EXAMINING HOUSEHOLDS ENERGY CONSUMPTION PATTERNS AND EFFECTS ON ENVIRONMENT IN SIAYA TOWNSHIP, SIAYA COUNTY, KENYA

BY

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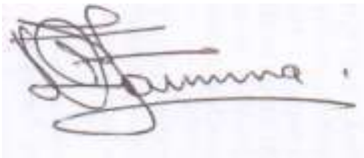
DECLARATION

This project is my original work and has not been presented for a degree in any other university or any other award.



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This project has been submitted for examination with my approval as a university supervisor.

Dr Moses Otieno Kola:________________________________

Date: ________________________________

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DEDICATION

I want to give all the glory to God. In Him, I live and have the strength to put this work together. I dedicate this to my family, who encouraged me to complete this project.

ABSTRACT

Previous reports on Siaya county energy consumption reveal that woodfuel is the primary source of energy. Such heavy dependence at 98% causes poverty and environmental problems in the form of deforestation, biodiversity loss, air pollution, depletion of water sources and land degradation. However, little is known about the energy consumption pattern in Siaya Township ward. The aim of this study, therefore, was to determine the households' energy consumption pattern and effects on the environment in Siaya Township. It was to specifically determine factors influencing household energy consumption, to spatially analyse household energy consumption pattern, and to establish environmental effects associated with the use of wood fuel. The study was a descriptive, analytical cross-sectional study design based on cluster sampling. 411 households were sampled out of 8,043. Primary and secondary data were analysed using SPSS descriptive statistical analysis and GIS spatial analysis, respectively. The results revealed that socio-economic and geographic factors influence energy consumption in Siaya Township. On the other hand, the direct effects on the environment are a reduction in forest cover, loss of wetlands, biodiversity loss, land degradation and depletion of water sources. The findings call for the county government in collaboration with all stakeholders to put policies in place to help subsidise the installation cost of green energy sources. Also, to train and build human capacity to install and maintain such sources and put in place a credit facility for households that would want to invest on the same. The finding of this study is expected to contribute to the knowledge of the energy consumption patterns in contexts like Siaya Township. To this end, it would be of interest for future studies to look at energy choice behaviour in the same context by choice modelling to help bring a deeper understanding of energy consumption for future energy planning.

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ABBREVIATIONS, ACRONYMS AND DEFINITION OF TERMS

Access- means the opportunity or right to use something in the context of this report.

Affordability- means the ability to afford or have something in the context of this study.

Wood fuel- means fuel such as firewood and charcoal in the context of this report.

Energy/fuel- means a source of power such as electricity, solar, kerosene etc. The two terms are used interchangeably to mean the same thing in this report.

Consumption/use- the act of using something like energy, food, materials, etc**.** The two terms are used interchangeably to mean the same thing in this report.

ESRI- Environmental Systems Research Institute.

KIPPRA- Kenya Institute for Public Policy Research and Analysis.

GIS- Geographic Information System.

IPPC- Intergovernmental Panel on Climate Change.

LPG- Liquid Petroleum Gas.

STIRPAT- Stochastic Impacts by Regression on Population Affluence and Technology.

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CHAPTER ONE: INTRODUCTION

1.1. Background

Energy is vital for the development of a country. It is the spine of the economy of a state and forms basic need of everyone. As people advance, they need energy to power homes, institutions, businesses, industry, transportation, electricity generation and other essential services (Legros, Havet, Bruce, & Bonjour, 2009). At the household level, energy satisfies the needs of lighting, cooking and heating. It also plays a decisive role in employment and income creation (Legros et al., 2009).

The world total primary energy supply per region between the years 1973 and 2010 was as summarised in table 1. In which case, as of the year 2010, OECD primary energy supply was the largest at 42.4%, while Africa accounted for 5.4%. Furthermore, according to International Energy Agency-IEA (2012), biomass accounted for 10%, hydro 2.3%, nuclear 5.7%, coal 27.3%, oil 32.4%, natural gas 21.4% and other (i.e. geothermal, solar, wind, heat etc.) 0.9% of the world total primary energy supply in 2010.

Table 1: 1973 and 2010 regional shares of total primary energy supply.

Region	**1973 (%)**	**2010 (%)**
Non-OECD Americas	3.5	4.6
Africa	3.4	5.4
Bunkers**	3.0	2.8
OECD	61.4	42.4
Middle East	0.8	4.8
Non-OECD Europe and Eurasia	15.4	8.9
China	7.0	19.1
Asia*	5.5	12.0

***Includes international aviation and international marine bunkers. *Asia exludes China.*
Source: International Energy Agency-IEA (2012)

The global energy consumption was estimated to rise from 549 quadrillions British thermal unit in 2012 to 815 quadrillions British thermal unit in 2040, an increase of 48% (Conti et al., 2016). The world total energy consumption was biomass 12.7%, electricity 17.7%, coal 9.8%, oil 41.2%, natural gas 15.2%, and other (i.e. geothermal, solar, wind, heat etc.) 3.4% by the year 2010 (Buba et al., 2012). Therefore, the world total primary energy consumption per region between the years 1973 and 2010 is as shown in table 2. In which case, in the year 2010, OECD primary energy consumption was the largest at 42.5%, while Africa consumption was at 5.8%. However, the most common challenge associated with energy consumption is how to access energy in terms that facilitate economic growth while respecting human and environmental integrity.

Table 2: 1973 and 2010 regional shares of total final consumption.

Region	**1973 (%)**	**2010 (%)**
Non-OECD Americas	3.6	5.0
Africa	3.8	5.8
Bunkers**	3.9	4.1
OECD	60.3	42.5
Middle East	0.7	4.6
Non-OECD Europe and Eurasia	13.5	8.2
China	7.9	17.5
Asia*	6.3	12.3

***Includes international aviation and international marine bunkers. *Asia exludes China.*
Source: International Energy Agency-IEA (2012).

According to the Intergovernmental Panel on Climate Change-IPCC (2007), in most Sub-Sahara Africa countries, the wood-based biomass energy sector employs a significant workforce by providing regular income. The IPCC report also pointed out that 94% of Africa rural population and 73% of the urban population use wood fuel as their primary source of energy, mainly in the form of firewood in rural areas and charcoal in urban areas. The IPCC report further noted that the disparity in energy use exists between rural and urban and also between high and low-income groups.

According to Owiro, Poquillon, Njonjo and Oduor (2015), Kenyan consumption of energy is primarily dominated by biomass (68%), followed by petroleum product (21%) and electricity (9%), the remaining (1%) consisting of solar and other forms of energy. Wood fuel and charcoal are the main biomass sources of energy and are mainly used in rural areas where it is estimated that 80% of the population of Kenya relies on this kind of energy. On the other hand, imported petroleum and electricity are the two principal components of the domestic energy market in Kenya and consequently directed to a more considerable extent toward urban areas, supplying both households and businesses. In 2012, the total Kenyan consumption of energy amounted 4,117 thousand tonnes of oil equivalent (ttoe), down 3.4% on the previous year, use of liquid fuels accounted for 83.2%, that of Hydro and Geothermal Energy (HGE) and coke and coal for 11.6% and 5.1% respectively (Owiro *et al.*, 2015). Biomass constitutes the main source of primary energy in Kenya as it accounts for about 68% of the total energy use. According to the last survey carried out by the Kenyan government in 2002, 34.3 million of tonnes of biomass was consumed annually, of which 15.1 million made of fuelwood (firewood) and 16.1 million made of wood for charcoal, outlining the apparent domination of wood fuels as the share of the total biomass (Owiro *et al*., 2015). At the county level, Ngugi, Kipruto, and Samoei (2013) reported that less than 1% of residents in Siaya County use Liquefied Petroleum Gas (LPG), and 2% use paraffin. 83% use firewood, 15% use charcoal and 4% of the residents use electricity.

Lusambo (2016) reported that consumption of traditional fuels (i.e. firewood and charcoal) has negative environmental, economic and health impacts. That is, increased use of firewood and charcoal leads to deforestation, leading to ecological imbalance, and increased use of agricultural residues and animal dung deprives the land of essential nutrients that are necessary for soil fertility. Furthermore, smoke from the use of fuelwood and dung for cooking contributes to acute respiratory infections. This latter problem, i.e., indoor air pollution is worse in Siaya County, where households' houses are not equipped with separate living and cooking places (GOK, 2012). The County has a heavy dependence on traditional energy consumption (i.e. firewood and charcoal), with all the negative repercussions associated with it (Ngugi *et al*., 2013). The sectoral breakdown reveals that about 90% of the overall energy consumption of the County is that of households out of which the share of urban households is only 6%. Rural households almost entirely rely on traditional fuels, whereas the share of modern fuels (i.e. LPG, Kerosene/paraffin, etc.) in urban households' consumption is about 5%. Thus, the extent of dependence on traditional fuels is very significant (Ngugi *et al*., 2013). According to some estimates, the proportion of land under forest cover has declined to less than 1%. Despite these all, consumption of biomass fuel has been increasing (Owiro *et al*., 2015).

Knowledge about the various factors underlying the existing consumption pattern helps policymakers to prescribe measures that should strengthen the conditions that encourage the use of modern fuels while opting for actions that should weaken reliance on traditional fuels. Furthermore, knowledge of household income and energy price scenarios should be crucial for planning and forecasting energy demand and in assessing the effects of energy-related policies such as subsidies, taxes and energy conservation measures. Therefore, formulation and implementation of energy-related policy require detailed knowledge of the existing consumption pattern, underlying socio-economic and demographic factors influencing choice and demand to changes in prices, income, preferences etc.

Little is known about household energy consumption pattern in Siaya Township. Also, the report by Ngugi *et al*. (2013) is a first step that gives statistical knowledge on this topic but calls for further studies. For instance, Ngugi *et al*. (2013) provide summary percentage estimation of energy consumption per constituency. It implies that the report needs to be supplemented by the lowest administrative level (i.e. sub-location) information. That is to enhance it as a direct policy input on energy services at the sub-location level. Furthermore, sub-locations are the smallest administrative units for any targeted people and place-based policies. Thus, in line with the limited number of the empirical literature for knowledge dissemination and to enhance direct policy input for lower administrative levels, it was significant to update Ngugi *et al*. (2013) report by examining households energy consumption patterns in Siaya Township ward.

1.2. Statement of the Problem

Generally, there is heavy dependence on wood fuel (i.e. 83% firewood and 15% charcoal) in Siaya county as the primary source of energy. Thus, the use of firewood and charcoal fueled stoves indoors is an everyday practice in most of the households in Siaya County. Such heavy dependence at 98% causes poverty and environmental problems in the form of deforestation, biodiversity loss, air pollution, depletion of water sources and land degradation (Ngugi *et al*., 2013). However, little is known about the energy consumption pattern, especially in Siaya Township ward. Also, little is known about any energy policy from the county (i.e. local) government that is addressing the lowest administrative levels (i.e. sub-locations). It may be attributed to the unavailability of data on household energy consumption at the sub-locations. Therefore, understanding household energy consumption pattern is paramount in assessing energy development, especially at the lowest administrative unit. Unavailability of baseline data on energy consumption seriously impedes energy planning, policy-related work and environmental protection (Birol, 2010). Hence, this study aimed to determine households' energy consumption pattern in Siaya Township ward of Siaya County in Kenya.

1.3. Objectives of the study

1.3.1. General Objective

The overall aim of this study was to determine the households' energy consumption pattern and effects on the environment in Siaya Township ward of Siaya County in Kenya.

1.3.1.1. Specific Objectives

1 To determine factors influencing households energy consumption in Siaya Township ward.

2 Spatial analysis of households energy consumption pattern in Siaya Township ward.

3 To establish environmental effects associated with the use of wood fuel in Siaya Township ward.

1.4. Research Questions

1. What are the factors influencing energy consumption in Siaya Township Ward?
2. What are the spatial patterns of households' energy consumption in Siaya Township Ward?
3. What are the environmental effects associated with the use of wood fuel (i.e. firewood and charcoal) in Siaya Township ward?

1.5. Significance of the Study

The findings of this study are expected to inform people and place-based planning policies. It is also likely to contribute to efforts towards the development of efficient, reliable and modern energy services. These efforts are hoped to consequently curb planning and environmental problems and foster improved livelihoods of the households in the area. The county policy and decision makers are expected to make use of the findings from this study to devise short-term, medium-term and long-term planning strategies for sustainable energy development and management. The residents are also expected to be made more aware of the situation on the ground and thus facilitate energy use related behaviour change and for prudent energy-related environmental management.

Because Kenya had devolved her governance structure, both economic and political emphases of any county are on citizens or consumers as the ultimate target. While economics deals with the allocation of scarce resources among consumers' competing wants, people's welfare is the central concern of the political systems (Wood & Baldwin, 1985). Thus placing the citizen as the focal point sounds non-inconsequential as may contribute to a significant thrust on the side of politicians as far as energy issues and planning are concerned, and may provide the common perspective for experts from various disciplines (e.g. energy planners) as well as decision-makers and the broader local citizens (L. P. Lusambo, Monela, & Katani, 2007).

As documented by Ngugi *et al*. (2013), Siaya County household cooking alone takes up to 83% of the total national biomass energy use. It was, therefore, necessary and of significance to update this information at sub-location level, to determine critical current trends on energy consumption pattern in Siaya Township.

1.6. The scope of the Study & Limitations

The study was to determine factors influencing households energy consumption, spatially analyse households' energy consumption pattern, and establish the environmental effects associated with the use of wood fuel within Siaya Township ward. These are the specific areas where this study focused, discussed and drawn some conclusions. The recommendations are based on particular issues but educational, and other institutions within the study area were not considered for the study.

CHAPTER TWO: LITERATURE REVIEW

This chapter reviews the literature on the factors influencing households' energy (i.e. fuel) consumption, spatial analysis of households' energy consumption patterns, and environmental effects associated with the use of wood fuel.

2.1. Factors Influencing Households Energy Consumption

Ding, Qu, Niu, Liang, Qiang and Hong (2016) looked at factors influencing the spatial difference in household energy consumption in China using STIRPAT (Stochastic Impacts by Regression on Population, Affluence and Technology) model. They concluded that at the household level, geographic factors, economic factors and social factors influence energy consumption. The geographic factors are climate, terrain, vegetation, energy, mineral resources endowment, etc. because the human existence and progress highly rely on the natural environment. The economic factors are issues to do with household income level, gross domestic products, etc. while social factors are matters like households demographic characteristics, impact on lifestyle, etc. All these can be traced back to the cumulative households energy consumption patterns.

The understanding of household energy consumption in developing countries, is mainly built on the concept of fuel substitution, commonly known as the energy ladder hypothesis. The hypothesis postulates that as household socioeconomic status rises, the household in question abandons lower-level energy source(s) and switches to modern ones (Hosier & Dowd, 1987). Another hypothesis that tries to describe the household energy consumption is the "inverted-U hypothesis". This hypothesis postulates that household energy consumption varies proportionally with per capita income up to a certain level after which it starts decreasing, thereby making an inverted-U shape graph (Liu, Gao, Hao, & Liao, 2016). Energy consumption is also explained by a popularly used poverty-environment hypothesis which claims that poor people rely heavily on biomass fuels and thus causing forest degradation and deforestation and that addressing poverty issues is the key for sustainable forest resources management (Samuel & Gamtessa, 2003).

When modelling household energy consumption, a distinction should be made between direct energy use and indirect energy use. Direct energy use refers to the consumption of energy carriers purchased by consumers to cater to energy services. Indirect energy use refers to the energy used during various stages of production of commodities, also referred to as ‘embodied energy’ or ‘grey energy’ (Lusambo *et al*. 2007).

Bhattacharjee and Reichard (2011) did a systematic review of the literature to look at socio-economic factors affecting individual household energy consumption in the U.S.A. They found out that various studies list household size, household age structure, time spent at home, level of urbanization, dwelling size, dwelling type, age and characteristics of dwelling, education and knowledge, inertia to change, economic condition, energy price, energy efficient equipment affordability, weather and climate zone, dwelling microclimate and increased use of renewable energy.

According to Kenya Institute for Public Policy Research and Analysis-KIPPRA (2010) usage of fuel types by various income categories reveals that the use of material residue, kerosene and fuelwood declines with the rise in income. However, the trend for the use of charcoal, electricity, biogas and solar is reverse. The use of these fuels increases with the rise in income. Given that charcoal is regarded as ‘unclean fuel’, it is expected that households to substitute it with more clean fuel as income increases. However, the results of the KIPPRA (2010) study show that usage of charcoal does not change with an increase in income. Cost of installation was the most cited reason for not using Liquid Petroleum Gas, Electricity and Solar Energy Sources with most households classified as lower income groups not utilising these fuels. While the lower prevalence of electricity use in rural areas was attributed to lack of connectivity, lower Liquid Petroleum Gas (LPG) use was attributed to lack of access and information.

The key determinants for kerosene choice at the household were occupation, total energy expenditure, household size, fuelwood price, education level and price of LPG. About fuelwood choice, essential factors included the cost of fuelwood, household size and total expenditure. The critical determinants of choice for the use of charcoal included household size, the cost of charcoal, the price of fuelwood, education level, and both formal and informal employment. The regional dummies for Central were positive, implying that a household in Central Kenya is likely to use charcoal compared to Nairobi. The choice of electricity was determined by employment level, the price of wood fuel, and education level. Interestingly, households in urban areas would consume Motor Spirit Premium, even if the price increases. The critical determinants of Automotive Gas Oil include formal employment, its price, total energy expenditure at the household level and price of lubricants (KIPPRA, 2010).

The energy choice model results according to KIPPRA (2010), showed that certain vital factors drive demand for cooking fuels such as fuelwood, charcoal, kerosene, electricity and Liquefied Petroleum Gas (LPG) and vary depending on whether the household is located in rural or urban areas. Analysis of fuel types in Kenya by urban and rural areas showed that the most popular fuel types in terms of their various uses are: kerosene (80%), followed by charcoal (60%), fuelwood (55%), electricity (37%) and LPG (21%) in that order. The use of firewood, charcoal and kerosene in rural areas is higher, compared to urban areas. However, the use of LPG and electricity in rural areas is lower, compared to that of urban areas.

Various studies like Sander, Haider, and Hyseni (2011); Leach and Gowen (1987) have pointed out factors affecting household energy consumption such as current disposable income, household size, household type, fuel accessibility, fuel affordability, fuel reliability, fuel flexibility, low-pollution, climatic conditions, effective household size, dwelling type and ownership, household power relation; tradition and customs, stock of liquid assets (wealth); future income expectation, urban-rural location differences, and level of consumer indebtedness.

2.2. Spatial Analysis of Households Energy Consumption Patterns

The amount of energy consumption varies greatly depending on the spatial context (i.e. the developed world and developing world). Some regions have high consumption than others based on their needs and actions. Therefore, the per-capita quantitative spatial variation energy consumption for 2001 globally was 48,132MJ compared to 19,995MJ in Africa (Lusambo, 2016). According to Brown and Le Feuvre (2017); Timmons, Harris, and Roach (2014), biomass accounts for 10% of world primary energy supply and is the world's largest single renewable energy source. Thus, much of the world's population uses wood, charcoal, straw, or animal dung as cooking fuel.

In most Sub-Sahara Africa countries, the wood-based biomass energy sector employs a significant workforce, providing regular income to tens-if not hundreds-of-thousands of people (Intergovernmental Panel on Climate Change, 2007). Also in Okoko, Reinhard, von Dach, Zah, Kiteme, Owuor and Ehrensperger (2017), 94% of Africa rural population and 73% of the urban population use wood fuel as their primary source of energy, mainly in the form of firewood in rural areas and charcoal in urban areas. Additionally, Lusambo (2016) and Okoko *et al*. (2017) noted that the imbalance in energy uses exists between rural and urban and also between high and low-income groups.

When analysing the Kenyan situation, Kenya Institute for Public Policy Research and Analysis (2010) reported that about 70% of the consumers use biomass, while 30% use other fuels. The study showed kerosene to be mostly used for lighting (52%) while biomass was widely used for cooking (60%). Except for the transport fuels, the average monthly consumption per household was high for electricity at 386.01 Mega Joules compared to the other fuels (Kenya Institute for Public Policy Research and Analysis, 2010). Spatially, the energy budget shares for families differed across the regions, fuels as well as location, either rural or urban. Fuelwood had the highest energy budget share on average for both rural 11.6% and urban 9.34% compared to the other fuels (Kenya Institute for Public Policy Research and

Analysis, 2010). To this end, the households that consume more based on their needs and actions are placing a much higher strain on energy sources and environmental systems than they need. Also, differences in household needs, household stock, access to services and many other factors all lead to different energy requirements to attain the acceptable quality of life. In this case, using Geographical Information System (GIS) can help map energy data to aid in visualising spatial variation in consumption and difference between areas of excessive energy use and those of high energy need. It may be the new geography of energy, which can help show areas that need intervention through targeted placed-based policies and energy infrastructure development.

2.3. Environmental Effects Linked to Energy Sources

The study can also uncover environmental effects linked to energy sources, according to Ding et al. (2016) of geographic factors influencing energy consumption. The aspects of wood energy use are diverse. They range from local land use to global climate change and from applications in smoky kitchens to electricity generation in large-scale power stations. Consequently, environmental impacts of wood energy use and production can be both positive and negative, and an assessment of these impacts should always be part of wood energy policy making (Bhattarai, Heruela, Hulscher, Koopmans, Koppejan, Siteur, & Kraijo, 1997).

The vast majority of households in Sub-Saharan Africa (SSA) depend on wood energy, comprising firewood and charcoal for their daily energetic needs. Such consumption trends are expected to remain a common feature of SSA's wood energy production and supply chains, at least in the short- to medium-terms. Notwithstanding its importance, wood energy generally has low priority in SSA national policies (Legros *et al*., 2009). However, the use of wood energy is often considered a key driver of unsustainable management and negative environmental consequences in the humid and dry forests (Cerutti *et al*., 2015).

Because of its generalized lack of access to modern energy sources such as kerosene, liquefied petroleum gas (LPG) and electricity, Sub-Saharan Africa (SSA) with the exception of South Africa, where coal is a necessary fuel, has the most substantial proportion of its population relying on traditional biomass, mostly comprised of firewood and charcoal (Bauen, Berndes, Junginger, Vuille, & Londo, 2009). SSA also represents the worlds' highest regional per capita wood energy consumption, with an average consumption of 0.69 m^3/year in 2011, compared with a global average of 0.27 m^3/year (Iiyama, Dobie, Njenga, Ndegwa, & Jamnadass, 2014). An estimated 93% of households in SSA depend on wood energy for their daily cooking needs.

While firewood remains the preferred choice in rural areas, charcoal is especially prevalent in urban markets because of its higher energy content, ease of storage and transport, and lower smoke production compared to firewood (Mwampamba, Ghilardi, Sander, & Chaix, 2013; Iiyama *et al*., 2014). Charcoal is likely to become even more critical in the future as fossil fuels become less attractive due to environmental and financial costs (Mwampamba *et al*., 2013). Various case studies have reported an increase in charcoal use in SSA urban centres and this trend is expected to increase in the future, due to the absence of affordable alternatives (Iiyama *et al*., 2014).

Destruction of forests and wetlands in Kenya and the resultant biodiversity loss is also a critical environmental challenge. Population growth, agricultural expansion, urbanisation, over-dependence on wood fuels, and low levels of afforestation has accelerated deforestation in Kenya (Okoko *et al*., 2017). Loss of forests and wetlands can have consequences for ecosystems and food security. The majority of Siaya County's population depends on wood fuel for cooking. With estimates that 98% of households use firewood or charcoal for cooking and heating, population growth and associated increases in demand for farming and residential land will undoubtedly accelerate deforestation and exacerbate the effects of climate change in the county (Abura, Tonui, & Hayombe, 2017).

The report by Kenya Institute for Public Policy Research and Analysis (2010); Sander et al. (2011); Baker, Blundell, and Micklewright (1989); Leach and Gowen (1987) reveal that in the residential sector, there is extensive empirical literature on household energy demand with most papers are on micro-economics household energy demand at global and national level. But most of these studies pay little attention to the spatial analysis of households energy consumption patterns at the lowest administration level (i.e. local government) to help inform targeted people and place-based policies.

The report by Kenya Institute for Public Policy Research and Analysis (KIPPRA) (2010) which dwelt deeply on the Kenyan situation failed to give a thorough analysis per counties even though the study was done two years after the formation of county governments. The issue of the economics of industrial and commercial sectors' energy demand as an input in production is more elaborate but fails to clarify the economic imbalance at the county level. It also failed to capture the gains and failures of the next mile connectivity programme (rural electrification programme) by Kenya Power and Lighting Company sponsored by World Bank. Areas to do with renewable energy sources known to curb environmental degradation and health problems are not well articulated in their policy recommendations. Though this was an academic study, the researcher strived to determine the households' energy consumption pattern and effects on the environment in Siaya Township ward of Siaya County in Kenya to inform policy on energy planning and fill the missing spatial analysis knowledge gap at the lowest administrative level.

2.4. Conceptual Framework

This conceptual framework identified the households' energy consumption patterns by various energy sources and effects on the environment as a cause-effect relationship. The house generates demand for energy, which is supplied by multiple energy sources. The need for energy in particular wood fuel is primarily for use in cooking and heating. For example, Wood fuel is sourced from the forest as well as non-forest resources like plantations and farms. Also, various underlying socio-economic factors influence household energy consumption. Such factors may include disposable income, household size, household type, household location (i.e. urban or rural area), traditions and customs, etc. Continued reliance on wood fuel does result in reduced wood fuel availability, loss of forests, biodiversity loss, land degradation, depletion of water sources, the effect on environment conservation and natural regeneration. It has presented a significant challenge to households as they struggle to meet their daily energy demands.

With alternative energy options (i.e. Kerosene, electricity, LPG, biogas, solar, etc.) being expensive or scarce as compared to wood fuel, families develop coping strategies to respond to this challenge. A family may choose to adopt one or a combination of various coping strategies. These strategies have diverse effects on the poverty or wealth status of families, socio-economic development of places (i.e. the lowest administrative units), energy supply or demand as well as on the physical environment. Both national and county governments should intervene by instituting sustainable energy planning policies and laws that focus on households needs. These policies should be both people and place-based that detail the cause-effect relationship. Therefore, the conceptual framework is broadly categorised into two sections; the independent and dependent variables as shown in figure 1:-

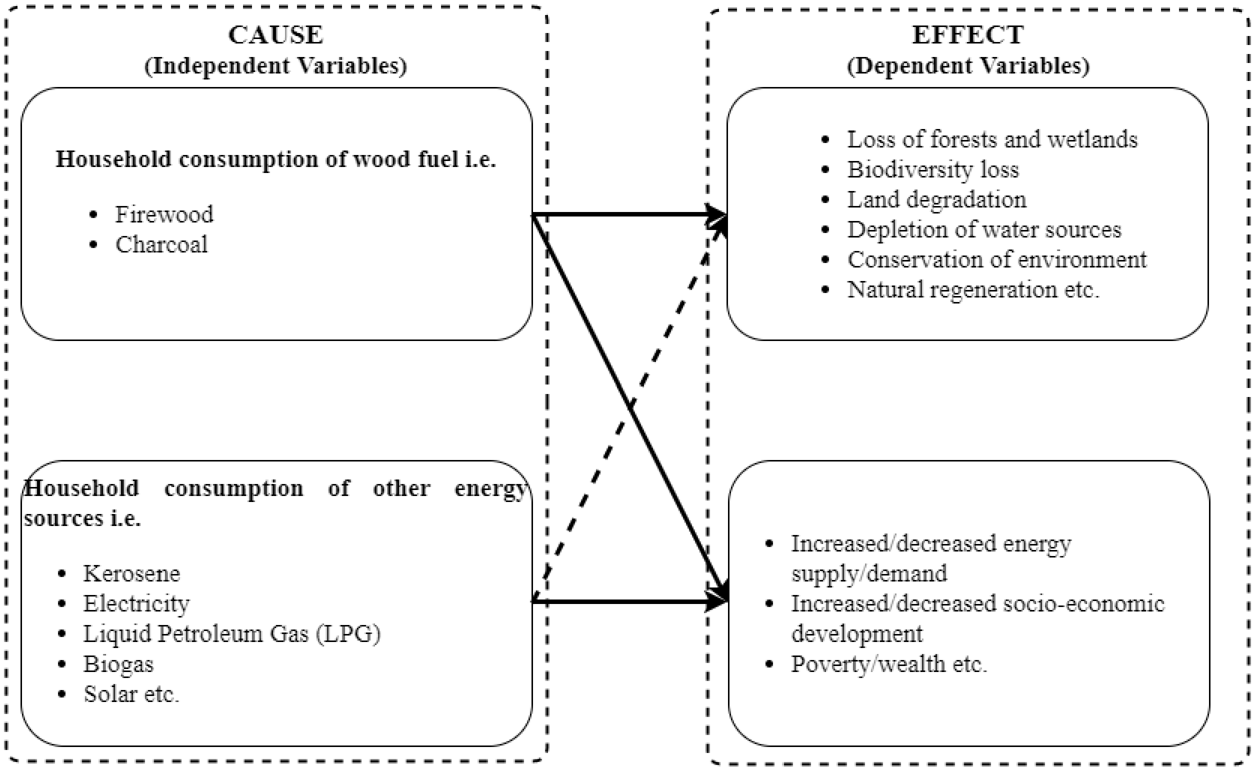

Figure 1: The research conceptual framework.

CHAPTER THREE: METHODOLOGY

After a review of the literature on factors influencing household energy consumption, spatial analysis of household energy consumption pattern and environmental effects linked to energy sources, this chapter gives a brief description of the study area in terms of its administrative boundaries, area and socio-demographic characteristics. Moreover, the chapter gives an overview of the research design, study population, sampling procedure and size, data collection methods, data analysis, and result presentation.

3.1. Study Area

Siaya County is one of the forty-seven (47) counties established under the new Constitution of Kenya 2010, made of the former Siaya district under the 1992 regions of Kenya (See Figure 2). It is made up of Alego-Usonga, Bondo, Rarieda, Gem, Ugenya and Ugunja sub-counties. On the other hand, Siaya county residents depend heavily on wood fuel as their primary source of energy despite having less than 1% forest cover. Siaya Township Ward has an area of 45.30 square kilometres with a population of 32,252 (i.e. 15,433 male and 16,819 female) forming 8,043 households as of 2009 National Housing and Population Census. It is made up of three sub-locations namely; Mulaha (2,220 households), Karapul (3,795 households) and Nyandiwa (2,028 households) as of 2009 National Housing and Population Census (See Figure 2).

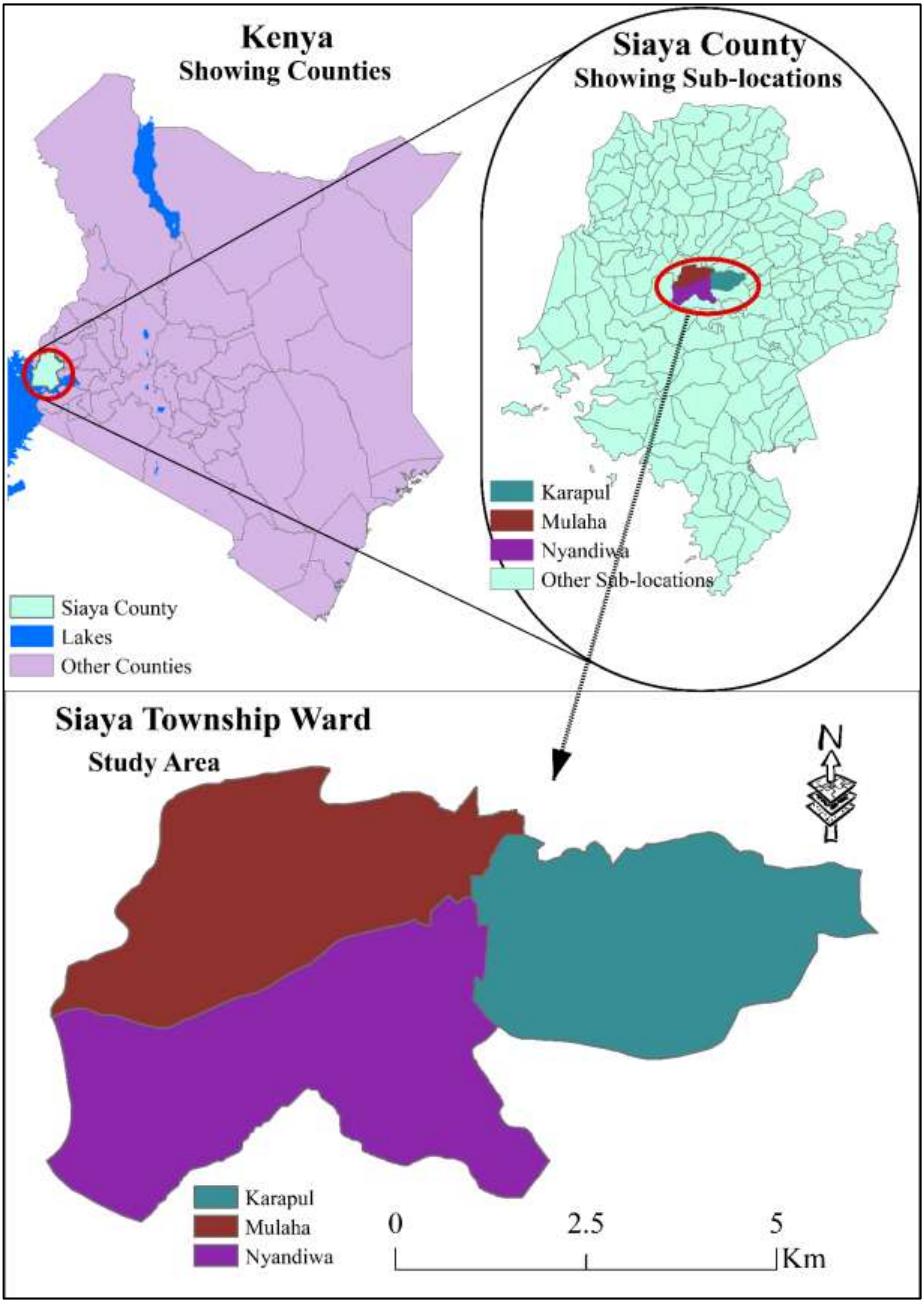

Figure 2: The study area.

3.2. Research Design

The study was a descriptive, analytical cross-sectional study design. It sought to determine the households' energy consumption pattern and effects on the environment. It was an analytic study because it entailed a spatial analysis of energy consumption in the study area. It was a one-time cross-sectional study; it could, therefore, not gauge the temporal variations or trends in the data collected. Regarding sample design, It entailed nine steps (see Figure 3). The overall objective was to have a sufficient study sample and representative of the Siaya Township target population. Therefore, the primary sampling units were the sub-locations of Mulaha, Nyandiwa and Karapul, but the unit of analysis was the individual/household.

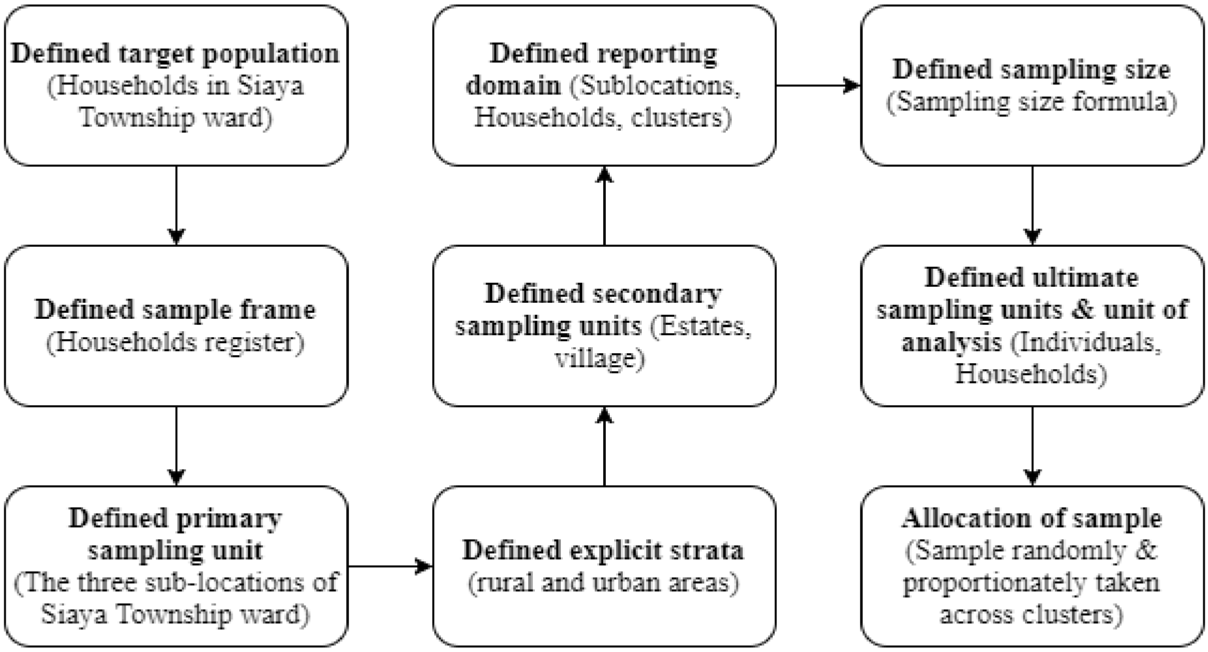

Figure 3: Steps in this study design. Source: Adapted from Shisana et al. (2004).

3.3. Study Population and Sampling

Siaya Township ward has a household population of 8,043 spread across its three sub-locations, as shown in table 3.

Table 3: Population distribution by sex, number of households, area and administrative units.

	Male	Female	Total	Households	Area Sq. Km.
Nyandiwa	4,063	4,184	8,247	2,028	17.8
Mulaha	4,275	4,651	8,926	2,220	13.7
Karapul	7,095	7,984	15,079	3,795	13.8
Siaya Township Total	**15,433**	**16,819**	**32,252**	**8,043**	**45.3**

Source: adapted from Wiesmann, Kiteme, and Mwangi (2016).

Sampling is a definite procedure determined before any data is collected for obtaining a sample from a given population (Kothari, 2004). The clustered random sampling design was used in this study. Clustering was done according to estates.

Siaya Township with a household population of 8,043 (i.e. 2,028 households in Nyandiwa, 2,220 households in Mulaha and 3,795 households in Karapul), the target was 95% confidence level of accuracy with the desired precision of 5%. The sample size was determined by the following general Solvins formula as stated by Madhuwanthi, Marasinghe, Rajapakse, Dharmawansa, and Nomura (2016) and the sub-locations sample sizes were arrived at as shown in table 4:-

Thus, the sample size;

$$n = \frac{\mathrm{N}}{(1+\mathrm{NE}^2)}$$

Where;

n	Sample size	
N	Household population size $\Rightarrow$	8,043
E	Error tolerance $\Rightarrow$	0.05

$$= \frac{8{,}043}{1 + (8{,}043)(0.05)^2}$$

$$= 381.05 \cong 381$$

Table 4: Sample size calculation per sub-location

Sub-location	Households	Sample size
Nyandiwa	2,028	$\frac{381}{8{,}043} \times 2{,}028 = 96$
Mulaha	2,220	$\frac{381}{8{,}043} \times 2{,}220 = 105$
Karapul	3,795	$\frac{381}{8{,}043} \times 3{,}795 = 180$
Siaya Township Ward Total	**8,043**	**381**

The primary reasons for using clustered sampling were:-

1. Cluster sampling is less expensive and quicker. It is more economical to observe clusters of units in a population than randomly selected groups scattered over throughout the study area.
2. Cluster sample permits each accumulation of large samples.
3. The loss of precision per individual case is more than compensated for by the possibility of studying larger samples for the same cost.
4. Cluster sample may combine the advantages of both random samplings as well as stratified sampling.
5. Cluster sampling procedure enables to obtain information from one or more areas.

3.4. Data Collection Methods

Tools used for primary data collection were questionnaires. A household questionnaire survey (see appendix 1) was designed to aid in primary data collection, which resulted in a total of 411 (i.e. 107.9 % of the sample size) questionnaires were administered. The summary in table 5 presents primary data collection per sub-location. In which case, Nyandiwa and Mulaha were oversampled by 56.3% and 11.4% respectively, whereas Karapul was undersampled by 20%. Oversampling was done in order to minimise and manage non-response rate to some questions and in some areas. It was necessary because the household survey was being carried out on weekdays and during working hours. It was anticipated that some target respondents might not have time for the field assistants.

Table 5: Primary data collection per sub-location

Sub-location	Households	Sample Size	Data Collected	Total Data Collected (%)	% of Sample Size
Nyandiwa	2,028	96	150	36.5	156.3
Mulaha	2,220	105	117	28.5	111.4
Karapul	3,795	180	144	35.0	80.0
Siaya Township Ward Total	**8,043**	**381**	**411**	**100**	**107.9**

Secondary data were obtained by database search from http://hub.arcgis.com/pages/open-data. The data were digitized in two steps using ArcGIS. The first step was to obtained Siaya county energy consumption data. The next step of digitization produced Siaya Township data. ArcGIS spatial analyst tool was used to analyse Siaya Township data to establish energy consumption pattern as per objective two of the study.

3.5. Data Analysis and Results Presentation

The household survey questionnaire data were analysed to find out the factors that influence energy consumption in Siaya township ward using descriptive analysis and Chi-Square tests of association using SPSS. The results are presented in tables and charts, as shown in chapter four.

Descriptive analysis is the mathematical clarification, solicitation and demonstration of the variables of interests or association between the variables in the collected data. Therefore, frequency tables, contingency tables, Chi-Square statistics tables etc. and bar charts, column charts etc. procedures summarising the data in a clear and understandable way is given (Kumar, 2011).

The chi-square statistic is a non-parametric (i.e. distribution-free) tool designed to indicate the level of evidence for an association between attributes. It is often supplemented by Cramer's V strength test to give more attribute information about the variables under study (Mchugh, 2013).

The data collected from the household survey questionnaire were mostly categorical data. It required the researcher to employ an appropriate analysis method to help unearth the data for proper interpretation. To this end, Chi-Square and Cramer's V statistics came in handy because of the richness with respect to the distribution of data, ease of computation, specific information given by the test, ability to help analyse multiple variables. The data from the household survey questionnaire did not meet parametric assumptions (Scott, Flaherty, & Currall, 2013; Miller & Siegmund, 2016). It takes the general formula given by Bryman (2012):

$$\chi^2 = \sum \frac{(O_{ij} - E_{ij})^2}{E_{ij}}$$

Where

χ^2= the cell Chi-Square value

O_{ij} = The observed frequency of the cell in the ith row and j column (i.e. gender by energy use variables)

E_{ij} = expected frequency of the cell in the ith row and j column (i.e. gender by energy use variables)

In which case, the following assumptions must hold: -

i. The data are a random sample from the population about which inferences are to be made; all the attributes are a nominal or ordinal (i.e. categorical data),
ii. Each item contributes data to only one cell. Therefore, the sum of all cell frequencies in the table must be the same as the number of elements in the sample (i.e. each observation is independent of all the others or one observation per subject).
iii. No more than 20% of the expected counts are less than 5, and all individual expected count are 1 or greater.

Environmental Systems Research Institute data was analysed using both ArcGIS. The data was available in kml and shapefile formats. Siaya county boundary data was extracted, and 100 by 100 metres tessellations was created (i.e. 1-hectare cluster polygon) and Siaya Township boundary was clipped. Also, the Siaya township energy consumption data was digitized from Siaya county data. The two attribute tables (i.e. Siaya Township boundary and energy data) were spatial joined based on spatial cluster cell location identity. Eventually, Siaya township ward data (i.e. 49 clusters) were obtained and analysed.

To seek clarity whether there is a clear pattern of energy consumption and to aid in further exploration, a cluster analysis (i.e. spatial analyst tool) was undertaken using the figures of average household energy consumption from electricity, paraffin/kerosene, LPG, Firewood, Charcoal and Solar. The one-hectare cluster analysis explained above was chosen as the most appropriate method for determining clusters and was carried out using ArcGIS based on the points mentioned in section 3.3. The final spatial analysis based on the ArcGIS defined clusters are presented and discussed in the form of consumption pattern maps and bar charts section 4.3.

3.6. Reliability and Validity

The primary data collection instrument (i.e. the household survey questionnaire) content reliability was ascertained through peer review and research supervisor scrutiny. This was to ensure the content was appropriate and relevant to the research as per the recommendation by Kothari (2004). In which case, a team of adjudicators can confirm the reliability of the instrument as was done by the research assessment panel during the research proposal defence. In this regard, Cronbach's Alpha was used to determine internal consistency, validity and reliability of the primary data collection instrument. It was done using SPSS, and the data collection tool was deemed reliable at Cronbach's Alpha of 0.908, as shown in appendix 2.

3.7. Research Ethics

Research ethics discussed by Bryman (2012) relating to the integrity of research such as informed consent, invasion of privacy, coercion and deception, any harm that might come to the participant, confidentiality, security and seeking permission from the relevant authorities to gain access to the field were critical to this research. It was to help collect the relevant data and get the information required.

Before embarking on household survey in Siaya Township, permission was sought from the Siaya county government and the County Commissioner. It was done by obtaining an introduction letter from the Dean School of Planning and Architecture, Maseno University explaining the purpose of the research. In this line, research assistants were trained to seek the informed consent of respondents by making them aware of the type of information required from them, why the information is being sought, explaining to them the purpose of the research, how they were expected to participate, how it will directly or indirectly affect them. The research assistants were also trained to explain to the respondents that the survey was a voluntary exercise, and they were not under any obligation to participate. In the whole exercise, the respondents' confidentiality was assured, and they were made aware that their individual identification was not attached to the household survey questionnaire.

CHAPTER FOUR: RESULTS AND DISCUSSIONS

The primary emphasis of this research concerned determining the households' energy consumption pattern and effects on the environment. Therefore, this chapter presents the results and discussion of the analysis of primary data from the household survey and secondary data from Environmental Systems Research Institute (ESRI). It covered the three specific objectives but starts with a summary descriptive statistics of the sample:-

4.1. Sample Socio-economic Characteristics

Individual and household characteristics are presented in table 6. Results show that female respondents represent more than half of the sample in Nyandiwa and Karapul (i.e. 58% and 59% respectively). Most of the respondents had a middle level (secondary and middle-level college) education. That is 82.1% in Mulaha, 77.2% in Nyandiwa, and 75.9% in Karapul. In terms of employment status, most of the respondents in all three sub-locations were self-employed (i.e. 54.4% in Mulaha, 48.9% in Nyandiwa, and 63.3% in Karapul). Also, more interviews were held in male-headed households (i.e. 70.9% in Mulaha, 66.2% in Nyandiwa, and 61.8% in Karapul). 68.4% of respondents in Mulaha, 54% of respondents in Nyandiwa and 64.6% of respondents in Karapul were married. Regarding energy consumption in the three sub-locations, 53% of respondents in Mulaha use firewood, whereas 36.7% of respondents in Nyandiwa use electricity and 33.3% of respondents in Karapul use charcoal, respectively.

Table 6: Sample socio-economic characteristics

Variables	**Mulaha n=117 (%)**	**Nyandiwa n=150 (%)**	**Karapul n=144 (%)**
Gender			
Male	58.1	42.0	41.0
Female	41.9	58.0	59.0
Educational level			
Low	8.5	11.4	12.8
Middle	82.1	77.2	75.9
High	9.4	11.4	11.3
Employment status			

Employed	17.6	23.9	20.3
Self-employed	54.4	48.9	63.3
Unemployed/other	28.0	27.2	16.4
Head of household			
Husband (Male)	70.9	66.2	61.8
Wife (Female)	19.7	27.7	30.6
Other	9.4	6.1	7.6
Marital status			
Single	31.6	46.0	35.4
Married	68.4	54.0	64.6
Energy use/consumption			
Electricity	30.4	36.7	30.5
Solar	3.5	2.7	0.7
Firewood	53.0	32.7	24.1
Charcoal	12.2	21.8	33.3
LPG	0.0	0.7	5.0
Kerosene	0.9	5.4	6.4

The results in table 6 show that socio-economic characteristics data of the households helped to bring knowledge of the end-user and choices of various sources of energy in Siaya Township. As evidenced by Jridi and Zouheir (2015), it also helps to identify the impact of the listed socio-economic and geographic variables on the study area households energy consumption, as discussed in sections 4.2 and 4.3. In this case, energy plays a role as a household commodity and as a cornerstone of socio-economic development (Bergasse, Dewulf, Paczynski, & Dabrowski, 2013). On the other hand, future research in Siaya Township household energy consumption or use can be facilitated by the same socio-economic characteristics data.

4.2. Factors Influencing Households Energy Consumption

After socio-economic characteristics of the sample, it was imperative to find out the factors influencing households' energy consumption as per objective one. It must be taken to note that most of the questions in the household survey questionnaire were designed to collect categorical data (see appendix 1). It called for an appropriate method. Hence, the Chi-Square (χ^2) test of association was used.

Chi-Square is a nonparametric statistical test to determine if two or more variables of the samples are related or independent or not. Thus, the test is used to discover if there is a relationship between two categorical variables (Ugoni & Walker, 1995; Zibran, 2007). The analysis was based on the hypothesis that there is no significant association or no relationship between the most energy or fuel consumed and household characteristics. Other parameters related to the test are explained in the methodology in chapter three, section 3.5.

From the analysis, as shown in table 7, the variable dwelling type violated the assumption that no more than 20% of the expected counts are less than 5, and all individual expected count are 1 or greater. It means that the data collected from the variable and energy use cross tabulation resulted in a negligible cell count. On the other hand, there was also no significant relationship between sub-location (i.e. household location), marital status with energy use, as shown in table 7.

Table 7: Factors influencing energy consumption.

Variable	**Chi-Square Statistic**	**The degree of Freedom (df)**	**Significance Level**	**Cramer's V**	**Excepted Cell Count Assumption (%)**
Head of Household/ Household type	17.1	2	$p<0.05$	0.2	0.0
Dwelling type	79.2	6	$p<0.05$	0.4	21.4
House ownership	47.3	1	$p<0.05$	0.3	0.0
Sub-location (Household location)	3.2	2	$p>0.05$	0.1	0.0
Marital status	1.1	1	$p>0.05$	0.1	0.0
Employment status	20.7	2	$p<0.05$	0.3	0.0
Educational level	55.6	2	$p<0.05$	0.4	0.0
Gender	13.8	1	$p<0.05$	0.2	0.0

The result suggests that these variables do not influence energy consumption or use in Siaya Township ward. But, there is a statistically significant association between each of the remaining five variables (see table 7) and energy consumption. It must be taken to note that among the statistically significant variables, almost all the variables had a small to moderate Cramer's V signifying the strength of the relationship (see appendix 3 for case processing summary).

Therefore, the type of energy consumed or used in a household in Siaya Township ward is influenced by whether one is a household head or not. The finding suggests that male, female and underage headed households energy consumption pattern is different in Siaya Township ward. Consequently, whether one owns the house they live in determines the energy or fuel consumed in that household. Furthermore, whether one is employed, self-employed or unemployed influences the energy consumed in a Siaya Township household. Educational level and gender are also factors found to be influencing energy consumption in Siaya Township. The findings corroborate what Buba, Abdu, Adamu, Jibir, and Usman (2017) found out when they looked at the socio-economic determinants of households fuel consumption in Nigeria and Bhattacharjee and Reichard (2011) review on socio-economic factors affecting individual household energy consumption. Thus, factors influencing energy consumption can only be unearthed based on the context of the study as pointed out in chapter two section 2.1 on the cases of Liu, Gao, Hao, and Liao (2016); Sander, Haider, and Hyseni (2011); KIPPRA (2010) Leach and Gowen (1987); Ding, Qu, Niu, Liang, Qiang and Hong (2016); Hosier and Dowd (1987).

4.3. Spatial Patterns of Households Energy Consumption

Figures 4 shows the energy consumption pattern in Siaya township ward per sub-location. Whereas Figure 4 compares the energy consumption patterns highlighting several cases per sub-location, Figure 5 maps the consumption pattern per household based on clusters per sub-location. The results in figure 4 and figure 5 were as per objective two. The homes were equally distributed within a group or cluster (i.e. cell tesselation) of one hectare (i.e. 10,000 square meters) using spatial analyst tool in ArcGIS explained in section 3.5.

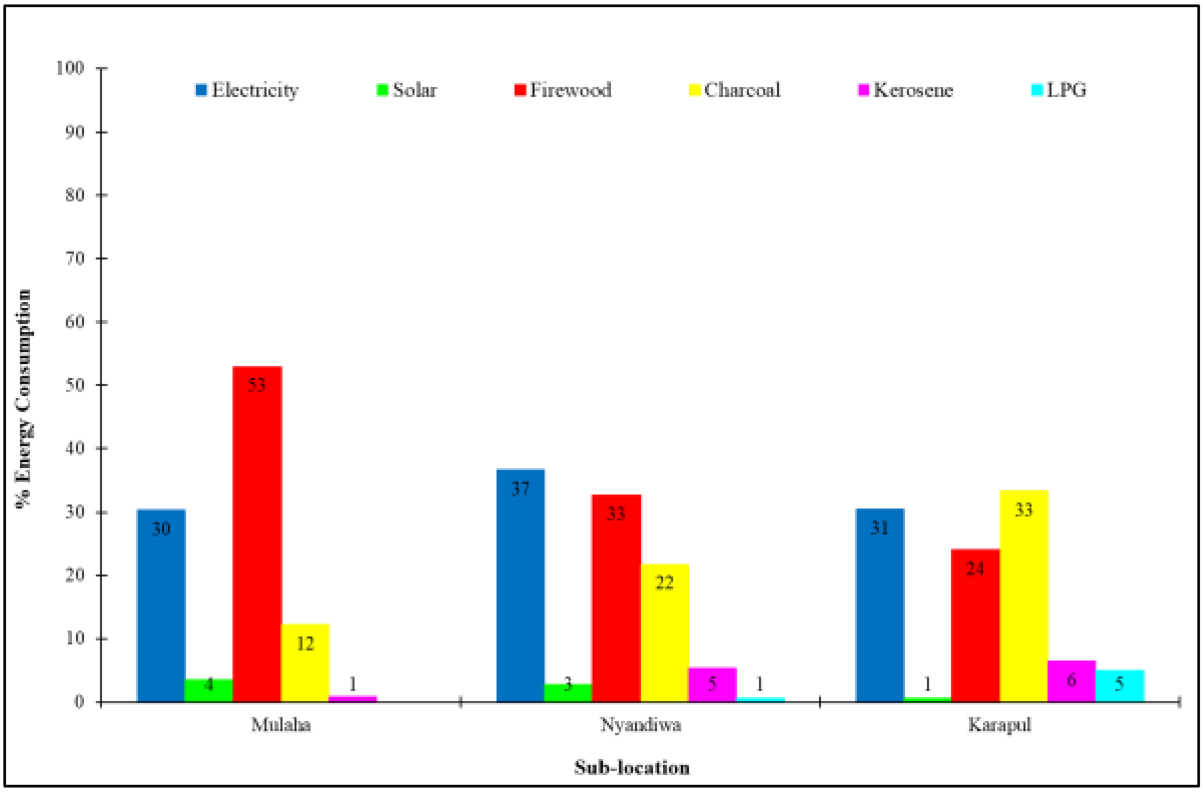

Figure 4: Siaya Township household energy consumption pattern.

Figure 4 shows that firewood is the primary source of energy for Mulaha households with more than half of the respondents (i.e. 53%) depending on it compared to Nyandiwa and Karapul households. Electricity is the most prefered energy source in Nyandiwa (37% of the respondents) compared to Mulaha and Karapul. Charcoal is the most prefered energy source in Karapul households (33% of the respondents) compared to Mulaha and Nyandiwa households. Figure 4 also helps to reveal that household geographic location (i.e. rural or urban) may be a factor that plays a role in the type of energy consumed in Siaya Township as found out in section 4.2.

Figure 5 also replicates the same picture but maps the spatial aspect of the energy consumption pattern in Siaya Township ward. Examining figure 5 reveals that on average most households in Mulaha use firewood (see figure 5a) followed by Nyandiwa, but charcoal (figure 5c) consumption is high in Karapul and Nyandiwa. In the same vein, most of the households that use Kerosene or Paraffin are found in Nyandiwa (see figure 5b). Further spatial analysis shows that on average, Nyandiwa is more serviced by electricity followed by Karapul and Mulaha as the least serviced (see figure 5d). Solar (see figure 5e) and LPG (see figure 5f) consumption is shared in small proportion in the three sub-locations.

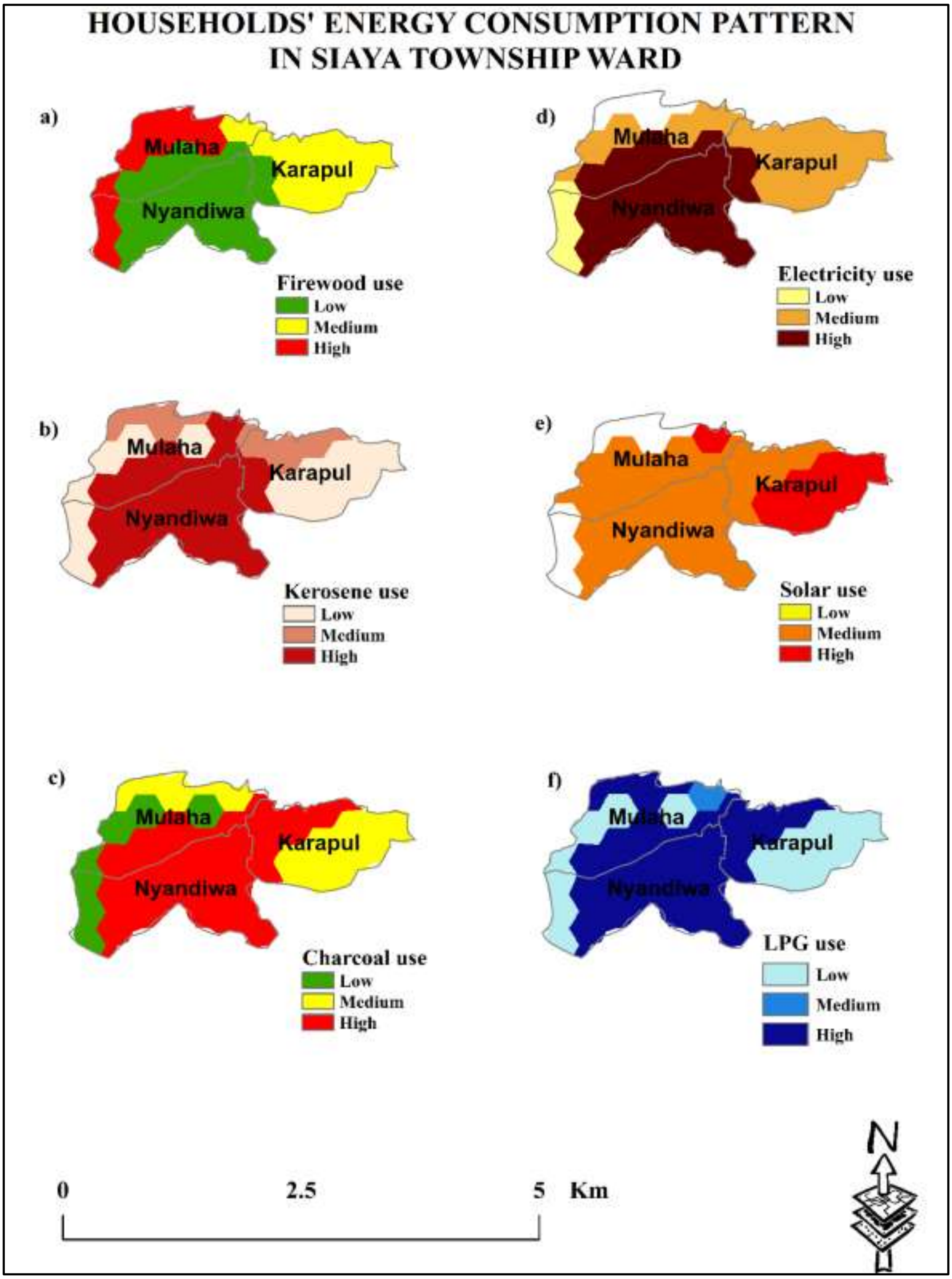

Figure 5: Siaya Township spatial pattern of energy consumption.

The spatial analysis of the energy consumption pattern in Siaya Township reveals that a large area of Nyandiwa fall is urban compared to other sub-locations. It means that access to petrol stations, LPG services, charcoal vendors and other energy service providers are within reach and are readily available. Most of the central business district is in Nyandiwa sub-location, and therefore, most modern energy services are concentrated here. On the other hand, households in this area can afford some of these services because of their geographic location, and they have the disposable income to trade for these services (i.e. 23.9% of the employed respondents reside in Nyandiwa as shown in table 6). The findings paint a very sorry state of the situation. It suggests a case of deprivation of essential modern energy services like electricity. It is like energy service providers in Siaya Township concentrate more on providing energy services to urban households than rural households. In this regard, analysing energy consumption pattern on a spatial scale (figure 5) comes in handy to help locate where the situation is worse and hence should inform and update targeted people and place-based policies at the lowest administrative level of the county government. The findings concur with what Ding, Qu, Niu, Liang, Qiang and Hong (2016) in the case of China on factors influencing the spatial difference in household energy consumption as reviewed in sections 2.1 and 2.2.

4.4. Environmental Effects Associated with the Use of Wood Fuel

In the third objective, the respondents were asked to fill a table based on a set of questions about wood fuel consumption and their view of the effects on the environment. The respondents answered using a Likert scale ranging from “strongly disagree” to “strongly agree” as shown in appendix 1. The scale was re-coded in SPSS from “disagree” to “agree” to meet the assumptions of the analysis method. The analysis method was the Chi-square test of independence. The results of the respondent's characteristics before re-coding are as shown in table 8.

Table 8: Effects on environmental as a result of woodfuel consumption.

Question	*Sub-location	Strongly disagree	Disagree	Do not know	Agree	Strongly agree
There has been a change in the environment; as a result of wood fuel use	Mulaha	0.0	5.2	3.4	35.3	56.0
	Nyandiwa	4.2	2.1	4.9	51.4	37.5
	Karapul	3.5	1.4	1.4	69.0	24.6
Vegetation cover has reduced as a result of wood fuel use	Mulaha	0.0	5.2	2.6	28.4	63.8
	Nyandiwa	2.1	7.6	1.4	36.6	52.4
	Karapul	2.8	6.4	2.1	63.8	24.8
Time spent on collecting firewood has increased over time	Mulaha	0.9	4.3	6.1	58.3	30.4
	Nyandiwa	8.3	9.7	9.0	42.4	30.6
	Karapul	4.3	23.0	6.5	53.2	12.9
Distance travelled to collect firewood has increased over time	Mulaha	0.9	7.8	5.2	55.2	31.0
	Nyandiwa	10.6	7.7	5.6	50.0	26.1
	Karapul	5.0	16.3	12.1	46.1	20.6
We are spending more on purchasing charcoal than before	Mulaha	0.0	1.7	2.6	38.8	56.9
	Nyandiwa	2.8	7.6	4.1	49.7	35.9
	Karapul	2.8	5.0	9.2	62.4	20.6
We are spending more on purchasing firewood than before	Mulaha	1.8	2.7	5.4	42.9	47.3
	Nyandiwa	15.6	4.3	12.8	38.3	29.1
	Karapul	12.1	15.2	9.1	50.8	12.9
We are cooking fewer times now	Mulaha	6.1	6.1	9.6	57.4	22.6
	Nyandiwa	16.0	22.2	11.8	22.2	27.8
	Karapul	21.8	39.1	9.8	18.8	10.5
We have shifted to using twigs and cow dung	Mulaha	24.6	27.2	4.4	14.9	28.9
	Nyandiwa	41.4	33.6	4.3	5.0	15.7
	Karapul	31.6	39.1	15.0	11.3	3.0
We are collecting firewood more times in a day than before	Mulaha	1.7	22.6	5.2	35.7	34.8
	Nyandiwa	13.3	14.7	12.6	35.0	24.5
	Karapul	21.3	30.1	11.8	30.1	6.6
We have reduced the amount of firewood used in a day as a result of scarcity	Mulaha	2.6	11.2	3.4	48.3	34.5
	Nyandiwa	13.3	16.1	7.7	29.4	33.6
	Karapul	9.5	21.9	11.7	39.4	17.5
We have reduced the amount of charcoal used in a day as a result of scarcity	Mulaha	2.6	13.0	3.5	40.9	40.0
	Nyandiwa	11.7	13.8	9.0	35.2	30.3
	Karapul	8.5	16.3	9.2	50.4	15.6
We have not adopted any strategy to cope with the challenges faced in sourcing for wood fuel	Mulaha	.9	4.3	2.6	38.8	53.4
	Nyandiwa	9.0	19.3	15.2	37.2	19.3
	Karapul	9.4	35.5	20.3	21.7	13.0

*Sub-location (Mulaha, n = 117, Nyandiwa, n = 150 and Karapul, n = 144)

Table 8 shows that almost all the respondents in all the three sub-locations agree that there has been a change in the environment (i.e 69% agree in Karapul, 51.4% agree in Nyandiwa, 56% stongly agree in Mulaha), reduction of vegetation cover as a result of wood fuel use (i.e 63.8% agree in Karapul, 52.4% strongly agree in Nyandiwa, 63.8% stongly agree in Mulaha). Also, almost all the respondents in all the three sub-locations agree that time spent in collecting firewood has increased over time (i.e 53.2% agree in Karapul, 42.4% agree in

Nyandiwa, 58.3% agree in Mulaha), they are paying more in purchasing charcoal (i.e 62.4% agree in Karapul, 49.7% agree in Nyandiwa, 56.9% strongly agree in Mulaha) and firewood than before (i.e 50.8% agree in Karapul, 38.3% agree in Nyandiwa, 47.3% strongly agree in Mulaha), they are cooking fewer times now because of the effect on environment (i.e 27.8% strongly agree in Nyandiwa, 57.4% strongly agree in Mulaha). On the contrary, most of the respondents in Nyandiwa and Karapul disagree that they have shifted to using twigs and cow dung (i.e 33.6% and 39.1% respectively). Thus, most of the respondents that use firewood and charcoal in all the three sub-locations, agree that they are collecting firewood more times in a day than before (i.e 30.1% agree in Karapul, 35% agree in Nyandiwa, 35.7% agree in Mulaha), they have reduced the amount of firewood and charcoal used in a day as a result of scarcity (i.e 39.4% agree in Karapul, 33.6% strongly agree in Nyandiwa, 48.3% agree in Mulaha), and they have not adopted any strategy to cope with the challenges faced in sourcing for wood fuel (i.e 21.7% agree in Karapul, 37.2% agree in Nyandiwa, 53.4% strongly agree in Mulaha).

The picture painted by the respondents' characteristics on environmental effects associated with the use of wood fuel alluded to the findings of Mwampamba et al. (2013) when they looked at dispelling common misconceptions to improve attitudes and policy outlook on charcoal in developing countries. In the case of Siaya Township, the signs of the adverse effects look like outway the positive results. To this end, further analysis to establish environmental impacts associated with the use of wood fuel in Siaya Township was carried out based on wood fuel consumption (i.e. firewood and charcoal) and environmental effects Likert scale questions. A Chi-square test of association was carried out to establish the independence of the relationship. The results in table 9 (see appendix 2 for case processing summary) shows that there is a significant relationship between the households' wood-fuel consumption and time spent (i.e. significant at χ^2 =17.4, df = 2, $p < 0.05$, N = 411 and validated by small association of Cramer's V = 0.2.), distance travelled to access the energy source (i.e. significant at χ^2 =18.1, df = 2, p < 0.05, N = 411 and validated by small association of Cramer's V = 0.2.), cost of the energy source (i.e. significant at χ^2 =12.4, df = 2, p < 0.05, N = 411 and validated by small association of Cramer's V = 0.2.), conservation and saving measures by the households (i.e. significant at χ^2 =16.3, df = 2, p < 0.05, N = 411 and validated by small association of Cramer's V = 0.2.), consideration of other alternative sources of energy (i.e. significant at χ^2 =16.9, df = 2, p < 0.05, N = 411 and validated by small association of Cramer's V = 0.2.) and the availability of the energy source in the Siaya Township (i.e. significant at χ^2 =16.1, df = 2, p < 0.05, N = 411 and validated by small association of Cramer's V = 0.2.).

Table 9: Chi-square statistic on wood-fuel consumption.

Variable	**Chi-Square Statistic**	**The degree of Freedom (df)**	**Significance Level**	**Cramer's V**	**Excepted Cell Count Assumption (%)**
Time spent on collecting firewood * Do you use charcoal in your household?	17.4	2	p<0.05	0.2	0.0
Distance travelled to collect firewood * Do you use charcoal in your household?	18.1	2	p<0.05	0.2	0.0
Spending more on firewood * Do you use charcoal in your household?	12.4	2	p<0.05	0.2	0.0
Cooking less * Do you use charcoal in your household?	16.3	2	p<0.05	0.2	0.0
Shifted to twigs and cow dung * Do you use charcoal in your household?	16.9	2	p<0.05	0.2	0.0
Collecting firewood more times * Do you use charcoal in your household?	16.1	2	p<0.05	0.2	0.0
Collecting firewood more times * Do you use firewood in your household?	16.4	2	p<0.05	0.2	0.0
Firewood use reduced because of	12.6	2	p<0.05	0.2	0.0

scarcity * Do you use charcoal in your household?					
Firewood use reduced because of scarcity * Do you use firewood in your household?	7.09	2	$p<0.05$	0.1	0.0
Charcoal use reduced because of scarcity * Do you use charcoal in your household?	16.1	2	$p<0.05$	0.2	0.0

The results in table 9 validate the findings evidenced by table 8 that there are environmental effects associated with the use of wood fuel, especially charcoal in Siaya Township ward. The environmental impact as a result of heavy dependence on woodfuel as a source of energy is what may be resulting to issues of climate change as highlighted by Abura et al. (2017) in their research on the influence of socio-demographic characteristics on perception climate change by fishers along Lake Victoria beaches in Siaya county. Also, the significance of the relationship of the variables, as shown in table 9 points to heavy dependence on wood-fuel as a source of energy in Siaya Township. It supports the findings of Iiyama et al. (2014) and Cerutti et al. (2015) that wood-fuel is the most depended upon as a source of energy in sub-Saharan Africa (SSA), and may be associated with adverse socio-economic and environmental outcomes such as deforestation, land degradation, soil erosion etc. Therefore, the case of Siaya Township may be a replica of what is happening in the entire county as far as environmental effects associated with the use of wood fuel is concerned.

CHAPTER FIVE: SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1. Summary of Findings

On objective one, determining factors influencing households energy consumption in Siaya Township ward, the study found out that being a household head places an individual in an everyday decision making position. That is why it influences household energy consumption. Also, house ownership, educational level and gender are other factors found to be influencing energy consumption in Siaya Township ward. House ownership goes with the responsibility of deciding whether to source for modern energy services like electricity, solar LPG, etc. Educational level carries with it the prestige and attitude to live a decent life hence its influence of energy consumption. Therefore factors influencing energy consumption in Siaya Township ward can be generalised into socio-economic and geographic or physical factors like gender, educational level, household head, household geographic location, house ownership etc.

Spatial analysis of households energy consumption pattern in Siaya Township as per objective two revealed that woodfuel (i.e. firewood and charcoal) is the most prefered source of energy. Also, the geographic location of the household (i.e. urban or rural) plays a role in the type of energy source preferred in the household. Despite the spatial difference, Kerosene or Paraffin and electricity are consumed by most households in urban placed sub-locations like Nyandiwa and Karapul.

On the other hand, environmental effects associated with wood fuel consumption as per objective three may be compounding by the day. It is because the study found out that there is a significant relationship between woodfuel consumption and several variables on respondents’views on environmental effects associated with the use of wood fuel. That is, time spent and distance travelled to access the energy source, cost of sourcing the energy, conservation and saving measures by the household, and availability of the energy source.

Thus, the direct effects on the environment are a reduction in forest cover, loss of wetlands, biodiversity loss, land degradation and depletion of water sources.

5.2. Recommendations and Conclusion

The heavy dependence on wood fuel as the primary energy source and its adverse effects may continue in Siaya Township ward until major policy interventions are initiated. It calls for an interdisciplinary approach to address the human and non-human factors that play a vital role in Siaya Township households' energy consumption. It can be done by public awareness of the effects of the current energy consumption pattern, the need to balance and institute conservation measures. Leadership from the county government in collaboration with the central government and private sector is called upon to subsidise the installation cost of green energy sources (e.g. solar, biogas, etc.). The same stakeholders are also called upon to help train and enhance human capacity to install and maintain such sources and put in place a credit facility for households that would want to invest the same.

The finding of this study is hoped to contribute to efforts towards the development of targeted people and place-based energy planning policies at the lowest administrative level like Siaya Township. The county policy and decision makers are hoped to make use of the findings from this study to meticulously consider devising short-term, medium-term and long-term multiple planning strategies for sustainable energy development and management. It can be accomplished by the manoeuvring of the various political, social, cultural, individual and economic influences on household energy consumption in Siaya Township. It is also expected that this study will contribute to the academic body of knowledge on the energy consumption patterns and effects on the environment in contexts like Siaya Township.

5.3. Areas for Further Research

Based on the limitations of the categorical data collected and analysis method employed, the researcher is of the view that future research may look at in-depth qualitative and quantitative analysis of energy choice behaviour (i.e. energy choice modelling) in the same context to help quantify factors affecting energy consumption and efficiency to bring a deeper understanding for future energy planning.

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APPENDICES

Appendix 1: Household Questionnaire.

10

Questionnaire

Basic Information:

1. Which is your sub-location? Please tick one.
   a) Mulaha
   b) Nyandiwa
   c) Karapul

Characteristics of Household:

2. What is your marital status? Please tick one.
   a) Married
   b) Never married
   c) Widowed
   d) Divorced
   e) Separated
3. Who is the head of household? Please tick one.
   f) Husband (male)
   g) Wife (female)
   h) Other (specify)
4. What is the dwelling type? Please tick one.
   a) Concrete/burnt bricks/iron roof
   b) Concrete/burnt bricks/grass roof
   c) Un-burnt bricks/iron roof
   d) Unburnt bricks/grass
   e) Mud-house/iron roof
   f) Mud-house/grass roof
   g) Other types
5. What is the educational level reached? Please tick one and specify.
   a) Illiterate
   b) Primary education
   c) Secondary education
   d) Adult education
   e) College education
   f) University education
   g) Others (specify)
6. What is your employment status? Please tick one.
   a) Employee
   b) Formally employed
   c) Informally employed
   d) Casual laborer
   e) Artisan
   f) Trade/shop
   g) Petty business
   h) Firewood/charcoal vending
   i) Housework
   j) Others

7. If employed, what is your income? —

8. Do you own the house you live in?
   a) Rented
   b) Owned
9. What is your gender? Please tick one.
   a) Male
   b) Female
10. What is your age? 32

11. How many are you in your household? 3

12. Which type of energy (fuel) do you use most?
    a) Electricity
    b) Solar
    c) Biogas
    d) Firewood
    e) Charcoal
    f) LPG
    g) Kerosene
    h) Other (specify)

Households' energy (fuel) use:

Electricity:

13. Do you use electricity in your household?
    a) Yes
    b) No
14. Source of electricity you use in your household?
    a) Generator
    b) Solar
    c) Main supply
    d) Other (specify)

Please indicate the total electricity used in the?

Duration	KWh	Kshs
Last 1 month		
Last 2 months	N/A	N/A
Last 3 months		
Last 4 months		

LPG:

15. Do you use LPG in your household?
    a) Yes
    b) No
16. Source of electricity you use in your household?
    a) Nearby LPG filling station
    b) Local retailer
    c) LPG distribution truck
    d) Other (specify)

17. Please indicate the size of LPG cylinders used by your household for the last four months (Kg)? N/A

18. How often do you fill your LPG cylinder(s)?

Duration	
Very often	
Once	
Weekly	N/A
Monthly	
After 4 months	
Quarterly	
Daily	

19. Please indicate the amount you spent on LPG in?

	Kshs
2014	
2015	N/A
2016	

Kerosene:

20. Do you use kerosene in your household?
   a) Yes
   b) No
21. Source of kerosene you use in your household?
   a) Nearby filling station
   b) Local retailer
   c) Distribution truck
   d) Other (specify)
22. How often do you buy kerosene?

Duration	
Very often	
Once	
Weekly	✓
Monthly	
After 4 months	
Quarterly	
Daily	

23. Please indicate the amount you spent on kerosene in?

	Kshs
2014	2000
2015	3000
2016	5000

24. Please indicate the size of your kerosene storage container?

Fanta/coke bottle	
Beer bottle	
Jerican 5 litres	✓
Others (specify)	

Charcoal:

25. Do you use charcoal in your household?
    a) Yes
    b) No
26. Source of charcoal you use in your household?
    a) Nearby agent
    b) Local retailer
    c) Distribution truck
    d) Local market
    e) Own farm
    f) Other (specify)
27. Use of charcoal in your household (Quantity)?
    Jiko approx. 2 kg daily
28. Use of charcoal in your household (Days)?
    Every day
29. Use of charcoal in your household (Amount)?
    Ksh. 500 per sack

Firewood:

30. Do you use firewood in your household?
    a) Yes
    b) No
31. Source of firewood you use in your household?
    a) Nearby agent
    b) Local retailer
    c) Distribution truck
    d) Local market
    e) Own farm
    f) Other (specify)
32. Use of charcoal in your household (Quantity)?
    N/A
33. Use of charcoal in your household (Days)?
    N/A
34. Use of charcoal in your household (Amount)?
    N/A

Biogas:

35. Do you use biogas in your household?
    a) Yes
    b) No
36. Source of biogas you use in your household?
    a) Nearby farm
    b) Own farm
    c) Other (specify)

- **Environmental effects associated with the use of wood fuel (Firewood & Charcoal)**

37. Please rate how strongly you agree or disagree with the following statements by ticking on the appropriate box

	Strongly disagree	Disagree	Do not know	Agree	Strongly agree
There has been change in environment as a result wood fuel use					✓
Vegetation cover has reduced as a result of wood fuel use					✓
Time spent on collecting fire wood has increased over time				✓	
Distance travelled to collect firewood has increased over time					✓
We are spending more in purchasing charcoal than before					✓
We are spending more in purchasing firewood than before			✓		
We are cooking fewer times now				✓	
We have shifted to using twigs and cow dung	✓				
We are collecting firewood more times in a day than before	✓				
We have reduced the amount of firewood used in a day as a result of scarcity	✓				
We have reduced the amount of charcoal used in a day as a result of scarcity					✓
We have not adopted any strategy to cope with the challenges faced in sourcing for wood fuel		✓			

Appendix 2: Cronbach's Reliability Statistics.

Case Processing Summary

		N	%
Cases	Valid	337	82.0
	Excluded[a]	74	18.0
	Total	411	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.908	.912	23

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
There has been a change in the environment as a result of wood fuel use	66.19	171.117	.408	.906
Vegetation cover has reduced as a result of wood fuel use	66.15	168.768	.464	.905
Time spent on collecting firewood has increased over time	66.65	163.461	.573	.903
Distance travelled to collect firewood has increased over time	66.60	163.901	.561	.903
We are spending more on purchasing charcoal than before	66.24	169.637	.464	.905
We are spending more on purchasing firewood than before	66.63	161.830	.572	.903
We are cooking fewer times now	67.24	159.021	.572	.903
We have shifted to using twigs and cow dung	68.00	165.158	.371	.910
We are collecting firewood more times in a day than before	67.01	158.363	.629	.901
We have reduced the amount of firewood used in a day as a result of scarcity	66.81	157.702	.662	.901
We have reduced the amount of charcoal used in a day as a result of scarcity	66.74	160.281	.593	.902
We have not adopted any strategy to cope with the challenges faced in sourcing for wood fuel	66.86	160.864	.573	.903
Vegetation cover reduction	67.61	174.502	.393	.907
Time spent on collecting firewood	67.83	168.748	.577	.903
Distance travelled to collect firewood	67.80	169.610	.548	.904
Spending more on charcoal	67.59	175.528	.355	.907
Spending more on firewood	67.84	169.978	.518	.904
Cooking less	68.29	164.938	.617	.902
Shifted to twigs and cow dung	68.84	170.673	.416	.906
Collecting firewood more times	68.15	165.615	.613	.902
Firewood use reduced because of scarcity	68.00	165.896	.631	.902
Charcoal use reduced because of scarcity	67.94	168.422	.531	.904
Adopted any strategy to cope	68.07	167.402	.557	.903

Appendix 3: Chi-Square Variables Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Who is the head of household? * Energy Use	401	96.9%	13	3.1%	414	100.0%
What is the dwelling type? * Energy Use	403	97.3%	11	2.7%	414	100.0%
Do you own the house you live in? * Energy Use	402	97.1%	12	2.9%	414	100.0%
Which is your sub-location? * Energy Use	403	97.3%	11	2.7%	414	100.0%
Marital Status * Energy Use	403	97.3%	11	2.7%	414	100.0%
Employment * Energy Use	232	56.0%	182	44.0%	414	100.0%
Education Level * Energy Use	401	96.9%	13	3.1%	414	100.0%

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Environment change * Do you use charcoal in your household?	400	96.6%	14	3.4%	414	100.0%
Environment change * Do you use firewood in your household?	394	95.2%	20	4.8%	414	100.0%
Vegetation cover reduction * Do you use charcoal in your household?	400	96.6%	14	3.4%	414	100.0%
Vegetation cover reduction * Do you use firewood in your household?	394	95.2%	20	4.8%	414	100.0%
Time spent on collecting firewood * Do you use charcoal in your household?	400	96.6%	14	3.4%	414	100.0%
Time spent on collecting firewood * Do you use firewood in your household?	394	95.2%	20	4.8%	414	100.0%
Distance travelled to collect firewood * Do you use charcoal in your household?	400	96.6%	14	3.4%	414	100.0%

Distance travelled to collect firewood * Do you use firewood in your household?	394	95.2%	20	4.8%	414	100.0%
Spending more on charcoal * Do you use charcoal in your household?	400	96.6%	14	3.4%	414	100.0%
Spending more on charcoal * Do you use firewood in your household?	394	95.2%	20	4.8%	414	100.0%
Spending more on firewood * Do you use charcoal in your household?	400	96.6%	14	3.4%	414	100.0%
Spending more on firewood * Do you use firewood in your household?	394	95.2%	20	4.8%	414	100.0%
Cooking less * Do you use charcoal in your household?	400	96.6%	14	3.4%	414	100.0%
Cooking less * Do you use firewood in your household?	394	95.2%	20	4.8%	414	100.0%
Shifted to twigs and cow dung * Do you use charcoal in your household?	400	96.6%	14	3.4%	414	100.0%
Shifted to twigs and cow dung * Do you use firewood in your household?	394	95.2%	20	4.8%	414	100.0%
Collecting firewood more times * Do you use charcoal in your household?	400	96.6%	14	3.4%	414	100.0%
Collecting firewood more times * Do you use firewood in your household?	394	95.2%	20	4.8%	414	100.0%
Firewood use reduced because of scarcity * Do you use charcoal in your household?	400	96.6%	14	3.4%	414	100.0%
Firewood use reduced because of scarcity * Do you use firewood in your household?	394	95.2%	20	4.8%	414	100.0%
Charcoal use reduced because of scarcity * Do you use charcoal in your household?	400	96.6%	14	3.4%	414	100.0%

Charcoal use reduced because of scarcity * Do you use firewood in your household?	394	95.2%	20	4.8%	414	100.0%
Adopted any strategy to cope * Do you use charcoal in your household?	400	96.6%	14	3.4%	414	100.0%
Adopted any strategy to cope * Do you use firewood in your household?	394	95.2%	20	4.8%	414	100.0%