also indirectly correlated and mediated by household size, age and gender. This is because households having high incomes tend to have higher number of energy sources (diversity) which are moderated by education.

A better understanding of the different factors that affect the diversification of household energy sources will help to design interventions by both Governmental and Non-Governmental organizations working on energy policy and energy related issues. The Kenyan Energy policy framework stipulates that cost-effective, affordable and quality energy services will be available to households by 2023 (Karanja & Gasparatos, 2019). This study contributes to the limited but growing empirical evidence of household energy factors affecting the utilization and diversification of household energy sources.

1.6 CONCEPTUAL FRAMEWORK

The conceptual path analysis of SEM in Figure 1.2 was used in this research to test the causal relationships between the household energy sources diversification and income and also the other relevant variables. Examining household energy utilization, changing behaviours and diversification is a complex issue sorely linked to the multitude of inter-related factors: household characteristics, location, accessibility and renewable energy. To enrich knowledge about household energy use, this thesis aims to explore indirect effect of household related attributes such as the residential status, household size, assets (cars), gender, location (peri urbanization) and isolate direct and indirect effects on household energy consumption.

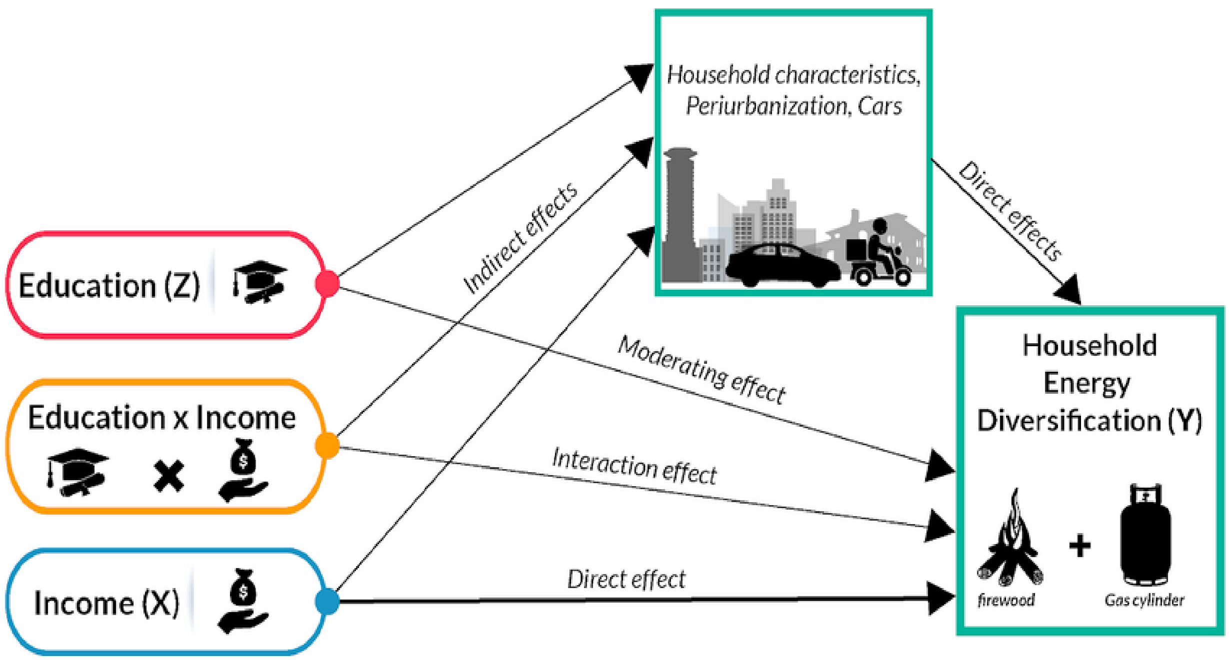

Figure 1. 2: Conceptual framework of the direct, moderating and indirect effects of peri urbanization and household-related features on household energy diversification

The indirect effect is characterized as the peri urbanization effect on household energy consumption. The assumption herein is that most of the indirect effects on household energy utilization, changing behaviours and diversification mediate through income and education. To examine the direct, indirect, and totals effects of different factors on household energy utilization, changing behaviours and diversification, structural equation modeling (SEM) approach was used. This involved a series of statistical methods such as; analysis of variance (ANOVA), regression, and some form of factor analysis (Gefen et al., 2000) that enable intricate relationships among one or more response factors (independent variables).

According to Gim (2019) the chief advantage that distinguishes SEM from most other actual modeling approaches is its prominence on estimating causal impacts through the analysis of path relationships. One of the greatest advantages of structural equation modeling (SEM) is the ability to include latent variables in causal models (Gefen et al., 2000). Others chief advantages of SEM over regression techniques is: capability to assess integral causal relationship networks simultaneously (Lowry & Gaskin, 2014); and capacity to integrate other multivariate regression models. Path analysis can be used to determine whether the theoretical model accounts for the actual relationships in the observed data. The output of path analysis provides significance tests for specific causal paths.

In this study, household characteristics, location, accessibility and renewable energy were used to explore determinants of household energy utilization, changing behaviours and diversification. Mediating factors includes: household characteristics such as residential status, age, gender and assets while location involves peri urbanization all through income (predictor) and education (moderator).

1.7 STRUCTURE OF THE THESIS

In order to capture and consolidate the results of the activities during the study, the thesis is organized into seven chapters:

Chapter 1 which is the introduction explains the back ground information of the study, problem statement, objectives, conceptual frame work and justification of the problem. Also, chapter 2; literature review gives the earlier work done such as household energy transitions, modelling, diversification and mediation – moderating models.

Chapter 3; methodology entails the choosing of the research study area, data collection and analysis while, chapter 4; household energy utilization and changing behaviours describes the trends in household energy utilization and determinants of fuels choices for lighting and cooking. Further, chapter 5 which titles the effects of renewable energy and accessibility in household energy utilization, changing behaviour and diversification. Moreover, chapter 6 involves moderating and mediating effects of household energy diversification and finally, chapter 7 which includes; summary, conclusion and recommendations.

CHAPTER 2

LITERATURE REVIEW

2.1 HOUSEHOLD ENERGY UTILIZATION AND ACCESSIBILITY

Utilization of energy refers to the household's actual use of energy. Household energy use may negatively be affected by the status of the household characteristics (e.g., Household size). Education and knowledge help households to construct better systems, increase efficiency and conduct maintenance of energy producing systems. On the other hand, an increase in household income and wealth may result in an increase of modern and clean energy use (Chu et al., 2017).

Energy utilization is primarily determined by the characteristics of a household (or such as, household size, age composition of household members, education, wealth, household resources including livestock, manure, biomass, land, trees, crop residues.); the quality of the energy; the status of the energy producing system (well /not maintained, safe in use, etc.). Adoption of energy efficient technologies like solar and biogas requires installation costs and awareness of the new technologies (Guta, 2014).

Energy access is achieved when a household has the opportunity to obtain affordable household energy of sufficient quantity and quality to ensure its energy needs. This is realized through the availability of energy at local level (e.g., electricity) but also through a household having access to necessary resources (such as land, livestock, biomass in the form of wood) to produce energy themselves (e.g., through biogas systems, solar panels) as well as access to assets (income and savings) to buy energy. There is not one measurement for energy access, yet, to a large extent, energy access is determined by household resources and energy prices (Bhatia & Angelou, 2015).

A household has a certain number of resources at its disposal, with the access to natural resources such as: water, land, livestock, and biomass being a major determinant of the productive capacity of an energy-producing household and therefore of household energy supply decisions. Access to income-generating activities is a major determinant of the ability of households to purchase energy (Authors, 2020).

In Kenya, the major sources of energy used at the household level are firewood, charcoal, kerosene, LPG and electricity (Githiomi & Oduor, 2012; Ngui et al., 2011). Thus, the hypothetical energy ladder at the micro-level for Kenya constitutes firewood and agricultural waste at the bottom, charcoal and kerosene in the middle, and LPG and electricity at the top. The underprivileged tend to use solid fuels domestically, which is damaging to the environment and to the human health. However, when their income increases, they generally, but not always switch to cleaner fuels (Choumert-Nkolo et al., 2019; Masera et al., 2000; Toole, 2015; van der Kroon, 2016).

Though factors on household energy choices and utilization are well researched on, information and data about modeling, effect of renewable energy on other household energy sources are not readily available. Consequently, it has become increasingly the difficult to well-understand the household energy changing behaviour including derailing the efforts by energy sector regulators, companies and organizations to improve product and service quality, as well as maintain consumer loyalty.

Clean energy uptake in the household sector in Kenya can be improved if service providers examine deeply, the factors that contribute to the use of traditional or advanced fuels and determine key areas to enhance performance. Thus, it is important to understand the factors other than income that play a role in a household's choice of energy in Kenya, and design appropriate policies for promoting the transition from dirty to clean fuels. It is for this reason that this study examines the effect of mediation and moderation factors in the household energy sector.

2.2 FACTORS AFFECTING HOUSEHOLD ENERGY UTILIZATION AND CHANGING BEHAVIOUR

2.2.1 Economic Factors

(i) Income and assets

Household assets and wealth play a significant role in a household's decision to choose a particular source of energy (Behera & Ali, 2017; Hou et al., 2018). With increased income, the opportunity cost of time also increases along with purchasing power, and consequently the household's willingness to pay for a better quality of fuel and greater convenience of use increases. Hence, with an increase in income, a household is more likely to move from using dirty energy sources such as firewood to using clean energy sources such as LPG and electricity. Household energy consumption generally increases with household wealth which is often measured by farm size and livestock in rural households. Therefore an increase in farm size and income from agricultural production can cause a decrease in the collection of firewood from the forest when households consume more energy and consequently switch to higher-quality energy sources (Behera & Ali, 2016).

Numerous studies point to income as the major driver behind the uptake of modern fuels (e.g Ajayi (2018)) . Karimu et al. (2016) in urban Ghana disclosed that households are likely to adopt LPG as the main cooking fuel with increase in income. Ouedraogo (2006) in Burkina Faso showed that a higher income induces urban households to choose natural gas over kerosene. Elsewhere, Baiyegunhi and Hassan (2014) reported that in rural Nigeria the transition from fuel wood to kerosene, natural gas and electricity occurs along with rising income. A similar trend is observed when household expenditure is used as a proxy for income. Gupta and Köhlin (2006) found out that in urban India there was some evidence for an energy transition from fuel wood and kerosene to LPG (liquefied petroleum gas), which is largely driven by expenditure levels. Lay et al. (2013) showed in Kenya that rising expenditure induces households to choose electricity and solar energy over wood and kerosene. In addition, as study by Démurger and Fournier (2011) indicated that Chinese rural households respond to rising wealth by substituting coal for firewood.

Hou et al. (2018) studied the choices for fuels for household cooking and economic poverty in China. Their findings indicated that an increase in income and assets encourages a lower probability that households choose biomass as their main cooking fuel rather than other fuel types. However, there was higher probability of choosing gas and electricity over traditional fuels. Furthermore, the household's choice of gas is sensitive to household income (Hou et al., 2018; Jingchao & Kotani, 2012).

In another study by Farsi et al. (2007) on fuel choices in urban Indian households, it was showed that lack of sufficient income is one of the main factors that retard households from using cleaner fuels especially LPG suggesting that higher LPG prices are associated with a significant negative shift away from LPG.

An econometric study on fuel switching in urban India reveals that household income has a positive and significant effects on the use of modern fuels, provided other variables remain constant (Ahmad & de Oliveira, 2015). These findings are in tandem with economic theory which suggests that "households consume more of the same goods and shift towards higher quality goods as household income increases" and this applies to energy services too. Higher quality fuels are those that provide more economic value per joule of energy content by being converted more efficiently, being more flexible or convenient to use and by producing less pollution. It is also expected that lower income households would be more willing to tolerate the inconvenience and pollution caused by using lower quality fuels to produce energy services. So as the household income increases, it would be expected that households gradually ascend an "energy ladder" by consuming higher quality fuels and more total energy. Enzler and Diekmann (2019) analyzed the effects of income and environmental concern on GHG emission using correlation analysis and found out that the total emissions as well as emissions from mobility are related to both higher income and lower environmental concern. On the other hand, emissions by households are only related to income but not to environmental anxiety.

The energy ladder illustrates a cycle by which households shift away from conventional fuels (e.g., biomass) as their income increases, first to embrace transitional fuels (kerosene, charcoal) and then to use advanced / modern fuels such as LPG and electricity (Muller & Yan, 2018). In that sense, the definition of the energy ladder serves as a stylized extension of the traditional economic theory income effect which explains how households replace inferior and essential goods with luxury goods as their income rises. Therefore, households turn to more sophisticated energy carriers as their income rises and at the same time reject less sophisticated alternatives. Although empirically such a hypothesis still has to be validated fully, it fits well with the common observations of the strong income dependency of household fuel use.

(ii) Dwelling characteristics

Behera and Ali (2016) explored the effects of the floor material (cement/wooden/plank/mud and other floors) of the house on household energy choices in Bhutan. The results revealed that the households with cement, wooden, plank, and other non-mud floors have a higher probability of choosing LPG and electricity and a lower probability of choosing fuel wood compared to households with mud floors. Furthermore, the material of the roof showed that households with metal, cement, and tiled roofs are more likely to choose LPG, electricity and candles, and less likely to choose fuel wood compared to the thatched roof households. The findings confirmed the role of a household's wealth status in energy choice decisions.

Results from another study conducted by Behera and Ali (2016) showed that that dwellings with a larger floor area have higher electricity consumption. These results corroborated the earlier research findings by Jones and Lomas (2015), Yohanis et al. (2008) and (Brounen et al., 2012; Mastrucci et al., 2014; Pachauri, 2004; Santin et al., 2009; Wyatt, 2013; Zheng et al., 2014).

Yohanis et al. (2008) investigated on how occupancy and dwelling characteristics affect domestic electricity use in Northern Ireland and found a strong correlation between average annual electricity consumption and floor area. This is because more floor area is obviously affordable to those with higher incomes and leads to greater electricity use. Furthermore, the electricity consumption per person decreases as the number of occupants' increases implying that the use of electricity is influenced more by dwelling characteristics than occupancy level. Elsewhere, Jones and Lomas (2015) reported that a smaller floor area reduces space heating requirements.

Jones and Lomas (2015) examined socio-economic and dwelling characteristics as determinants of high electrical energy demand in UK homes. It was revealed that the number of floors did not increase the probability of a household being a high electricity consumer. The findings further reflected that floor area varies little between homes with one and two or more floors and instead storey buildings have a reduced foot-print area. Moreover, homes with a floor area greater than 100 m^2 were significantly more likely to be high electricity consumers than those with a floor area between 50 and 100 m^2.

(iii) Fuel prices

Nlom and Karimov (2015) studied on modeling of fuel choice among households in Northern Cameroon and found out that electricity and kerosene prices have a negative impact on moving toward cleaner fuels. The findings suggested that higher fuel prices for electricity and kerosene lower energy status and discourage adoption of cleaner fuels. The lack of funding may result in a scarcity of cash within the budgeting period of the household, which can be considerably shorter for poor households with no savings as compared to more affluent ones (Ekholm et al., 2010).

A study by Mwangi (2013) on energy consumption among rural households in Mukaro location of Nyeri County, in Kenya indicated that households reacted to change in prices by either reducing consumption, increasing their consumption while for some change in price did not affect the amount of wood fuel they consumed. In addition, suppliers' price of fire wood depended on the distance travelled to acquire the wood fuel and price at which they bought it.

Research by Stoppok et al. (2018) in Bungoma, Kenya found that the fuel choice is driven by price and availability. Furthermore, households opted for firewood as the ground is spacious, where a number of trees are grown to give free of charge amount of firewood. Hence, sufficient firewood; for comfort but security reasons charcoal and LPG are used in addition in early morning and at night (Stoppok et al., 2018).

2.2.2 Social Factors

Social factors such as family size, the age and gender of the household head play an important role in influencing a household's decision to choose household energy.

(i) Age

Some studies find that age is positively associated with a preference for traditional fuels. For instance, Baiyegunhi and Hassan (2014) found that an increase in the age of the household head induces Nigerian rural households to shift away from natural gas towards fuel wood. Edwards and Langpap (2005) establish a positive and significant association of the household head's age with wood consumption in Guatemalan households. (Démurger & Fournier, 2011) found that the household average age has a positive and significant association with firewood consumption in rural households of northern China. Gebreegziabher et al. (2012) found that older household heads are more likely to consume charcoal but less likely to consume kerosene and electricity in Ethiopia, while Rahut et al. (2017) showed that households with older heads prefer fuel wood to electricity in Bhutan. Such preferences for traditional fuels support the notion that older people tend to perpetuate traditional habits related to fuels more than young people. Hou et al. (2018) studied household cooking fuel choice and found that increase in the age of the household financial decision maker is associated with a slightly decrease in the probability of choosing clean fuels.

(ii) Gender

Numerous literature reports indicate that female-headed households prefer modern fuels to traditional fuels (Das et al., 2014; Farsi et al., 2007; Rahut et al., 2016; Rao & Reddy, 2007; Woldeamanuel, 2017). This is largely attributed to the fact that women are often responsible for household cooking and thus are directly affected by the air pollution emitted from the burning of the dirty fuels. However, such claims have been challenged by Abebaw (2007), An et al. (2002) and Ouedraogo (2006), who observe that the measurement of gender of the household's head is insignificant in some contexts. Link et al. (2012) show that large proportions of female members encourage households to use fuel wood in Nepal because women are the main gatherers of fuel wood. On the contrast, Heltberg (2005) observed that large proportions of females do not affect the use of fuel wood in Guatemala. Moreover, Israel (2002) found an association of a large female share of the family earned income with a low probability of using firewood in urban Bolivia. Women who work for monetary compensation may have higher opportunity costs of time and thus prefer time-saving fuel. Nonetheless, Gupta and Köhlin (2006) found that a number of women unemployed does not affect fuel use in India. The general impression produced by all these results is that the role of gender in explaining fuel use stems from a combination of preference characteristics, time opportunity cost considerations and the within-household bargaining position of women.

A study by Gregory and Stern (2014) on fuel choices in rural Maharashtra found that while a larger female share is associated with greater energy use, it was opposite for children. Presumably, more female household members mean more cooking activity, while children need less food than adults. The study further showed that use of higher quality energy sources reduces total energy use.

Furthermore, female-headed households tend to use clean and renewable energy sources such as electricity, solar and batteries for lighting, compared to their male counterparts (Ali et al., 2019). This could be because the use of clean energy positively affects the health and overall wellbeing of the women and children in the household (Rahut, Behera, & Ali, 2017) . This is corroborated by Imran and Ozcatalbas (2020) who found that the use of traditional biomass with traditional devices had negative impacts on rural women's life. Hou et al. (2018) studied household cooking fuel choice and found that a male head household is less likely to choose clean fuels than a female financial decision maker.

(iii) Household size

According to Behera & Ali (2016), the number of children in a household is positively associated with LPG, kerosene, candles and fuel wood, whereas it is negatively associated with electricity. Households in rural developing countries tend to use children as labour for gathering firewood and cow dung; hence the choice of energy source is positively associated with household size. The negative and significant relation between children and electricity use is a cause of concern because it may affect the education and overall development of children below 15 years of age. Interestingly, the number of adult male members in the family is positively associated with a household's choice of kerosene and firewood, indicating that male members in the household are more likely to choose dirty and traditional fuels like kerosene and fuel wood. Studies by Ouedraogo (2006), Özcan et al. (2013), Pandey and Chaubal (2011), Rao and Reddy (2007) and Reddy (1995) indicate that larger households prefer dirty fuels to clean fuels. One possible reason is that the household size is often larger in poorer households that cannot afford modern fuels. However, Baiyegunhi and Hassan (2014), Gupta and Köhlin (2006) and Hosier and Dowd (1987) found the opposite trend whereby: households with more members are more likely to choose clean fuels. Besides, Chen et al. (2006) and Guta (2012) indicate an insignificant impact of household size on household fuel transition. Heltberg (2005) further contrasts that larger households are more likely to be involved in fuel stacking.

(iv) Culture and fear

Hamlin (2012) assessed the social and economic impacts of biogas digesters in rural Kenya and found that cultural norms in which at dish is made with wood or charcoal is shared among biogas users, preventing the complete adoption of biogas for all cooking needs. Many biogas users reported using wood or charcoal to cook particular Kenyan dishes, such as githeri, ugali and chapati indicating that in many cases there seemed to be a cultural hurdle preventing full adoption of modern and sustainable energies such as biogas fuel.

A study conducted by Akintan et al. (2018) culture, tradition, and taboo: sought to understand how culture, tradition and taboo affects the social shaping of fuel choices and cooking practices in Nigeria. The findings showed that there is high dependency on free access to wood fuel as a socio-economically and culturally appropriate way to meet domestic energy needs and cooking preferences. Further, wood smoke is associated with valuable additional benefits in the form of food preservation and building longevity.

Williams et al. (2020) explored the factors affecting fuel choices considering; the socio-cultural dynamics of liquefied petroleum gas (LPG) stove adoption in Peru. Results showed that barriers to LPG use included: fears of LPG, problems with LPG brands, delays in obtaining LPG refills, social pressure, perceived incompatibility of traditional dishes, perceived inability to use clay pots, separate kitchens for LPG and traditional stoves, designated pots for use on the traditional stove, and lack of heat. It was further found that these barriers did not prevent participants from using LPG nearly exclusively.

2.2.3 Education Level

The education level of household head and members has two-fold effect on the household energy: first, education improves income and, hence, purchasing power and the opportunity cost of time and second, education increases knowledge and affects cultural and consumer preferences. Households with an educated head and spouse tend to use modern and cleaner household energy sources because of the convenience of use, health benefits and the opportunity cost of their time. In India, the education level of the household head has been found to increase a household's interest in choosing a clean and efficient source of energy such as LPG (Behera & Ali, 2016).

Several studies have shown that the education level is negatively related with firewood consumption {Abebaw (2007), Démurger and Fournier (2011), Mislimshoeva et al. (2014), Baland et al. (2010) and Reyes et al. (2018)}. More education generally implies a higher income and the opportunity costs of fuel collection time, seen as increasing with education, may explain some of the observed results (Gregorio & Lee, 2002). It may thus be that the estimated education effect is partly an ill-observed income effect, which is consistent with typical rankings of fuels according to necessities and luxuries. Baiyegunhi and Hassan

(2014) and Gupta and Köhlin (2006) observed that a higher education level induces households to move away from firewood dependence towards the use of kerosene and LPG in Nigeria and India, respectively. Gebreegziabher et al. (2012)observes that, the higher the education level in Ethiopia, the less likely it is that the households will choose wood, while the more likely it is that the households will choose electricity. Lay et al. (2013) show that a higher education level in Kenya is associated with a higher probability of using electricity and solar energy and a lower probability of using wood and kerosene. Baland et al. (2015) found that in Nepal, increased education is associated with falling fuel wood collection. Farsi et al. (2007) reported that beyond its effect on tastes and time opportunity costs, education, as a powerful determinant of fuel switching, could also be explained by better education translating into greater awareness of the negative health impacts of dirty fuels and enhanced knowledge about the efficiency and convenience of modern fuels.

Education is believed to raise awareness about negative health impacts or increase the cost of poor health opportunities (Alem et al., 2016; Fullerton et al., 2008). One of the challenges of future research is to identify how such distinct educational channels exert an influence in combination or separately. Behera & Ali (2016) study showed that there is a positive correlation between the level of education and the amount of electricity and LPG used, whereas there is a negative relation between the level of education of the head of the household with the amount of dirty and conventional sources of energy used, such as kerosene and wood. Identifying how level of education exert an influence in combination or separately is one of the challenges of research in different regions.

2.2.4 Accessibility

Kenya, like other developing countries, is striving to adopt different ways of ensuring affordable and accessible energy supply to achieve renewable energy development. Household access to clean and affordable modern energy is also critical to improving living standards in developing countries (Kaygusuz, 2007, 2012; Mboumboue & Njomo, 2016). Energy access is achieved when a household has the opportunity to obtain sufficient quantity and quality of energy to meet the energy demands. The distance to the market selling fuels or major fuel supply infrastructure plays an important role in household's decision to choose a particular source of energy (Sehjpal et al., 2014). For example, the choice of firewood as the main cooking fuel is positively correlated to the distance to the most commonly used. Research by Rahut et al. (2016) showed that distance is positively associated with a household choice of firewood and negatively associated with LPG, electricity and candles. This is indication that households which are further from the retail shops (market) are more likely to use traditional energy such as firewood, agricultural residues and less likely to use advanced clean energy such as LPG because of less accessibility. The choice of clean fuels, however, is negatively correlated to the distance, both of which are consistent with expectations.

Access to diversity of fuel suppliers is another important factor in energy accessibility in terms of economic, environmental, social and institutional dimension Kucharski and Unesaki (2015); Månsson et al. (2014). All sources of household energy supply are unlikely to fail at the same time. There is no known number explaining adequate diversity of suppliers (Kruyt et al., 2009), but there is potential for reducing threats such as bad weather and disturbances such as disruptions, increased cost of fuel by diversification among suppliers.

Reliance on any one supplier or group of suppliers can be an energy security risk if supplies from that region are disrupted (Cohen et al., 2011; Costantini et al., 2007) . There is no magic number signaling adequate diversity of suppliers, but more diversity is generally thought to be better for accessibility (Kucharski & Unesaki, 2015; Månsson et al., 2014). As household energy systems have become more complex and pervasive in societies, the issues arising from the role of household energy have increased in number and complexity, hence a growing interest in household energy diversification to enhance energy security.

The increasing number of households using electric appliances and electronics can be attributed to the increasing electricity accessibility (Behera & Ali, 2016, 2017). Research done in rural India showed that availability of traditional fuels and poor accessibility to modern fuels discourage the use of LPG or kerosene as primary cooking fuel, even among high-income households. Similarly, slum dwellers largely use traditional fuels because of inadequate access to modern fuels and poor socio-economic conditions (Ahmad & de Oliveira, 2015). It is observed that when a household is engaged in agriculture, they may have more accessibility to available crops residues, so they are less likely to choose clean and modern fuels (Hou et al., 2018).

Distance and poor transportation infrastructure were found to be the main reasons for poor fuel accessibility (Hou et al., 2017). The distance to market is positively and significantly related to a household's energy choice (Rahut et al., 2016). According to Hou et al. (2017) households in communities closer to the most commonly used farmers markets are more likely to purchase clean energy carriers such as LPG as gas fuels supplied in cylinders. Access to electricity had a significantly ($p < 0.05$) negative influence on the adoption of biogas technology (Shallo, Ayele, & Sime, 2020). Households' access to electricity decreased the probability of adopting biogas technology by a factor of 0.047 compared to households lacking access to electricity as opposed to this in the study findings by Kelebe et al. (2017).

Kenya is an interesting case because a significant proportion of the households still use dirty fuels such as firewood, straw, manure, and kerosene as sources of energy for lighting. Only a small fraction of these households uses electricity for lighting and the number of households using solar energy is minimal. The study established the distance between the household residence and the nearest fuel supplying shop serves as one indicator used for assessing household access to energy sources. The second indicator is the number of shops where a household at a given location can buy one or more types of fuels. Therefore, the current study aims to examine the accessibility as factors that influence the household use determinants of solar (renewable source) and electricity (Luo et al., 2020) energy sources used for lighting purposes in Kenya using the data from household level. The nearness of forest or wood sources and the quantity / size of these sources can determine accessibility of the firewood and charcoal sources.

2.2.5 Renewable Energy

Renewable energy (RE) sources from energy security of supply perspective are that RE sources are based on energy flows while petroleum fuels are based on resources that can be seen as depletable stocks. This, therefore, means that with RE sources, it is possible to sustain energy supply/demand and improve household energy security over the long term as long as the renewable resources are utilized in a sustainable way. It is believed that the number of household energy used increase with increasing use of RE such as biogas. The uptake of RE sources majorly increase diversification and hence increase energy security by reducing dependence on fossil fuels, LPG, charcoal and other which are vulnerable to price fluctuations (Hamed & Bressler, 2019).

The use of RE as household energy is a key strategy by the Government on climate change to reduce greenhouse gas emissions (Dalla Longa & van der Zwaan, 2017; Wang et al., 2018) and therefore it is critical for the success of this strategy to establish whether consumers are willing to pay to increase the proportion of renewable energy sources. Many literature reports focus mainly on economic, social, and demographic factors, disregarding the potential role of RE and diversification in the household energy changing behaviour. The findings by Lwiza et al. (2017) showed that an increase in the family size, the number of cattle, number of pigs and the age of the household head reduced the likelihood of biogas technology dis-adoption. Lwiza et al. (2017) also showed that other factors that contributed to dis-adoption included the failure to sustain cattle and pig production that are necessary for feedstock supply, reduced availability of family labor and the inability of the households to repair biogas digesters after malfunctioning. Uhunamure et al. (2019) found that the distance to firewood source positively and significant influences the adoption and utilization of biogas technology.

A study by Shallo et al. (2020) established the determinants of biogas technology adoption in southern Ethiopia to be; education level, cattle size, household income, farmland size, number of planted trees, the distance to water sources, market places, and firewood sources on biogas adoption. Elsewhere, Shallo et al. (2020) revealed that the quality of education, quality of employment, access to credit, distance to firewood sources, and exposure to electronic media had a significantly positive impact on the adoption of biogas technology. On the other hand, distance to water supplies and access to electricity had a substantially negative impact on the adoption of biogas technology. Sovacool et al. (2015) found that female heads of households that have adopted biogas system have cited improvements in their own financial status.

There is need for additional evidence on the effectiveness of renewable energy technologies in designing future policies aimed at promoting the deployment of these technologies (Muller & Yan, 2018). The diversification generated by renewable energy technologies is expected to improve the household energy consumption structure in developing countries. However, an understanding of the role that renewable energy technologies play in household fuel shift is still lacking.

2.3 HOUSEHOLD ENERGY TRANSITION AND MODELLING

The impact of rising energy demands on the development of the various regions and the standard of living of people is not clearly understood (Danlami et al., 2018). The projected trend in urbanization may increase pressure on available energy resources to an extent that acute shortages may develop at a temporary basis leading to price fluctuations, as happened in the past (Karekezi et al., 2008). Government efforts are therefore directed at accelerating the transition towards innovative energy technologies based on more sustainable and cleaner fuels. However, in most counties, the data on energy consumption behavior among rural and urban households are incomplete or even lacking (Cheboiwo et al., 2015; Mutua et al., 2012; Pundo & Fraser, 2006; van der Kroon, 2016).

The transitions in energy source utilization reflect a change in households' energy consumption behavior (ECB) with the mode and direction of change depending on multiple factors, aside from scarcer biomass resources. These include factors, such as, household income or socio-economic status (Arnold & Persson, 2003; Joyeux & Ripple, 2007);

household composition and size; gender; cultural preference (Akpalu et al., 2011; Clancy et al., 2012); education(Behera & Ali, 2016); rural or urban residence (Karekezi et al., 2008; Pundo & Fraser, 2006); fuel use purpose; monetary or technological investment; reliability of fuel supply; fluctuations of energy prices (Burger et al., 2015) (on concept of ECB); (Choumert-Nkolo et al., 2019; Louw et al., 2008; Lusambo, 2016; Rahut et al., 2017; Rahut et al., 2016; Van der Kroon et al., 2013); pattern of stove use (Ruiz-Mercado & Masera, 2015) and accessibility (Musango, 2014; Rahut et al., 2019).

The academic literature on household energy transition reveals, however, contrasting views on how households move towards the use of other fuels as income rises (Choumert-Nkolo et al., 2019; Toole, 2015; Van der Kroon et al., 2013). One school of thought supports the *energy ladder* concept, i.e., discontinuation of the use of conventional fuels and adoption of cleaner and modern fuels such as electricity and gas; e.g., (Andadari et al., 2014; Toole, 2015). The other school adheres to the *energy (or fuel) stacking* concept of simultaneous use of various types of fuels, i.e., continued use (temporarily) of conventional fuels and gradual adoption of cleaner and modern ones (Baiyegunhi & Hassan, 2014; Rahut et al., 2019; Shankar et al., 2020; Zhu et al., 2018). However, the process of fuel stacking has not been carefully examined, especially in Africa (Bisaga & Parikh, 2018; Masera et al., 2000). There is need to undertake study on household energy utilization, accessibility and diversification in order to understand the dynamics that can improve the shift to clean ans improve household energy security in the contexts of developing countries and Kenya in particular using structural equation modelling.

Relations between variables affecting household energy use and sources are often more complex than simple bivariate relations between a predictor and a criterion as used by many researchers. Correlation analysis and regression modeling are the most familiar methodologies for analyzing the relationship between household energy and factors influencing its use. However, there are some concerns regarding the estimation of these factors based on regression modeling. Multiple regressions modeling may be a well-fitted model, but correlated predictors may not produce trustable results of research model coefficients. Moreover, regression modeling does not facilitate estimating causal and indirect effects in a single and integrated equation. Besides, accurate interpretation of the analysis of results based on multidimensional modeling is not achievable and the results are not usable for a comprehensive evaluation. Analyzing household energy utilization with the help of Structural Equation Modelling (SEM) may be useful, as it describes simultaneous examination of the effects which are relevant and allows for the investigation of more varied and complex research (Denny et al., 2018; Motawa & Oladokun, 2015). This methodology is at the same time capable of testing the generated model by evaluating the overall fit indices.

SEM is considered a more advanced method vis-a-vis the other multivariate techniques because it can estimate a series of interrelated dependence relationship simultaneously (Motawa & Oladokun, 2015; Nasrabadi & Hataminejad, 2019; Wang & Sun, 2017). According to Cangur and Ercan (2015) SEM is a confirmatory rather than exploratory approach to test the relationships; Accounts for measurement errors in the course of model testing;

Can incorporate observed (indicator) variables as well as latent (unobserved) variables and most importantly, tests a priori relationships rather than allowing the technique or data to define the nature of relationship between the variables.

Tóth-Király et al. (2018) prefers to call SEM a method which consists of exploratory factor analysis combined with multiple regressions. However, Schreiber et al. (2006) assert that SEM is rather a combination of CFA (Confirmatory factor analysis) and multiple regressions, since it is more a confirmatory technique than an exploratory one.

2.4 HOUSEHOLD ENERGY DIVERSIFICATION AND SECURITY

Diversity of household energy supply sources especially for cooking can reduce vulnerability to the disruption of a single supply source and also reduce the market influence of each supply source; thus, the risk of rising energy prices in production and services can be reduced. Ensuring household energy security is the most critical goal for achieving sustainable development. According (Le & Nguyen, 2019), household energy security is defined as "the ability of a household to guarantee the availability of the supply of energy resources in a sustainable and timely manner with the energy price being at a level that will not adversely affect the economic performance of the household".

Having a diverse energy mix is generally considered an essential part of energy security, since having more energy sources enables a household to continue without interruption in case one household energy source fails or there is shortage in supply. This indicates that a household that diversifies its energy mix insulates itself from energy disruptions and strengthens its household energy security. According to Novikau (2019) diversification of the household energy sources protect households from market risks such as fluctuations in supply or pricing which can result from political unrest or natural disasters or curtailment and threats. Each household has a unique blend of natural resources, household characteristic, energy demands and geographical locations, so approaches to understand the energy diversification dynamics is important. The critical importance of implementing successful energy diversification strategies that benefit current and future generations cannot be over-emphasized. The solution for energy insecurity is diversification of risks through an increasing diversity of household energy fuel type (Cauz et al., 2020; Cohen et al., 2011). For this reason, household energy diversification must always be at the front and center of the concerns of the developing countries like Kenya.

"One source means you're putting your eggs in one basket, so you're more susceptible to market fluctuations and interruptions and various market conditions. When you have a lot of other resources to draw on, you've got an edge and you're better protected." explains Chris Womack.

*Chris Womack, *at the time of drafting this thesis*, was Executive Vice President and President of External Affairs for Southern Company, one of America's largest energy providers, comments on diversification (Ouchi, 2019).

Household energy diversification helps a household respond to external changes, shocks and furthermore, reduce the vulnerability of a single energy source to supply shocks and the market power of various energy supply sources (Chuang & Ma, 2013; Ouchi, 2019). Treiber et al (2015) studied on increasing fuel choices in Kenya and found that diversification of a minimum of two and a maximum of ten house energy sources among the study area. In addition, it showed that every household in the sample applies a mix of various fuels to satisfy its needs and moreover proofed that socioeconomic opportunities and demographic situations changes plays major role in the explanation of the forms of household energy diversification.

Presently, due to the recent unprecedented peri urbanization, energy consumption in developing counties like Kenya is increasing at an enormous speed. However, this process should go hand in hand with sustainable energy development based on household energy security (Willkomm et al., 2020). Many scholars neglect household energy security problems to an extent of forgetting that the rise of energy consumption due to peri urbanization leads to the gradually increasing energy demands threatening energy security (Li et al., 2019).

2.5 EMPIRICAL STUDIES ON MODELLING

The factors that dominate the change in household energy usage reportedly vary by country, between urban and rural regions and between high- and low-income groups such as in Ethiopia, Nigeria, Cameroon, China, India and Mexico. This implies that each country needs a country-specific designing policy (Armel et al., 2015; Chen et al., 2016; Danlami et al., 2018; Kayode et al., 2015; Pachauri & Jiang, 2008).

Mbaka et al. (2019) examined households' energy preference and consumption intensity in Kenya utilizing a nationally representative cross-sectional household dataset (3663 households). For this purpose, Cragg's double-hurdle model was chosen on the fact that the model postulates that households must pass two separate hurdles before a positive level of consumption is observed. Results found that households' energy preference and consumption intensity are mainly affected by location (rural or urban), household's decision maker on energy use, education level, age of the household head, and the average monthly income.

Mutua et al. (2012) investigated the main determinants of household energy conservation and savings using discrete choice and Tobit models from National Energy Survey Data for Kenya 2009. They found that demographic variables, such as the household head's gender and occupational and educational attainment, as well as household location and size, are key determinants of not only the propensity to conserve energy but also levels of actual energy savings.

Relations between variables affecting household energy use and sources are often more complex than simple bivariate relations between a predictor and a criterion as used by many researchers. Correlation analysis and regression modeling are the most familiar methodologies for analyzing the relationship between household energy and factors influencing its use. However, there are concerns regarding the estimation of these factors based on regression modeling (Tso & Guan, 2014) on multilevel regression (MR) model to calculate the effects of environmental indicators and household features to predict household energy consumption..

Multiple linear regressions on household energy utilization using generalized linear models with the help of SPSS may be useful, as it describes simultaneous examination of the effects which are relevant and allows for the investigation of more complex research relationships. Generalized linear models have a common algorithm for the estimation of parameters by maximum likelihood; this uses weighted least squares with an adjusted dependent variant, and does not require preliminary guesses to be made of the parameter values. Generalized linear models accommodate unequal variances through the introduction of variance functions that may depend on the mean value through a known function of the mean (McCullagh & Nelder, 1989).

Also, little or no attention has been paid to model the complex interrelationships that exist among the various variables involved, especially for the effect of number of household energy sources. The relevance of the model for solving the household energy related problems of today can be emphasized in several respects. First, the strength of the approach adopted here is that it develops a structural relationship between model variables. In the household sector, such relationships are grounded in physical laws and defined by economic relationships. Structural Equation Modelling (SEM) is highly preferable because of its ability to explain both the direct and indirect effects among the related variables and produce total effects which is the summation of both the direct and indirect effects as opposed to multiple linear regression which only deals with direct effects (Motawa & Oladokun, 2015). With SEM it is also possible to specify, estimate, assess and present models in an intuitive path diagram to show hypothesized interrelationships among variables. Moreover SEM allows both confirmatory and exploratory modelling (Byrne, 2010, 2013), which by implication means that it can be used in developing new theories while at the same time serve as the platform upon which theory can be tested.

According to Denny et al. (2018), SEM has several benefits over the linear regression model because it can accommodate multiple relationships between multiple variables by simultaneously estimating multiple regression models. This allows one to model indirect (mediating) and co varying relationships in addition to the direct relationships possible with simple regression models. Furthermore, the ability to include latent variables in an SEM (i.e., structural equation modeling with latent variables) provides a way to include more abstract concepts, as well as additional error terms. Denny et al. (2018) further found that latent variables are constructed as measurement models and tested using confirmatory factor analysis. A SEM is used to calculate the magnitude and significance of explanatory variables on the trends of household energy utilization (Kelly, 2011). The benefit of this approach is that it explains the complex relationships that exist between manifest variables and their overall effect through direct, indirect and total effects on household energy utilization.

This study develops a bottom-up SEM model to examine direct, moderating and mediating factors on household energy utilization, changing behaviour and diversification, focusing on the household attributes such as peri urbanization, cars among others which has rarely been done.

2.6 MEDIATION AND MODERATION ANALYSIS

2.6.1 Moderation Analysis

A moderator is a third variable (Z) that changes the relation between a predictor (independent variable, X) and an outcome (dependent variable, Y), thereby affecting the strength and/or path of the relation between the two variables as shown in Figure 2.1. The moderator (typically a covariate or secondary interest predictor) interacts with the primary predictor variable to influence the result, so any effect of the primary predictor on the dependent variable is conditional on, or contingent on, moderator values. In a regression perspective, this dependency yields different bivariate regression lines predicting Y from X for different values of the moderator variable, Z. In an ANOVA context (or alternatively in a regression with categorical predictor variables), this dependency can be illustrated by non-parallel lines for moderator-based subgroups. Moderators may improve, decrease, or directionally change the effect of the predictor on an outcome, such that the effects of one variable depend on levels of the other variable in analysis. In the presence of moderation, the major effects are no longer additive and need to be interpreted with reference to the moderator variable, because the outcome variable is explained by the simultaneous effect of the variables (Fairchild & McQuillin, 2010; Morin et al., 2016).

Moderator effects are one of two forms in general: ordinal or distortionary interactions (Levant et al., 2015). For data plots, ordinal interactions are highlighted by lines not crossing each other in the map, while chaotic interactions are highlighted by lines crossing in the map. There may be two sub types of the ordinal interactions, when a change in the moderator variable level enhances the bivariate relationship between X and Y, a synergistic interaction effect occurs (Levant et al., 2015). A buffering interaction effect occurs when a change in the moderator variable level reduces the magnitude of the X-Y bivariate relation.

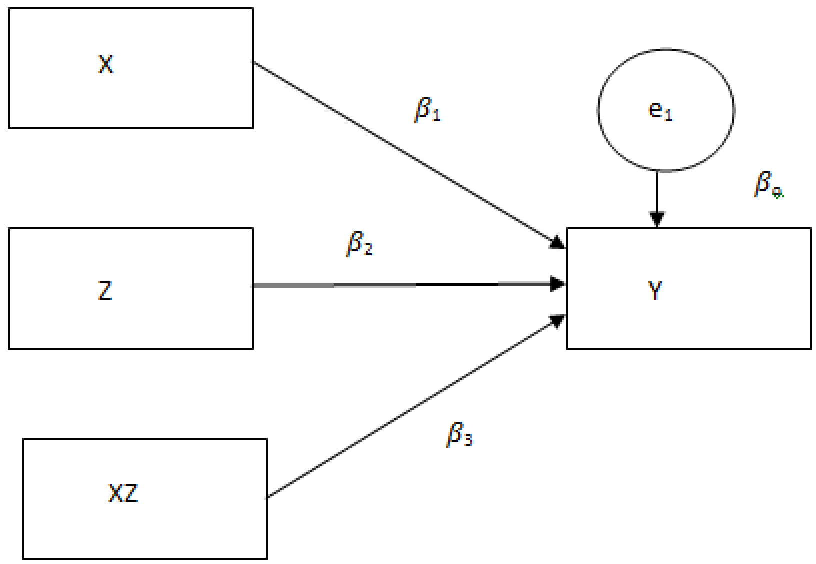

Figure 2. 1: The moderation model

The basic moderation model is estimated with the following multiple regression equation

$$Y = \beta_o + \beta_1 X + \beta_2 Z + \beta_3 XZ + e_1 \qquad (2.1)$$

Where, X = the independent variable, Y = the dependent variable, Z= the moderator variable, XZ = the relationship of the independent and moderator variable, β_0 and e_1 (for unstandardized estimates) are the intercept and the residual, β_1= the effect of the independent variable on the outcome controlling for Z and XZ, β_2 = the effect of the moderator on the outcome controlling for X and XZ, and β_3 = the effect of the XZ relationship on the outcome controlling for the inferior order effects. A t-test of the correlation coefficient associated with the term XZ interaction (i.e., β_3) in Checking for moderation is one way to assess if there is statistical moderation. If the β_3 coefficient is significant, then the effect of moderation is considerable. The parameter estimate, its standard error and the level of significance of the interaction coefficient are important. Also, to fully understand the association, the relationship between X and Y must be analyzed at different values of the moderator variable, Z. Plotting the interaction helps explain the interaction effect and provides a way of exploring how the relationship between Y and X varies through the moderator variable stages.

Due to the small effect sizes typically observed in the social sciences, power is often low in moderation analyses (Stone-Romero & Liakhovitski, 2002). Substantive literature reviews in the social sciences show that interaction effects in real data typically explain the variance in the dependent variable between 1 and 3 per cent. Thus, interactions can be meaningfully explained even at1 per cent of the variance. Researchers may use the largest available sample to maximize the power of detection of moderator effects, consider using extreme groups to increase variance in design (e.g., oversample participants that are either very high-scoring or very low-scoring on a non-manipulated independent variable), and choose measures that have high reliability (Namazi & Namazi, 2016).

2.6.2 Mediation Analysis

A mediator variable (*M*) is a third variable that explains how or why two other variables (i.e., *X* and *Y*) are related as shown in Figure 2.2. A Mediator Variable is the variable that causes mediation in the relationship between the dependent variable (called result) and the independent variable (called causal variable) (Baron & Kenny, 1986; Kenny & Judd, 2014; Muller et al., 2005). In a mediation model, the independent variable (X) predicts the mediator variable (M) which in turn predicts the outcome (Y). Thus, a mediator is intermediate in the relation between X and Y. By modeling an intermediate variable in the X–Y relation, the main effect between X and Y can be decomposed into component parts called the direct effect of X on Y and the indirect effect of X on Y through M (i.e., the mediated effect) (Agler & De Boeck, 2017).

Investigating both direct and indirect (mediated) effects often provide more insight than simply evaluating the bivariate X–Y relation alone, and many researchers have proposed several different ways to statistically test mediation using the component parts. In a meditational analysis, it is hypothesized that there is no direct relationship between the dependent and independent variables. Instead, the independent variable first influences the mediator variable, and then the mediator influences the dependent variable. Thus, there is a causal chain of effects which characterizes the relationship between the dependent and independent variables (Deboeck & Preacher, 2016).

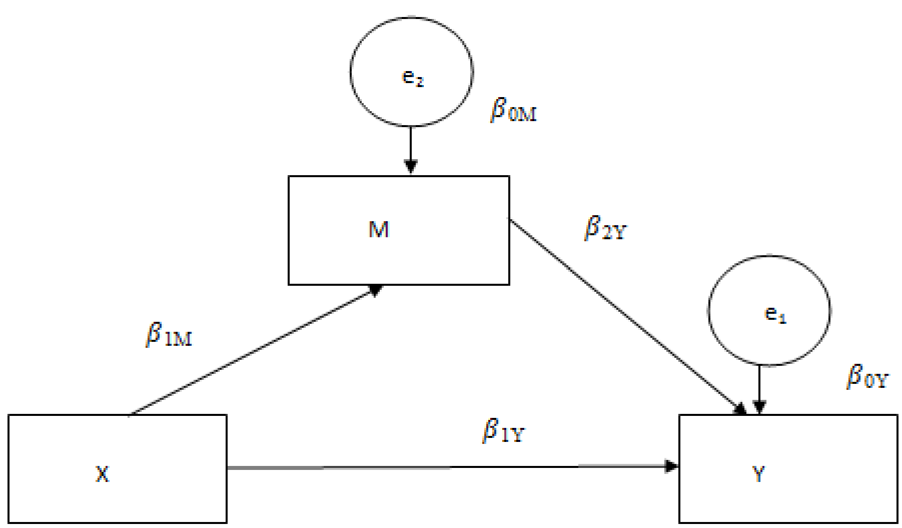

Figure 2. 2: Typical mediation model

Where; *X*= the independent variable, *Y*= the dependent variable, *M* = the mediator variable, β_{1M} = the effect of the independent variable on the mediator, β_{2Y} = the effect of the mediator on the outcome controlling for X, and β_{1Y} = the direct effect of the X on Y controlling for *M*.

The mediation model uses two regression equations to decompose the overall effect into its direct and indirect components as follows

$$Y = \beta_{0Y} + \beta_{1Y} X + \beta_{2Y} M + e_1 \qquad (2.2)$$

$$M = \beta_{0M} + \beta_{1M} X + e_2 \qquad (2.3)$$

where; β_{0Y} and β_{0M} are regression intercepts, and the β_{1Y}, β_{2Y} and β_{1M} terms are regression slopes while e_1 and e_2 are the error terms. The regression coefficients in the equations measure various effects of predictors on the mediator and outcome variables.

The indirect influence of *X* on Y through mediator M quantifies the approximate difference in *Y* that results from a one-unit shift in *X* through a series of causal steps in which *X* influences *M*, which in turn influences *Y*. And it's the sum of X's effect on M and M's effect on Y. Since the magnitude of the mediated effect is bounded by the individual coefficients from which it is produced, the power to detect mediation effects is conventionally lower than the power to detect main effects. Also, while the sample size requirement for normal standard theory error estimators is smaller, the methods are still underpowered relative to newer methods which account for asymmetry in the mediated effect sampling distribution (Montoya & Hayes, 2017).

If a third variable M is indeed a mediator, a reasonable implication is that its addition in the model will decrease the relation between X and Y. At the same time, though, the finding that controlling for M reduces the relation between X and Y do not in fact imply that M is indeed a mediator. Said otherwise, whether a selected causal variable reflects a real cause or not cannot be determined statistically. To be sure, statistical mediation is a necessary condition if one wants to support the conjecture that some third variable is a true mediator, but researchers ought to realize that it is not a sufficient condition (Hayes, 2018).

2.6.3 Mediated- Moderation Models

Mediated moderation is a combination of both moderation (Z) and mediation (M) variables (Edwards & Lambert, 2007; Muller et al., 2005). Figure 2.3 illustrates the Mediated-Moderation case according to Kang et al. (2015) and Belaïd (2017) research. Here, moderation variable must be established first into the model, hence the focus of the research is usually on the prediction of the interaction of X and moderator on Y. Then a search for injecting a mediated variable should begin, if there is a theoretical reason to believe that there is a fourth variable that acts as the mechanism or process that causes the changes. Hence, mediated moderation model assumes that moderation effect is achieved by introducing a mediator variable as the fourth variable (X, moderator, and Y already exist). In this situation, an interaction between X and moderator exists which affects mediator, and then this mediator variable affects Y. The model is thus mainly based on a moderator and mediator variables. In mediated moderation model, all the Baron and Kenny (1986), Byrne (2013) and Kenny and Judd (2014) steps for mediating testing is repeated with variable X as the main dependent variable and the two main effects would be treated as “covariates”. Consequently, the total effect or the initial moderation effect, the direct effect or how much moderation remains after emergence of the moderator, and the indirect effect of the mediator, can be computed.

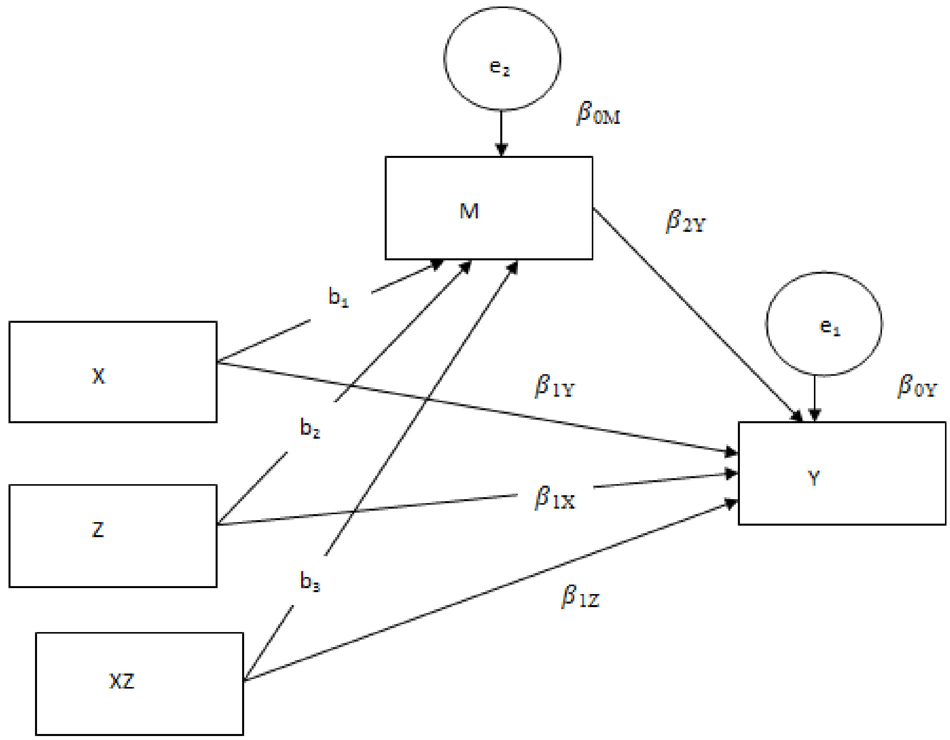

Figure 2. 3: Mediated- Moderation Models

(Weng et al., 2020)

The following two regression equations form the model:

$$M = \beta_{0M} + b_1X + b_2Z + b_3XZ + e_2 \quad (2.4)$$

$$Y = \beta_{0Y} + \beta_{1Y}X + \beta_{1X}Z + \beta_{1Z}XZ + \beta_{2Y}M + e_1 \quad (2.5)$$

The mediation of a moderator effect involves exploring mediating mechanisms to explain an overall interaction of XZ in predicting Y, whereas the moderation of an indirect effect involves investigating whether a mediated relation holds across levels of a fourth, moderating variable. These effects have previously been referred by many researchers as mediated-moderation and moderated-mediation in most literature, respectively. Such a model unifies the methods into a single presentation where different models are represented as special cases of the larger framework.

2.6.4 Moderated –Mediation Models

Models of moderation- mediation are used when researchers think that mediated models will become stronger by introducing moderating variables. In these situations, first mediation is performed and then investigation is begun to find out if the mediated effects will be altered by adding a moderator variable (Judd et al., 2014; Muller et al., 2005; Preacher & Hayes, 2008; Preacher et al., 2007; Vandenabeele, 2009).

Figure 2.4 illustrates the main possible models of moderated- mediation (Muller et al., 2005). The model involves two new moderator variables, one moderating the A path and the other moderating the B path.

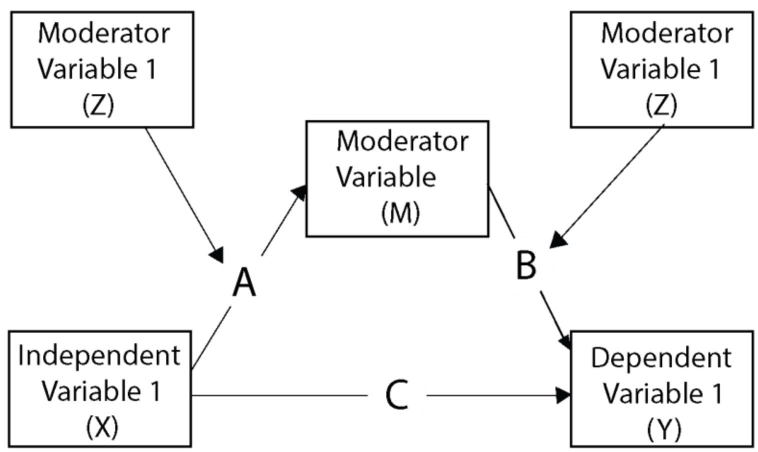

Figure 2. 4: Moderated –Mediation Model

The results of mediation and moderation variables can be analyzed simultaneously in an effort to capture more truth of the household energy dynamics.

2.6.5 SEM Model Fitness

The evaluation of model fit has attracted widespread attention by researchers in the structural equation modeling literature for several years. Various model fit test statistics have been suggested for performing this assessment. Selecting an appropriate test statistic in order to determine model fit, however, can be difficult as the selection depends on the distributional characteristics of the measured data, the magnitude of the sample size, and/or the proposed model features (Zhang et al., 2016).

Table 2. 1: Model Fit and their Level of acceptance

Name of index	**Level of acceptance**
CMIN	2df ≤ CMIN≤ 3df
CMIN/df	≤ 5
GFI	0.9 ≤ GFI≤ 1.0
AGFI	0.85 ≤ AGFI ≤ 0.9
PNFI	≥ 0.6
PCFI	≥ 0.5
RMSEA	0.05 ≤ RMSEA ≤ 0.08
C.R	-1.96 ≥ C.R ≥ 1.96

Source: (Gholami & Khalaji, 2017); Smith and McMillan (2001) and (Schreiber et al., 2006))

The model fitness and their level of acceptance in SEM analysis are shown in Table 2.1. The model fitness parameters include; $\chi 2$ statistics (CMIN) (Bt Wan Mohamed Radzi et al., 2017) and its ratio to the model degree of freedom (CMIN/df), the goodness-of-fit index

(GFI), the adjusted goodness-of-fit index (AGFI) (Smith & McMillan, 2001), parsimony-adjusted normed fit index (PNFI), parsimony-adjusted Comparative fit index (PCFI)(Schreiber et al., 2006) and root mean square error of approximation (RMSEA)(Zhang et al., 2016). The CR (critical ratio) is also the commonly recommended basis for testing statistical significance of SEM components with CR values greater than 1.96 or less than -1.96 and has low standard error with significance at $p \leq 0.05$ level.

From the literature, model-fit indices seem useful in their usability. Generally speaking, the more suitable the indices applied to a SEM, the more likely a miss-specified model would be rejected indicating an improvement in the likelihood of rejection of successful models. This also means that a combination of at least two match indices should be used (Hu & Bentler, 1999). There are recommended cutoff values for some indices, though none serve as the excellent rule for all applications (Chen et al., 2008; Fan et al., 1999; Hoyle, 2011; Kline, 2005, 2012).

Model fit indices assess how well the anticipated model caught the covariance between all the items or measures in the model (Götz et al., 2010). If the constraints the researcher has imposed on the model are inconsistent with the sample data, then the results of statistical tests of model fit will indicate a poor fit, and the model will be rejected. If the fit is poor, it may be due to some items measuring multiple factors. It might also be that some items within a factor are more related to each other than others. The model fit indices are:

Chi-square test ($\chi2$): $\chi2$ tests the hypothesis that there is a difference between model-implied covariance matrix and the original covariance matrix. Therefore, the non-significant discrepancy is preferred. For optimal fitting of the chosen SEM, the $\chi2$ test would be ideal with $p > 0.05$ (Barrett, 2007; Bentler & Bonett, 1980; Hooper et al., 2008; Hu & Bentler, 1999). One should not be overly cautious as it is very sensitive to the sample size and not comparable between different SEMs (Bentler & Bonett, 1980; Curran & Hussong, 2002; Hu & Bentler, 1999)

Root mean approximation square error (RMSEA): RMSEA is an index of "badness of fit" where 0 indicates the ideal fit and higher values indicate the lack of fit (Chen et al., 2008; Fan et al., 2016; Nasser & Wisenbaker, 2003). It is useful for detecting misspecification of the model and is less sensitive to sample size than the check for $\chi 2$. The appropriate RMSEA should be under 0.06 and should be less than 0.09 for a good model fit (Hu & Bentler, 1999). A value of 0.08 or less is an indication of an acceptable model. The RMSEA also takes the model complexity into account as it reflects the degree of freedom as well. A RMSEA value smaller than 0.05 is said to indicate a convergence fit to the analyzed data of the model while a fit close to good occurs the value is between 0.05 and 0.08 (Cangur & Ercan, 2015; Kenny et al., 2015; Marsh et al., 2004; NE & Cudeck, 1993).

Comparative fit index (CFI): CFI is the sum of variance that was accounted for in a matrix of covariance. This ranges from 0.0 up to 1.0. A higher CFI value indicates a better match to the model. The CFI should be equivalent to 0.95 or greater in practice (Hu & Bentler, 1999).

When the CFI value is between 0.05 and 0.08, it indicates a "close fit suggesting a reasonable model–data fit (Marsh et al., 2004). This index is largely independent of sample size and boosts output in small sample analysis (Chen, 2007).

Goodness-of-fit (GFI) index: GFI scale is 0 –1.0, with best fit at 1.0. The GFI range between 0 and 1, with a value of over 0 .9 but less than 1 generally indicating acceptable model fit (Chen et al., 2008; Hu & Bentler, 1998).

Adjusted goodness of fit index (AGFI): The adjusted goodness of fit index (AGFI) corrects the GFI, which is affected by the number of indicators of each latent variable. The GFI and AGFI range between 0 and 1, with a value of over 0.9 (but less than 1) generally indicating acceptable model fit.

Normed fit index (Binfield): NFI is highly sensitive to the sample size (Bentler, 1990; Bentler & Bonett, 1980). For this reason, NFI is no longer used to assess model fit (Bentler, 1990; Hoyle, 2011).

Tucker-Lewis index (Kang et al.): TLI is a non-normed fit index (NNFI) that partly overcomes the disadvantages of NFI and also proposes a fit index independent of sample size (Bentler, 1990; Bentler & Bonett, 1980). A value of TLI > 0.90 is considered appropriate (Hu & Bentler, 1999). The greater TLI value suggested that the model matched better. While values greater than 0.95 are viewed as acceptable match, in many researches 0.97 is recognized as the cut-off value. In addition, TLI does not have to be between 0 and 1 as it is non-standard. The key advantage of this fit index is the fact that it is not affected significantly by sample size (Chen et al., 2008; Chen, 2007; Hu & Bentler, 1998).

2.6.6 Cross -validation of the structural equation model

SEM models are increasingly being used to solve problems and to aid in decision-making. The creators and users of such models, the decision makers using knowledge derived from the results of these models, and the individuals impacted by decisions based on these models are all rightly concerned with whether a model and its results are “correct”. This problem is addressed by validation, which is the process to improve the reliability and stability of the model. In cross-validation, a sample is randomly split into two parts, whereby, one part is used for deriving the model, while the other is used for evaluating the derived model. Cross-validation simulates prediction on an independent sample. Thus, model assessment *via* cross-validation is less likely to be affected by the particular sample. The cross-validation in the structural equation model takes the following steps. First, the given sample is randomly split into two sub samples (often halves); a derivation sample and a validation sample. On the derivation sample, all the parameters are estimated for a hypothesized model by minimizing the discrepancy function. The model reproduces the variance-covariance matrix, and the resulting $\chi 2$ is the usual goodness-of-fit measure for the derivation sample. Lastly, on the validation sample, the derived model is applied with some or all of the parameters fixed to the estimates obtained from the derivation sample (Chen and Zhou (2020) and Li et al. (2020)).

Assessing the fit of a proposed model in structural equation modeling (SEM) applications is of paramount importance to researchers in the social, behavioral, business, educational, medical sciences and engineering. This is because any elaboration concerning the parameter estimates or the connecting relationships among examined variables is conditional upon establishing support for the suggested model.

An application of the bootstrapping method was recently suggested by Chen and Zhou (2020), Li et al. (2020), Marcoulides et al. (2020) and Jebali et al. (2017) for testing model fit in SEM. According to Melchinger et al. (2004) bootstrapping resampling methods were recommended for performing model selection, bias reduction and subsequent inferences with complex models. With bootstrapping, statistical interpretations could be made by thorough computations and provide solutions to problems that would otherwise be obstinate (Tibshirani & Efron, 1993). Through a bootstrap selection mechanism, the method identifies the test statistic among any set of possible applicants that exhibits the best sampling distribution of the *p*-values for the observed data and model conditions. It does this by selecting the best test statistic that most closely follows a uniform distribution through an evaluation of a Kolmogorov-Smirnov distance metric (Marcoulides et al., 2020).

2.6.7 Towards Mediation and Moderation Analysis

Household energy utilization is a non-linear process which does not consist of a single practice but rather of numerous different practices related to one another, both vertically and horizontally, with changes in one practice affecting other related practices (Bisaga & Parikh, 2018). Research by investigating mediator and moderator variables has the potential to direct and refine the development of evidence-based interactions because it can shed light on how relations achieve its effects. Additionally, studying contextual effects by investigating moderator variables has the potential to extend the validity of evidence-based policy making to different groups or in different locations and countries. Investigating mediation and moderation effect also helps towards understanding the energy utilization and changing behaviours in household energy use.

Belaïd (2017) studied the complexity of the direct and indirect determinants of the residential energy consumption in France using a structural equation modeling approach. Results confirmed that the direct effect of household-related attributes on domestic energy demand was notably lower than the corresponding effect from the dwelling attributes. But, considering the indirect effect of household factors on energy use, across housing choices, the total impact of household-related attributes on the French household energy consumption was just slightly lower than that of dwelling characteristics. Therefore, to highlight the spectrum of residential energy use, the present research calls to incorporate both direct and indirect effects of household attributes and choices.

Sharaai et al. (2015) performed a study on the primary factor contributing to household carbon emission (HCE) using SEM in China. The factors studied included; the numbers of occupants, household income, transportation fuel, electricity and liquefy petroleum gas (LPG) consumption, and waste generated by households. It was found that there are significant and positive correlations between total household income, electricity consumption, and transportation fuel with the amount of HCE. Transportation fuel was the main contributors for HCE at the residential area ($\beta = 1.003$, C.R. = 301.315, $p < 0.05$) and hence the need for reduction in usage of petrol in transportation by using public transport while going out or walking or cycling to a short distance (Sharaai et al., 2015).

Understanding of household energy utilization is a complex issue greatly connected to the wide range of inter-related variables including direct factors such as household characteristics of the dwellings, household socio-demographics attributes, lifestyle of householders, location and their behaviour but also other factors such as accessibility and level of satisfaction. Because of this complexity, this theme is generally studied using disciplinary and fragmented research from a broad range of disciplinary fields such as economics, engineering, psychology and sociology. Admittedly, models which include all of these factors and analyze holistically the household energy utilization, patterns, changing behavior and diversification are rather limited.

Thus, the investigation of mediation and moderation effects can refine factors or interventions effects by removing components that do not work, and or promoting factors that do work. The literature study confirms the strong association between income and household energy use. However, the moderation and mediation effects of renewable energy, accessibility and household characteristics on diversification and energy utilization is widely unseen in the previous literature, which is deemed desirable to evaluate for sound policy vista in a country like Kenya. The study results provide sound empirical estimates for robust policy inferences in the context of Kenya. The study therefore, on the direct, moderation and mediation effect on household energy utilization, changing and diversification in the case of developing countries like Kenya can derive new estimates for policy inferences.

2.7 CONCLUSIONS

With the increased exposure to the smoke and particulate matter due to biomass fuels which causes health problems to the household members, like coughing, irritating and painful eyes and more severe health issues like pneumonia, stroke and lung cancer, there is a need to shift toward more sustainable and clean energy (Edwards & Langpap, 2012; Fullerton et al., 2008; Schilmann et al., 2019). Also, environmental degradation and erosion occur due to the dependency on biomass resulting to the loss of forests cover, the burning of biomass and consequently more greenhouse gasses being emitted into the atmosphere (Ziming Liu et al., 2020; Schilmann et al., 2019).

Undoubtedly, there is a need to shift toward more sustainable household energy which reduces the health, environmental consequences and enhance energy security, and to understand the transition pathways towards sustainable and modern household energies. Analyzing household energy utilization, changing behaviour and diversification with the help of SEM may be useful, as it describes simultaneous examination of the effects which are relevant and allows for the investigation of more varied and complex research (Fairchild & MacKinnon, 2009; Tóth-Király et al., 2018).

The model approach intends to describe household energy transition pathways for sustainable energy. The structural equation model will help to explore future transitions and what might enable or inhibit them; to design and evaluate transition pathways towards modern energy sources and infrastructure for sustainable energy: and to understand where appropriate, the roles of independent variables and opportunities of large and small ‘actors’ in the dynamics of transitions.

CHAPTER 3

METHODOLOGY

3.1 RESEARCH AREA AND STUDY SITE

The present research work was conducted in the counties of Bungoma and Uasin Gishu, both located in the semi-humid region of Kenya (Figure 3.1). Selection of both counties as study area was guided by the following: the ASALI project and experts at the Kenya Forestry Research Institute (KEFRI) and researchers who carried out a baseline survey to identify the regions within the country where critical ecosystem services for human well-being are stressed (Ogut, 2015; Stoppok et al., 2018). and baseline Survey Report on Energy Sources in Mt. Elgon and Cherengany Ecosystems (Forest, 2015).

Table 3. 1: Forest coverage and population in the counties of BG and UG, Kenya

County (Area in ha)	Public Forests (ha)		Community/Private Forests (ha)		County Cover	Agro Forest	Total forest	Population*	
	Natural	Plantation	Natural	Plantation	% area	Trees on farm		Urban	Rural
Bungoma (359,300)	39,082	1,473	38,359	2,263	21	297,197	81,177	214,220	1,160,843
Uasin Gishu (334,500)	13,925	10,421	17,529	805	11	333,739	42,680	289,380	604,799

*Population densities are 552 and 343 inhabitants/km^2 for Bungoma and Uasin Gishu Counties respectively;

SOURCE: KNBS ,Statistics (2019) and Musoka (2018)

Moreover, the level of urbanization and availability of forest resources, using *forest area* (i.e., area under different types of forest as shown in Table 3.1) as indicator, served as criteria for site selection

Bungoma County is located in Western Kenya; its geographical coordinates are 0° 34' 0" North, 34° 34' 0" East. It covers an area of 3,032.2 km^2**.** According to the 2019 Kenya Population and Housing Census the population is 1,670,570 and has 358,796 households (KNBS, 2019). The major economic activity is maize farming, making the county a vital component of the country's bread basket.

On the other hand, Uasin Gishu County is situated in the former Rift Valley Province. It borders Nandi County to the South, Trans nzoia County to the North, and Elgeyo -Marakwet County to the East. Its geographical coordinates are 0.5528° N, 35.3027° E shares some rather short borders with Bungoma County to the West and Kericho County to its South Eastern strip. It occupies an area of 3,345 Km^2 with a population of 1,163,186 people and 304,943 households (KNBS, 2019). The County's headquarters is Eldoret town that boasts of population taking just over 32% of the county's population.

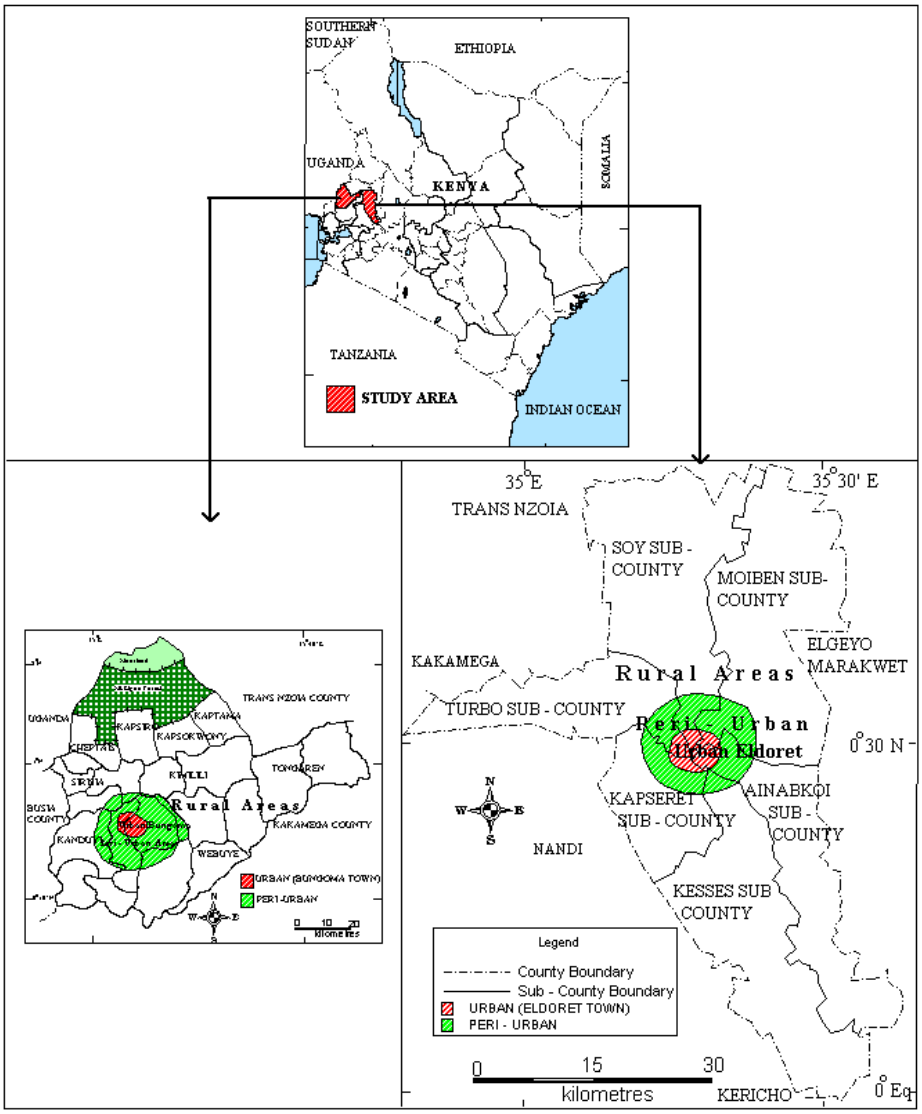

Figure 3. 1: Map of two Counties Bungoma and Uasin Gishu showing the urban, peri – urban and rural areas.

World Maps (2020)

3.2 TARGET POPULATION

The study targeted a total number of 304,943 and 358,796 households in Uasin Gishu and Bungoma counties respectively (KNBS, 2019). The stratified random sampling technique was used to select a sample of 640 rural and peri-urban households in total.

3.3 DETERMINATION OF ADEQUATE SAMPLE SIZE

The adequate sample size was determined according to Bujang and Baharum (2017) formula for as follows;

$$S = \frac{NP(1-P)}{(B/C)^2\,(N-1)+P(1-P)} \qquad (3.1)$$

where; *S* = Minimum required sample size (384);

N = the population size (= 663,739);

P = the population proportion expected to answer in a particular way (the most conservative proportion is 0.50);

B = the degree of accuracy expressed as a proportion (0.05); and

C = the Z statistic value based on the confidence level (in this case, 1.96 is chosen for the 95 per cent confidence level Hogg and McKean (2003).

From equation 3.1 the calculated minimum population size was 384. However, for purpose of this study, 640 samples were used, whereby; 560 samples were used to analyze the effect of the household utilization, changing behaviour, accessibility and diversification while the remaining 80 samples were used to analyze the effects of biogas on household energy utilization.

3.4 DATA COLLECTION

Data on energy consumption behavior was collected by means of a household survey, using a structured questionnaire (see Appendix). Likewise, focus group discussions with local communities in both counties were conducted to provide additional background information on energy consumption and energy conservation programs. Specifically, the surveys included the collection of data on household composition, gender of household head, average income, main livelihood, type and number of energy sources used, level of household satisfaction with energy sources, distance to nearest fuel collection point, renewable energy use and number of energy sources supplying shops in the village. To find the cost savings caused by a biogas system, questions were asked directly to biogas users. Households were asked to compare their monthly energy cost before and after they started to use biogas.

3.5 DATA ANALYSIS

Data analyses were conducted using both the statistical program for social sciences (SPSS version 23.0) and structural equation modeling (SEM) by utilizing AMOS (23.0). The software features included descriptive statistics to characterize energy consumption behavior in terms of type, number, and use frequency of energy sources employed by households. Path analysis currently called SEM was used to quantify the relationships among multiple variables. SEM was used to investigate relationships among factors influencing the households' energy consumption behavior (e.g., gender, income, livelihood, distance to fuel collection point,) and moderated mediated models to assess which factors have a significant effect on the household energy diversification and use frequency of energy sources used by households at the study sites. Validation of model parameters was accomplished by the application of Bootstrap software.

3.5.1 SEM Modelling

The AMOS 23.0 software package was employed to examine CFA and SEM. Five logical steps in SEM were used: model specification, identification, parameter estimation, model assessment, and model modification. Model specification defined the hypothesized relationships among the variables in SEM based on the objectives while, Model identification was used to check if the model was identified. Model coefficients were found in the just identified or over-identified model.

Then model evaluation was employed to assess the model fitness, with quantitative indices calculated for the overall goodness of fit. During the entire process, modification was done to adjust the model to improve model fit, i.e., the post hoc model modification. Investigation on the mediation and moderation factors was also done and the two effects analyzed included: (a) the mediation of a moderator effect, and (b) the moderation of an indirect effect. Three regression equations form the model:

$$Y = i_1 + c_1X + c_2Z + c_3XZ + e_1 \tag{3.2}$$

$$M = i_2 + a_1X + a_2Z + a_3XZ + e_2 \tag{3.3}$$

$$Y = i_3 + \beta_1X + \beta_2Z + \beta_3XZ + b_1M + b_2MZ + hXM + jXMZ + e_3 \tag{3.4}$$

In equation 3.2, c_1 is the effect of the independent variable on the outcome when Z = 0 (also the average effect of X on Y because the mean of Z = 0), c_2 is the effect of the moderator variable on the outcome when X = 0 (also the average effect of Z on Y because the mean of X = 0), c_3 is the effect of the interaction between the independent variable and the moderator on the outcome, and i_1 and e_1 are the intercept and the residual in the equation, respectively. In equation 3.3, a_1 is the effect of the independent variable on the mediator when Z = 0 (also the average effect of X on M because the mean of Z = 0), a_2 is the effect of the moderator variable on the mediator (also the average effect of Z on M because the mean of X = 0), a_3

is the effect of the interaction between the independent and moderator variables on the mediator, and i_2 and e_2 are the intercept and the residual in the equation, respectively.

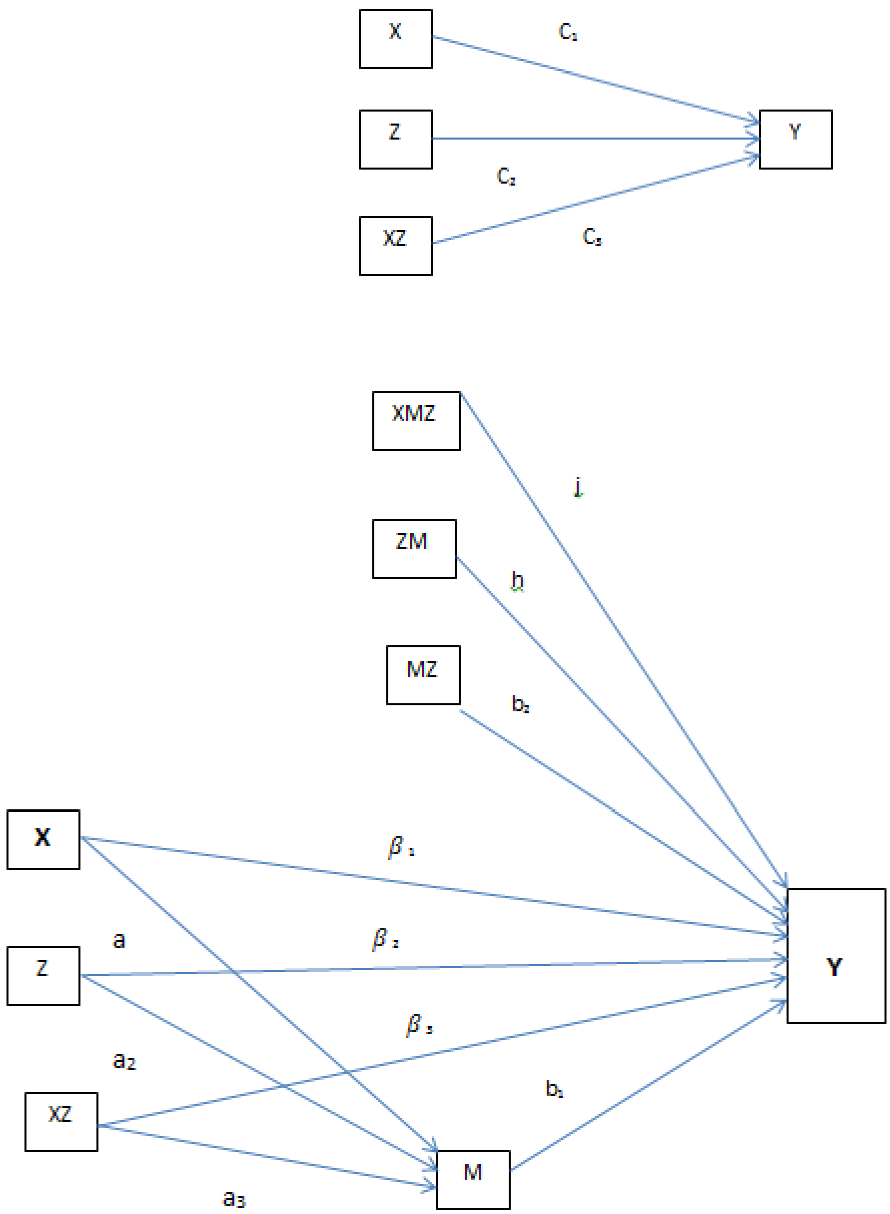

Figure 3. 2: The illustration of the mediation - moderation model

X= the independent variable, *Y*= the dependent variable, *Z*= the moderator variable, *M*= the mediating variable, *XZ*= the interaction of *X* and *Z*, *MZ*=the interaction of *M* and *Z*, *XM*= the interaction of *X* and *M*, and *XMZ* = the three-way interaction between *X, M*, and *Z* where all predictors in the model are centered at zero to improve interpretation of the lower order coefficients. In equation 3.4, β_1 is the effect of the independent variable on the outcome when M = 0 and Z = 0 (the average effect of X on Y), β_2 is the effect of the moderator on the outcome when X = 0 and M = 0 (the average effect of Z on Y), β_3 is the effect of the interaction between the independent and moderator variables on the outcome when M = 0 (the average effect of XZ on Y), b_1 is the effect of the mediator on the outcome when X = 0 and Z = 0 (the average effect of M on Y), b_2 is the effect of the interaction between the moderator and mediator variables on the outcome when X = 0 (the average effect of MZ on Y), h is the effect of the interaction between the independent and mediator variables on the outcome when Z = 0 (the average effect of XM on Y), and j is the effect of the three-way interaction of the mediating, moderating, and independent variables on the outcome. The intercept and residual in equation 3.5 are coded i_3 and e_3, respectively.

3.5.2 Model evaluation

The SEM assessment was based on the fit indices for evaluating a single path coefficient (i.e., p value, standard error and critical ratio) and the overall fit model (i.e., $\chi 2$, RMSEA, GFI) (Muller et al., 2005), (Preacher et al., 2007).

3.5.3 SEM model validation

In order to test both the measurement and structural model significance Bollen-Stine Bootstrap and boot-strap re-sampling were run with 500 samples. To generate significance measures, i.e., standard errors and t values a bootstrapping procedure was carried out. The data on bootstrapping test showing the path coefficient of the structure model were presented in tables' format.

CHAPTER 4

HOUSEHOLD ENERGY UTILIZATION AND CHANGING BEHAVIOURS

4.1 CHARACTERISTICS OF HOUSEHOLDS IN THE SURVEY

This section provides information on study characteristics of the household population and the individual survey respondents, such as age, sex, income, location, household size, county and educational level. The section also examines the conditions of the households in which the survey population lives, including access to electricity, accessibility (distance to the nearest retail shops selling and number of suppliers) and intensity of household energy sources. Information collected on the characteristics of the households and respondents is important in understanding and interpreting the findings of the survey and also provides indicators of the representativeness of the survey. Table 4.1 and Table 4.2 presents the results of the statistics on household characteristics across the study locations, showing the description of explanatory variables and on household energy utilization for cooking and lighting.

Table 4. 1: Description of explanatory variables

Explanatory variable	**Description**	**Expected sign for house hold energy:**	
		utilization	***diversification***
County	Location by county; 1= Uasin Gishu, 2 = Bungoma	-/+	-/+
Peri urbanization	Location of dwellers; 1 = rural, 2= peri urban	-/+	-/+
Age	Age of the household head; 1= 0-18, 2= 19-30, = 31-50 and 4 = 51 and above	-/+	-/+

Gender HH	Gender of the household head; 1= Male and 2= female	-	+
Marital status	1= Single and 2 = married	+	+
Sex	Sex of the respondent; 1= Male and 2= female	-/+	-/+
House size	Number of persons in the households	-	-
Household composition	Children under 5 years	-	-
	Youth 6-14 years	+	-
	Female 15-50 years	+	+
	Male 15-50 years	+	+
	Female over 50 years	+	+
	Male over 50 years	-	-
Education	Education level of the household head: 1 = primary level and below; 2= secondary; 3 = tertiary; 4= masters and above	+	+
Assets			
Income	Average income of the household head	+	+
Cars	Number of cars	+	+
Cattle		–	–

Table 4. 2: Descriptive statistics on household energy use across the study locations

Household energy use characteristics	**Description**	**Expected sign for house hold energy:**	
		utilization	***diversification***
Household diversification for cooking	Average number of household energy sources used for cooking		
Firewood	Intensity of fire wood use; 1= not used, 2= rarely used, 3= moderately used and 4= frequently used	-/+	-/+
Charcoal	Intensity of charcoal use; 1= not used, 2= rarely used, 3= moderately used and 4= frequently used	-/+	-/+
Kerosene	Intensity of kerosene use; 1= not used, 2= rarely used, 3= moderately used and 4= frequently used	-/+	-/+
LPG	Intensity of LPG use; 1= not used, 2= rarely used, 3= moderately used and 4= frequently used	-/+	-/+
Electricity	Intensity of electricity use; 1= not used, 2= rarely used, 3= moderately used and 4= frequently used	-/+	-/+
Biogas	Intensity of biogas use; 1= not used, 2= rarely used, 3= moderately used and 4= frequently used	-/+	-/+
Agricultural residue	Intensity of agricultural residue use; 1= not used, 2= rarely used, 3= moderately used and 4= frequently used	-/+	-/+
Household diversification for lighting	Average number of energy sources used for Lighting	-/+	-/+

Electricity	Intensity of electricity use; 1= not used, 2= rarely used, 3= moderately used and 4= frequently used	-/+	-/+
Solar	Intensity of solar use; 1= not used, 2= rarely used, 3= moderately used and 4= frequently used	-/+	-/+
Kerosene (%)	Intensity of charcoal use; 1= not used, 2= rarely used, 3= moderately used and 4= frequently used	-/+	-/+
Accessibility			
Mean distance to the nearest retail shops selling			
Firewood (Km)	Distance to fire wood selling shops	–	–
Charcoal (Km)	Distance to charcoal selling shops	–	–
Kerosene (Km)	Distance to Kerosene selling shops	–	–
LPG (Km)	Distance to LPG selling shops	–	–
Number of suppliers			
Charcoal	number of retail shops selling charcoal	+	+
Firewood	number of retail shops selling firewood	+	+
Kerosene	number of retail shops selling kerosene	+	+
LPG	number of retail shops selling LPG	+	+
Electricity	Access to electricity (%)	+	+

4.2 TRENDS IN HOUSEHOLD ENERGY UTILIZATION

4.2.1 Pattern of Household Energy for Cooking

Figure 4.1 presents the percentage of households that use specific type of household energy source for cooking between peri urban and rural areas in the study area. The proportion of households that use fire wood declines from 87.5 % to 72.4 % as one moves from rural to peri-urban, while the use of charcoal increases from 39.4 % to 53.8% in the same case. On the other hand, the use of LPG and kerosene increases from 26% and 39.4% to 42% and 53.8 % respectively.

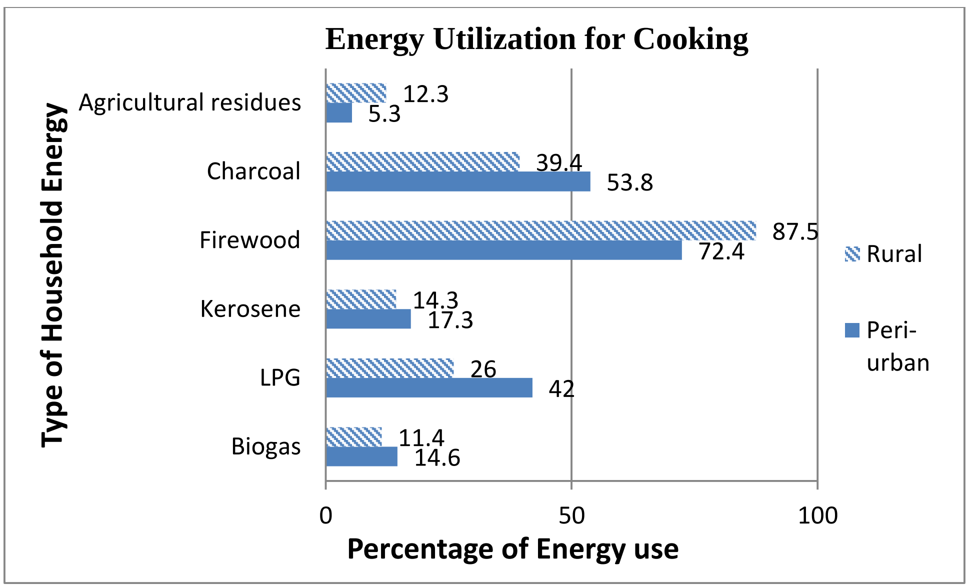

Figure 4. 1: Household Energy for cooking by households

The results also show the reduced use of modern fuels such as LPG and charcoal among rural households. This can be attributed to the heavy dependence of these households on biomass energy for cooking among rural settlements. The findings are in line with the observation that households in rural areas were observed collecting their firewood rather than purchasing, reflective of the occasional use. The results further showed that although biogas technology uptake is still low as it represents a small fraction of the energy mix at local level.

In addition, households in peri-urban have significantly higher fuel choices than households in the rural areas with firewood and charcoal are the most common combination of multiple fuel use for both peri urban and rural households. These results are in agreement with the findings of previous studies where firewood was found to be a key source of energy for rural dwellers in developing countries (Bisu et al., 2016); Edwards and Langpap (2005); (Ouedraogo, 2006; Van der Kroon et al., 2013, 2014; Zhang et al., 2019) and Duguma et al. (2019).

Among the rural households, firewood remains the main fuel source signifying that majority households still depend on firewood for their cooking needs. Households using liquid fuels (LPG), charcoal, and kerosene are mostly found in peri-urban areas. Notably, there is a shift towards charcoal, LPG and kerosene as one moves from the rural to peri-urban areas and these findings corroborates the research done by Hanif (2018), Wang and Dong (2019) and Arnold and Persson (2003). Nonetheless, the experimental evidence in the study is in support of the energy stacking model rather than the energy ladder model – of household fuel utilization which suggests that households do shift to superior fuels but do not abandon the inferior fuels altogether (Choumert-Nkolo et al., 2019).

The results of biogas utilization indicates its low consumption on social-economic and environment development among the local communities which concurs with the research done by Katikiro (2016), Ouedraogo (2006), Sana et al. (2020).

Table 4.3 presents the pairwise correlation coefficients which reveal the relationship between the household energy choices made by the households for cooking. They include; firewood, charcoal, kerosene, LPG, biogas and agricultural residues. For rural, the results showed positive and significant association between the use of firewood – agricultural residues (0.103*), LPG – charcoal (0.361***), biogas – LPG (0.144***) and charcoal – biogas (0.189***) while on the other hand negative and significant association between the use of charcoal – firewood (- 0.546), LPG-firewood (- 0.095*), firewood – kerosene (- 0.335***) and biogas – firewood (- 0.073) among the rural households. The results indicate that the households tend to choose dirty, transitional and modern energy sources in bundles. On the other hand, the results for peri urban show positive and significant association between the use of firewood – agricultural residues (0.111***), LPG - charcoal(0.289***), and charcoal – kerosene (0.230***), while a negative and significant association between the use of firewood – charcoal (- 0.454***), LPG – firewood (- 0.448***), LPG- kerosene (- 0.038***), firewood – kerosene (- 0.364***), LPG- agricultural residues (- 0.19**), kerosene – agricultural residues (- 0.208**) and biogas –kerosene (- 0.207***) is observed. The peri urban result shows a positive correlation among the low-quality energy source, transitional and clean/modern energy sources and also a negative relationship is observed between low quality energy source, transitional and clean/modern. The results further more show a negative and significant pairwise correlation between firewood – charcoal and LPG – firewood signifying the general reduction of fire wood with peri urbanization.

Moreover, the results on household energy for cooking by households support the fuel stacking energy utilization model than energy ladder in study households which can be presented as shown in Figure 4.2.

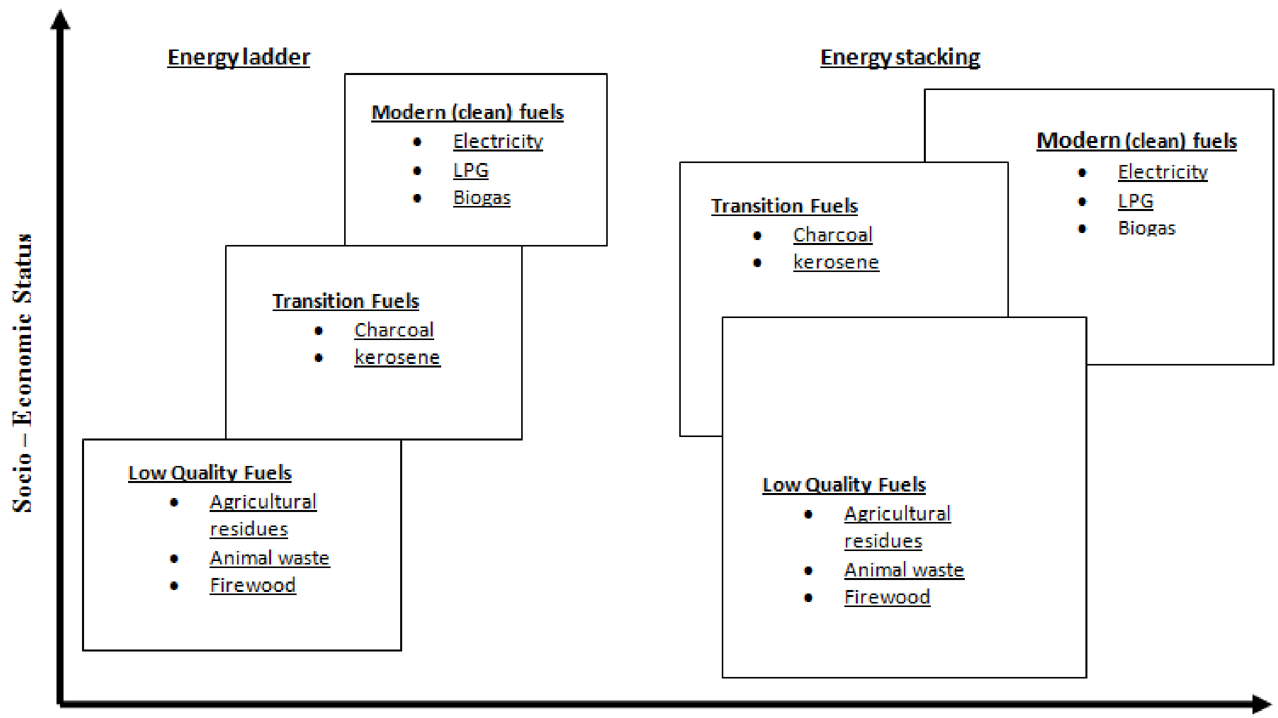

Figure 4. 2: Household energy transition model for the study area

Table 4. 3: Correlation's coefficients of household energy sources for cooking

Correlations between household energy choices								
Peri-urban and rural			***LPG***	***firewood***	***charcoal***	***Kerosene***	***biogas***	***Agricultural Residue***
Rural	LPG	Correlation	1	-.095*	.361***	-.049	.144***	-.195***
		Sig.		.084	.000	.371	.008	.000
	Firewood	Correlation	-.095	1	-.546***	-.335***	-.073	.103*
		Sig.	.084		.000	.000	.180	.061
	Charcoal	Correlation	.361***	-.546***	1	.240***	.189***	-.300***
		Sig.	.000	.000		.000	.001	.000
	Kerosene	Correlation	-.049	-.335***	.240***	1	.067	-.198***
		Sig.	.371	.000	.000		.220	.000
	Biogas	Pearson Correlation	.144***	-.073	.189***	.067	1	-.112**
		Sig.	.008	.180	.001	.220		.040
	Agricultural Residue	Pearson Correlation	-.195***	.103	-.300***	-.198***	-.112**	1
		Sig.	.000	.061	.000	.000	.040	
Peri urban	LPG	Correlation	1	-.448***	.289***	-.038	-.024	-.190***
		Sig.		.000	.000	.568	.721	.004
	Firewood	Correlation	-.448***	1	-.454***	-.364***	.036	.111*
		Sig.	.000		.000	.000	.596	.096
	Charcoal	Correlation	.289***	-.454***	1	.230***	.106	-.208***
		Sig.	.000	.000		.001	.114	.002
	Kerosene	Correlation	-.038	-.364**	.230**	1	-.207**	-.097
		Sig.	.568	.000	.001		.002	.149
	Biogas	Correlation	-.024	.036	.106	-.207***	1	.041
		Sig.	.721	.596	.114	.002		.539
	Agricultural Residue	Correlation	-.190***	.111*	-.208***	-.097	.041	1
		Sig.	.004	.096	.002	.149	.539	

***. Correlation is significant at the 0.01 level.

**. Correlation is significant at the 0.05 level.

*. Correlation is significant at the 0.1 level.

Sig. means significance

4.2.2 Pattern of Energy Use for Lighting

Figure 4.3 presents results on the percentage of households that use a specific type of energy source for lighting. As can be seen, there is reduced tendency of using solar as one move towards peri urban (from 44.8% to 39.6%). However, the use of kerosene (68.4% to 72%) and electricity (55.5% to 58.2%) also increases as households move from rural to peri urban areas. The pattern of energy use for lighting shows that there is a small difference in the use of kerosene and solar between the rural and peri urban households. The results are in agreement with the findings of Maharaj (2013).

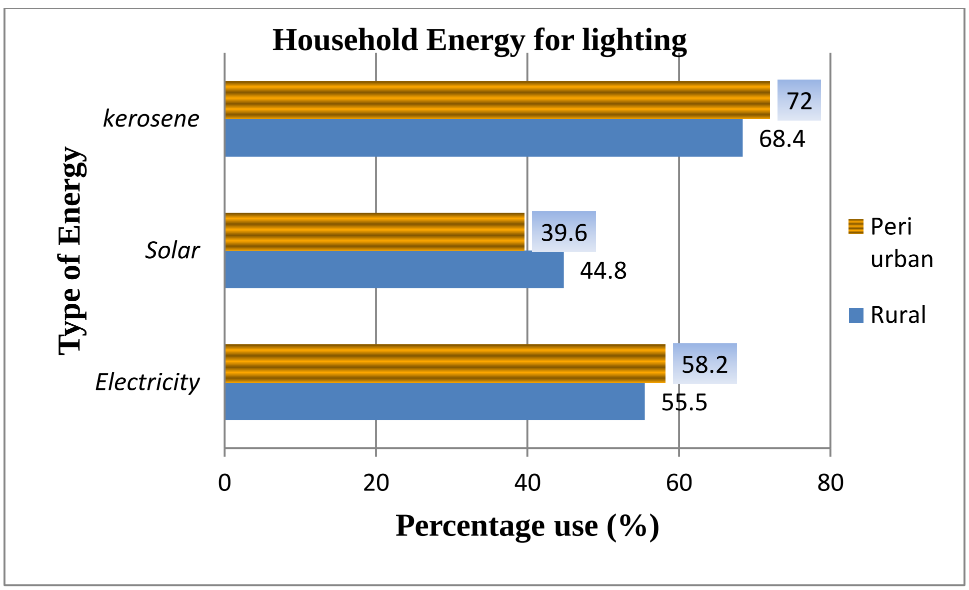

Figure 4. 3: Sources of household energy for lighting households

The results for the sampled households with access to the electrical network use a variety of backup lighting sources (such as solar, mobile phone light, candles, and kerosene lamp) to enhance energy security. For instance, in rural areas, results show that in addition to solar, kerosene fueled lamps is used for enhancing the energy security.

Furthermore, it was found that the solar lantern form of light was common due to the fact that it is faster and easier to turn for sudden need than the more complicated task of lighting a kerosene lamp and it can be used in wind or rain. The results are in agreement with the findings of Munro (2020).

Table 4. 4: Pairwise correlation coefficients of the household energy source for Lighting

Peri-urban and rural/ Household energy			Solar	Kerosene	Electricity
Rural	Solar	Coefficient	1.000	0.136**	- 0.244***
		Sig.	.	.013	.000
	Kerosene	Coefficient	0.136**	1.000	- 0.520***
		Sig.	.013	.	.000
	Electricity	Coefficient	- 0.244***	-.520***	1.000
		Sig.	.000	.000	.
Peri urban	Solar	Coefficient	1.000	.095	- 0.408***
		Sig.	.	.154	.000
	Kerosene	Coefficient	0.095	1.000	- 0.511**
		Sig.	.154	.	.000
	Electricity		- 0.408***	- 0.511***	1.000
		Sig.	.000	.000	.

*. Correlation is significant at the 0.1 level.

**. Correlation is significant at the 0.05 level.

***. Correlation is significant at the 0.01 level.

The pairwise correlation coefficients of the household energy sources result for lighting are shown in Table 4.4. For rural, the results showed positive and significant association between the use of solar – kerosene (0.136**) while on the other hand negative and significant association between the use of solar – electricity (- 0.244***) and kerosene - electricity (- 0.520***) implying that the majority of rural households use solar and kerosene as a source of energy for lighting. For peri urban, it was found that there is negative association between solar – electricity (- 0.408***) and kerosene – electricity (- 0.511***). The findings indicate that the majority of rural households rely on solar and kerosene while peri urban households majorly depend on electricity and solar as back up. The results are in line with Behera and Ali (2017).

4.3 DETERMINANTS OF HOUSEHOLD FUEL CHOICE FOR COOKING

The description of the SEM model analysis on the effects of variables in household energy choices and changing behaviour for cooking is presented in Figure 4.4 and Table 4.5. According to the SEM model the household energy utilization and changing behaviours are influence by income, education level, peri urbanization, household size, residential status, gender and age of the household head. In the study, the determinants of household energy for cooking were analyzed to find standard estimate (path coefficients), standard error, critical ratios and the level of significance.

For the overall structural model, the goodness-of fit indices were computed and presented in Table 4.5. As can be seen the values of model fit indices (CMIN/df = 2.53, CFI = 0.994, TLI = 0.938, GFI = 0.991, AGFI = 0.938, RFI = 0.902, NFI = 0.990 and RMSEA = 0.052) exceed the threshold value, indicating that the model fitted the data absolutely fine (Bentler & Bonett, 1980; Byrne, 1994, 2013; Kline, 2005; Thompson, 2004). The structural model was validated to test SEM model reliability. The computed R^2 values which is a measure of the degree of variation in the dependent variable illustrated by independent variables were found to be 0.422 (Charcoal), 0.441 (LPG) and 0.578 (firewood).

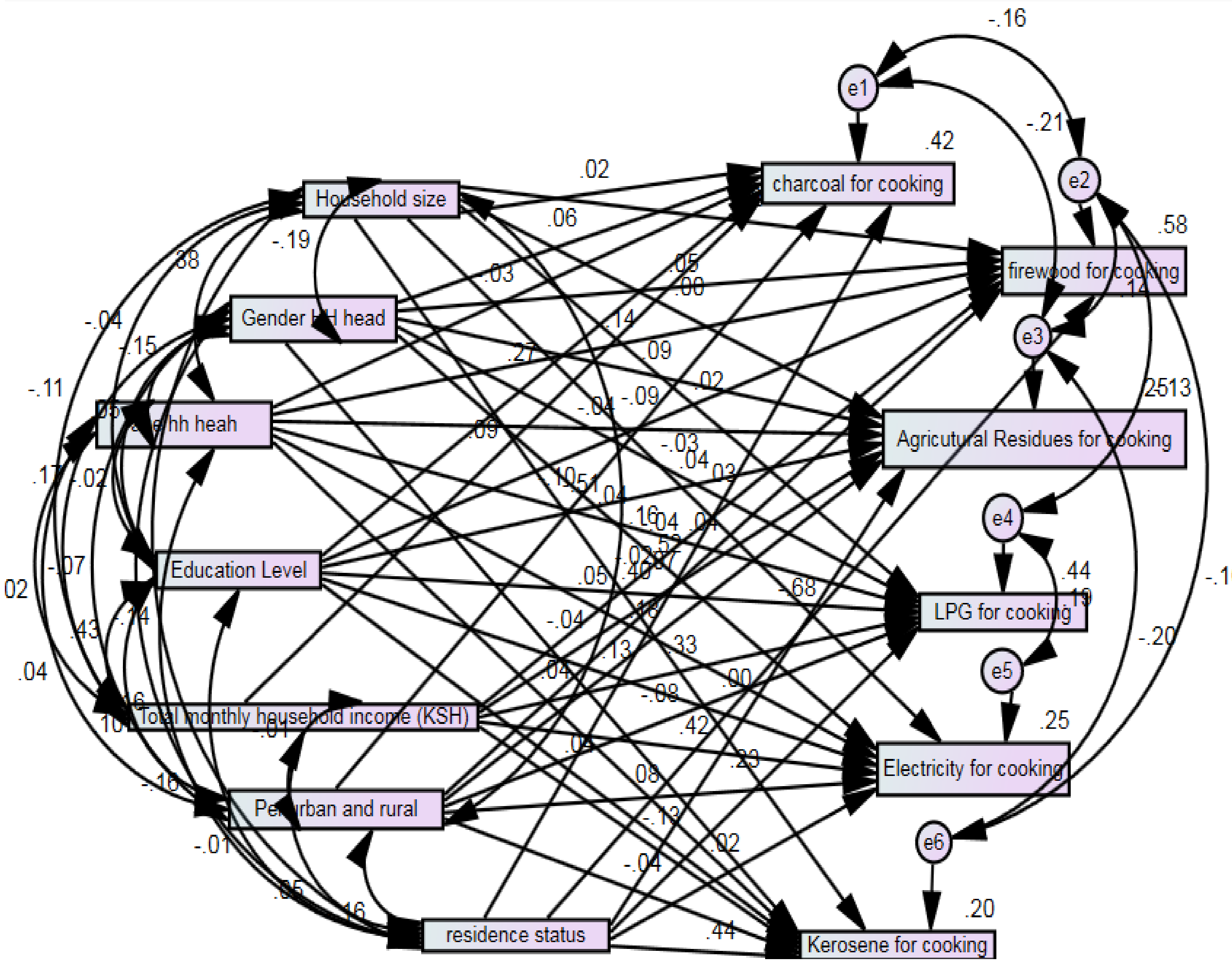

Figure 4. 4: Path diagram of Structural Equation showing regression weights that explain determinants of household fuel choice for cooking

The results further show that Bollen-Stine bootstrap model the model fits well in 498 bootstrap samples and fits worse or failed to fit in 2 bootstrap samples (Bollen-Stine bootstrap p = 0.006). The results on the determinants of household energy utilization and changing behaviour for cooking found the major drivers that cause gradual change from dependence on dirty fuels to modern and clean energy sources are; household income and educational levels. This result concur with other research by Sarkodie and Adom (2018), Rahut et al. (2019), Azam et al. (2016), Semenya and Machete (2019) and Acharya and Marhold (2019).

Table 4. 5: Standardized Regression Weights results for household energy drivers for cooking

Relationship between variables			*Standardized Estimate (β)*	*S.E.*	*C.R.*	*P-Value*
Firewood	<---	Household size	.123	.012	4.011	***
Electricity	<---	Household size	.039	.004	.942	.346
Charcoal	<---	Gender HH	.063	.095	1.885	.05**
Firewood	<---	Gender HH	.046	.077	1.610	.107
LPG	<---	Gender HH	-.031	.085	-.940	.347
Electricity	<---	Gender HH	-.041	.024	-1.080	.280
Charcoal	<---	Age HH	-.034	.050	-.966	.334
Firewood	<---	Age HH	.144	.041	4.768	***
LPG	<---	Age HH	.042	.045	1.197	.231
Electricity	<---	Age HH	.048	.013	1.204	.229
Charcoal	<---	Education level	.272	.051	7.607	***
Firewood	<---	Education level	-.091	.041	-2.966	.003***
LPG	<---	Education level	.403	.046	11.457	***
Electricity	<---	Education level	.130	.013	3.187	.00***
Charcoal	<---	Income	.090	.000	2.489	.01**
Firewood	<---	Income	.030	.000	.952	.341
LPG	<---	Income	.330	.000	9.229	***
Electricity	<---	Income	.423	.000	10.221	***
Charcoal	<---	Residence status	.522	.086	15.656	***
Firewood	<---	Residence status	-.684	.070	-24.032	***
LPG	<---	Residence status	.234	.077	7.147	***
Electricity	<---	Residence status s	.022	.021	.591	.555
Agricultural residues	<---	Gender of HH	.090	.070	2.353	.019**
Agricultural residues	<---	Age of HH	-.043	.037	-1.083	.279
Agricultural residues	<---	Education level	-.510	.037	-12.551	***
Agricultural residues	<---	Income	.067	.000	1.632	.103

Relationship between variables			*Standardized Estimate (β)*	*S.E.*	*C.R.*	*P-Value*
Kerosene	<---	Household size	-.022	.013	-.519	.604
Kerosene	<---	Gender of HH	-.042	.082	-1.066	.286
Kerosene	<---	Age of HH	.043	.044	1.028	.304
Kerosene	<---	Education level	.041	.044	.968	.333
Kerosene	<---	Income	-.133	.000	-3.121	.002***
Kerosene	<---	Residence status	.439	.075	11.230	***
Charcoal	<---	Peri-urban - rural	.102	.080	3.063	.002***
Firewood	<---	Peri-urban - rural	-.044	.065	-1.569	.117
Agricultural residues	<---	Peri-urban - rural	-.178	.059	- 4.726	***
LPG	<---	Peri-urban - rural	.077	.072	2.358	.018**
Electricity	<---	Peri-urban - rural	-.077	.020	-2.049	.04**
Kerosene	<---	Peri-urban - rural	.036	.070	.937	.349
Agricultural residues	<---	Household size	-.001	.011	-.019	.985
LPG	<---	Household size	.023	.014	.640	.522
Charcoal	<---	Household size	.020	.015	.569	.570
Agricultural residues	<---	Household size	-.002	.063	-.054	.957
Model summary: Chi-square = 20.241; Degrees of freedom = 8; Probability level = 0.009; CMIN/DF = 3.53; GFI = 0.995; AGFI= 0.938 and RMSEA= 0.05						

*Denotes values significant at 10% level of significance.

** Denotes values significant at 5% level of significance.

*** Denotes values significant at 1% level of significance.

4.3.1 Income Level

The results presented in Table 4.5 show that income is positively and substantially associated with the use of electricity (β = 0.423, S.E = 0.00, C.R = 10.221), LPG (β = 0.33, S.E = 0.00, C.R = 9.229) and Charcoal (β = 0.09, S.E = 0.00, C.R = 2.489) for cooking while it is negatively associated with the use of kerosene (- 0.133, S.E = 0.00, C.R = -3.121) at *P* <

0.01 significant level. Income is also positively and but not significant with the use of firewood and agricultural residues. Household income also shows the lowest S.E. value, 0.00 which means it has the strongest ability to predict the use of electricity, LPG, charcoal and kerosene in households. It is further shown that the C.R. value between household income and electricity, LPG and Charcoal are out of ± 1.96 ranges and therefore, these three variables are significant to income. Cars as assets are negatively and significantly associated with the modern fuel (LPG and electricity); implying that households in rural or peri-urban areas who are farmers are less likely to consume modern cooking fuels. The findings are in agreement with the research done by Joshi and Bohara (2017).

In addition, the results suggest that higher income encourages a lower probability that households choose low quality fuels as their main cooking fuel rather than other fuel types but a higher probability of choosing LPG and electricity over traditional fuels. Income level is positively correlated with the consumption of modern fuels and further shows why household's choice of LPG is sensitive to household income. Household energy utilization of agricultural residues and firewood generally increases with household income/wealth which is often measured by farm size and livestock especially in rural households. Therefore, an increase in farm size improves the availability of firewood and agricultural residues.

The results support economic theory which states that "households consume more of the same goods and shift towards higher quality goods as household income increases". Higher quality fuels are those that have more economic benefit per joule of energy content by being converted more effectively, being more versatile or easy to use, and by generating fewer emissions (Ahmad & de Oliveira, 2015). It is expected that lower income households are capable of tolerating the discomfort and emissions generated by the use of lower-quality fuels for energy services production. Therefore, as household income increases, by consuming higher-quality fuels and more total energy, it would be expected households gradually ascend an "energy ladder." The findings concur with results from others researchers (Hou et al., 2018; Rahut et al., 2019).

4.3.2 Location (Peri – urbanization)

The results on location (1= rural and 2 = Peri urban) showed positively and significant relationship between the use of LPG (β = 0.077, S.E = 0.072, C.R = 2.358) and charcoal (β = 0.102, S.E = 0.08, C.R = 3.063) and while a negative association with the use of agricultural residues (β = - 0.178, S.E = 0.059, C.R = 4.726) and electricity (β = - 0.077, S.E = 0.020, C.R = 2.049) in peri-urban and vice versa for rural is observed. The use of kerosene showed positive association with peri-urban while firewood reveals positive association with rural areas though not significant. The results suggest that there is a shift towards LPG and charcoal use in cooking as one moves from the rural to peri-urban which supports the research done by Van der Kroon et al. (2013) and Gatama (2014).The results are in line with the various energy studies on Sub-Saharan Africa which confirm an increase in charcoal consumption with rising urbanization levels (Arnold & Persson, 2003; Hanif, 2018; Mwampamba, 2007; Wang & Dong, 2019). According to Farsi et al. (2007) living in larger cities or metros also increases the probability of choosing cleaner fuels, as does having more LPG distributors and hence easier accessibility suggesting that there are differences in the choice behavior of households living in different regions of the country. The results are in line with the findings by Ahmad and de Oliveira (2015) who found out that peri urban amenities were main drivers for changing household fuel usage (Özcan et al., 2013) while peri urban and rural dwellers choose LPG and conventional fuels (such as firewood), respectively.

The results suggest that the use of LPG, kerosene and charcoal is significantly higher in peri-urban as compared to rural households while firewood and agricultural residues usage is lower in peri-urban compared to rural areas. Moreover, it is observed that rural households collect biomass for cooking mainly from the wild/farms and do not participate in market exchange. These results concur with findings by Chun-sheng et al. (2012) who established that peri urban households are dominated by the fossil energy in terms of energy structure, while rural households are dominated by both biomass energy and fossil fuels due to an unequivocal difference in energy consumption per capita between peri urban and rural. Hence, Chun-sheng et al. (2012) indicate that rural household emissions are significantly greater than those of peri urban households.

4.3.3 Residential status

Residential status (1= Permanent vs. 2 = rental) is one of the factors that often has a direct and significant influence on house-holds' housing choice and changing behaviour. The findings of the study in Table 4.5 shows positive and significant association in the study area between renter ship and the use of charcoal (β = 0.522, S.E = 0.070, C.R = -24.032); Kerosene (β = 0.439, S.E = 0.075, C.R = 11.230) and LPG (β = 0.234, S.E = 0.077, C.R = 7.147) while on the other hand negative relationship with the use of firewood at 1% statistical significance level. Electricity showed positive (β = 0.22, S.E = 0.021, C.R = 0.591) association while agricultural residues (β = 0.067, S.E = 0.00, C.R = 1.632) publicized negative association with renter ship but no significance. The results support the findings of

Behera and Ali (2016) who studied the effects of the floor material of the house on household energy choices in Bhutan who found that those in rented dwellings tend to use higher fuels (such as kerosene and LPG) because they are compact and will not require large space for storage, since the rented houses usually do not have sufficient space for fuel storage. The results also are in agreement with Bisu et al. (2016) findings.

4.3.4 Household head Gender

The female-headed households are positively associated with charcoal ($\beta = 0.063$, S.E = 0.095, C.R = 1.885) firewood ($\beta = 0.046$, S.E = 0.077, C.R = 1.61) and agricultural residues ($\beta = 0.067$, S.E = 0.000, C.R = 1.632) at 5% significance level. Also, female-headed households are positively associated with firewood and negatively associated with kerosene, LPG and electricity with no significance, indicating that the male household head in the study area tends to give more emphasis to clean energy sources such as electricity and LPG. Most women during interview said they are not able to cook certain traditional dishes such as ugali and githeri with LPG because the food cooked with LPG was less delicious. Others still used primarily LPG because of the smoke reductions and reduction in cooking time. This research evidence is supported by Abebaw (2007), Sharma et al. (2019) and Ouedraogo (2006), who observe that the effect of gender of the household's head is insignificant in some contexts. Link et al. (2012) showed that households in Nepal are encouraged by large proportions of female members to use firewood. This is due to women being the primary fuel wood gatherers. Heltberg (2005), on the other hand, found that significant proportions of females in Guatemala do not affect the use of fire wood. In addition, Israel (2002) found an association of a large female share of the earned income family with a low likelihood of using firewood in urban Bolivia.

4.3.5 Education level

The results on Table 4.5 showed that education level is positively and statistically significant with the use of LPG (β = 0.403, S.E = 0.046, C.R = 11.457), charcoal (β = 0.272, S.E = 0.051, C.R = 7.607), and electricity (β = 0.13, S.E = 0.013, C.R = 3.187), for cooking at $P < 0.01$ significance level while, it is negative and statistically significant with the use of firewood ((β = - 0.091, S.E = 0.041, C.R = - 2.966), and agricultural residues) (β = - 0.510, S.E = 0.037, C.R = - 12.551) for cooking at $P < 0.01$ significance level. The results also showed that education level is positively associated with the use of kerosene (β = 0.041) though not significant. Growing education level may increase awareness regarding negative externalities of using solid fuel for cooking and therefore higher education can positively influence the LPG transition as explained by Peng et al. (2010) and Sharma et al. (2019). These results corroborates the findings by Farsi et al. (2007), whereby it was established that with the household head being illiterate or only having primary education increases the probability of choosing firewood or kerosene as a cooking fuel, whereas those households where the head has a higher level of education are more likely to use LPG.

The structural equation model suggests that households with an educated head and spouse tend to choose cleaner energy because of the convenience of use, health benefits and the opportunity cost of their labor. Educated respondents were more likely to pick cleaner fuels, which is consistent with Ifegbesan et al. (2016) findings. The results are similar to those reported in India by Rao and Reddy (2007), whereby it was found that household head education increases the interest of a household in choosing a clean and efficient energy source such as LPG. The results also agrees with Zhong Liu et al. (2020) findings, who observed that more educated households are more inclined to choose clean cooking fuels and less inclined to use firewood and agricultural residue.

Furthermore, the results concurs with those reported by Kemmler (2007) in India who found that the probability of electricity use is 8.5 % lower if the man in the household is uneducated than if the man has a primary education, whereas a man having a secondary or higher education increases the probability by 7.7 %. The opportunity costs of fuel collection time, seen as increasing with education, may explain some of the observed results. Likewise, more education generally implies a higher income. It may thus be that the estimated education effect is partly an ill-observed income effect, which is consistent with typical rankings of fuels according to necessities and luxuries.

4.3.6 Household size and composition

The structural equation model results in table 4.5 showed that household size is positive and statistically significant with the use of firewood ($\beta = 0.123$, S.E = 0.012, C.R = 4.011) at $P < 0.01$significance level for cooking while on the other hand it is negatively associated with the use of agricultural residue ($\beta =-0.001$) and kerosene ($\beta = - 0.022$) though not significant. The results further show that household size is positively associated with the use of LPG ($\beta = 0.023$), charcoal ($\beta = 0.020$) and electricity ($\beta = 0.039$) though insignificantly.

In addition, the structural equation model results showed positive relation between children under 5 years with firewood, agricultural residues and kerosene while negatively associated with charcoal, LPG and electricity. Moreover, a positive relation between youth5-14 years with firewood and charcoal while negatively associated with electricity, LPG, kerosene and agricultural residues was observed. The negative relationship between youth and electricity use is a cause of concern as this can affect children under the age of 15 years of education and overall development.

The results further show a positive relation between female aged 15-50 years with firewood, electricity, kerosene and agricultural residues while negatively associated with LPG and charcoal. On the other hand, positive relation exists between male aged 15-50 years with firewood and electricity while negatively associated with LPG, charcoal, kerosene and agricultural residue. There is also a positive relation between adult female above 50 years with firewood, electricity and kerosene while negatively associated with LPG, charcoal and agricultural residue. On the other hand, positive relation exists between adult male aged 50 years with firewood, charcoal, agricultural residue and LPG while negatively associated with electricity and kerosene.

Interestingly, all categories of household composition within the family residing in rural areas are positively associated with the choice of firewood by a household, indicating that all rural household members are more likely to choose dirty and traditional fuels such as fire wood. Elsewhere, the results of the studies by Rao and Reddy (2007), Ouedraogo (2006), Özcan et al. (2013), Pandey and Chaubal (2011), Miah et al. (2010) and Reddy (1995)indicate that larger households prefer dirty fuels to clean fuels. One possible reason for this could be that the household size is often larger in poorer households that cannot afford modern fuels. Also, households in rural developing countries tend to use children as labor to gather firewood and cow dung; hence, firewood is positively associated with the choice of energy source. In addition, large households are often used to indicate more labour, which might reduce the cost of collecting solid fuels (Heltberg, 2005). On the contrary, a large size of a household may not indicate more labour, but rather more income, which increases the use of clean and modern fuels.

The findings herein corresponds with those by Bisu et al. (2016) whereby it was established that household size is negatively related to kerosene consumption indicating that when the number of people in a family increases, the quantity of food to be cooked also increase, making kerosene consumption uneconomical.

4.3.7 Age of Household Head

The structural equation model results in Table 4.5 showed that age of HH is positive and statistically significant with the use of firewood ($\beta = 0.144$, S.E = 0.041, C.R = 4.768) at $P < 0.01$significance level for cooking while on the other hand it is negatively associated with the use of charcoal ($\beta = -0.034$) and agricultural residue ($\beta = -0.043$) though not significant. The results further show that age of HH is positively associated with the use of LPG ($\beta = 0.042$), kerosene ($\beta = 0.043$) and electricity ($\beta = 0.048$) though not significant. In contrast to younger heads of households, older heads of households are most resistant to modern fuel developments and cling to conventional energy as a matter of habit. According to Estiri and Zagheni (2019) the age-energy consumption profiles showed a higher level of energy consumption of fire wood in the cold region. Research results are in line with findings from Rahut et al. (2016), (Hou et al., 2018), (Baiyegunhi & Hassan, 2014) and (Edwards &

Langpap, 2005). This observation, which is consistent with previous research, becomes especially clear as age increases there is need for warmed.

4.4 DETERMINANTS OF HOUSEHOLD ENERGY FOR LIGHTING

Figure 4.5 and Table 4.6 presents the results of structural equation model estimation on the determinants of household choice of energy sources for lighting. According to the SEM model the household energy utilization and changing behaviours are influence by income, education level, peri urbanization, household size, residential status, gender and age of the household head. For the determinants of household energy for lighting were analyzed depending on standard estimate (path coefficients), standard error, critical ratios and the level of significance as shown in Table 4.6.

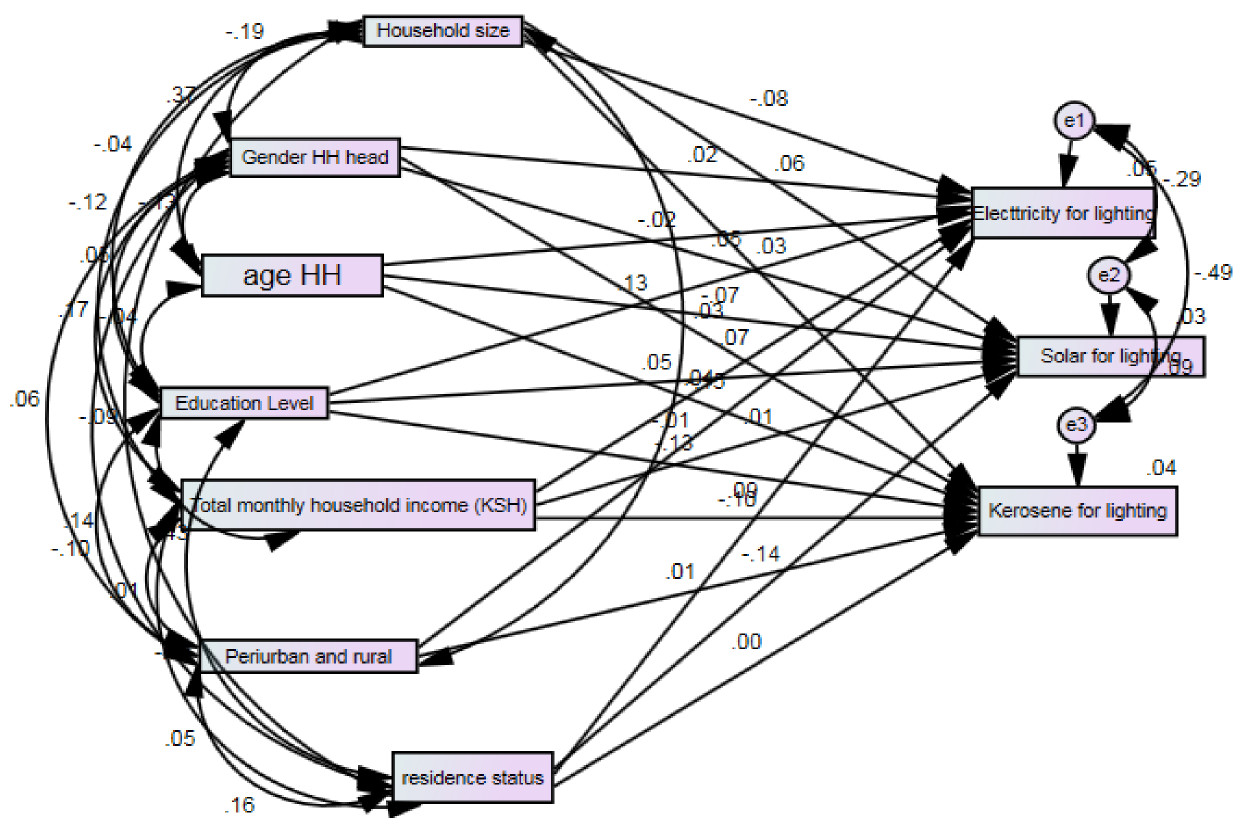

Figure 4. 5: Determinants of household energy for lighting.

Table 4. 6: Determinants of household energy for lighting

Relations between variables			**Estimate**	**S.E.**	**C.R.**	**P-value**	**S. Estimate** *(Miller et al.)β)*
Solar	<---	Household size	.024	.019	1.299	.194	.060
Solar	<---	Gender head	.133	.117	1.141	.254	.050
Electricity	<---	Education level	.233	.081	2.865	.004***	.131
Solar	<---	Education level	.062	.062	1.002	.316	.046
Electricity	<---	Income	.000	.000	1.604	.109	.075
Solar	<---	Residence status	-.336	.103	-3.244	.001***	-.137
Kerosene	<---	Gender head	.062	.099	.624	.533	.027
Kerosene	<---	Education level	-.146	.053	-2.768	.006***	-.128
Kerosene	<---	Income	.000	.000	-2.224	.026**	-.104
Electricity	<---	Rural – peri urban	-.029	.123	-.235	.814	-.010
Kerosene	<---	Rural – peri urban	.022	.083	.265	.791	.011
Kerosene	<---	Household size	.012	.016	.745	.456	.034
Electricity	<---	Household size	-.043	.024	-1.739	.082*	-.079
Kerosene	<---	Residence status	-.002	.089	-.024	.981	-.001
Electricity	<---	Gender head	.075	.152	.494	.621	.021
Solar	<---	Income	.000	.000	.188	.851	.009
Electricity	<---	Age head	-.043	.080	-.544	.586	-.024
Solar	<---	Age head	-.089	.061	-1.460	.144	-.066
Kerosene	<---	Age head	.048	.052	.931	.352	.042
Electricity	<---	Residence status	.281	.136	2.064	.039**	.087
Model summary: Chi-square = 17.644; Degrees of freedom = 4; Probability level = 0.001; CMIN/DF = 4.4116; GFI = 0.994; AGFI= 0.915; NFI = 0.970; CFI = 0.975; IFI = 0.977; FMIN = 0.032 and RMSEA= 0.078							

*Denotes values significant at 10% level of significance.

** Denotes values significant at 5% level of significance.

*** Denotes values significant at 1% level of significance.

4.4.1 Education

The SEM model results showed that education is positively and statistically significant with the use of electricity (β = 0.131, $S.E$ = 0.081, C.R = 2.865) at $P < 0.01$ significance level indicating that as the level of education of household heads increases, the percentage of households dependent on electricity for lighting increases. Conversely, education level is negatively and statistically significant with the use of kerosene (β = -0.128, S.E = 0.053, C.R = - 2.768) at $P < 0.01$ significance level indicating that the proportion of households using kerosene for lighting decreases with the increase in the level of education. Utilization of solid fuels for lighting among the households in rural areas with lower levels of education was noted demonstrating that education plays an important role in a household's choice of energy sources for lighting. The moral of the argument is that education can or is correlated with raising household income, thus increasing household disposable income.

The results also show a positive association exists between education level and solar (β = 0.062) use for lighting though not significant. The result concur with the research done by Rahut et al. (2018), who found that the level of education of the household head and household wealth play major roles in the choice of solar energy. According to Van der Kroon et al. (2013), highly educated people prefer clean and modern energy such as electricity fuels compared with their less-educated counterparts. In our case, education level of the household head is negatively associated with the likelihood of choosing kerosene as compared to electricity. It was further; found that the access to electricity makes the use of all other available sources of energy significantly unlikely. This result supports the research done by Behera and Ali (2017) and Van der Kroon et al. (2013). The results of education confirm that household heads with a higher level of education, wealthy households, and rural households are more likely to use solar energy. The finding proves that with the increase in level of education, purchasing power and awareness level also improves and preference for cleaner and more efficient energy increases.

4.4.2 Income

The results presented in Table 4.6 show that income is positively associated with the use of electricity ($\beta = 0.075$, S.E = 0.000, C.R = 1.604) and solar ($\beta = 0.009$, S.E = 0.000, C.R = 0.851) for lighting though with no significance while it is negatively and statistically significant with the use of kerosene ($\beta = - 0.104$, S.E = 0.00, C.R = - 2.224, $P < 0.01$) for lighting at 1% significance level. According to Chen et al. (2016), household income is among the leading factor that influences the choice and use of certain forms of energy resource in households. The coefficients of the proxy for household income are negative for kerosene implying that with an increase in income, households are less likely to use kerosene relative to electricity which is the source of better-quality energy given available options. These results are in conformity with the Lay et al. (2013) and Danlami et al. (2019) who found that income level and the availability of electricity have positive impacts on the probability of electricity adoption

4.4.3 Household size

The results in Table 4.6 show that household size is positively associated with the use of kerosene ($\beta = 0.034$, S.E = 0.016, C.R = 0.745) and solar ($\beta = 0.060$, S.E = 0.019, C.R = 1.299) for lighting though not significant while household size is negatively and statistically significant with electricity ($\beta = -0.079$, S.E = 0.024, C.R = -1.739, $P < 0.10$) at 10% significance level. These results suggest that household size have negative effect on electricity use for lighting. As far as the household size is concerned, the probability of using solar and kerosene increases compared to electricity as the size of the household increases. However, households with higher proportions of dependent members are more likely to use kerosene than electricity. Larger households could also exert a heavier burden of dependence on the insufficient family resource to extend that there are hardly any savings available for investment in electricity. Under such circumstances, larger household size would negatively influence the decision to adopt electricity.

4.4.4 Age of household head

Table 4.6 also shows how age of a household head influences the choice of fuel for lighting. As can be seen the age of household head is positively associated with the use of kerosene (β =0.042) for lighting while on the other hand age of household head is negatively associated with electricity (β =-0.024) and solar (β = -0.066) for lighting with no significance. Age of the household head showed negative relationship with the use of electricity and solar which concur with literature that older heads of households are most resistant to new fuel technologies and cling to traditional fuels as a matter of habit compared to younger heads of households (Buba et al., 2017; Rahut et al., 2016). The findings are in line with Danlami et al. (2019) who found that age of the household head and the availability of electricity have positive impacts on the probability of electricity adoption.

4.4.5 Gender of household head

Table 4.6 further shows how gender of a household head influences the choice of fuel for lighting. The results shows that female household head is positively associated with the use of electricity (β =0.021), solar (β =0.050) and kerosene (β = 0.027) for lighting though no significant. The results contradict the results by Rahut et al. (2018) who indicated that male-headed households are more likely to adopt solar energy compared to female-headed households.

4.4.6 Peri urbanization

The study results in table 4.6 shows that peri urbanization is positively associated with electricity use ($\beta = 0.034$, S.E = 0.016, C.R = 0.745) and on the other hand it is negatively associated with kerosene use for lighting. This can be due to a lack of access to electricity by rural households forcing them to use solar energy for lighting. The results indicate that rural households are more likely to adopt solar energy for domestic use because rural areas are isolated and disconnected from the power grid. The results concurs with Danlami et al. (2019) who found that urban location and the availability of electricity have positive impacts on the probability of electricity uptake**.**

4.4.7 Residence status

Table 4.6 furthermore shows how residence status of a household head influences the choice of fuel for lighting. The results shows that rentership is positively and statistically significant with electricity ($\beta = 0.087$, S.E = 0.136, C.R = 2.064, $P < 0.05$) use for lighting at 5% significance level while on the other hand rentership is negatively and statistically significant with the use of solar ($\beta = - 0.336$, S.E = 0.103, C.R = - 3.244, $P < 0.01$) for lighting. Further, the results show that rentership is negatively associated with kerosene ($\beta = - 0.001$, S.E = 0.089, C.R = - 0.981) use though not significant.

This could be explained is that rented dwellings tend to use electricity for lighting because it is compact and do not require space for storage, since the rented buildings usually do not have sufficient space for fuel storage. More so, the landlords may restrict fuel use to a range of fuels to safe guard their properties. The results agree with the findings by Bisu et al. (2016)

who observes that while those in owned dwellings have more freedom to use cheaper, lower fuels, they have no restrictions by way of rules to install solar structures on rooftops.

4.4.8 Covariance and correlations

Table 4. 7: Covariance and correlations between variables on determinants of household energy for lighting

Relationship between variables			Estimate	S.E.	C.R.	P
Education level	<-->	Income	33421.580	3601.763	9.279	***
Education level	<-->	Residence status	-.006	.016	-.348	.728
Gender head	<-->	Education level	.017	.015	1.125	.260
Gender head	<-->	Residence status	.027	.008	3.281	.001
Household size	<-->	Residence status	-.108	.050	-2.161	.031
Gender head	<-->	Income	6721.339	1667.747	4.030	***
Household size	<-->	Income	-30147.645	10243.603	-2.943	.003
Household size	<-->	Education level	-.097	.097	-1.000	.317
Income	<-->	Rural – peri urban	454.170	1939.150	.234	.815
Education level	<-->	Rural – peri urban	-.040	.017	-2.311	.021
Gender head	<-->	Rural – peri urban	.012	.009	1.434	.152
Household size	<-->	Rural – peri urban	-.201	.054	-3.731	***
Household size	<-->	Gender head	-.218	.050	-4.379	***
Education level	<-->	Age head	-.026	.027	-.988	.323
Gender head	<-->	Age head	-.045	.015	-3.074	.002
Household size	<-->	Age head	.860	.102	8.405	***
Income	<-->	Residence status	2149.360	1820.854	1.180	.238
Residence status	<-->	Rural – peri urban	.037	.010	3.825	***

*Denotes values significant at 10% level of significance.

** Denotes values significant at 5% level of significance.

*** Denotes values significant at 1% level of significance.

Table 4.7 illustrates the results of covariance and correlations between variables on determinants of household energy for lighting. The results further show that there is a strong positive association between income and education level which support the notion that income increase with education in developing countries like Kenya. The results also reveal that there is negative relationship between rentership and household sizes.

4.5 EFFECTS OF HOUSEHOLD FUELS ON THE HOUSEHOLD ENERGY DIVERSIFICATION

Figure 4.6 shows there is one endogenous variable and seven (7) exogenous variables which are agricultural residues, electricity, firewood, LPG, charcoal, kerosene, biogas and e_1. LPG and biogas have the strongest positive relationship with household energy diversification, while electricity and agricultural residues size have a weaker relationship with household energy diversification.

Regression results in Table 4.8 shows unstandardized coefficients (estimates), standardized coefficient (E. estimates), S.E. and critical ratio. The lower the value of standard error, the stronger the ability of exogenous variable to predict the endogenous variable. As shown, charcoal shows the lowest S.E. value, 0.027 which means it has the strongest ability to predict the number of different energy sources used; electricity has the highest value of S.E., 0.107 which showed the weakest ability to predict the household energy diversification for cooking

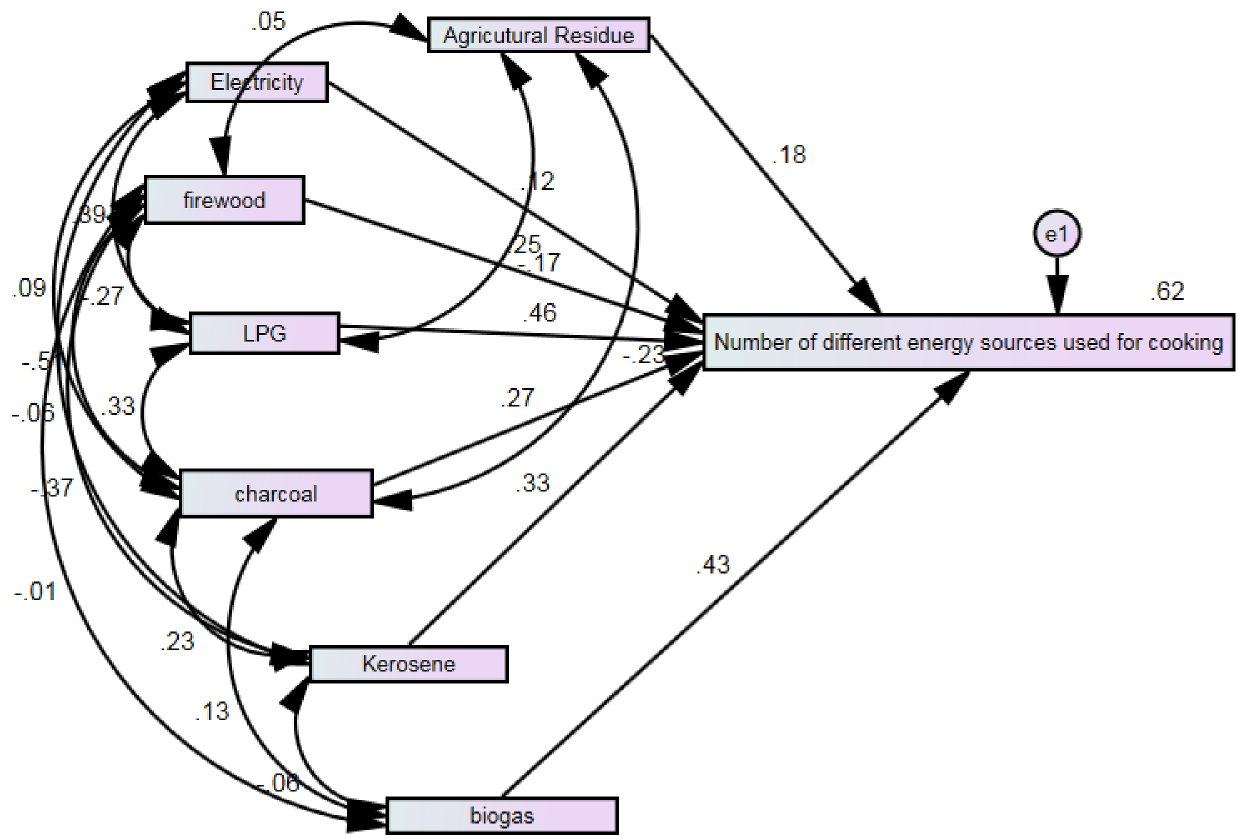

Figure 4. 6: The household energy diversification Regression model analysis results

The model equation can be summarized as follows

$$Y = 0.62 + 0.46LPG + 0.43BIO + 0.33KER + 0.27\ CHA + 0.25\ FIR + 0.18\ AGR + 0.11\ ELE + e_1 \quad (4.1)$$

where;

LPG - Liquefied petroleum gas, BIO – biogas, KER – kerosene, CHA – charcoal, FIR – firewood, AGR -Agricultural residue and ELE – electricity.

SEM result revealed that the regression model is suitable to predict the household energy diversification. This is because all the exogenous variables, which are agricultural residues, electricity, firewood, LPG, charcoal, kerosene and biogas significantly contribute to household energy diversification (LPG: $\beta = 0.461$, C.R. = 15.024, $p < 0.01$; Biogas: $\beta = 0.425$, C.R. = 16.110, $p < 0.01$; Kerosene: $\beta = 0.333$, C.R. = 11.738, $p < 0.01$; Charcoal: $\beta =$

0. 266, C.R. = 8.232, $p < 0.01$; Firewood: β = 0. 254, C.R. = 7.856, $p < 0.01$; Agricultural residues: β = 0. 179, C.R. = 6.587, $p < 0.01$).

Table 4. 8: Regression weights and standardized regression weights on household energy diversification

Relationship between variables			Estimate	S.E.	C.R.	P	S. Estimate *(β)*
Number of different energy sources used	<---	Agricultural residues	0.225	0.034	6.587	***	0.179
Number of different energy sources used	<---	Electricity	0.438	0.107	4.109	***	0.117
Number of different energy sources used	<---	firewood	0.217	0.028	7.856	***	0.254
Number of different energy sources used	<---	LPG	0.416	0.028	15.024	***	**0.461**
Number of different energy sources used	<---	charcoal	0.220	0.027	8.232	***	0.266
Number of different energy sources used	<---	Kerosene	0.368	0.031	11.738	***	0.333
Number of different energy sources used	<---	biogas	0.483	0.030	16.110	***	0.425
Model summary: Chi-square = 26.637; Degrees of freedom = 7; Probability level = 0.000; CMIN/DF = 3.80; GFI = 0.988; AGFI= 0.940; P_{close} = 0.09; NFI = 0.976; RFI = 0.902; TLI = 0.926; CFI = 0.981 and RMSEA= 0.071							

*Denotes values significant at 10% level of significance.

** Denotes values significant at 5% level of significance.

*** Denotes values significant at 1% level of significance.

As can be seen in Table 4.8, all the seven exogenous variables pose a positive correlation with the household energy diversification. The results demonstrate that LPG followed by biogas has the greatest correlation and is the most important contributor to the diversification of household energy. According Treiber et al (2015) LPG is the household energy fuel that increases stacking of fuel significantly with urbanization.

Table 4.9 shows the covariance and squared multiple correlations of SEM. Covariance shows the correlation between the exogenous variables in the study. C.R. values which are located out of ±1.96 range (for example, LPG – charcoal: C.R. = 7.887, firewood – charcoal, C.R. = -10.888) shows significant correlations between the variables. This means these variables are affecting each other.

Table 4. 9: Analysis of Covariance and correlations between exogenous variables

			Estimate	*S.E.*	*C.R.*	*P*
LPG	<-->	charcoal	.418	.053	7.887	***
firewood	<-->	charcoal	-.672	.062	-10.880	***
Electricity	<-->	charcoal	.028	.011	2.636	.008
Agricultural residues	<-->	charcoal	-.210	.038	-5.587	***
charcoal	<-->	biogas	.131	.040	3.308	***
firewood	<-->	biogas	-.014	.039	-.348	.728
charcoal	<-->	Kerosene	.237	.042	5.718	***
firewood	<-->	Kerosene	-0.368	.043	-8.513	***
firewood	<-->	LPG	-0.323	.046	-6.959	***
Electricity	<-->	LPG	0.109	.012	9.031	***
Agricultural residues	<-->	LPG	- 0.144	.033	-4.390	***
Agricultural residues	<-->	firewood	0.045	.034	1.312	.190
Electricity	<-->	Kerosene	- 0.014	.008	-1.733	.083
Kerosene	<-->	biogas	-0.042	.032	-1.332	.183

*Denotes values significant at 10% level of significance.

** Denotes values significant at 5% level of significance.

*** Denotes values significant at 1% level of significance.

Table 4.9 also shows that the correlation between LPG and charcoal consumption is the highest (Standard estimate (β) = 0.418) while the others are weaker and one has negative correlation. The finding supports the energy stacking models (Choumert-Nkolo et al., 2019). This indicates high energy stacking between LPG and charcoal. This results are in agreement with Masera et al. (2000) findings that it is ‘‘*unusual for households to make a complete fuel switch from one technology to another; rather they begin to use an additional technology without abandoning the old one’’.*

Table 4. 10: Variances and Squared Multiple Correlations of SEM on household energy diversification

	Estimate	*S.E.*	*C.R.*	*P*
Agricultural residues	0.595	0.036	16.718	***
Electricity	0.068	0.004	16.729	***
firewood	1.284	0.076	16.886	***
LPG	1.158	0.068	16.973	***
charcoal	1.372	0.081	16.931	***
Kerosene	0.772	0.046	16.728	***
biogas	0.729	0.044	16.718	***
Residue	0.356	0.021	16.718	***
Squared Multiple Correlations				0.622

*Denotes values significant at 10% level of significance.

** Denotes values significant at 5% level of significance.

*** Denotes values significant at 1% level of significance.

The covariance’s results of SEM (Table 4.10) further suggest that household energy use decisions conform to the energy stacking hypothesis. The household cooking fuels is characterized by the mixture of traditional, transition and higher fuels. Hence instead of switching fuels, households choose to consume a portfolio of energy options at different points along the energy ladder (Masera et al., 2000).

Confirmatory factor analysis (CFA) was also conducted to confirm whether the data is adequately fit for the estimated model. Different model fitness tests were conducted that generated values (Chi-square = 26.637; CMIN/df = 3.80; GFI = 0.988; AGFI= 0.940; PCLOSE = 0.09; NFI = 0.976; RFI = 0.902; IFI = 0.982 TLI = 0.926; CFI = 0.981 and RMSEA= 0.071) which have been suggested by (Bentler & Bonett, 1980; Byrne, 1994; Kline, 2005; Thompson, 2004). Thus, it suggests that the model is a suitable model with regard to these indices' values.

Squared Multiple Correlations of SEM (R^2) value was computed that reveals the degree of variation in the dependent variable illustrated by independent variables. The R^2 value was found to be 0.622 which surpasses the threshold value of 0.35 as reported by Cohen (1988) and Gholami and Khalaji (2017).

Table 4.11 shows the bootstrapping test results for the path coefficient of the structure model, which demonstrated that in the structure model; all path coefficients were significant at 0.01 levels (P-Value < 0.01). The bootstrapping result moreover shows the lowest S.E. values which means the model has the strongest ability to predict the household energy diversification.

Table 4. 11: Bootstrapping test of path coefficients on household energy diversification

Parameter			SE	Estimate	Mean	Bias	SE-SE	P-value
Number of different energy sources used	<---	Agricultural residues	.025	.179	.179	.000	.001	.005***
Number of different energy sources used	<---	Electricity	.032	.117	.116	-.002	.001	.004***
Number of different energy sources used	<---	firewood	.038	.254	.253	-.001	.002	.003***
Number of different energy sources used	<---	LPG	.030	.461	.460	-.001	.001	.004***
Number of different energy sources used	<---	charcoal	.032	.266	.267	.001	.001	.006***
Number of different energy sources used	<---	Kerosene	.024	.333	.333	.000	.001	.004***
Number of different energy sources used	<---	biogas	.024	.425	.427	.001	.001	.006***

*Denotes values significant at 10% level of significance.

** Denotes values significant at 5% level of significance.

*** Denotes values significant at 1% level of significance.

4.6 DETERMINANT OF BIOGAS UPTAKE

Table 4.12 presents the determinant of biogas uptake in the study area. From among the 8 variables included in the SEM , a total of ten (10) variables were significantly affecting the adoption decision of biogas utilization in the study area.

Peri urbanization, age of household head, gender, level of education, household composition, land size (farmer), householdsize, residence status, income, education level and number of cows were found to affect biogas adoption decision of households as shown on Table 4.12. The results of analysis of the SEM model indicated that the model reasonably fitted with the observed data. The complete model comprising the full number of predictors was found to be statistically significant (p = 0.00).

Table 4. 12: Standardized Regression Weights results of determinant of biogas uptake

Relationship between variables			Estimate (β)	S.E.	C.R.	P
biogas	<---	Rural- Peri urban	.022	.065	.586	.558
biogas	<---	land size (farmers)	-.138	.068	-3.612	***
biogas	<---	Age of HH	-.212	.038	-5.553	***
biogas	<---	Gender of HH	.201	.076	5.261	***
biogas	<---	Household size	-.155	.011	- 4.056	***
biogas	<---	female15 to 50 yrs.	-.048	.056	-1.247	.213
biogas	<---	femalegt50	.025	.065	.646	.518
biogas	<---	Residence status	-.107	.069	-2.789	***
biogas	<---	Male over 50 yrs.	.150	.064	3.928	***
biogas	<---	Youth 5 - 14	.039	.027	1.030	.303
biogas	<---	Education level	.085	.038	2.231	.026**
biogas	<---	Cattle number	.013	.001	.352	.725
biogas	<---	Income	.094	.000	2.470	.013**
Model summary: Chi-square = 26.637; Degrees of freedom = 7; Probability level = 0.000;						

*Denotes values significant at 10% level of significance.

** Denotes values significant at 5% level of significance.

*** Denotes values significant at 1% level of significance.

4.6.1 Peri urbanization

The study results in Table 4.12 shows that peri urbanization is positively associated (β = 0.022, S.E = 0.065, C.R = 0.586) with biogas adoption and use for cooking though not significant. The results indicate that peri urban households are more likely to adopt biogas energy for domestic use due to lack of availability of firewood in nearby areas. The relationship between distance to fire wood collection site and biogas adoption exhibited a positive coefficient, indicating that as the distance in peri urban to the nearest firewood collection site increases biogas uptake.

The reason why households in peri urban also decide not to adopt biogas technology is because of majorly the unavailable space for constructing the digester and lack of funding. The results agrees with Wahyudi (2017). Therefore, it can be argued that peri urban households depend on the purchased energy sources which require significant portion of their time and transport for delivery. Households may therefore opt for the adoption of biogas energy as an alternative source of energy in such cases.

4.6.2 Income

Table 4.12 also shows how income of a household influences the adoption of biogas. The results show that household income showed positively and significant ($\beta = 0.094$, S.E = 0.00, C.R = 2.47) effect on the rate of adoption of biogas at 5% statistical level of significance. Income shows the lowest S.E. value, 0.00 which means it has the strongest ability to predict the household biogas uptake. This can be explained by the fact that as the income of a household increases, the household biogas uptake increases due to the creation of better financial ability that will enable it to install a biogas system and keep it operational. Also, having good income increases the willingness and ability to pay in biogas project and encourages potential adopters to join the biogas projects. This is contrary to the negative association of biogas use with increased income due to concerns that bio digestion is unhygienic due smelly and bacteria-infested waste to produce energy. This findings are in line with the study done by Kabir et al. (2013). and contrary to the findings by Kelebe et al. (2017), who argues that most high income earners fears exposure and contact with the dangerous bacteria in the waste material. For example, while preparing the slurry feed for the digester that this would be harmful to their health.

4.6.3 Household size

The results in Table 4.12 also show how household size influences the adoption of biogas. The household size was established to have negative and significant effect on biogas uptake (β = - 0.155, S.E = 0.011, C.R = - 4.056, $P < 0.01$) as shown in Table 4.12. Often, a large family means having more support for the routine maintenance and operation of a technology such as biogas (Uhunamure et al., 2019). Further, biogas energy is a labour intensive tech nology that requires conducting activities such as loading animal manure and carrying water into the biogas fermentation tank. Thus, households that don't have enough capital are more less likely to adopt biogas technology. This finding is in agreement with that of Kabir et al. (2013) and (Ndereba, 2013) who indicated that household size and biogas uptake have significantly negative inter-relationship but, contradictory to the findings of Walekhwa et al. (2009) and Kelebe et al. (2017).

4.6.4 Education level

The results in Table 4.12 show how education level of household head influences the adoption of biogas. Education level of household head revealed a positively and significantly (β = 0. 085, S.E = 0.038, C.R = 2.231, $P < 0.5$) associated with the biogas uptake. This can be attributed that as the level of education increases, the ratio of biogas uptake increases because households with no formal education are more likely to be lagging behind in information modern technologies. Also, low level of literacy often hinders the effective flow of knowledge about new technology for decision taking. Similar findings were reported on the positive relationship between education and adoption of new technologies (Guta, 2012; Kabir et al., 2013; Kelebe et al., 2017; Lwiza et al., 2017).

4.6.5 Age of household head

The results of the study in Table 4.12 showed that age of a household head is negative and significant associated ($P < 0.01$, $\beta = - 0.212$, C.R = - 5.553, S.E = 0.038) with the adoption of biogas uptake. This suggests that the chance of younger household heads adopting biogas technology is higher than their older counterparts. This can be attributed that as age increases , the biogas uptake reduces.This is possibly due to the fact that older people are rigid and not flexible to new technologies . Even though previous studies indicated that the association between age and adoption of new technologies is sensitive to variation in parameters and the net effect of age on adoption cannot be determined (Bekele & Drake, 2003; Kabir et al., 2013). Likewise, aged heads of households were more likely to embrace biogas resources than younger counterparts. The results are in agreement with study by Somda et al. (2002), Mengistu et al. (2016) and Walekhwa et al . (2009) who found a negative association between age and adoption of biogas. This confirms that older people are more affected with indoor pollution because they are less willing to take on clean and new innovations while the young household heads are likely to be more flexible and liable to accept new technologies.

4.6.6 Gender of household head

As shown in Table 4.12, female household heads showed positive and significant association ($P < 0.01$, $\beta = 0.201$, C.R = 5.261) with the biogas uptake. This designates that male dominated households are less likely to embrace biogas resources. Women and children are more responsible for collecting firewood in most parts of Kenya, including the study area, a time-consuming and exhausting task. In addition, women can suffer severe long-term physical harm from strenuous domestic work, including fuel wood gathering and smoke-related respiratory diseases in the kitchen house, mainly from firewood and dung lump sources. Consequently, it seems realistic to conclude that women are more likely to take part in the process of adopting biogas plants than their male counterparts, given that other variables are constant. Kabir et al. (2013) reported a similar result, observing that female-headed households are more likely to adopt biogas than male-headed households. Contrary, both Mwirigi et al. (2014) in Kenya and Mengistu et al. (2016) in Ethiopia found that male-headed households were more likely than female-headed households to implement biogas technology.

4.6.7 Land size and farmers

Table 4.12 results showed that land size of household is negative and significant relationship (β = - 0.138, S.E = 0.068, C.R = -3.612, $P < 0.01$) with biogas technology adoption. This shows that the probability of less land size especially in peri urban household heads adopting biogas technology was higher than that of their more land size owners. This result is similar to findings by Mwirigi et al. (2014) and (Mengistu et al., 2016). Most of households in rural areas, unlike peri urban areas, have relatively large land size; hence less likely to adopt biogas due to available biomass in their farms. The results are in agreement with Lwiza et al. (2017) and Mengistu et al. (2016). Lwiza et al. (2017) found that an increase in the land size reduces the probability of biogas adoption by 7.13%.

4.6.8 Number of cows

The effect of the number of cattle owned by a household showed positive association on the biogas technology adoption decision (β = 0.013, S.E = 0.01, C.R = 0.352) as shown in Table

4.12. Households with more cattle may have more substrates to feed the digester and will be more likely to implement biogas technology. This means that households must be able to use biogas technologies to collect sufficient quantities of dung for the proper functioning of digesters. Similar findings were reported by Kelebe et al. (2017) in Ethiopia and Walekhwa et al. (2009) in Uganda. Walekhwa et al in Uganda found that an increase of the number of cattle owned by household increased the likelihood of a household to adopt biogas technology by 11% at1 % statistical level of significance.

In the study area, cattle dung and water are the major sources of substrate for biogas digestion. Other substrate sources, such as crop residues, household waste, are not used, mainly because of limited technical skills and knowledge of various types of feed stocks generating higher biogas energy (Pöschl et al., 2010).

4.6.9 Residential status

From Table 4.12, rentership residential status showed negative and significantly (β = - 0. 107, C.R = - 2.789, S.E = 0.069, $P < 0.01$) associated with the biogas uptake. The negative association is due to lacks the space requirement of biogas technology in terms of area for installing the biogas plants as well as providing pastures for the cattle and poultry birds by rentership.

4.6.10 Household composition

The results in Table 4.12 showed positive and significant association ($P < 0.01$, β = 0. 150, C.R = 3.928, S.E = 0.064) with increased male composition of over 50 years in the household and the biogas indicating that older composition dominates the decision-making processes within and over the family matters compared to their young counterpart. The female composition of over 50 years of age showed positive association also with biogas uptake though not significant. Female and male composition of between the ages of 15 to 50 years showed negative association with the biogas. The youth of 5 to 14 years showed positive relationships with biogas adoption with though not significant, indicating that households with youths have adequate labour force are more likely to adopt biogas technology. This is probably due to the possibility that older compositions are more likely to have wealth accumulation, hence can afford the initial investment cost of biogas construction and installation.

CHAPTER 5

EFFECTS OF RENEWABLE ENERGY AND ACCESSIBILITY IN HOUSEHOLD ENERGY USE AND CHANGING BEHAVIOUR

5.1 INTRODUCTION

In this study, the distance between the household residence and the nearest fuel supplying shop was used to serve as an indicator used for assessing access to household energy sources. The second indicator is the number of shops where a household at a given location can buy one or more types of fuels. The nearness of forest or wood sources and the quantity / size of these sources can determine accessibility of the firewood and charcoal sources. Further the research analyses the effects of renewable energy on the use of conventional fuels and its relationship to accessibility.

5.2 EFFECTS OF ACCESSIBILITY ON HOUSEHOLD ENERGY FOR COOKING

Accessibility is explained by distance to fuel supplying shops and number of different fuel supplying shops. The description of variables affecting accessibility on household energy for cooking using SEM analysis is presented in Figure 5.1 and Appendix I.

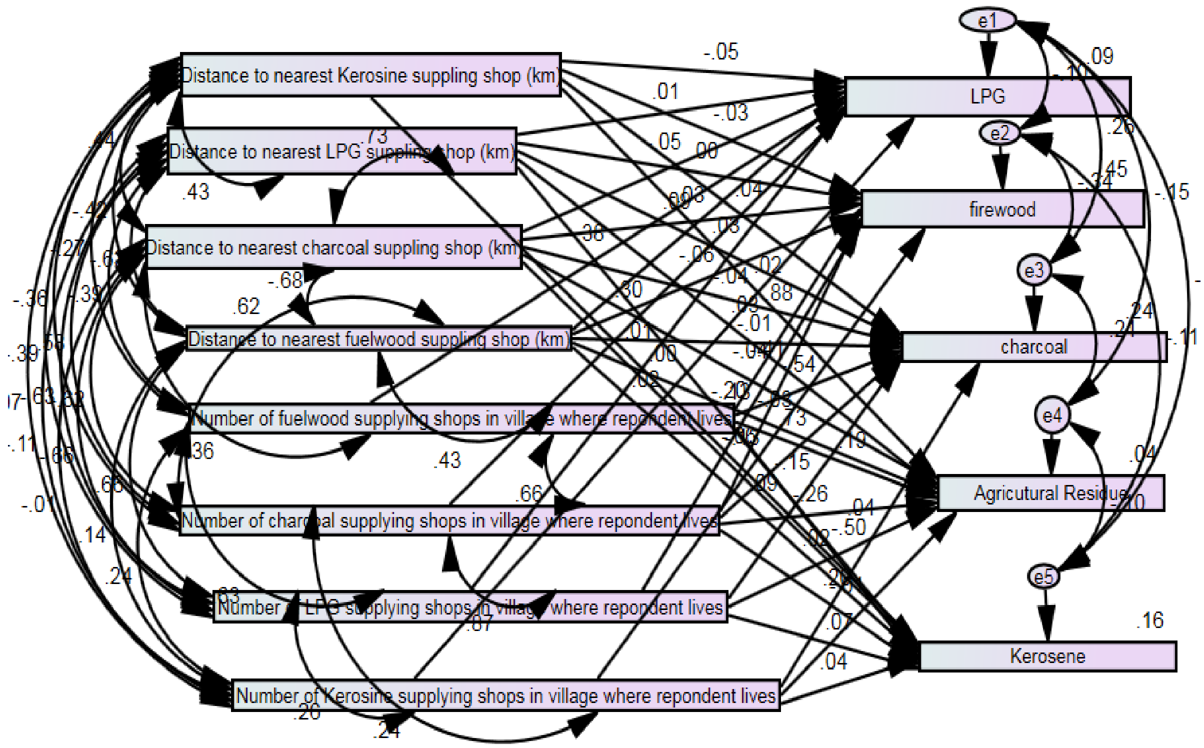

Figure 5. 1: Effects of accessibility on household energy for cooking

5.2.1 Distance to fuel supplying shops

The variable distance to the market (measured in kilometers) was negatively associated with a household's choice of fire wood and positively associated with LPG, charcoal and kerosene (see Appendix I), indicating that households which are further away from the LPG, charcoal and kerosene market are more likely to use dirty energy such as fire wood and less likely to use LPG, charcoal and kerosene. The results also show that with increase in distance to LPG retail shops ($\beta = 0.016$, S.E = 0.008, C.R = 2.017, $P < 0.05$) most households tend to use kerosene for cooking at statistically significant level of 5%. The findings show that distance to nearest retail shops selling fuel in kilometres is negatively associated with household changing behaviour to fuel choices thus indicating a reducing trend in the use of the fuels with the increase in distance of energy sources for firewood, charcoal, LPG and Kerosene in both rural and peri urban. The results are consistent Zhong Liu et al. (2020) who found a strong negative relationship between distance to market and the use of electricity. This result further concurs findings by Brouwer et al. (1997) and Imran and Ozcatalbas (2020) who found that distance from the market were found to be significant factors affecting the choice of fuels for cooking.

It was also observed that the average distance to the nearest retail shops for the purchase of charcoal and LPG is greater for households in rural areas compared to those in peri-urban areas, indicating that as one moves from rural to peri-urban the distance to retail shops selling charcoal and LPG reduces as shown the Table 5.1.

Table 5. 1: Distance to retail shops selling household energy

Area	*Statistics*	*Distance to nearest supplying shop (km)*			
		Firewood	*charcoal*	*LPG*	*Kerosene*
Peri urban	Mean	1.65	1.05	1.98	1.03
	Std. Dev.	0. 544	0. 507	1.592	0.626
Rural	Mean	0.32	11.39	12.03	2.02
	Std. Dev.	0.339	4.84	6.26	1.073

The results may not be correct for rural households since most of the energy sources such as agricultural wastes, fire hood, leaves and twigs are internally/locally available (Baul et al., 2018; Berhe et al., 2017).

5.2.2 Number of different fuel supplying shops

The variable number of fire wood supplying shops in village where respondent live is positive and significant at 1% level for choice of firewood (β = 0.699, S.E = 0.034, C.R =

20.548, $P < 0.01$) and agricultural residues ($\beta = 0.105$, S.E = 0.031, C.R = 3.415, $P < 0.01$), and it is negative and significant at the 1% level for LPG ($\beta = - 0.291$, S.E = 0.042, C.R = - 6.875, $P < 0.01$), charcoal ($\beta = - 0.451$, S.E = 0.042, C.R = 10.692, $P < 0.01$) and kerosene ($\beta = - 0.309$, S.E = 0.033, C.R = - 9.391, $P < 0.01$). these values indicate that number of fire wood supplying shops in village where respondent live play an important role in a household's decision on the choice of household energy for use. The results infer that households which are further away from the market for LPG and charcoal are more likely to use dirty energy such as fire wood and agricultural residues. This shows that the rural household chooses fire wood because of the proximity to the firewood source.

The number of charcoal supplying shops in village where respondent live is positive and significant at the 1% level for choice of charcoal ($\beta = 0.436$, S.E = 0.048, C.R = 9.148, $P < 0.01$), LPG ($\beta = 0.165$, S.E = 0.048, C.R = 3.447, $P < 0.01$) and kerosene ($\beta = 0.087$, S.E = 0.037, C.R = 2.328, $P < 0.05$), while it is negative and significant at the 1% level for firewood ($\beta = - 0.230$, S.E = 0.038, C.R = - 5.978, $P < 0.01$) and agricultural residues ($\beta = - 0.1$, S.E = 0.035, C.R = - 2.876, $P < 0.01$). The results designate that there is strong covariance relationship of the diversity of suppliers of LPG, charcoal and kerosene.

In addition, the number of LPG supplying shops in village where respondent live is positively associated with the use of kerosene ($\beta = 0.065$, S.E = 0.033, C.R = 0.739) and LPG ($\beta = 0.007$, S.E = 0.080, C.R = 0.936) with no significant indicating that other factors influence the use of LPG other than the number of LPG supplying shops in village. The findings furthermore show that the number of LPG supplying shops in village where respondent lives is negative and significant at the 1% level for charcoal ($\beta = - 0.154$, S.E =

0.042, C.R = - 1.840, P < 0.1) and firewood (β = - 0.202, S.E = 0.034, C.R = - 2.835, P < 0.01). The peri-urban dwellers have access to greater number of fuel supplying shops in on average for charcoal, LPG and kerosene in contrast with rural residence as shown in Table 5.2. This results are in line with Fall et al. (2008) who found that peri urban in Dakar, Senegal have access to modern household energy sources.

Table 5. 2: Number of retail shops supplying household energies in the village

Area/Fuel	*Statistics*	*Number of different fuel supplying shops*			
		Firewood	*Charcoal*	*LPG*	*Kerosene*
Peri urban	Mean	2.22	3.66	3.88	4.94
	Std. Dev.	1.937	1.987	2.176	1.903
Rural	Mean	0.88	0.67	0.2	4.31
	Std. Dev.	0.334	0.638	0.884	1.761

The results indicate that there is positive association between the number of retail shops selling household energy and the type of fuel used at household level for cooking implying that nearest to diverse supplying shops selling fuel is positively associated with household changing behaviour as shown in appendix I. Accessibility to electricity also is associated with its use for cooking which concur with Hartono et al. (2020). It was observed that there is lack of distribution, selling points and storage facilities of LPG among rural areas hence constraining its accessibility while in the peri-urban area concentration of selling points, distributors and storage units is high. The reason that there are fewer firewood and charcoal shops in rural areas is because more than half of households in rural areas have available biomass for firewood which make them gather easily wood themselves as compared to households in peri-urban areas. The results conclude that there is correlation between the number of retail shops supplying household energies and fuel energy use.

Appendix II shows the correlation between the exogenous variables in the study. C.R. values which are located out of ±1.96 range shows significant correlations between the variables and showed that the variables are affecting each other. For example, Table 5.3shows that the correlation between the number of LPG supplying shops in village and the number of Kerosene supplying shops in village is positive (C.R = 6.016) while the others are weaker and one has negative correlation.

The structural equation model effects of accessibility on household energy utilization, goodness-of fit indices were computed. The values of fit indices Probability level = 0.018; CMIN/df = 4.008; GFI = 0.998; AGFI= 0.900; NFI = 0.998; RFI = 0.91; CFI = 0.998; IFI = 0.998; TLI = 0.931: FMIN = 0.014 and RMSEA= 0.073 exceed the threshold value, indicating that the model fitted the data absolutely fine. Squared multiple correlations (R^2) value was also computed to reveal the degree of variation in the dependent variable demonstrated by independent variables. Table 5.3 presents the R^2 value as shown;

Table 5. 3: Squared Multiple Correlations on effects of accessibility

R^2	*Estimate*
Kerosene	.155
Agricultural residues	.038
charcoal	.239
firewood	.452
LPG	.091

The findings indicate that the structural equation model can significantly interpret the use of firewood with the value of 0.452 surpassing the threshold value of 0.35 as reported by Cohen (1988). This show that 54.8% variance in fire wood cannot be predicted in this structural equation model.

With Bollen-Stine Bootstrap method, the model fit better in 492 bootstrap samples out of 500 samples and it fit worse or failed to fit in 8 bootstrap samples. The testing proved the null hypothesis that the model is correct with Bollen-Stine bootstrap ($p = 0.018$).

5.3 EFFECTS OF ACCESSIBILITY ON HOUSEHOLD ENERGY FOR LIGHTING

Table 5.4 presents the results of effects of accessibility on household energy for lighting. Access to electricity net was positively and statistically significantly associated ($\beta = 0.749$, S.E = 0.085, C.R = 26.422, $P < 0.01$) with electricity utilization for lighting and on the other hand negatively and strongly associated with the use of kerosene ($\beta = - 0.399$, S.E = 0.076, C.R = - 10.221, $P < 0.01$) and solar ($\beta = - 0.2769$, S.E = 0.093, C.R = - 6.780, $P < 0.01$) indicating that accessibility to electricity is associated with its use for lighting. The results support Adkins et al. (2010) findings of Millennium Villages Project in Malawi that in the absence of reliable grid electricity, households across the developing world depend on kerosene.

The distance to market for kerosene is positively and but not significantly related to a household's choice of electricity and solar indicating with increase in distance to kerosene shops people likelihood of adopting electricity, solar energy and even batteries increase also.

The results further disclosed that there is positive association between the number of kerosene supplying shops in village selling household energy and the kerosene($\beta = 0.061$, S.E = 0.020, C.R = 2.973, $P < 0.01$) for lighting.

Table 5. 4: Effects of accessibility on household energy for lighting

Relationship between variables			*Estimate*	*S.E.*	*C.R.*	*P value*	*S. estimate* (Miller et al.)
Electricity	<---	Number of Kerosene supplying shops	-.134	.023	-5.873	***	-.167
Kerosene	<---	Number of Kerosene supplying shops in village	.061	.020	2.973	***	.116
Electricity	<---	Distance to nearest Kerosene supplying shop	.048	.040	1.198	.231	.034
Kerosene	<---	Distance to nearest Kerosene supplying shop	-.047	.036	-1.312	.189	-.051
Solar	<---	Distance to nearest Kerosene supplying shop	0.022	.044	0.509	.611	0.021
Electricity	<---	Access to electricity net	2.255	.085	26.422	***	.749
Kerosene	<---	Access to electricity net	-.781	.076	-10.221	***	-.399
Solar	<---	Access to electricity net	-.630	.093	-6.780	***	-.276
Model summary: Chi-square = 8.018; Degrees of freedom = 2; Probability level = 0.018; CMIN/DF = 4.967; GFI = 0.994; AGFI= 0.9390; NFI = 0.986; RFI = 0.913; CFI = 0.988; IFI = 0.989; TLI = 0.913: FMIN = 0.018and RMSEA= 0.08							

*Denotes values significant at 10% level of significance.

** Denotes values significant at 5% level of significance.

*** Denotes values significant at 1% level of significance.

This implies that despite the revolution in clean and renewable energy sources in recent years, households in developing countries, particularly in Kenya, still use unhealthy sources of energy, damaging both the environment and human development though having abundant renewable energy resources such as solar. On the other hand, the number of kerosene supplying shops is negatively and significantly associated to electricity (β = - 0.134, S.E = 0.023, C.R = - 5.873, $P < 0.01$) use. This suggests that the reduction of the number of kerosene supplying shops has detrimental health and environmental impacts. The findings further indicate that even households with electricity access for lighting have standby kerosene lamps to enhance energy security in case of power black outs, hence supporting energy stacking model.

Testing the model fit

Results in Table 5.4 indicated that the CFI = 0 .955, the TLI = 0 .933, and the IFI = 0 .956 were all beyond the literature- supported threshold of ≥ 0.90 (Kline, 1998; Schumacker & Lomax, 1996). The observed value of RMSEA = 0.08 was within the acceptable limits of between 0.05 and 0.10 (Browne & Cudeck, 1993; Hu & Bentler, 1998).

Table 5. 5: Squared Multiple Correlations for effects of accessibility on lighting.

R^2	*Estimate*
Solar	0.076
Kerosene	0.162
Electricity	0.559

As shown in Table 5.5, the squared multiple correlations for the effects of accessibility on household energy for lighting range from a high of 55.9% (Electricity for lighting) to a low of 7.6% (solar). Comparing the predictive power of this combined model to that of each of its three components alone, it is clear that this model enhances the prediction of effects of accessibility on electricity household energy for lighting. Small squared multiple correlation coefficients suggest that the variable showed low effects in the analysis.

Using Bollen-Stine Bootstrap, the model fit better in 498 bootstrap samples and it fit worse or failed to fit in 2 bootstrap samples on the effects of accessibility. The Bollen-Stine bootstrap ($p = .006$) proved the null hypothesis that the model is correct.

5.4 EFFECTS OF ACCESSIBILITY ON HOUSEHOLD ENERGY DIVERSIFICATION FOR LIGHTING

Table 5.6 presents the results of the effects of accessibility on household energy diversification for lighting. As can be seen the results show that number of kerosene supplying shops in village where respondent lives for the purchase of kerosene is positively ($\beta = 0.218$, S.E = 0.010, C.R = 5.321, $P < 0.01$) and significantly associated with number of different energy sources used for lighting. This implies that nearest to diverse supplying shops selling fuel is positively associated with household energy diversification. The distance to nearest kerosene supplying shop in kilometres for the purchase of kerosene is positively but with no significantly associated with number of different energy sources used for lighting in the study areas.

In addition, it is shown that access to electricity net demonstrates a positively and significantly associated ($\beta = 0.18$, S.E = 0.036, C.R = 5.028, $P < 0.01$) with number of different energy sources used for lighting. This implies that electricity for lighting is substitute indicating that to reduce kerosene use, which pose a formidable challenge especially health and the environmental problems (Balachandra, 2011) , electricity should be promoted for instance by subsidizing the connection prices.

Table 5. 6: Regression Weights and Standardized Regression Weights on effects of accessibility on HED for lighting

Relationship between variables			Estimate (β)	S.E.	C.R.	P	S. Estimate
Number of different energy sources used for lighting	<---	Distance to nearest Kerosene supplying shop (km)	0.023	.017	1.358	.174	.055
Number of different energy sources used for lighting	<---	Number of Kerosene supplying shops in village where respondent lives	.051	.010	5.321	***	.218
Number of different energy sources used for lighting	<---	Access to electricity net	.180	.036	5.028	***	.205
Model summary: Chi-square = 2.861; Probability level = 0.091; CMIN/DF = 2.861; GFI = 0.997; AGFI= 0.975; NFI = 0.952; CFI = 0.968; IFI = 0.968; FMIN = 0.005 and RMSEA= 0.058							

*Denotes values significant at 10% level of significance.

** Denotes values significant at 5% level of significance.

*** Denotes values significant at 1% level of significance.

The Bollen-Stine Bootstrap validation results on effects of accessibility on household energy diversification for lighting found that the model fit better in 452 bootstrap samples and it fit worse or failed to fit in 48 bootstrap samples (Bollen-Stine bootstrap p = .098), hence proving the null hypothesis that the model is correct.

Table 5. 7: Variances on effects of accessibility on HED for lighting

	Estimate	S.E.	C.R.	P
Distance to nearest Kerosene supplying shop (km)	1.080	.065	16.718	***
Number of Kerosene supplying shops in village where respondent lives	3.397	.203	16.720	***
Access to electricity net	.244	.015	16.718	***
e_2	.173	.010	16.718	***

Table 5. 8: Covariance on effects of accessibility on HED for lighting

			Estimate	S.E.	C.R.	P
Distance to nearest Kerosene supplying shop (km)	<-->	Number of Kerosene supplying shops in village	-0.155	.081	-1.917	.055
Number of Kerosene supplying shops in village	<-->	Access to electricity net	-0.105	.039	-2.716	.007

*Denotes values significant at 10% level of significance.

** Denotes values significant at 5% level of significance.

*** Denotes values significant at 1% level of significance.

The result in Table 5.8 shows covariance on effects of accessibility on household energy diversification for lighting. The results show that there is a negative relation between accesses to electricity network and the number of kerosene supplying shops in village.

However, there negative relations between distance to nearest kerosene supplying shop and the number of Kerosene supplying shops in village. This finding indicates that the kerosene supply retail shops reduce with the electricity access which is in agreement with Rehman et al. (2005).

5.5 EFFECTS OF BIOGAS ON HOUSEHOLD ENERGY UTILIZATION

The utilization of biogas in Kenya is a potentially clean development mechanism and has insightful implications on household energy. This research section analyzes the economic and social influence of biogas on household energy usage by comparing household with and without biogas digesters.

5.5.1 Effect of biogas on household energy utilization

Table 5.9 and Figure 5.2 presents results of the effects of biogas on other household energy sources utilized for cooking. The regression weight results of the SEM found negative association between the use of renewable energy sources (biogas) and LPG (β =-0.464, $p < 0.01$), firewood (β = -0.19, $p < 0.1$) and charcoal (β = -0.2, $p < 0.05$) all statistically significant. The results further show reduced use of LPG (- 46.4%), firewood (– 19%) and charcoal (- 20%) implying a decrease deforestation, indoor pollution and dependency on imported fuels with the use of biogas for cooking. This finding concurs with Shams *et al.*, (2014). The result also shows positive relationship between biogas usage and electricity. As depicted in Table 5.9, electricity showed positive relations with the use of biogas, while kerosene showed negative association but both with no significance.

Table 5. 9: Regression weights and standardized regression weights on effects of biogas on household energy utilization

Relationship between parameters			Estimate	S.E.	C.R.	P	S. Estimate
Biogas	<---	Firewood	-.179	.098	-1.824	.068*	-.164
Biogas	<---	Charcoal	-.181	.092	-1.976	.048**	-.178
Biogas	<---	Electricity	.285	.173	1.650	.099*	.149
Biogas	<---	LPG	-.464	.090	-5.165	***	-.465
Biogas	<---	Kerosene	-.214	.209	-1.025	.305	-.092
Biogas	<---	Agricultural residues	-.642	.410	-1.568	.117	-.141
Model summary: Chi-square = 28.543; Degrees of freedom = 15; Probability level = 0.018; CMIN/DF = 1.903							

*Denotes values significant at 10% level of significance.

** Denotes values significant at 5% level of significance.

*** Denotes values significant at 1% level of significance.

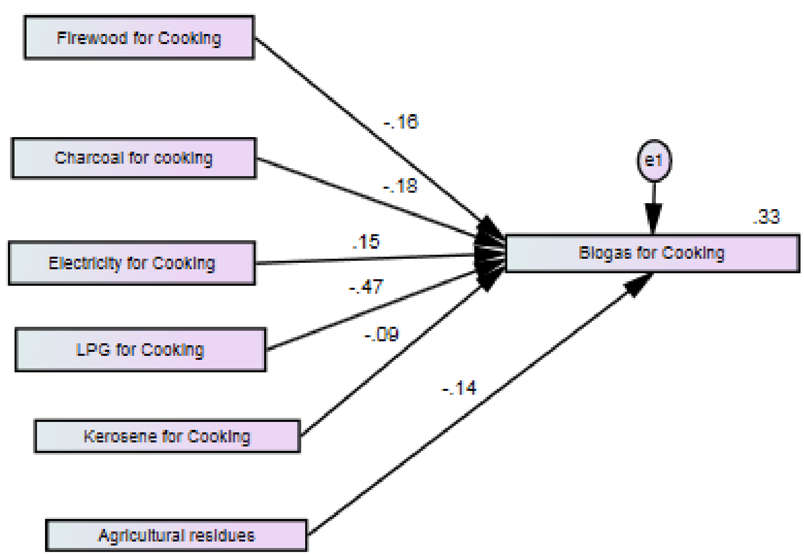

Figure 5. 2: SEM model results on effects of biogas on household energy utilization

There are vast biomass resources including organic waste in Kenya that have the potential for use as feedstock for biogas production to reduce the over reliance of fire wood and fossil fuel, and to help further reduce greenhouse gas emissions which may be affecting climate change.

The use of biogas reduces the use of traditional fuels (firewood (16.4%) and charcoal (17.8%)) and household's energy diversification, as well as lead to time-savings due to a reduction in time spent gathering firewood (Anderman et al., 2015). This implies that uses biogas reduces their use of firewood and charcoal leading to slows down deforestation and reduces greenhouse gas emissions.

5.5.2 Social and economic effects of biogas use

Table 5.10 presents the benefits of biogas at households at household levels in both peri-urban and rural areas. It can be seen that has numerous benefits including biogas hours of cooking per day, cost savings with biogas per month, time savings with biogas per day and cost expenditure of firewood, charcoal and LPG.

5.5.3 Time savings with Biogas

The daily time savings reported by biogas users on average per household is around 1hour 36 minutes per day. As shown in Table 5.10 there is no single household that reported time savings of less than 1 hour per day or increased efforts. Most think that they save more than one hour, since they use biogas for cooking. Some even save more than two hours per day. The results are in line with the research by Mwangi (2013) who explained that as long as wood fuel remains or continues to be scarce this will continue to rob the woman most of her time as she searches for a dwindling commodity.

Table 5. 10: The economic benefits of biogas usage

Biogas use/ Description		Biogas hours of Cooking	Estimated Cost savings with Biogas per month	Estimated time savings with Biogas Per month	Cost of charcoal per month	Cost of firewood per month	Cost of LPG per month
NO	Mean	0.00	0.00	0.00	1408.33	1520.24	800
Yes	Mean	4.87	2557.14	**1.63**	665.48	947.62	120.00

The study furthermore concurs with previous studies which show close results (Gwavuya et al., 2012; Meeks et al., 2019). Yasar et al. (2017) found that the use of biogas for cooking purposes saved women's cooking time of 3 h per day to generate more income, thus biogas usage result in generating of greener jobs. The results also support the findings by Cuong (2011), who found that on average, a household can save up to about half an hour a day for the collection or purchase of fuel. EPRO (2016) further more found that, on average, a household of biogas users saves about one and a half hours a day from cooking due to the use of biogas, and a woman in a household of biogas saves on average 2.3 hours a day from firewood collection, cooking and cleaning of appliances.

According to Mwangi (2013) research done in Nyeri, Kenya it was found out that the number of fire wood collecting times had increased from an average of 2 times a week to 3 times a week. The research gives solution to the problems associated with collecting firewood, which involves younger children and women.

Cooking on biogas is much faster compared with cooking on firewood and charcoal. No fire has to get started every time and the amount of collecting hours for firewood is decreased. These time savings enable household members to spend their time on other things, like studying or working. This will increase their education level; improve their financial situation and health of women. The duty to collect firewood frequently falls on girls, leading to lower rates of school enrollment for school-aged girls. In comparison with male-headed households, women household heads are more likely to be worried about the health risks associated with domestic energy use.

5.5.4 Cost savings with Biogas

The results in Table 5.10 revealed that biogas households save about 2,557 KES per month on average. This shows that there is economic savings with biogas, which is major contributor of a biogas system to the livelihood of the household members. Table 5.11 also shows the decrease in traditional household energy utilization. The results showed the reduction in the cost of firewood (Kshs1520 to Kshs 948), charcoal (Kshs1408 to Kshs 665.50) and LPG (Kshs800.00 to Kshs 120.00) with biogas use. This indicates that firewood, LPG and charcoal consumption are significantly lower among biogas users, despite the high rates of stacking. The finding supports the claim of fuel savings following adoption of biogas by others researchers (Bekere & Megerssa, 2020; Mwirigi et al., 2014).

This corresponds well with the calculated cost savings based on the actual use of all types of energy (LPG, Charcoal and firewood). The derived cost savings from the actual energy uses were equal to 1,996 KES per month, rather close to the perceived 2,557 KES cost savings. So users have a clear image of their cost savings.

The results in Figure 5.3 show furthermore that with increase in feed rate and biogas size there was increase in time savings and biogas cooking time. This indicates that there is significant reduction in the use of conventional (traditional) household energy sources with the increase in biogas plant size (in m^3).

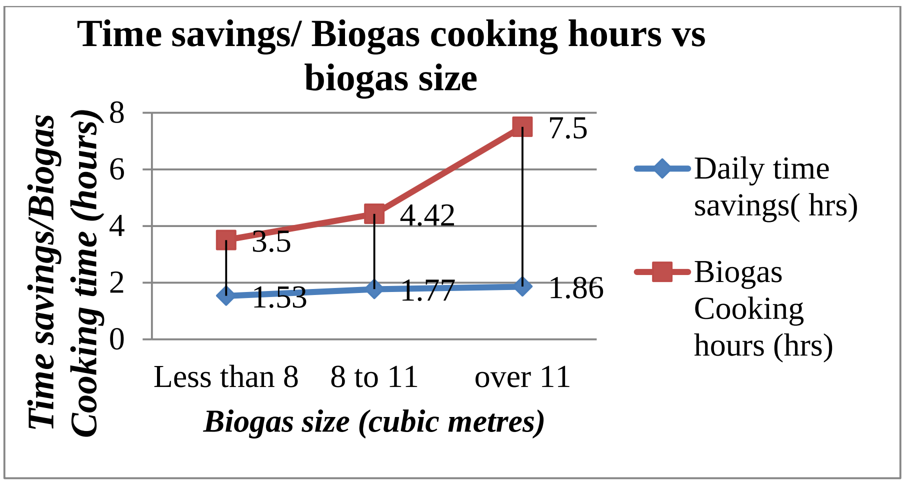

Figure 5. 3: Time savings/biogas verses biogas size

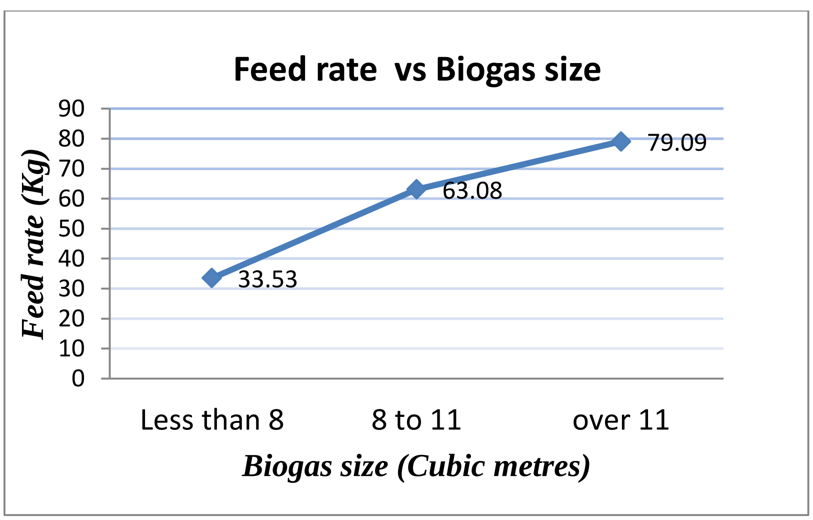

Figure 5. 4: Feed rate verses biogas size

5.5.5 Environmental and Health impacts

Household with biogas were asked to state and rate its positive effects on their household on environmental and health change and results are presented in Table 5.11. Major positive effects were made upon installation of a biogas plant including; cleanliness improved both in the kitchen and the natural surroundings. Combined together, cleanliness/health change scored 95.2% due biogas installation. The results on health changes showed that with increased biogas use at the household level yields a number of positive benefits. Moving away from wood-based energy sources will help to mitigate climate change, reduce energy costs and demands on natural resources, decrease the time and energy women and girls spend collecting wood, and lessen exposure to smoke induced consequences, nose and eye problems, carbon monoxide induced hazards and respiratory issues.

Table 5. 11: Environmental and Health impacts

Biogas use	Environmental and health Change	Percent (%)
Yes	No change	0
	Abit change	4.8
	Much Change	95.2

5.6 MEDIATING ROLE OF RENEWABLE ENERGY ON HOUSEHOLD ENERGY DIVERSIFICATION

In addition to their direct impacts conventional household energy on household energy diversification, renewable energy (biogas) also has indirect impacts on the total household energy utilization and diversification as shown in Table 5.12. Table 5.13 presents the result of mediating effects of biogas on household energy utilization and diversification. The result on standardized indirect (mediated) effect of biogas on kerosene for cooking on household energy diversification is -.042 and significant at 1% level.

Table 5. 12: Regression Weights and Standardized Regression Weights results

			Estimate	S.E.	C.R.	P	S. Estimate
Biogas	<---	charcoal	.142	.036	3.932	***	.197
Biogas	<---	firewood	.029	.038	.753	.451	.038
biogas	<---	Electricity	.037	.150	.248	.805	.011
biogas	<---	LPG	.002	.039	.064	.949	.003
Biogas	<---	Agricultural residues	-.036	.048	-.741	.459	-.032
Biogas	<---	Kerosene	-.095	.044	-2.182	.029	-.098
Household energy diversification	<---	charcoal	.224	.027	8.242	***	.273
Household energy diversification	<---	LPG	.460	.026	17.756	***	.514
Household energy diversification	<---	firewood	.226	.028	8.078	***	.263
Household energy diversification	<---	Agricultural residues	.229	.035	6.497	***	.182
Household energy diversification	<---	Biogas	.485	.031	15.842	***	.427
Household energy diversification	<---	Kerosene	.363	.032	11.247	***	.329

*Denotes values significant at 10% level of significance.

** Denotes values significant at 5% level of significance.

*** Denotes values significant at 1% level of significance.

That is, due to the indirect (mediated) effect of biogas on kerosene for cooking on household energy diversification, when Kerosene for cooking goes up by 1 standard deviation, household energy diversification goes down by 0.042 standard deviations.

Table 5. 13: Mediating effects of biogas on household energy utilization and diversification

Standardized effect/ Fuel	***Firewood***	***charcoal***	***Kerosene***	***LPG***	*Electricity*	***Agricultural residues***
Direct	0.253	0.268	0.329	0.459	0.117	0.174
Mediated (indirect)effects	0.016	0.084***	- 0.042**	0.001	0.005	- 0.014
Total	0.269	0.350	0.287	0.460	0.122	0.182

***, ** and * indicate significance at the 1% and 5% and 10% levels

This is in addition to direct (unmediated) effect that kerosene may have on household energy diversification. The findings also show that the standardized indirect (mediated) effect of charcoal for cooking on number of energy sources used for cooking is .084 with 1% significant level. This imply that due to the indirect (mediated) effect of biogas on number of energy sources used, when charcoal goes up by 1 standard deviation, number of energy sources used for cooking goes up by 0.084 standard deviations.

The indirect (mediated) effect of firewood for cooking on household energy diversification though insignificant, illustrates that when firewood for cooking goes up by 1 standard deviation, household energy diversification goes up by 0.016 standard deviations. The standardized indirect (mediated) effect of Agricultural residues and on household energy diversification is -.013 and .001 respectively but without statistically significance. Further, the indirect (mediated) effect of Agricultural residues and LPG on household energy diversification indicates that when agricultural residues and LPG goes up by 1 standard deviation, household energy diversification goes down by 0.013 and 0.001 standard deviations respectively.

These findings demonstrate that utilization of charcoal for cooking fuels in addition to the biogas support the energy stacking practice where various energy sources are used at the same time to enhance energy security in case of failures.

It was also established that the squared multiple correlations (R^2) are equal to 0.626 for the household energy diversification endogenous latent variable (i.e., for the variable total consumption because of the single item construct), was reasonably high (see Table 5.14). Thus, the latent variables (charcoal, LPG, firewood, kerosene and Agricultural residues) moderately explain 62.6% of the variance of the total residential energy consumption. Similarly, mediating role of renewable energy (biogas) on household energy diversification explains about 3.9 % of the variance of household energy diversification.

Table 5. 14: Squared Multiple Correlations on mediating effects renewable energy (biogas)

R^2	Estimate
Biogas	0.039
Household energy diversification	0.626

CHAPTER 6

MODERATING AND MEDIATING EFFECTS OF HOUSEHOLD ENERGY DIVERSIFICATION

6.1 INTRODUCTION

This chapter presents results in untangling the complexity of direct, moderating and mediating determinants of the household energy sources diversification using the structural equation modelling approach.

6.2 DETERMINANTS OF HOUSEHOLD ENERGY DIVERSIFICATION

The SEM model analysis in this section suggests that households seem to diversify their household energy sources as their socio- economic and demographic situations changes. In this regard, the fundamental question that arises is which socio-economic and demographic factors significantly contribute to household energy diversification. Many studies corroborate this finding that most households use at least two kinds of household's energy for cooking, respectively (Desalu et al., 2012; Farsi et al., 2007). Use of multiple fuels provides a sense of energy security, since complete dependence on a single fuel or technology leaves households vulnerable to price variations and unreliable service (Coelho et al., 2018). In this section, the factors that affect a household energy diversification were identified and analyzed using structural equation model. Figure 6.1 and Table 6.1 show unstandardized regression and standardized regression results SEM model on factors affecting household energy diversification. Factors which influence the study area household energy sources diversification were compiled and explained using standardized estimate (path coefficients) as shown below:

6.2.1 Income

The structural equation model results in Table 6.1 illustrate that income is positively and statistically significant with the numbers of energy sources ($\beta = 0.173$, S.E = 0.00, C.R = 4.194) at 1% significance level. The standard error for income is 0.000 (the lowest of all) which means it has the strongest ability to predict the endogenous variable, number of energy sources (diversification). The C.R for income is 4.194 which are out of ± 1.96 indicating that the variable is a significant variable to household energy diversification of sources for cooking.

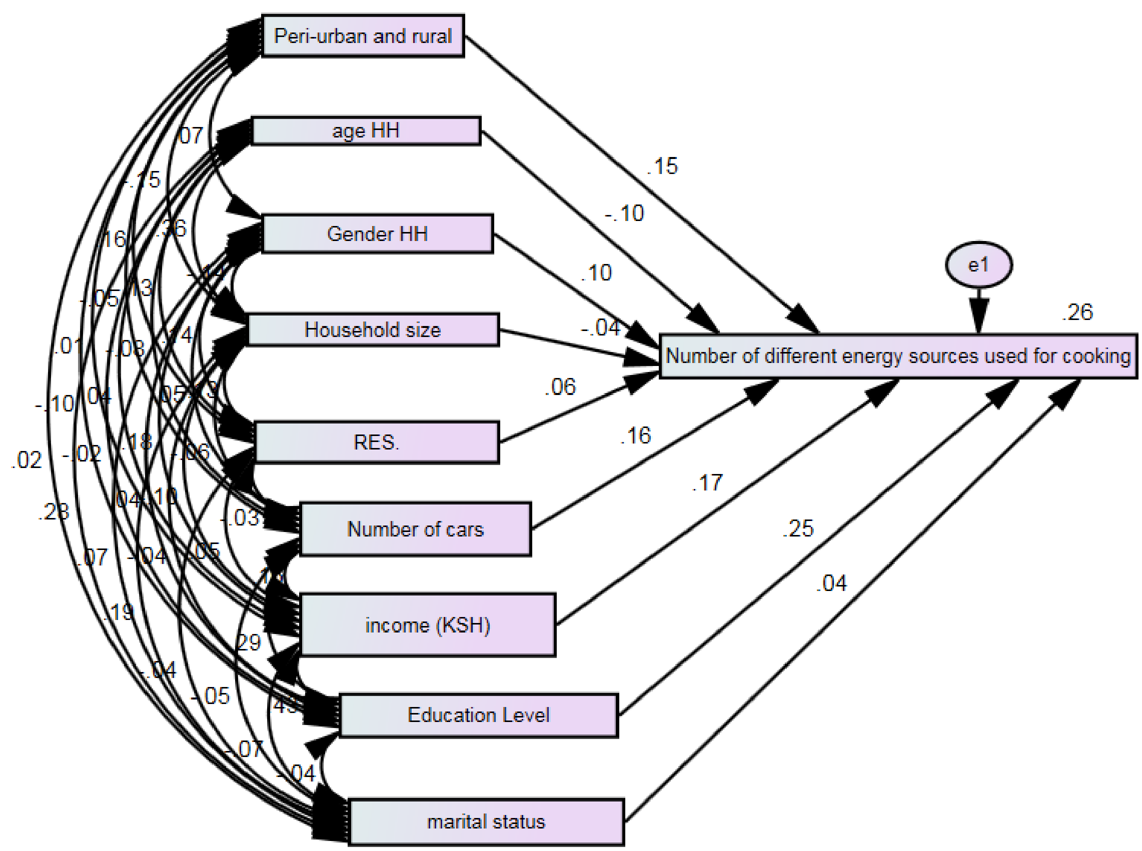

Figure 6. 1: Determinants of household energy diversification

With the increased income of the household, the opportunity cost of time also increases along with purchasing power to pay for a variety of fuel and greater convenience of use increases. Moreover, with an increase in income, a household is more likely to enjoy more household energy sources such as charcoal, LPG and electricity. The diversification of a household's energy sources is called its energy mix and is important to enhance household energy security. As incomes increase and fuel options widen, the fuel mix may change, but wood is rarely entirely excluded" (Adama et al., 2020).

Table 6. 1: Unstandardized estimates and standardized estimate results on determinants of household energy diversification

Variables associations			*Estimate*	*S.E.*	*C.R.*	*P*	*S. estimates*
Number of different energy sources used	<---	Rural – peri urban	.298	.074	4.017	***	.151
Number of different energy sources used	<---	Gender HH	.230	.087	2.641	.008***	.100
Number of different energy sources used	<---	Household size	-.015	.014	-1.064	.287	-.043
Number of different energy sources used	<---	Residence status	.132	.079	1.662	.097*	.062
Number of different energy sources used	<---	cars	.192	.045	4.286	***	.164
Number of different energy sources used	<---	Income	.000	.000	4.194	***	**.173**
Number of different energy sources used	<---	Education level	.294	.048	6.078	***	**.254**
Number of different energy sources used	<---	Age HH	-.117	.047	-2.472	.013**	-.101
Number of different energy sources used	<---	Marital status	.056	.060	.927	.354	.036
Model summary: Chi-square = 12.739; Degrees of freedom = 3; Probability level = 0.005; CMIN/DF = 4.246; GFI = 0.996; AGFI= 0.918; NFI = 0.979; CFI = 0.982;IFI = 0.984;FMIN = 0.023 and RMSEA= 0.076							

*Denotes values significant at 10% level of significance.

** Denotes values significant at 5% level of significance.

*** Denotes values significant at 1% level of significance.

In addition, the results can be explained by the economic theory, as household disposable income increase the purchase of household appliances also increases and, in the process, the household energy diversification increases in terms of quantity. Furthermore, the results can be explained by Wei and Liao who found that household energy use will become more diversified (Wei and Liao, 2016), with income increases the share of disposable income on energy consumption so the affordability of the households is also higher which influences the energy consumption pattern of households.

6.2.2 Cars

Table 6.1 shows how the number of cars influences household energy diversification. The results show that cars are positively and statistically significant with the household energy sources diversification ($\beta = 0.164$, S.E = 0.045, C.R = 4.286) at $P < 0.01$ significance level. The C.R for cars was found to be 4.286 which fall outside ± 1.96 range signifying that the number of cars is a significant variable to the household energy diversification. Household cars are an asset which improves the transportation of fuels (such as firewood, charcoal and LPG) from the retail shops/suppliers/ farms hence the possibility of enhancing household energy diversification.

The results are in line with Lyndon et al (2016) that the diversification of household energy mixes in most countries is limited by the need for transportation. The ease of transport, charcoal has become a prevalent cooking fuel in many urban/peri urban areas of the developing countries, while firewood is more prevalent in rural areas.

6.2.3 Education level

The results in Table 6.1 show that education level is positively and strongly associated with the number of energy sources ($\beta = 0.254$, S.E = 0.048, C.R = 6.078) at 1% significance level. The C.R for education level is 6.078 which is way out of ±1.96 range. This indicates that education level plays a significant role in a household's decision to choose a diverse household source of energy. Education of the individual is deemed to have an influence on the mixture of fuels a household consumes. This can be ascribed that an educated person is better employed and earn some appreciable level of income than an uneducated counterpart. Further, an educated person may be aware of the dangers of using single fuel and thus, will try to avoid interruptions in case failure of household energy source. Further more educated persons understand the use of various types of fuels like LPG and electric cookers which require technical skills to operate.

Beyond its effect on tastes and time opportunity costs, education as a powerful determinant of fuel diversification could also be explained by better education translating into diverse awareness of variety of household energy sources, and enhanced knowledge about energy security. According to a study on household choices in urban Nepal by Bhatta et al. (2018), it was found that as people get more knowledge on energy security, they are more health conscious and efficiency oriented because they are more aware of opportunity cost of different fuels portfolio.

6.2.4 Age of household head

The structural equation model result shown in Table 6.1, it shows that age of household head is negatively and strongly significant with the number of household energy sources (β = - 0.101, S.E = 0.047, C.R = - 2.472) at 1% significance level. The C.R for age was found to be -2.472 which are above ±1.96 showing that age does not play a role in household energy diversification. This may be due to the tact that older household heads are most resistant to new fuel technologies and limit themselves to traditional fuels such as fire wood only as compared to younger heads of households (Nlom & Karimov, 2015). It is also due to culture by older people who prefer food cooked using firewood rather than LPG and electricity (Ravindra et al., 2019; Van der Kroon et al., 2013) citing difference in taste. Older people complain about food cooked on improved cooking stoves, LPG and electricity hence limiting household energy diversification.

6.2.5 Gender of household head

The results in Table 6.1 show that female household head is positively and statistically significant with the number of household energy sources (β = 0.100, S.E = 0.087, C.R = 2.641). The C.R for gender household head was 2.641 which are above ±1.96 signifying that it plays a major role in household energy diversification. The findings illustrate that female household head are more concerned about the household energy security than the male counterparts and hence preferring the diversification. Also, according to some women, LPG would not be suitable for the preparation of some local dishes that often require a long cooking time. In households that combine biomass and LPG for cooking and where gas is the second-order fuel, it is often used mainly to prepare breakfast, and warm up the meals.

6.2.6 Peri urbanization

The structural equation model results presented in Table 6.1 show that location is positive and strongly associated with the number of energy sources (β = 0.151, S.E = 0.074, C.R = 4.017) at $P < 0.01$ significance level. The C.R for rural-peri urban is 4.017 which are outside ± 1.96 range. This suggests that the variable plays a major role in household energy diversification. This can be explained by the circumstance that rural areas do not have access to diverse household energy sources as compared to peri urban areas. Peri urban have access to varied supplying shops selling fuel and there is also reduced distance to diverse suppliers.

Therefore, the rural population relies severely on biomass as fuel for cooking whereas the peri urban enjoy diverse and accessible fuel choices because of easy availability of LPG, kerosene and charcoal at nearby retail shops. The findings concur with Rahut et al. (2019) that peri urban proximity to household energy fuel sources provides easy access to diverse energy while rural household have easy access to firewood and seasonal agricultural residues. Also, peri urban household generally reside in location where basic services are accessible as opposed to rural communities.

6.2.7 Residential status

Residential status is positively associated with the household energy fuel sources (β = 0.62, S.E = 0.079, C.R = 1.662) and significant at 10% statistical significance level (Table 6.1). it can be seen that the critical ratio for residential status is 1.662 which is within ± 1.96 range signifying that the variable does not play a major role in household energy diversification. This can be attributed to the fact that rental encourages household to choose variability of fuel for cooking with their normal location mostly found in urban/peri urban. Further, the economic progress, infrastructure development and other energy related policies in peri urban cause increase in household energy accessibility. This result shows that with increase in accessibility, the diversity increases and hence gives households an opportunity to choose variety of household energy sources.

6.2.8 Marital status

The results in Table 6.1 show that marital status is positively associated with the household energy diversification (β = 0.036, S.E = 0.060, C.R = 0.927) though not significant. The C.R for marital status is 0.927 which is within ±1.96 range indicating that the variable does not play significant role in household energy diversification. Also, a household head increases the probabilities of using diversified energies for cooking purpose. Thus, a married individual might pool together resources with his/her spouse to afford the diverse sources for cooking than an unmarried person. The results supports the researchers by Adu et al. (2013), (Ahmed, 2012); Karakara et al. (2019), (Okeke, 2017) and (Ismail, 2015).

6.2.9 Household size

The structural equation model results in Table 6.1 show that household size is negatively associated with the household energy diversification (β = (- 0.043, S.E = 0.014, C.R = -1.064). The variable showed the lowest S.E. value, 0.014 which means it has the strongest ability to predict the household energy diversification. This can be explained by the fact that larger household incur more expenditure in terms of food, shelter, clothing education, health and other needs leaving little resources for house energy diversification (Virola et al., 2007).

Generally, these results found education and income of the household to strongly influence the household energy diversification. Some households are reluctant to discontinue cooking with single fuel due to taste preferences and the familiarity of cooking with traditional technologies.

6.3 MODERATION AND MEDIATION EFFECT OF EDUCATION

Analyses were conducted to test the first hypothesis on moderating effect of education on household energy diversification and results are presented in Table 6.2. As shown, education demonstrate a moderating effect as there was positive and significant association between education (β = 0.266, C.R = 6.759, $p < 0.01$) and interaction effect of education and income on household energy diversification (β = 0.257, S.E = 000, C.R = 6.536, $p < 0.01$). Income and the interactions effects of income and education showed the lowest S.E. value, 0.00 which means it has the strongest ability to predict the household energy diversification.

Table 6. 2: Results of SEM testing moderation effects of education on HED

Relationship between parameters			S. Estimate	S.E.	C.R.	P
Household energy diversification	<---	Education level (moderator)	0.266	.037	6.759	***
Household energy diversification	<---	Income x education	0.257	.000	6.536	***
Household energy diversification	<---	Income (predictor)	- 0.030	.000	- 0.776	0.438

*Denotes values significant at 10% level of significance.

** Denotes values significant at 5% level of significance.

*** Denotes values significant at 1% level of significance.

Findings from the moderation model (Figure 6.2, Figure 6.3 and Table 6.2) showed that education acts as a moderator, whereby upon addition of education into the model, reduces the beta weight of income rendering it ineffective/non-significant in predicting the household energy diversification.

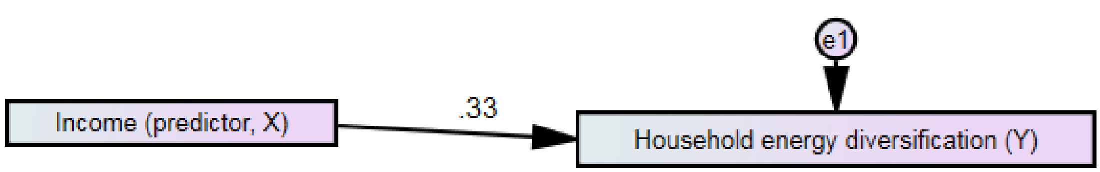

Figure 6. 2: SEM model of income as predictor and HED as output

$$Y = 2.425 + 0.329 X + e_1 \tag{6.1}$$

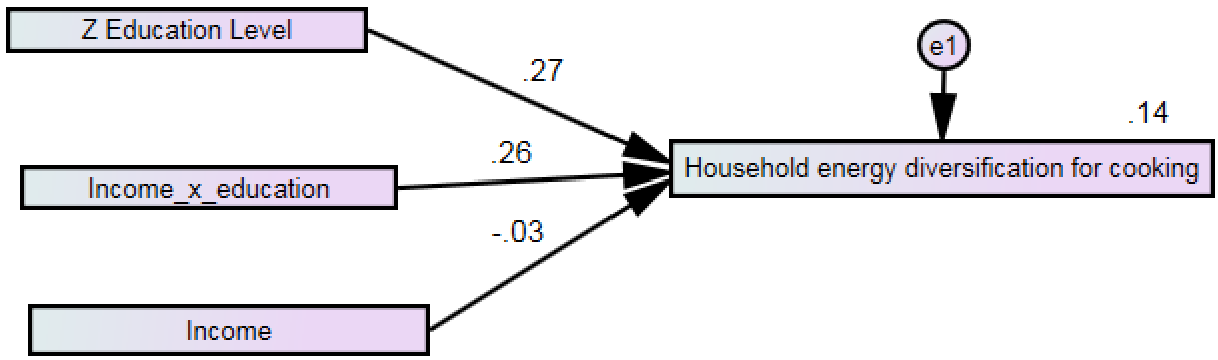

Figure 6. 3: SEM Model of education as Moderation and income as predictor on HED

The basic moderation model is estimated with the following multiple regression equation.

$$Y = 0.14 + 0.266\,Z + 0.257\,XZ + e_1 \qquad (6.2)$$

Y is the predicted value of household energy diversification, *X* represents income, *XZ* is the interaction term formed by multiplying the income and education codes.

This reduction in beta weight and insignificance (see equation 6.1 and 6.2) reflects the full moderating effect of education on the relationship between income and household energy diversification. The opportunity costs of household energy diversity for cooking, seen as increasing with education, may explain some of the observed results. Likewise, more education generally implies a higher income. It may thus be the estimated education effect is partly an ill-observed income effect, which is consistent with typical rankings of fuels according to necessities and luxuries. Explanations for these effects have demonstrated how education directly affects prejudices towards the diversity of fuel options. There has also been mention of indirect effects, as a higher level of education might increase a household's income, enabling it to afford diverse fuel options.

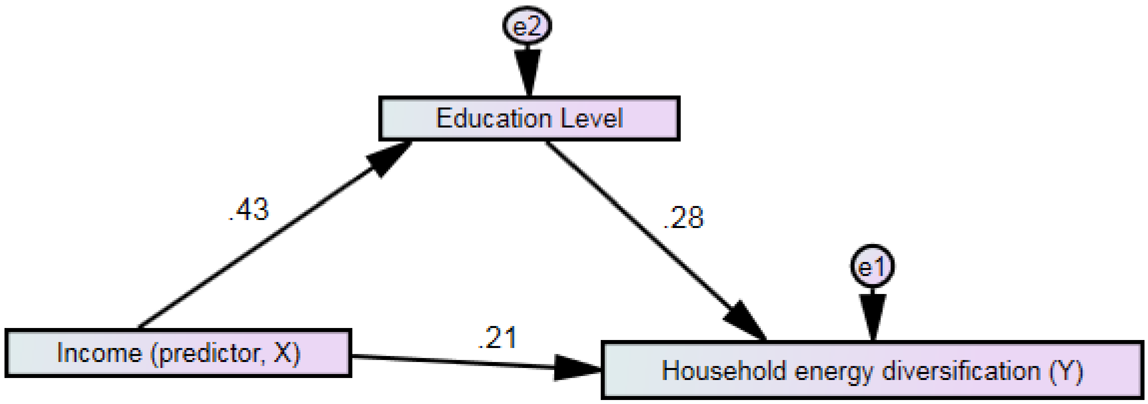

Figure 6. 4: SEM model of education as mediation and income as predictor on HED

Table 6. 3: Results of SEM testing mediating effects of education on HED

Relationships between variables			S. Estimate	S.E.	C.R.	P
Education level	<---	Income	0.426	.000	11.133	***
Household energy diversification	<---	Income	0.211	.000	4.952	***
Household energy diversification	<---	Education level	0.277	.049	6.509	***

*Denotes values significant at 10% level of significance.

** Denotes values significant at 5% level of significance.

*** Denotes values significant at 1% level of significance.

The mediation model regression equation to decompose the overall effect into its direct and indirect components as follows

$$Y = 1.715 + 0.21\,X + 0.28\,M + e_1 \qquad (6.3)$$

$$M = 2.212 + 0.43\,X + e_2 \qquad (6.4)$$

where; 1.715 and 2.212 are regression intercepts while e_1 and e_2 are the error terms. The regression coefficients in the equations measure various effects of predictors on the mediator and outcome variables.

Education demonstrated mediating effect whereby the indirect effect of income on household energy diversification through education (mediator) was statistically significant ($\beta = 0.426 \times 0.277 = 0.118$, $P < 0.01$). This indirect impact means that an increase by 1 standardized unit in the education is likely to increase in the total household energy diversification by 0.118 (11.8%) through income as a predictor variable. Table 6.3 and Figure 6.4 illustrates the output model for the mediation effect of education.

The findings from the mediation model (in Table 6.3) show that education can act as a mediator or third variable, whereby upon addition of education into the model, reduces the standard estimate (path coefficient from 0.329 to 0.211) of income in predicting the household energy diversification. This reduction in path coefficient reflects the mediating effect of education on the relationship between income and household energy diversification.

6.4 MEDIATION EFFECTS OF PERI URBANIZATION ON HOUSEHOLD ENERGY UTILIZATION AND DIVERSIFICATION

Peri urbanization is an important factor that affects the pattern of energy consumed in developing countries especially Kenya. As a given area becomes urbanized or per urbanized, the level of household energy utilization also increases. This level may be accompanied by increases in income that comes together with urbanization. There is also a shift from traditional to modern/clean fuels in peri urban areas but the use of traditional fuels in many urban areas of developing countries is still high especially among low-income groups. Furthermore, instead of shifting to modern fuels, people are consuming diverse types of energy sources that constitute both traditional and modern fuels. The purpose of this part is to explaining the mediation effects of peri urbanization on household energy utilization and diversification.

Table 6.4 and figure 6.5 presents on the mediating effects of peri urbanization on energy utilization and diversification. The results showed that the direct and indirect effect on the household energy utilization and diversification factors is positive and statistically significant.

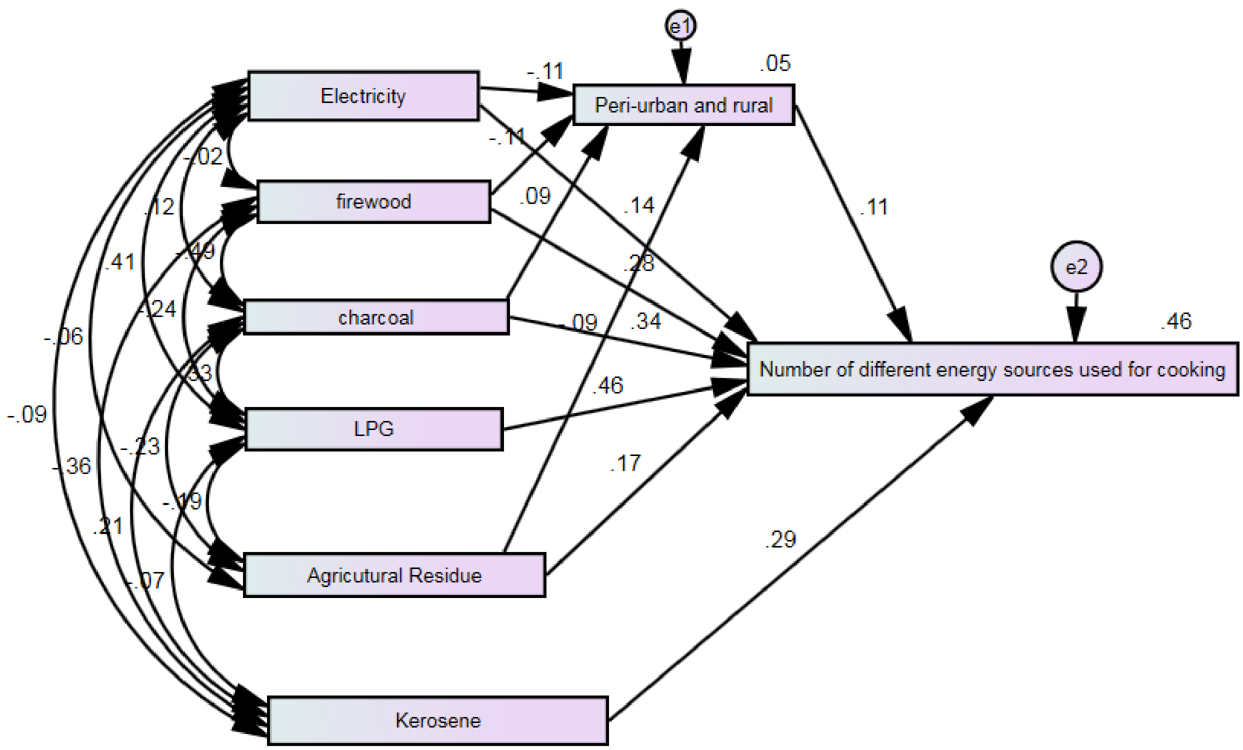

Figure 6. 5: Mediation effects of peri urbanization on HED

In addition to their direct impacts, household energy utilization also has indirect contribution on the household energy utilization and diversification as shown in Figure 6.5 and Table 6.4. The mediating effects indicates that peri urbanization as an exogenous variable has a considerable impact on the household energy diversification with the following standardized indirect (mediated) coefficients as shown in the Table 6.4 all statistically significant at 5%

level except the indirect effect of peri urbanization on charcoal at 10 % significant level. Kerosene and LPG showed no significance on the mediating role of peri urbanization on the household energy utilization and diversification.

Table 6. 4: Mediated effects of peri urbanization on household energy utilization and diversification

Relationship between variables			Estimate	S.E.	C.R.	P
Rural –Peri urban	<---	Firewood	-.116	.021	-2.423	.023**
Rural –Peri urban	<---	Electricity	-.111	.078	-2.659	.008***
Rural –Peri urban	<---	Agricultural residues	-.085	.027	-1.996	.045**
Rural –Peri urban	<---	charcoal	.092	.021	1.869	.007*
Household energy diversification	<---	charcoal	.338	.032	8.860	***
Household energy diversification	<---	firewood	.280	.033	7.258	***
Household energy diversification	<---	LPG	.460	.033	12.421	***
Household energy diversification	<---	Agricultural residues	.174	.041	5.331	***
Household energy diversification	<---	Kerosene	.289	.038	8.493	***
Household energy diversification	<---	Rural –Peri urban	.115	.063	3.599	***
Household energy diversification	<---	Electricity	.137	.128	3.976	***
Model summary: Chi-square = 19.494; Degrees of freedom = 4; Probability level = 0.001; CMIN/DF = 4.873; GFI = 0.991; AGFI= 0.923; Pclose = 0.056; NFI = 0.978; CFI = 0.982 and RMSEA= 0.08						

*Denotes values significant at 10% level of significance.

** Denotes values significant at 5% level of significance.

*** Denotes values significant at 1% level of significance.

The mediated results in Table 6.5 exposed a positive and significant increase of charcoal (0.115 * 0.092 = 0.01) energy diversification with peri-urbanization at 5% significant level while on the other hand there is reduction in the use of firewood, electricity and agricultural residues with peri- urbanization at statistically at 1% significant level. Kerosene and LPG indirect effects showed positive association with peri urbanization though not significant.

Table 6. 5: Mediating effects of peri urbanization on household energy utilization

Standardized effect/ Fuel	***Firewood***	***charcoal***	***Kerosene***	***LPG***	***Electricity***	***Agricultural residues***
Direct	0.28	0.338	0.289	0.46	0.137	0.174
Mediated (indirect)effects	- *0.013*	*0.01*	(0.04)	(0.01)	- 0.013	- 0.01
Total	0.268	0.349	0.329	0.47	0.124	0.164

The results further in Table 6.5 revealed a transition towards charcoal, LPG and kerosene as one shift from rural to peri-urban areas. The findings corresponds with the findings by Van der Kroon et al. (2013), Lusambo (2016) and Gatama (2014). Such significant impacts make sense because the socioeconomic household characteristics in peri urban have an important role on determining housing energy utilization and diversification, which is consistent with housing consumption theories. That is, a standard unit increase of the kerosene, LPG and charcoal factors with urbanization will have a significant impact on household energy policy making. The findings suggest that targeting of efforts towards the household energy incentive policy is vital to achieving the central policy goals of reducing dirty fuels.

The coefficient of determination (R^2) is equal to 0.46 for the consumption endogenous latent variable, and is average given that the dependent variable was estimated in together. Similarly, mediation effects of peri urbanization on household energy utilization and diversification explains about 5% on household energy utilization and diversification.

The structural model generated was validated with the use of bootstrapping resampling. To generate significance measures, i.e., standard errors and t values a bootstrapping procedure was carried out. Table 4.11 shows the bootstrapping test results for the path coefficient of the structure model, which demonstrated that in the structure model, all path coefficients except electricity were significant at 0.05 levels (p-Value < 0.05). Therefore, the results indicate that the peri urbanization has the mediating role effects in household energy utilization and diversification of firewood, agricultural residues and charcoal, while electricity had a little effect.

The bootstrapping indirect effects test results of the structural model suggests that LPG has the strongest direct effect on energy utilization and diversification (0.458), followed by charcoal (0.341), kerosene (0.292), firewood (0.280), agricultural residues (0.176) and electricity (0.136). The bootstrapping validates the results of the SEM model on mediating effects which concludes that LPG, charcoal, kerosene and firewood fuels are strong predictors of energy utilization and diversification as shown in table 6.5.

Bollen-Stine bootstrap was also done and proved that the model is valid. Bollen-Stine bootstrap found that the model fit better in 495 bootstrap samples and it fit worse or failed to fit in 5 bootstrap samples. Hence, testing the null hypothesis that the model is correct with Bollen-Stine bootstrap $p = .012$.

The findings advance existing mediating (indirect) effects of peri urbanization on household on energy utilization and diversification by linking household fuels with the number of household energy diversification. This linkage allows a targeted approach in household energy shift policy as a result of peri urbanization/ urbanization.

Table 6. 6: Bootstrapping test on the mediating effects of peri urbanization

Parameter association			***S. E***	***Path coefficient***	***Mean***	***T statistics***	***P-value***
Rural –Peri urban	<---	Firewood	.055	-.108	-.110	- 1.964	.05**
Rural –Peri urban	<---	Electricity	.048	.091	.093	1.896	.112
Rural –Peri urban	<---	Agricultural residues	.035	-.085	-.082	- 2.429	.022**
Rural –Peri urban	<---	charcoal	.033	-.110	-.110	3.333	.015**
Household energy diversification	<---	charcoal	.040	.339	.341	8.475	.010***
Household energy diversification	<---	firewood	.045	.279	.280	6.20	.019**
Household energy diversification	<---	LPG	.036	.458	.458	12.72	.015**
Household energy diversification	<---	Agricultural residues	.030	.174	.176	5.80	.012**
Household energy diversification	<---	Kerosene	.030	.289	.292	9.63	.025**
Household energy diversification	<---	Rural –Peri urban	.031	.115	.116	3.71	.012**
Household energy diversification	<---	Electricity	.035	.137	.136	3.914	.010**

*Denotes values significant at 10% level of significance.

** Denotes values significant at 5% level of significance.

*** Denotes values significant at 1% level of significance.

6.5 MEDIATING EFFECTS OF HOUSEHOLD CHARACTERISTICS ON HOUSEHOLD ENERGY DIVERSIFICATION

The purpose of this section was to examine the association of income and household energy diversification with education as the moderator and to also assess whether household characteristics such as peri urbanization, cars, gender of household head, household size, dwelling characteristics, accessibility and renewable energy sources mediates the associations of income and household energy diversification for cooking. The main drivers of household energy diversification were found to be education followed by income in the study areas as shown in section 6.2.

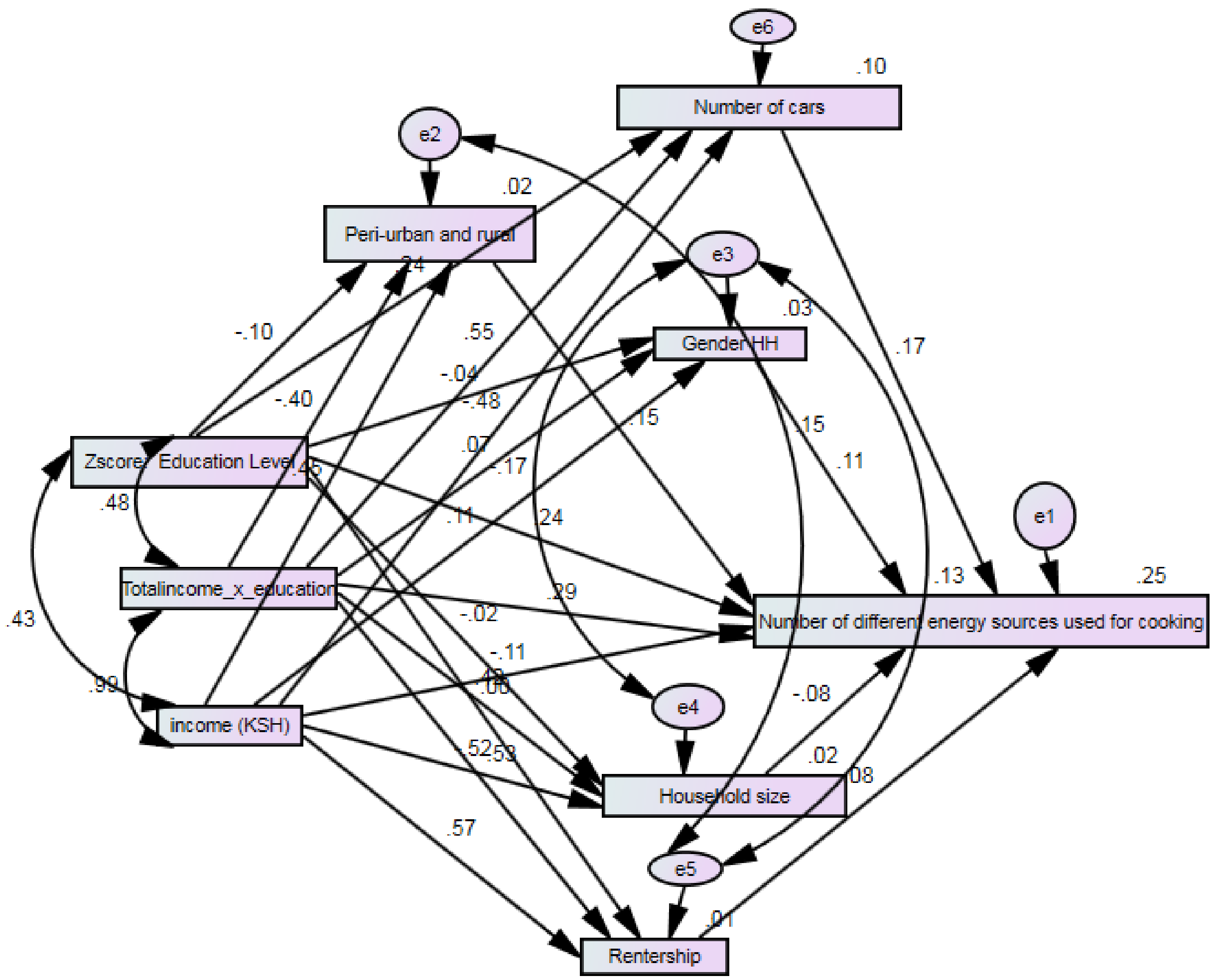

Figure 6. 6: Mediated moderation effects of household characteristics on HED

Table 6.7 presents the mediated moderation effects, path coefficient sizes and their significance on household energy diversification.

Table 6. 7: Mediated moderation effects of household characteristics on HED for cooking

Relationship between variables			*Estimate*	*S.E.*	*C.R.*	*P*	*S. Estimate*
Rural- peri urban	<---	Z Education level	-.047	.024	-1.922	.05**	-.096
Gender HH	<---	Z Education level	-.015	.021	-.735	.463	-.036
Rural- peri urban	<---	Income x education	.000	.000	-1.509	.131	-.405
Rural peri urban	<---	Income	.000	.000	1.724	.085*	.450
Gender HH	<---	Income	.000	.000	.441	.659	.114
Gender HH	<---	Income x education	.000	.000	.269	.788	.072
Household size	<---	Income	.000	.000	-1.999	.046**	-.522
Household size	<---	Income x education	.000	.000	1.583	.113	.425
Household size	<---	Z Education level	-.043	.138	-.308	.758	-.015
Residence status	<---	Income	.000	.000	2.183	.029**	.571
Residence status	<---	Income x education	.000	.000	-1.963	.050**	-.528
Residence status	<---	Z Education level	-.001	.023	-.022	.982	-.001
cars	<---	Z Education level	.197	.040	4.964	***	.237
cars	<---	Income x education	.000	.000	2.138	.033**	.550
cars	<---	Income	.000	.000	1.917	.05**	0.480
Household energy diversification	<---	Income x education	.000	.000	1.214	.225	.287
Household energy diversification	<---	Income	.000	.000	.494	.621	.114
Household energy diversification	<---	Z Education level	.232	.043	5.375	***	.239
Household energy diversification	<---	Rural- peri urban	.299	.074	4.055	***	.151
Household energy diversification	<---	Gender HH	.250	.088	2.855	.004***	.108
Household energy diversification	<---	Residence status	.158	.079	2.003	.045**	.075
Number of energy sources for cooking	<---	Household size	-.027	.013	-2.042	.041**	-.076
Household energy diversification	<---	Cars	.193	.045	4.297	***	.165
Model summary: Chi-square = 25.356; Degrees of freedom = 7; Probability level = 0.001; CMIN/DF = 3.622; GFI = 0.990; AGFI= 0.938; NFI = 0.990; RFI = 0.948; CFI = 0.993; IFI = 0.993; TLI = 0.962: FMIN = 0.045 and RMSEA= 0.068							

*Denotes values significant at 10% level of significance.

** Denotes values significant at 5% level of significance.

*** Denotes values significant at 1% level of significance.

As shown in Figure 6.6 and Table 6.7, the results of the effects of peri urbanization, cars, gender of household head, household size, and dwelling characteristics to mediate the associations of income and household energy suggests that age, accessibility, renewable and marital statuses are not important mediators in the association of income and household energy diversification with education as a moderator.

The structural model results in Table 6.7 suggests that income (β = 0.114, S.E = 000, C.R = 1.214) has the direct effect though insignificant while education (β = 0.239, S.E = 000, C.R = 6.536, $p < 0.01$) shows the strongest moderating effects. Therefore, suggests that income and education are strong predictors in mediated moderation effects of household characteristics. The effects of income (independent variable) and interactions effects in the model showed the lowest S.E. value, 0.00 which means it has the strongest ability to predict the number of energy sources for cooking**.**

Table 6. 8: Model fit and their level of acceptance of mediated moderated model

Parameter	**Model fitness indices**	**Level of acceptance**
CMIN	25.622	2df ≤ CMIN≤ 3df
CMIN/df	3.622	≤ 5
GFI	0.99	0.9 ≤ GFI≤ 1.0
AGFI	0.938	0.85 ≤ AGFI ≤ 0.9
NFI	0.99	0.9 ≤ NFI≤ 1.0
CFI	0.993	0.9 ≤ CFI≤ 1.0
IFI	0.99	0.9 ≤ IFI≤ 1.0
TLI	0.962	0.9 ≤ TLI≤ 1.0
RMSEA	0.068	0.05 ≤ RMSEA ≤ 0.08
C.R	16.718	-1.96 ≥ C.R ≥ 1.96

For the mediated moderated structural model, the computed goodness-of fit indices are shown in the Table 6.8. Generally, the values of fit indices exceed the acceptance level, indicating that the model fitted the data absolutely fine (Gholami & Khalaji, 2017; Kline, 2005).

6.5.1 Peri urbanization

The mediated-SEM results showed that the indirect (mediating) impact of peri urbanization on the household energy diversification (β = - 0.096, S.E = 0.024, C.R = -1.922, $P < 0.05$) is negative and statistically significant at 5% level. Based on the design of the conceptual model, this indirect effect can be calculated as the product of the two effects paths: rural-peri urban - number of energy sources for cooking and rural- peri urban - Z Education level (0.151 * - 0.096 = - 0.015). This indirect impact means that an increase by 1 standardized unit in the peri urbanization is likely to reduce in directly household energy diversification by 0.015 (through education as a moderator). The mediating effects of peri urbanization on the household energy diversification through income and the interaction effects of income and education showed positive and negative association respectively though not significant (0.151 x 0.45 = 0.068 and 0.151 x - 0.405 = - 0.61). Such significant impacts make sense because the peri urbanization is accessible to more diverse energy sources and improved infrastructure, hence enhanced household energy security leading to reduced diversification. This can be explained moreover by the better accessibility of modern fuels in peri urban regions as well as the higher income of households, which has been identified as a major factor supporting the switch to modern fuels (Muller & Yan, 2018) and less diversity.

6.5.2 Cars

The SEM results revealed that the direct impact of cars on the household energy diversification is positive (β = 0.165, C.R = 4.297) and statistically significant at 1% level. The mediating effects of cars on the household energy diversification through income (independent variable) (β = 0.48, S.E = 0.000, C.R = 1.917, $P < 0.05$), education (moderator) (β = 0.237, S.E = 0.040, C.R = 4.964, $P < 0.01$) and the interaction effects of income and education (β = 0.55, S.E = 0.000, C.R = 2.138, $P < 0.01$) showed positive and negative association respectively though not significant (0.165 x 0.48 = 0.0792 , 0.165 x 0.237 = 0.039 and 0.165 x 0.55 = 0.09), giving the total indirect effects as 0.21 .The results suggests interesting findings in the strong interactive effects of education level and income on household energy diversification for cooking mediated with the presence of a car.

6.5.3 Gender

The study showed that the male-headed households are less likely to adopt diverse household energy compared to their female counterparts (β = 0.108, S.E = 0.088, C.R = 2.855, $P < 0.01$) with 1% significant level. The mediating role of gender showed positive indirect effects of female head to enjoy diversity of household portfolio of fuels with increase in income (0.108 x 0.114) and interactions effects of income and education (0.108 x 0.076) even though without significance. This can be explained by the fact that women are traditionally responsible for cooking in the developing world, and are therefore usually responsible for the utilization of household energy; hence, they have a strong interest in food taste, energy security and more convenient energy sources for different use.

The results further show that there is a negative indirect effect of female head to enjoy diversity of household portfolio of fuels with increase in education (0.108 x - 0.096 = - 0.104) even though without significance indicating that educated female use only modern and few portfolios of household energy sources for cooking. Women may suffer serious long-term physical damage from domestic strenuous work and especially in case of household energy failure. As a result, it can be reasonably assumed that women are more likely to engage themselves into the energy diversification adoption process than their male counterparts assuming other factors are constant.

6.5.4 Household size

Although the direct effect of household size on diverse household energy for cooking was positive but not significant, the mediating role of household size on income to predict diversity of household portfolio fuels for cooking showed positive association and significance (- 0.076 x – 0.522 = 0.0397) at 5% significant level. This positive indirect effect, which is contrary to normal thinking, may be due to the positive effect of income and knowledge with more members in a household. The results support finding by Heltberg (2005) and Alem et al. (2016), who reports that larger households are more likely to be involved in fuel stacking.

The mediating role of household size also with the moderator as education showed positive association with household energy diversification and on the other hand showed negative relations with the interactive effects of income and education with no significance.

6.5.5 Residential status

The results showed that households living in their own home do not prefer to diversify energy sources, compared to households that rent 0.075 with 5% significant level. The mediating role of residential status on diversification showed positive and significant improvement diversity of household portfolio of fuels with increase in income (0.075 x 0.571 = 0.043) and on the other hand found negative and significant relationship with interactions effects of income and education of (0.075 x - 0.528 = - 0.0396). The mediating role of residential status on diversification showed negative association with education with no significant. Those in owned dwellings tend to have less diversity because they have enough space for storage since the rented buildings usually do not have sufficient space for constant supply of one portfolio of household energy such as firewood. This can be explained further by the fact that rental people understand that diversity can reduce the negative impact of supply shocks. Diversity can also help household energy systems effectively respond to the changes and shocks of the external environment, such as changes in environmental conditions, price changes for a specific energy and supply shortages.

6.5.6 Model validation

The structural model was employed to test the hypotheses after achieving reliable and valid measures. As a key step, squared multiple correlations (R^2) value was computed that reveals the degree of variation in the dependent variable illustrated by independent variables. Value 0.276 shows 27.6 % variance in household energy diversification can be predicted by the mediated moderated variables. Only 72.4% variance in household energy diversification cannot be predicted in this regression model. Cars, residential status, household size, gender of household head and peri urbanization showed 9.6%, 10%, 17%, 30%, and 17% respectively to predict the mediating role on household energy diversification.

Bootstrap model selection method was used to validate the SEM model for predicting household energy diversification and a threshold of P = 0. 05 were used for eliminating a variable from the model. 500 bootstrap samples were used (see Table 6.9).

The validation measure findings showed that closeness to the mediated moderated structural model. Bollen-Stine Bootstrap also found that the model fit better in 500 bootstrap samples and it fit worse or Bollen-Stine Bootstrap found that the model fit better in 500 bootstrap.

Table 6. 9: Bootstrapping test of mediated moderated model

Parameter			SE	Original sample	Sample Mean	Bias	P value
Rural- peri urban	<---	Z Education level	.051	-.096	-.098	-.002	.061
Gender HH	<---	Z Education level	.050	-.036	-.040	-.004	.431
Rural- peri urban	<---	Income x education	.260	-.405	-.394	.011	.128
Rural peri urban	<---	Income	.256	.450	.441	-.009	.087
Gender HH	<---	Income	.264	.114	.111	-.003	.684
Gender HH	<---	Income x education	.273	.072	.074	.002	.773
Household size	<---	Income	.252	-.522	-.521	.001	.038
Household size	<---	Income x education	.259	.425	.424	-.001	.105
Household size	<---	Z Education level	.050	-.015	-.011	.004	.840
Residence status	<---	Income	.247	.571	.557	-.014	.032
Residence status	<---	Income x education	.252	-.528	-.513	.016	.056
Residence status	<---	Z Education level	.050	-.001	-.001	.000	.959
cars	<---	Z Education level	.047	.237	.233	-.004	.004
cars	<---	Income x education	.258	.550	.570	.020	.027
cars	<---	Income	.249	0.480	-.495	-.016	.039
Number of energy sources for cooking	<---	Income x education	.235	.287	.280	-.007	.245
Number of energy sources for cooking	<---	Income	.227	.114	-.107	.007	.596
Number of energy sources for cooking	<---	Z Education level	.045	.239	.239	.000	.004
Number of energy sources for cooking	<---	Rural- peri urban	.038	.151	.151	.000	.004
Number of energy sources for cooking	<---	Gender HH	.040	.108	.109	.001	.009
Number of energy sources for cooking	<---	Residence status	.039	.075	.075	.000	.048
Number of energy sources for cooking	<---	Household size	.038	-.076	-.074	.002	.050
Number of energy sources for cooking	<---	cars	.040	.165	.167	.002	.004

*Denotes values significant at 10% level of significance.

** Denotes values significant at 5% level of significance.

*** Denotes values significant at 1% level of significance.

samples and it fit worse or failed to fit in 0 bootstrap samples, hence showing that testing the null hypothesis that the model is correct (Bollen-Stine bootstrap p = .002). Mediation model investigation is useful in model evaluation where it is used to understand the underlying mechanisms of a model. Whether a manipulation was effective or unsuccessful, mediation analysis is able to identify components of the model that contributed to its success or failure. By evaluating specific components of a model that produce intended or unintended change, mediation analysis can identify: (i) supportive elements, or those components that encouraged anticipated behavior, (Yonemitsu et al.) ineffective elements, or those components that did not contribute to changing the behavioral outcome, and/or (iii) those elements that promoted unintended effects of the model. To that end, it is important to differentiate overall model effect hypotheses from mediation model hypotheses. Although testing the overall relation between X and Y is vital in its own right, a non-significant overall model effect does not stop a statistically significant mediation effect (Fairchild & MacKinnon, 2009; Fairchild & McQuillin, 2010). By identifying the successful and unsuccessful components of a model, interferences can be iteratively developed on household energy systems to be more efficient and cost effective.

CHAPTER 7

SUMMARY, CONCLUSION AND RECOMMENDATIONS

7.1 REVIEW OF THE RESEARCH OBJECTIVES

This study investigated the household energy utilization, changing behaviours and diversification in Uasin Gishu and Bungoma counties, Kenya using structural equation modelling approach. Specifically, the study achieved the following objectives:

(i) investigated the household energy utilization and examined factors that influence the changing behaviours and diversification among households.

(ii) analyzed the effects of renewable energy and accessibility on energy utilization, changing behaviour and household energy sources diversification**.**

(iii) developed models to assess the effects of moderators and mediators on the household energy sources diversification, and

(iv) validated the SEM models parameters.

7.2 KEY FINDINGS

The study investigated household energy utilization, changing behaviours and diversification in western Kenya with more emphasis on modelling the effects of moderators and mediators on the household energy sources diversification using SEM approach and finally validate the SEM model parameters. The research was carried out in the counties of Bungoma and Uasin Gishu.

Biomass in the form of firewood and charcoal remain the most prominent fuel in both rural and peri urban areas for cooking in Kenya. The pattern of energy uses for cooking showed that the proportion of households that use fire wood declines as one move from rural to peri-urban, while the use of charcoal increases in the same case. On the other hand, the use of LPG and kerosene increases as one move from rural to peri-urban respectively. The results further showed that although biogas uptake is rising, it still represents a small fraction of the energy mix at local level.

The pattern of energy uses for lighting showed that there is reduced tendency of using solar as one move towards peri urban. The use of kerosene and electricity for lighting also increases as households move from rural to peri urban areas. The pattern of energy uses for lighting also shows that there are small differences in the use of kerosene and solar between the rural and urban households. The household energy utilization conformed to the energy stacking model than energy ladder in the study area. The uptake of renewable energy sources such as solar lamps for lighting also increase household energy diversification and hence increase energy security.

SEM model analysis found that factors affecting household energy choices and changing behaviour for cooking and lighting are; education level, income, residential status, peri urbanization, household size, household composition, age and gender of the household head and with the major drivers that cause gradual change from dependence on dirty fuels to modern and clean energy sources as household income and educational level. SEM model was used to analyze household energy contributor such as agricultural residues, electricity, firewood, LPG, charcoal, kerosene and biogas to predict household energy diversification. LPG followed by biogas showed the most important contributor to the diversification of household energy in the study.

The effects of distance to fuel supplying shops on household energy use and changing behaviour findings show that distance to nearest retail shops selling fuel in kilometers is negatively associated with household changing behaviour to fuel choices thus indicating a reducing trend in the use of the fuels with the increase in distance of energy sources for firewood, charcoal, LPG and Kerosene in both rural and peri urban. Further it was seen that the average distance to the nearest retail shops for the purchase of charcoal and LPG is greater for households in rural areas as compared to those in peri-urban areas, indicating that as one moves from rural to peri-urban the distance to retail shops selling charcoal and LPG reduces and hence more accessibility. The effects of number of different fuel supplying shops on household energy use and changing behaviour found that households which are further away from the market for LPG and charcoal are more likely to use dirty energy such as fire wood and agricultural residues and, hence proves why rural household chooses fire wood. To improve the uptake of modern clean fuels, there is need to enhance accessibility of their energy technologies such as LPG in the community.

Access to electricity network was found to be positively associated and statistically significant with electricity utilization for lighting and on the other hand negatively associated with the use of kerosene and solar indicating that accessibility to electricity is associated with its use for lighting. Also, there was positive association between the number of kerosene supplying shops in village selling household energy and kerosene for lighting implying that despite the revolution in clean and renewable energy sources in recent years, households in developing countries, particularly in Kenya, still use unhealthy sources of energy, damaging both the environment and human development though having abundant renewable energy resources such as solar.

Besides, some environmental, institutional and economic attributes were significantly associated with diffusion of biogas technology. From among the variables included in the SEM model, income, education level, age of household head, family size, level of education, cattle size owned, gender and land size were found to positively affect biogas adoption decision of households. On the other hand, distance to the nearest market negatively affected the adoption decision of the households. Interestingly, households that use biogas found saving of about 2,557 KES per month on average with the reduction in the cost of firewood, charcoal and LPG with biogas use indicate that firewood, LPG and charcoal consumption are significantly lower among biogas users, despite the high rates of energy stacking. Furthermore, economic savings and biogas cooking time increase with increase in feed rate and biogas size. The use of biogas reduces the use of conventional fuels such as and household's energy diversification, as most households without biogas multiple sources while accessibility on the other hand increases the fuel choices and the household's energy diversification.

The mediating effects peri urbanization showed positive and significant increase in the use of charcoal and LPG with peri-urbanization while on the other hand there is reduction in the use of firewood and agricultural residues with peri- urbanization implying that there is a shift from traditional to modern/clean fuels and even consuming diverse types of energy sources especially for cooking with peri urbanization/urbanization. The effects of peri urbanization, cars, gender of household head, household size, and dwelling characteristics were found to mediate the associations of income and household energy suggests that age, accessibility, renewable and marital statuses are not important mediators in the association of income and household energy diversification with education as a moderator. Squared multiple correlations (R^2) value was computed that reveals the degree of variation in the dependent variable illustrated by independent variables and found that 27.6 % variance in household energy diversification can be predicted by the mediated moderated variables. Only 72.4% variance in household energy diversification cannot be predicted in the SEM model. Cars, residential status, household size, gender of household head and peri urbanization showed 9.6%, 10%, 17%, and 30% respectively.

7.3 CONCLUSIONS FROM THE STUDY

The study demonstrates that, with the increase in household income and level of education, households opt for modern, clean, renewable energy sources (such as biogas) and improve their energy security through household diversification. Regardless of the efforts to encourage the use of biogas in Bungoma and Uasin Gishu, their adoption level and use is still low with firewood and charcoal as the most common combination of multiple fuel use for both peri urban and rural households. LPG followed by biogas revealed the greatest correlation and the most important contributor to the diversification of household energy.

The variable distance from the market (measured in kilometres) showed negatively associated with a household's choice of fire wood and positively associated with LPG, charcoal and kerosene, indicating that households which are further away from the LPG, charcoal and kerosene market are more likely to use dirty energy such as fire wood and less likely to use LPG, charcoal and kerosene. On the other hand, households which are further away from the market for LPG and charcoal are more likely to use dirty energy such as fire wood and agricultural residues showing that the rural household chooses fire wood because of the proximity to the firewood source. Biogas users showed time saving on average per household of 1hour 36 minutes per day.

This study will serve as a guide for stakeholders, enterprises, and government departments concerned with household energy development, supply and distribution and improving the distribution by understanding the association among all the factors affecting the adoption, utilization and diversification in Kenya. Study has contributed to the effects of renewable energy and accessibility on household energy utilization, changing behaviour and diversification. The study further more broadens the understanding of the concept of modelling on household energy changing behaviour and diversification which has rarely been studied.

7.4 RESEARCH CONTRIBUTIONS

7.4.1 The theory

It is now widely accepted that household energy utilization patterns and changing behaviour are a complex technical and socio-cultural phenomenon and to understand this phenomenon, it must be viewed from both engineering and social science perspectives. This research has demonstrated that, in addition to their direct impacts, household attributes such as peri urbanization, number of cars, household size, gender, age, accessibility and renewable energy showed interesting indirect impacts on the household energy utilization, changing behaviour and diversification.

The modeling approach adopted in this study revealed that it is feasible to disaggregate the relative extent of the various impacts. Consequently, it is feasible to obtain an improved understanding of which factors have the greatest effect when attempting to untangle the household energy utilization and diversification spectrum. In fact, the presented study offers a new outlook to help design smart future household energy policies, where innovative housing and social solutions could play important roles in indoor pollution and suppliers risks reduction goals. In addition to the concerns of enriching the policy debate, this thesis attempts to expand knowledge to prior research studies in the field by proposing a more comprehensive analysis on the various aspects of household energy utilization.

Furthermore, the study employs different research methods in an attempt to understand the household energy utilization and diversification spectrum. In doing so it demonstrates that qualitative investigation methods are essential to designing effective household energy interventions.

7.4.2 The practice

Household energy utilization, changing behaviour and diversification are an important forerunner for sustainability and energy security transitions. Through energy diversification, a household can increase its energy access rates, improve energy security, and environmental sustainability through the development of its vast modern, advanced and renewable energy resources. This study is an attempt to shed light on the household energy utilization, effects of renewable energies (such as biogas) and diversification situation and transition trends in Kenya with a focus to understanding the drivers through an application of the SEM model. The research asserts that the greater the variety of household energy sources in the energy mix, the greater the diversity. Also, residents can adopt biogas technology due to its significant impact on financial and time savings.

7.5 RECOMMENDATIONS

a) Currently, people give little priority to indoor pollution due to traditional household fuels and even household energy security. Therefore, the education curriculum should be reformed in such a way that students from a very early age attach importance to these values and later, this routine will have pleasant effects on the human health. Also, capacity building among households would promote creation of awareness in clean energy utilization. This could be enhanced through workshops and seminars that dwell on household energy issues.

b) Integrated and coherent efforts are needed from all stakeholders at different levels to increase household energy accessibility to diverse fuels, affordability and security awareness.

c) The government should utilize print, electronic and social media to highlight the significance of household energy utilization in order to improve and adopt modern, clean and sustainable energy sources.

d) The government should strengthen the relationship with local administration to make sure that the government policy targets of incorporating renewable energy in the country are producing the required results. For the proper execution, there should be a two-way flow of information, i.e., government plans and strategies should be deliberated, and stakeholders' input should be attained. These include (i) adopt integrated household energy policy approaches and improve stakeholder relationship; (ii) raise awareness of the benefits of clean bioenergy cooking options; (iii) enhance research, development, and technical capacity.

e) Involvement of government and NGOs in household energy related activities such as in order to facilitate shift to sustainable, modern household energy utilization and diversification. The government, NGOs' and policy makers should take adequate steps to ensure that all households have access to modern; clean household energy resources and the relevant technologies for their sustainable consumption at affordable costs. The factors which influence household energy consumption and diversification should be used as a guide. The government should develop clear policy incentives such as tax exemptions for increased private sector participation in delivery of clean energy fuels and equipment.

7.6 FURTHER RESEARCH

This study researched on household energy utilization, changing behaviours and diversification using structural equation modelling approach in Kenya's Uasin Gishu and Bungoma counties only. Consequently, data obtained from the two counties may not be representative of the real situation in other parts of the country. To this end therefore, a future research should be carried out in other areas in Kenya to establish if the same results would be obtained.

In doing that:

- Since data were collected from different location with different demographic factors (such as education, income, and consumers' awareness) which may vary from peri urban to rural areas, future research work be conducted separately for rural and peri urban areas of the counties with a larger sample size.

- Future research also should examination the influence of factors such as fear, fuel prices, beliefs, level of satisfaction, and moral obligations on consumers’ intention, environmental concerns and willingness to pay for renewable energy.

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APPENDICES

Appendix I

Table 1: Regression weights and standardized regression weights results on effects of accessibility

			Estimate	S.E.	C.R.	P-value	S. Estimate
LPG	<---	Distance to nearest Kerosene supplying shop	-.055	.048	-1.135	.256	-.052
firewood	<---	Distance to nearest Kerosene supplying shop	-.032	.039	-.834	.404	-.030
charcoal	<---	Distance to nearest Kerosene supplying shop	.044	.048	.906	.365	.038
Agricultural residues	<---	Distance to nearest Kerosene supplying shop	.013	.035	.360	.719	.017
Kerosene	<---	Distance to nearest Kerosene supplying shop	.003	.038	.082	.935	.004
LPG	<---	Distance to nearest LPG supplying shop	.002	.010	.192	.848	.012
firewood	<---	Distance to nearest LPG supplying shop	.000	.008	-.004	.997	.000
charcoal	<---	Distance to nearest LPG supplying shop	.005	.010	.539	.590	.031
Agricultural residues	<---	Distance to nearest LPG supplying shop	.004	.007	.496	.620	.032
Kerosene	<---	Distance to nearest LPG supplying shop	.016	.008	2.107	.035	.128
LPG	<---	Distance to nearest charcoal supplying shop	-.008	.012	-.706	.480	-.049
firewood	<---	Distance to nearest charcoal supplying shop	.016	.010	1.618	.106	.087

			Estimate	S.E.	C.R.	P-value	S. Estimate
charcoal	<---	Distance to nearest charcoal supplying shop	-.008	.012	-.649	.516	-.041
Agricultural residues	<---	Distance to nearest charcoal supplying shop	-.005	.009	-.586	.558	-.042
Kerosene	<---	Distance to nearest charcoal supplying shop	-.018	.009	-1.938	.053	-.130
LPG	<---	Distance to nearest fire wood supplying shop	-.039	.085	-.453	.650	-.028
firewood	<---	Distance to nearest fire wood supplying shop	-.091	.068	-1.333	.182	-.063
charcoal	<---	Distance to nearest fire wood supplying shop	-.009	.085	-.105	.916	-.006
Agricultural residues	<---	Distance to nearest fire wood supplying shop	-.025	.062	-.400	.689	-.025
Kerosene	<---	Distance to nearest fire wood supplying shop	.104	.066	1.576	.115	.093
LPG	<---	Number of fire wood supplying shops in village	-.291	.042	-6.875	***	-.378
firewood	<---	Number of fire wood supplying shops in village	.699	.034	20.548	***	.877
charcoal	<---	Number of fire wood supplying shops in village	-.451	.042	-10.692	***	-.538
Agricultural residues	<---	Number of fire wood supplying shops in village	.105	.031	3.415	***	.193
Kerosene	<---	Number of fire wood supplying shops in village	-.309	.033	-9.391	***	-.497
LPG	<---	Number of charcoal supplying shops in village	.165	.048	3.447	***	.302

			Estimate	S.E.	C.R.	P-value	S. Estimate
firewood	<---	Number of charcoal supplying shops in village	-.230	.038	-5.978	***	-.406
charcoal	<---	Number of charcoal supplying shops in village	.436	.048	9.148	***	.733
Agricultural residues	<---	Number of charcoal supplying shops in village	-.100	.035	-2.876	.004	-.259
Kerosene	<---	Number of charcoal supplying shops in village	.087	.037	2.328	.020	.196
LPG	<---	Number of LPG supplying shops in village	.003	.042	.080	.936	.007
Firewood	<---	Number of LPG supplying shops in village	-.096	.034	-2.835	.005	-.202
charcoal	<---	Number of LPG supplying shops in village	-.077	.042	-1.840	.066	-.154
Agricultural residues	<---	Number of LPG supplying shops in village	.007	.031	.228	.820	.021
Kerosene	<---	Number of LPG supplying shops in village	.024	.033	.739	.460	.065
LPG	<---	Number of Kerosene supplying shops in village	.012	.026	.452	.651	.020
Firewood	<---	Number of Kerosene supplying shops in village	-.038	.021	-1.832	.067	-.062
Charcoal	<---	Number of Kerosene supplying shops in village	.024	.025	.961	.336	.038
Agricultural residues	<---	Number of Kerosene supplying shops in village	-.002	.019	-.121	.904	-.005
Kerosene	<---	Number of Kerosene supplying shops in village	.020	.020	.982	.326	.041

			Estimate	S.E.	C.R.	P-value	S. Estimate
Model summary: Chi-square = 8.018; Degrees of freedom = 2; Probability level = 0.018; CMIN/DF = 4.008; GFI = 0.998; AGFI= 0.900; NFI = 0.998; RFI = 0.91; CFI = 0.998; IFI = 0.998; TLI = 0.931: FMIN = 0.014 and RMSEA= 0.073							

*Denotes values significant at 10% level of significance.

** Denotes values significant at 5% level of significance.

*** Denotes values significant at 1% level of significance.

Appendix II

Table 2: Covariance and correlations of exogenous variables

			Estimate	S.E.	C.R.	P
Number of LPG supplying shops in village	<-->	Number of Kerosene supplying shops in village	1.150	.191	6.016	***
Number of charcoal supplying shops in village	<-->	Number of Kerosene supplying shops in village	.894	.160	5.597	***
Number of firewood supplying shops in village	<-->	Number of Kerosene supplying shops in village	.635	.113	5.607	***
Distance to nearest firewood supplying shop	<-->	Number of Kerosene supplying shops in village	.206	.062	3.336	***
Distance to nearest charcoal supplying shop	<-->	Number of Kerosene supplying shops in village	-.106	.491	-.216	.829
Distance to nearest LPG supplying shop	<-->	Number of Kerosene supplying shops in village	-1.401	.547	-2.562	.010
Distance to nearest Kerosene supplying shop	<-->	Number of Kerosene supplying shops in village	-.139	.081	-1.713	.087
Number of charcoal supplying shops in village	<-->	Number of LPG supplying shops in village	4.125	.265	15.544	***
Number of fire wood supplying shops in village	<-->	Number of LPG supplying shops in village	2.102	.167	12.560	***
Distance to nearest firewood supplying shop	<-->	Number of LPG supplying shops in village	1.230	.094	13.043	***
Distance to nearest charcoal supplying shop	<-->	Number of LPG supplying shops in village	-9.948	.760	-13.090	***

			Estimate	S.E.	C.R.	P
Distance to nearest LPG supplying shop	<-->	Number of LPG supplying shops in village	-10.436	.828	-12.610	***
Distance to nearest Kerosene supplying shop	<-->	Number of LPG supplying shops in village	-.959	.112	-8.575	***
Number of firewood supplying shops in village	<-->	Number of charcoal supplying shops in village	1.860	.143	13.031	***
Distance to nearest fire wood supplying shop	<-->	Number of charcoal supplying shops in village	.972	.078	12.493	***
Distance to nearest charcoal supplying shop	<-->	Number of charcoal supplying shops in village	-7.763	.625	-12.424	***
Distance to nearest LPG supplying shop	<-->	Number of charcoal supplying shops in village	-8.120	.681	-11.925	***
Distance to nearest Kerosene supplying shop	<-->	Number of charcoal supplying shops in village	-.749	.093	-8.045	***
Distance to nearest fuel wood supplying shop	<-->	Number of fuel wood supplying shops in village	.476	.051	9.341	***
Distance to nearest charcoal supplying shop	<-->	Number of fuel wood supplying shops in village	-3.244	.401	-8.086	***
Distance to nearest LPG supplying shop	<-->	Number of fuel wood supplying shops in village	-3.826	.447	-8.555	***
Distance to nearest Kerosene supplying shop	<-->	Number of fuel wood supplying shops in village	-.394	.064	-6.134	***
Distance to nearest charcoal supplying shop	<-->	Distance to nearest fuel wood supplying shop	-3.368	.253	-13.309	***

			Estimate	S.E.	C.R.	P
Distance to nearest LPG supplying shop	<-->	Distance to nearest fuel wood supplying shop	-3.450	.274	-12.615	***
Distance to nearest Kerosene supplying shop	<-->	Distance to nearest firewood supplying shop	-.339	.037	-9.081	***
Distance to nearest Kerosene supplying shop	<-->	Distance to nearest charcoal supplying shop	2.883	.303	9.519	***
Distance to nearest Kerosene supplying shop	<-->	Distance to nearest LPG supplying shop	3.119	.334	9.345	***
Distance to nearest LPG supplying shop	<-->	Distance to nearest charcoal supplying shop	31.990	2.301	13.903	***

*Denotes values significant at 10% level of significance.

** Denotes values significant at 5% level of significance.

*** Denotes values significant at 1% level of significance

Appendix III

HOUSEHOLD ENERGY UTILIZATION, CHANGING BEHAVIOURS AND DIVERSIFICATION

QUESTIONNAIRE

SECTION A:

GENERAL INFORMATION

Date _________________________

County_______________________ District_____________________

Village________________________

Name of interviewer _________________________ Supervisor____________________________

DEMOGRAPHIC INFORMATION

No	Questions	Answers	Codes
A 1	Name of respondent		
A 2	Name of household head		
A 3	Age of household head		
A 4	Sex of household head:	Male---------------1 Female-------------2	
A 5	What is the marital status of the household head	Single------1 Married------2 Widow------3 Widower------4 Divorced------5 Separated------6	
A 6	Sex of respondent:	Male---------------1 Female-------------2	
A 7	Indicate Household size		

A 8	Indicate household Composition (numbers)	Boys Under 5 yrs: Girls under 5 yrs: Boys 6– 14 yrs: Girls 6 – 14yrs:	Men 15-50yrs: Women 15-50 yrs: Men >50yrs: Women >50yrs:	
A 9	Indicate the household Residence Status		Permanent Resident…………1 Rentership…………………...2 Others (specify)…………....3	
A 10	Indicate highest level education of the HH head		Primary and below …………1 Secondary ……………...2 Tertiary ………….…….3 Above masters …………..4	
A 11	Location		Rural ……………………….1 Peri urban …………………2	

LIVELIHOOD ASSETS

Livestock Profile

A11. Do you have livestock? (1) Yes (2) No

Livestock type	Number Owned
Cattle	
Goats	
Sheep	

Donkey	
Poultry	
Others (Specify)	

Land Holdings Profile

A.13. Do you have land (1) Yes (2) No ……..If yes. How many acres? …….

A.12... Other Significant Productive Household Assets

Are there educated / working persons within households? (1) Yes (2) No; if yes how many?

____

Main physical assets owned by family (cars, motor bike, floor characteristics etc)

Asset	Number

Income

A.13. How many household members currently earn an income for the HH?						
A.14. How many sources of income does your household currently have?						
In order of importance rank the sources of income for your family? How much did each source contribute to total household income in the last month?						
Income Sources		1 (Very Low)	2 (Low)	3 (Moderate)	4 (High)	5 (Very high)
Livestock (sale of animals and animal products – milk, butter, hides, etc)						
Crop farming (sale of cereals, pulses, oil seeds, vegetables etc)						

Business / Self-employment / petty trade					
Wage employment					
Casual labour					
Remittances and gifts from family					
Sale of charcoal / firewood					
Cash for work opportunities					
Loan					
Other (Specify)					

A.15. How much is your household's total income per month from all sources (work, cash for work, business sources, animal products, relatives)? Shillings.______________________________

SECTION B:

HOUSEHOLD ENERGY UTILIZATION AND DIVERSIFICATION OF HH ENERGY SOURCES

Specific research objective: To investigate household energy utilization and the diversification of HH energy sources

Research question: What are the prevailing traditional household energy utilized and its diversification?

B.1 what are the main household energy sources of energy for:

Cooking?

Electricity	Solar	LPG	Kerosene	Firewood	Charcoal	Others

Lighting?

Electricity	Solar	Candles	Kerosene	Firewood	Charcoal	Others

B.2. What are the Household sources of energy do you utilize in your household for:

Cooking?

source	Frequently used	Moderately used	Rarely used	Not used
Electricity				
Solar				
LPG				
Kerosene				
Firewood				
Charcoal				
Others				

b) Lighting?

source	Frequently used	Moderately used	Rarely used	Not used
Electricity				
Solar				
LPG				
Kerosene				
Firewood				
Charcoal				
Others				

B.3 What number of household energy sources (in total) do you use for?

Lighting ………. b) Cooking……….

SECTION C:

ASSESSMENTTHE EFFECTS OF ACCESSIBILITY AND RENEWABLE ENERGY ON HOUSEHOLD ENERGY

Specific research objective: To analyze the effects of renewable energy and accessibility on fuel choice behaviour and diversification of household energy sources.

Research question: What are the effects of accessibility on household fuel choices, changing behaviour and diversification?

C. 1 Do you think Renewable energy sources can reduce your monthly energy expenses? Yes [ ] No [ ].

Give the estimate………………

C.2 How much do you for spend per month on household energy for lighting when using

a) Solar lamps/solar for lighting………… b) Biogas for cooking……

C.3 What number of energy sources do you use for the following now that you are using RE

a) Number for Cooking……………… b) Number for lighting………….

C.4 How many retail selling shops around are there in village for the following:

a) Fire wood…..b) LPG…………c) Charcoal………d) Kerosene……..e) Briquettes….

C.5 What is the least distance (in Kilometres) do you cover to purchase the following fuels;

a) fire wood…..b) LPG…………c) Charcoal………d) kerosene……..e) Briquettes….

C.6 Do you have to the following household fuels in you farms?

a) Fire wood [ ] b) Agricultural residues [ ] c) Others…………………….

SECTION D:

Specific research objective: To analyze the determinants of renewable energy uptake and level of satisfaction.

Research question: What are the factors influence the usage of renewable sources

D.1 What factors influence the usage of renewable sources?

Rank the factors in order of the strength					
Factors	1 (Strongly disagree)	2 (Disagree)	3 (Undecided)	4 (Agree)	5 (Strongly Agree)
Cost					

Knowledge and skills					
Land					
Alternative sources of Energy (such as Kerosene)					
Culture					
Don't know					
Other (Specify)					

D.2. Are you satisfied with the energy supply used in the household at present? *Indicate the number in the space provided*

Energy Source	Satisfaction Yes OR No	Reason for dissatisfaction 1. Unreliable 3. Too expensive 2. Inefficient 4. Others (specify)
Fire Wood		
Charcoal		
Electricity		
Paraffin/ Kerosene		
LPG		
Biogas		
Agricultural residues		
Solar		
Others Specify		

D.3. Explain your rating……

D.4. What do you consider to be the main challenges of adopting renewable energy sources (e.g biogas) in your opinion?

Limitations	Very Important	Moderately	Less important	Not Important

		Important		
Lack of adequate funds				
Poor infrastructure				
Inadequate skilled disseminators				
Poverty				
Community's negative attitude				
High installation cost				
Lack of interest				
Any others Specify				

D.5. In your opinion what are some of the measures that would improve the use Renewable energy among community?

Possible Measures	Very Important	Moderately Important	Less important	Not Important
Provision of Micro-finance				
Increased government will and support				
Increased training programs for disseminators				
County leadership program in renewable energy				
Establish demonstration centres				
Any other specify………………………………				

D.6. Explain your rating…………..

D.7. In your opinion do you think enough has been done to promote renewable energy in the area?

If yes, how? ……………………………………………………

D.8. If no, what needs to be done? Briefly explain………

D.9. Are you willing to change renewable energy sources? Yes [ ] No [ ]

If yes, how much are you willing to invest to have Renewable energy sources (such as biogas or solar)

(i) below 5000 ii) 5001-20000 iii) 20001-50000 iv) above 50,000

THANK YOU FOR THE TIME AND INFORMATION

Appendix IV

A SURVEY ON THE EFFECTS OF BIOGAS SYSTEMS IN UASIN GISHU COUNTY, KENYA

Date ________________________ *Name*_______

*County*______________________

*Area*_____________________________________

Name of interviewer ________________________

*Supervisor*___________________________

Remarks and Observations (type of house, assets, neighborhood, and other comments)

SECTION A: HOUSEHOLD CHARACTERISTICS

A1. How old is the household head?

<15	15-25	26-35	36-45	46-55	>55

A2. What is your gender?

- *Male* ☐
- *Female* ☐

A3. What is the gender of the household head?

- *Male* ☐
- *Female* ☐

A4. What is the highest education level of your household head?

- *No education followed* ☐
- *Primary school* ☐
- *Secondary school* ☐
- *College* ☐
- *University* ☐

A5. How large is your household (number of people)? …….. persons

A6. Do you use firewood or charcoal for cooking?

- *Fire wood* ☐
- *Charcoal* ☐

A7a. Which other energy sources do you use for cooking? Indicate each used type with an X. If no other types are used**.**

Household energy	**Cost (Kshs)**
LPG	
Electricity	
Solar	
Agricultural residues	
Kerosene	
Other (specify)	

A7b. If other type is used: How much do you approximately spent monthly on this/these energies in total in KES? …….

A8a. Do you have an own biogas system?

- *Yes* ☐
- *N0.* ☐

A8b For how many years do you have the system*?*

- *Less than 3* ☐
- *3-6* ☐
- *>6* ☐

A8c. What is the capacity of the system*?*

- *<8 m3* ☐
- *8-11 m3* ☐
- *>11 m3* ☐
- *Don't know* ☐

A8d. What kind of biogas system is it?

- *Fixed Dome* ☐
- *Floating drum* ☐
- *Tubular digester* ☐

A8e. How much did the system costs approximately?

Kshs …………

SECTION B: HEALTH AND ENVIRONMENT OFHOUSEHOLD ENERGY USE

B1a. To what extent do you agree with the following statement: Firewood use for cooking indoors is healthy? Indicate the given opinion with an X.

Strongly agree	*Agree*	*Neutral*	*Disagree*	*Strongly disagree*

B1b To what extent do you agree with the following statement: Charcoal use for cooking indoors is healthy? Indicate the given opinion with an X.

Strongly agree	*Agree*	*Neutral*	*Disagree*	*Strongly disagree*

B2a. Can you name a few health consequences known or experienced by you or other members of your household by using firewood indoors?

B2b. Can you name a few health consequences known or experienced by you or other members of your household by using charcoal indoors?

B3a. Can you name some environmental consequences caused by using firewood?

B3b. Can you name some environmental consequences caused by using charcoal?

SECTION B: EFFECTS OF BIOGAS USAGE

For biogas users

C1. *With how many cows or other livestock do you supply the biogas?*

1-2 ☐
3-4 ☐
5-6 ☐
>6 ☐

C2. *Does the system produce enough gas in order to be able to cook every day on it?*

- *Yes* ☐
- *No* ☐
- *Don't know* ☐

C3. *How many hours can you cook on the gas per day? ……….. hours*

C4. *Did you experience monthly energy cost savings after you switched to biogas?*
Kshs ………….

C5. *Did you experience time savings after you switched to biogas? ……….. hours*

C6. *Regarding your households health, did you experienced a cleaner situation in your house*

- *Yes, much cleaner* ☐
- *Yes, a bit cleaner* ☐

- *No changes. We still have the same issues* ☐

C7. *What type of maintenance did you have to do? …………………………….*

C8. *What were the costs of the maintenance?*

Kshs ………….

Income

D.1. How much your household does earn on average during a normal period per month in Kenyan Shillings?

Kshs ………….

Appendix V

SCIENTIFIC OUTPUT

Publications

1) Stephen K. Kimutai; Zachary O. Siagi and Paul M. Wambua (2021). Determinants of Household Energy Utilization and changing Behaviour in Kenya: Structural Equation Modelling Approach, *European Journal of Energy Research, 1*(4) (Accepted and in process).

2) Kimutai, S. K., & Talai, S. M. (2021). Household Energy Utilization Trends in Kenya: Effects of Peri Urbanization. *European Journal of Energy Research, 1*(2), 7-11. https://doi.org/10.24018/ejenergy.2021.1.2.9

3) Kimutai, S. K., Kiprop, A. K., & Siagi, Z. O. (2020). Factors Affecting the Number of Household Energy Sources in Kenya: Generalized Linear Model. *International Journal of Novel Research in Engineering and Science, Vol. 6 (2), Pp: 27-32*

4) Kimutai, Stephen K; Kiriamiti, Henry K and Snelder, Denyse. (2019). Effects of Renewable Energy and Accessibility on Household's Fuel Choices: A Case Study in Kenya. *Journal of Energy Technologies and Policy, Vol.9 (7), Pp 29-34*

5) Kimutai, S., Kiprop, A., & Snelder, D. (2019). Household Energy Utilization and Changing Behaviours: Evidence from Western Kenya, *International Journal of Energy Engineering, Vol. 9 (2), Pp: 36 – 44*

Appendix VI

DATA USED FOR ANALYSIS

File Edit View Data Transform Analyze Direct Marketing Graphs Utilities Add-ons Window Help

	Name	Type	Width	Decimals	Label	Values	Missing	Columns	Align	Measure	Role
1	Nameofresp...	String	20	0	Name of respon...	None	None	14	Left	Nominal	Input
2	Constituency	Numeric	20	0	village/contitue...	{1, Kesses}...	None	11	Right	Nominal	Input
3	county	Numeric	12	0	county	{1, uasin Gi...	None	8	Right	Nominal	Input
4	Periurbrural	Numeric	12	0	Peri-urban and ...	{1, Rural}...	None	9	Right	Nominal	Input
5	GenderHHh...	Numeric	12	0	Gender HH	{1, Male}...	None	12	Right	Nominal	Input
6	maritalstatus	Numeric	12	0	marital status	{1, Single}...	None	12	Right	Nominal	Input
7	sexrespond	Numeric	12	0	sex respond	{1, Male}...	None	12	Right	Nominal	Input
8	Householdsi...	Numeric	12	0	Household size	None	None	12	Right	Scale	Input
9	childrenlt5	Numeric	12	0	children<5	{0, No}...	None	12	Right	Nominal	Input
10	youth514	Numeric	12	0	youth 5-14	{0, No}...	None	12	Right	Nominal	Input
11	female1550	Numeric	12	0	female 15-50	{0, No}...	None	12	Right	Nominal	Input
12	male1550	Numeric	12	0	male 15-50	{0, No}...	None	12	Right	Nominal	Input
13	femalegt50	Numeric	12	0	female>50	{0, No}...	None	12	Right	Nominal	Input
14	malegt50	Numeric	12	0	male>50	{0, No}...	None	12	Right	Nominal	Input
15	residencest...	Numeric	12	0	Rentership	{1, Permane...	None	12	Right	Ordinal	Input
16	cattlenumber	Numeric	12	0	cattle number	None	None	12	Right	Scale	Input
17	poultrynumber	Numeric	12	0	poultry number	None	None	12	Right	Scale	Input
18	cars	Numeric	12	0	Number of cars	None	None	12	Right	Nominal	Input
19	tractor	Numeric	12	0	Number of cars	None	None	12	Right	Scale	Input
20	motorbike	Numeric	12	0	Number of mot...	None	None	12	Right	Nominal	Input
21	Totalmonthl...	Numeric	12	0	income (KSH)	None	None	12	Right	Scale	Input
22	Electricityfo...	Numeric	12	0	Electricity	{1, Not used...	None	12	Right	Ordinal	Input
23	Solarforcoo...	Numeric	12	0	Solar	{1, Not used...	None	12	Right	Ordinal	Input
24	LPGforcooki...	Numeric	12	0	LPG	{1, Not used...	None	12	Right	Ordinal	Input
25	Kerosenefor...	Numeric	12	0	Kerosene	{1, Not used...	None	12	Right	Ordinal	Input
26	firewoodforc...	Numeric	12	0	firewood	{1, Not used...	None	12	Right	Ordinal	Input
27	charcoalforc...	Numeric	12	0	charcoal	{1, Not used...	None	12	Right	Ordinal	Input
28	biogasforco...	Numeric	12	0	biogas	{1, Not used...	None	12	Right	Ordinal	Input
29	Agriculturalr...	Numeric	12	0	Agricutural Res...	{1, Not used...	None	12	Right	Ordinal	Input
30	Numberofdiff...	Numeric	12	0	Number of differ...	None	None	12	Right	Scale	Input
31	Electricityfo...	Numeric	12	0	Electricity for li...	{1, Not used...	None	12	Right	Ordinal	Input
32	Solarforlighti...	Numeric	12	0	Solar for lighting	{1, Not used...	None	12	Right	Ordinal	Input
33	LPGforlighting	Numeric	12	0	LPG for lighting	{1, Not used...	None	12	Right	Ordinal	Input
34	Kerosenefor...	Numeric	12	0	Kerosene for lig...	{1, Not used...	None	12	Right	Ordinal	Input
35	firewoodforli...	Numeric	12	0	firewood for ligh...	{1, Not used...	None	12	Right	Ordinal	Input
36	Numberofdiff...	Numeric	12	0	Number of differ...	None	None	12	Right	Scale	Input
37	Accesstoel...	Numeric	12	0	Access to elect...	{0, No}...	None	12	Right	Nominal	Input
38	Numberoffu...	Numeric	12	0	Number of fuel...	None	None	12	Right	Scale	Input
39	Numberofch...	Numeric	12	0	Number of char...	None	None	12	Right	Scale	Input
40	NumberofLP...	Numeric	12	0	Number of LPG...	None	None	12	Right	Scale	Input
41	NumberofKe...	Numeric	12	0	Number of Kero...	None	None	12	Right	Scale	Input
42	Distanceton...	Numeric	12	0	Distance to nea...	None	None	12	Right	Scale	Input
43	Distanceton...	Numeric	12	0	Distance to nea...	None	None	12	Right	Scale	Input
44	Distanceton...	Numeric	12	0	Distance to nea...	None	None	12	Right	Scale	Input
45	Distanceton...	Numeric	12	0	Distance to nea...	None	None	12	Right	Scale	Input
46	ZHousehold...	Numeric	11	0		None	None	16	Right	Scale	Input
47	ZAverageInc...	Numeric	11	0		None	None	31	Right	Scale	Input
48	householdsi...	Numeric	8	0		None	None	31	Right	Scale	Input
49	Zcharcoalfor...	Numeric	11	0		None	None	21	Right	Scale	Input
50	ZLPGforcoo...	Numeric	11	0		None	None	16	Right	Scale	Input

Appendix VII

DATA USED FOR ANALYSIS ON EFFECTS OF BIOGAS (RENEWABLE ENERGY)

File Edit View Data Transform Analyze Direct Marketing Graphs Utilities Add-ons Window Help

	Name	Type	Width	Decimals	Label	Values	Missing	Columns	Align	Measure	Role
1	Area	Numeric	8	0	Namof area	{1, Outspan...	None	8	Right	Nominal	Input
2	ageHH	Numeric	8	0	Ageof HH	{1, less 15}...	None	8	Right	Nominal	Input
3	Gender	Numeric	8	0	Genderrespond...	{1, male}...	None	8	Right	Nominal	Input
4	GenderHH	Numeric	8	0	Genderof HH	{1, male}...	None	8	Right	Nominal	Input
5	Education	Numeric	8	0	Education Level	{1, None}...	None	8	Right	Nominal	Input
6	Job	Numeric	8	0	Type of job	{1, Entrepre...	None	8	Right	Nominal	Input
7	Householdsi...	Numeric	8	0	Household size	None	None	8	Right	Scale	Input
8	Firewood	Numeric	8	0	Firewood for Co...	{0, No}...	None	8	Right	Ordinal	Input
9	Charcoal	Numeric	8	0	Charcoal for co...	{0, No}...	None	8	Right	Ordinal	Input
10	Costcharcoal	Numeric	8	0	Cost Of charco...	None	None	8	Right	Scale	Input
11	Costfirewood	Numeric	8	0	Cost of firewoo...	None	None	8	Right	Scale	Input
12	Electrictyco...	Numeric	8	0	Electricity for C...	{0, No}...	None	8	Right	Ordinal	Input
13	Solarcooking	Numeric	8	0	Solar for cooking	{0, No}...	None	8	Right	Ordinal	Input
14	LPGcooking	Numeric	8	0	LPG for Cooking	{0, No}...	None	8	Right	Ordinal	Input
15	Keroseneco...	Numeric	8	0	Kerosene for C...	{0, No}...	None	8	Right	Ordinal	Input
16	Agriculturalr...	Numeric	8	0	Agricultural resi...	{0, No}...	None	8	Right	Ordinal	Input
17	Biogascooki...	Numeric	8	0	Biogas for Coo...	{0, No}...	None	8	Right	Ordinal	Input
18	Biogasuse	Numeric	8	0	Biogas use	{0, No}...	None	8	Right	Ordinal	Input
19	YearsofBiog...	Numeric	8	0	Years of Biogas	None	None	8	Right	Scale	Input
20	SizeofBiogas	Numeric	8	0	Size of Biogas	{0, not Kno...	None	8	Right	Nominal	Input
21	TypeofBiogas	Numeric	8	0	Type of Biogas	{0, None}...	None	8	Right	Nominal	Input
22	CostBiogas	Numeric	8	0	Appox. Cost of ...	None	99	8	Right	Scale	Input
23	NumberCows	Numeric	8	0	Number of Cows	None	None	8	Right	Scale	Input
24	Enoughgas	Numeric	8	0	Enough gas	{0, No}...	None	8	Right	Ordinal	Input
25	Biogashours	Numeric	8	0	Biogas hours of...	None	None	8	Right	Scale	Input
26	Feedrate	Numeric	8	0	Feed rate in Kg	None	None	8	Right	Scale	Input
27	Maintenace...	Numeric	8	0	Cost of mainten...	None	None	8	Right	Scale	Input
28	Costsavings	Numeric	8	0	Estimated Cost...	None	None	8	Right	Scale	Input
29	Timesaving	Numeric	8	0	Estimated time...	None	None	8	Right	Scale	Input
30	HeathChange	Numeric	8	0	Health and Envi...	{0, No chan...	None	8	Right	Nominal	Input
31	Income	Numeric	8	0	Income per Mo...	{1, 0 - 1000...	None	8	Right	Nominal	Input
32	CharFirewo...	Numeric	8	0	Charcoal and Fi...	None	None	8	Right	Scale	Input
33	ZNumberCo...	Numeric	11	5	Zscore: Numb...	None	None	13	Right	Scale	Input
34	ZJob	Numeric	11	5	Zscore: Type o...	None	None	13	Right	Scale	Input
35	Age_x_num...	Numeric	8	2		None	None	19	Right	Scale	Input