AN ANALYSIS OF DETERMINANTS OF ADOPTION OF CLEAN ENERGY COOKING TECHNOLOGIES AND ENERGY SOURCES IN KIBERA, NAIROBI COUNTY - KENYA

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DECLARATION

This thesis is my original work and has not been presented for any degree in any other university

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DEDICATION

This thesis is dedicated to my family: my parents, Mr and Mrs Amesa and my siblings Jude and Miriam.

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ABSTRACT

Acknowledgement of the effects of climate change on the planet over the last 3 decades led to the United Nations Framework Convention on Climate Change (U.N.F.C.C.C.) and the Kenyan government to champion for climate change mitigation. One of the mechanisms identified by the government towards climate change mitigation was the increased use of clean energy technologies (CETs). These are technologies that have a significantly lower effect on the environment than their alternatives. At the household level, the clean energy technologies are mostly used for cooking and lighting purposes and they play a role in improving the welfare of the household members through improved fuel efficiency and lower energy costs. Though these technologies are available, their adoption has been low even as demand for energy is continuously increasing. This study aimed at characterizing the different clean energy technologies used for cooking and assessing the unique factors that influence the decision to adopt multiple clean energy cooking technologies. The study was based on the Random Utility Model (RUM) and was supported by the energy stack model. Multistage sampling was used to get a sample of 378 respondents in Kibera; a low income and densely populated area in the outskirts of Nairobi. The Kenya ceramic *jiko* was found to be the most adopted cooking technology while charcoal was found to be the most used cooking energy source. The key decisions on cooking technologies and energy sources adopted by the household were made by both male and female members in varying proportions. The adoption decisions of cooking technologies were found to be influenced by a variety of technologies' traits. Using the Poisson regression model, the sex of the individual who did most of the cooking was found to be a statistically significant factor in the adoption of multiple clean energy cooking technologies. The prices of the cooking technologies, as well as the prices of the cooking energy sources, were also found to have a statistically significant effect on the adoption of multiple cooking technologies. To facilitate the adoption of clean energy cooking technologies (CECTs), the

study advocates for regulation of clean energy cooking technologies and energy source prices to make them more affordable to the low-income earners. Investment in the innovation of cheaper and cleaner cooking technologies is also recommended to encourage further adoption. The study also recommends the improvement of access to the CECTs in the area through clean energy entrepreneurship programs in the area and this will facilitate economic empowerment; making them more likely to finance a portion of the energy needs of the household.

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ACRONYMS

CETs	Clean Energy Technologies
CECTs	Clean Energy Cooking Technologies
COP	Conference of Parties
DOI	Diffusion of Innovation
GHG	Greenhouse Gas
kWh	Kilowatt-hour
LPG	Liquefied Petroleum Gas
SDG	Sustainable Development Goals
RUM	Random Utility Model
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
US$	United States Dollar

DEFINITION OF TERMS

- Clean energy cooking technologies - Cooking systems that produce negligible or minimal amounts of environmental pollution compared to conventional technologies
- Energy source – this is the commodity that is used by a cooking technology to generate heat for cooking
- Fuel efficient – consumption of lower quantities of an energy source. This can be through more intensive combustion of the energy source hence lower waste relative to other combustion processes by other cooking technologies

CHAPTER ONE

1.0. INTRODUCTION

1.1. Background

1.1.1 Introduction to Clean Energy Technologies

Interests to encourage the adoption of clean energy technologies with the goal of reducing the human effect on global warming have been on the rise in today's world. Global warming has been viewed as a key limitation to sustainable development and has an effect on the survival of life on earth in the long run.

Clean energy technologies are electricity and/or heat-producing systems that produce negligible or minimal amounts of environmental pollution compared to conventional technologies (Herzog *et al*. 2001). These technologies have both small-scale uses for households as well as large scale commercial uses. For commercial purposes, the technologies are often used in the large-scale production of electricity while at the household level, the technologies are used for a wider variety of purposes. The most common household uses include heating, cooking and off-grid electricity production. In the generation of electricity, renewable energy sources such as solar, geothermal, wind, tidal, wave and hydro-power are often used due to their economies of scale benefits. Their utilization is meant to increase the amount of electricity going into the national grid however the improvement in solar and wind power generation has led to the development of household electricity solutions that are cost-effective at the household level. For heating purposes at household level; electricity, biofuels as well as solar and wind are used either independently or in varying proportions to meet the individual houses' needs.

Climate change mitigation has been a topic of discussion among a majority of the countries and is being spearheaded by the United Nations. This is because climate change has been identified as the main threat to the world's sustainable development. In an effort for nations to have a common approach towards climate change mitigation, the United Nations Convention for Climate Change (UNFCCC) was formed to provide a forum in which the nations can engage and work together to combat climate change. One of the identified courses of action was the increased use of clean energy technologies in energy generation and consumption (UNIDO, 2006).

The Kenyan government is a strong proponent for the use of clean energy technologies. Through legislation and direct investment in clean energy production, the government has motivated the use of clean energy technologies (CETs) in the country (Ministry of Energy, 2018). These investments are aimed at achieving the goal of reducing greenhouse gas emissions in the country by 30% before 2030 (Ministry of Environment And Natural Resources, 2015a). to achieve this goal, use of clean energy technologies together with clean energy sources is being encouraged in the country. In Kenya, the most used energy source is biomass accounting for 80% of urban energy consumption and 34% of rural energy consumption (Mugo & Ong, 2006). The other popular cooking energy sources are electricity, biogas, liquefied petroleum gas (LPG) and kerosene.

1.1.2 Adoption of Clean Energy Cooking Technologies

Based on Herzog *et al*., (2001) definition of clean energy technologies, clean energy cooking technologies can be defined as cooking systems that produce negligible or minimal amounts of environmental pollution compared to conventional technologies. Conventional technologies are often referred to as traditional cooking technologies. These clean energy cooking technologies do utilize a variety of cooking energy sources and are designed to be better than the previously used technologies. These technologies have higher efficiencies in energy source consumption and thermal utilization with lower GHG emissions. They are also more secure to use and have lower costs of maintenance compared to their predecessors due to their higher combustion efficiency.

1.1.3. Risks associated with the lack of use of clean energy cooking technologies in the household

The lack of adoption of CECTs at the household level presents a number of risks to the household members. It is often the female members who are most exposed to the negatives associated with traditional cooking technologies' use. This can be attributed to the gender assigned roles given by society to female members.

Cooking is one of the key activities that is associated with female household members hence puts them at more risk situations linked to using cooking technology use. These risks include increased exposure to harmful gases associated to the use of cooking technologies and risk of being physically harmed by the use of specific cooking technologies (Cecelski, 2000; Karakesi *et al*.2004; Lam *et al*. 2012; Sikei *et al*. 2009). The reduction in smoke produced from the use of clean energy cooking technologies reduces the woman's exposure to the poisonous by-products of firewood combustion such as carbon monoxide and various Sulphur and nitrous oxides (Lam *et al*., 2012).

The children in the household are also associated with the risks experienced in the case where the female member is a mother. By staying close to the mother when cooking is being done, the children are just as exposed as the mother to the harmful gaseous emissions. The duty of cooking in some cases is however also delegated to the children in the household and this increases their exposure to the negative gases. The use of kerosene has a number of negative effects of the users' health which include carbon poisoning from inhaling carbon dioxide and carbon monoxide upon its combustion while the fumes it produces before combustion can cause poisoning due to its chemical composition (UNEP, 2005).

1.1.4. The role of CECT in climate change mitigation and environmental conservation

Focus on sustainable development has led to increased concerns over issues of climate change. The late Kofi Annan acknowledged that "…the carbon-intensive energy systems that drive our economies have set us on a collision course with our planetary boundaries" (Africa Progress Panel, 2015). Given the evidence of climate change and its adverse effects, clean energy technologies have been identified as a worthwhile solution to climate change mitigation at the household level (Jain *et al*. 2015). However, due to the lack of consistent and sufficient data, the reduction in global emissions from the use of CECTs cannot be accurately determined.

The CECTs that use biomass have two main effects on climate change. First, they use fewer units of the energy source, therefore, saving the planet's forest cover which serves as water towers and natural carbon sequestration systems. Secondly, clean energy technologies minimize the level of GHG emissions in the household through the efficient combustion of the energy source used.

On large scale operations, wind and solar technologies are used in clean electricity generation as opposed to using petroleum-based energy sources the use of clean energy technologies have been found to significantly reducing fossil fuel use in electricity generation (Randall, 2016). The high rate of innovation in the energy sector is what has led to the lower costs of generating electricity through solar and wind power. With more investment and research in the sector, the cost of production of clean electricity is bound to get even lower (IRENA, 2016). This increases the chances of use of electricity as a major cooking energy source hence reduce pressure on the dwindling forest resources. The use of such clean technologies has proven to meet the energy needs of entire countries and have even surpassed the demand in some instances such as in Germany (Coren, 2016).

Given that household energy consumption accounts for over 25 % of the total energy consumption in developing nations (Dzioubinski & Chipman, 1999), the use of CETs at the household level is a viable approach to climate change mitigation. It has been documented that the use of clean energy cooking technologies reduced greenhouse gas emissions by up to 50 % (Stone *et. al*, 2008). This is in line with the Kenyan government's goal of reducing the overall nation's GHG footprint.

1.1.5. Adoption of clean energy sources

There are different energy sources being consumed for commercial and domestic purposes. Fossil energy sources which are energy sources that are a product of decomposed prehistoric organic material have been the main source of energy. Since the 19th century, coal and oil-based energy sources have been the mainly consumed fossil energy sources. Biomass is also a commonly used energy source, especially among the developing nations. These are "organic, non-fossil material of biological origin constituting an exploitable energy source" (Herzog *et al*., 2001). The energy produced from biomass is known as bioenergy. Both fossil and biomass energy sources have by-products from the combustion process that results mainly in the production of heat and other forms of energy. The gaseous by-products contribute to the global warming process by increasing the GHG concentration in the atmosphere. Fossil energy sources are considered to be unclean energy sources due to the negative footprint they leave once they are used and their use is not sustainable in the long run. This is due to the limited availability of oil which will be depleted over time. Clean energy sources are the sources that have little or no negative footprint on the earth's atmosphere while being sustainably available for use. The technologies used to capitalize on these energy sources take advantage of naturally occurring resources and processes to generate energy. Solar, wind and geothermal energy are the mainly used clean energy sources in Kenya; with other technologies such as the use of tidal power being increasingly accepted for large scale electricity production. Though biomass has

GHG emissions, it is considered a clean source due to its ability to be reproduced over time through natural processes.

1.1.6. Energy consumption in Kenya

Demand and consumption of energy in general within Sub-Saharan Africa has been on a steady increase and is expected to continue growing as African economies continue to pursue economic development. In 2001, biomass and petroleum products accounted for 59 % and 25 % respectively as the main energy sources while electricity accounted for 8% with coal and gas accounting for 4% each (Karakesi *et al*., 2004). Sub-Saharan Africa highly depends on biofuels such as wood, charcoal and agricultural residue for energy needs at the household level mostly for cooking purposes. For the lighting needs, kerosene is used by the majority of rural Sub-Saharan Africa.

Kenya' energy consumption patterns bare some similarities to those of the rest of Sub-Saharan Africa countries. In 2006 the biofuels, petroleum-based energy source and electricity in Kenya accounted for 82, 16.7 and 0.6 % of the total energy consumption respectively. There were notable differences in the consumption of the urban population and the rural population. The top three energy sources among the urban population were charcoal, kerosene and liquefied petroleum gas while the top three energy sources among the rural population were firewood, charcoal and kerosene (Waweru, 2014).

Charcoal and firewood are used to meet the cooking energy demand while kerosene is used for the rural household lighting needs. Liquefied petroleum gas (LPG) and electricity are however popular in the urban areas for cooking and lighting respectively. This is due to the fact that most of the urban population have limited living space and higher income from formal employment; which consume a significantly larger portion of their time. This causes them to use energy technologies that require little time to light, minimal physical energy to maintain and occupy minimal area when in use. Electricity is often only used to meet the lighting and entertainment needs of the urban population. Electricity costs per unit (cost per kWh) have traditionally been high due to the use of fossil energy sources in the generation of electricity and seasonality in electricity generation due to dependence on hydro-electricity. LPG is used mostly for cooking purposes. Nationally, the consumption of LPG doubled between 2003 and 2008 from 40,000 metric tonnes to 80,000 metric tonnes (KIPPRA, 2010).

According to Dalberg's analysis of the 2009 census data (Dalberg Global Development Advisors, 2013), charcoal was the most used energy source in the urban areas since 45% of the population was using it. LPG and kerosene were consumed by 21% of the population each while wood and other energy sources were consumed by 9% and 3% of the population respectively. Biogas consumption was categorized under the other energy sources due to its low adoption in the urban areas of the country.

The government has acknowledged the need for better management in the energy sector through improved energy efficiency and reduced use of petroleum-based energy sources. The use of CETs is one of the avenues of increasing energy efficiency at the national and household level. Additional investment in the energy sector has been recommended through increased public-private partnerships to achieve the goal of promoting the use of energy-efficient technologies (Mutua & Kimuyu, 2015). Some of the CETs use the traditional biofuels for heating and cooking, however, they have higher energy efficiency hence lower energy source consumption.

1.1.7. Implications of household energy consumption on agricultural productivity

Household energy consumption in rural areas is more directly linked to agriculture production than it is to urban households. Households in rural areas are found to rely more on biomass as an energy source compared to the urban households who adopt a more diverse variety of energy sources. Since most of the agricultural activities are carried out in the rural areas, the agricultural residue is often used by the rural households as an energy source for cooking (Njogu & Kung'u, 2015; Sikei *et al*., 2009; UNEP, 2005). The biomass consumed in the urban areas (charcoal and wood) is sourced from the resources in rural areas such as the natural forests and private farms. This creates a linkage between urban energy consumption and household farm decision making on what to produce. Incorporation of agroforestry in the farming system is one of the ways in which biofuel production coexists with food crop production in rural areas.

1.2. Statement of the research problem

The literature on energy use at the household level has shown that the use of traditional cooking technologies that use biomass and fossil energy sources have a negative effect on the health of household members (Lam *et al*., 2012). These negative health effects have a ripple effect on the social and economic well-being of individuals, households and society as a whole. The use of clean energy cooking technologies at the household level has been proven to have relatively higher health and social benefits to the users and their households (Shankar *et al*. 2015; Hart & Smith, 2013; Lewis & Pattanayak, 2012;). The use of traditional cooking technologies also has a wider negative effect on the current climate change mitigation efforts at the household level. The adoption of clean energy cooking technologies is viewed as an effective way of not only reducing GHG emissions but also improving efficiency in energy source use at the household level. The guide by Hart & Smith, (2013) highlights that the technologies have a variety of welfare and economic benefits through their higher energy source and energy-efficient traits. Studies on general household energy consumption have over the years placed more focus on the analysis on the household energy source choice and household energy source consumption behaviour (Ndolo, 2017; George & Gicheru, 2016; Waweru, 2014; Adepoju *et al*. 2012; Manyo-Plange, 2011; Djandoh, 2010; KIPPRA, 2010; Nyang, 1999). However, focus on clean energy cooking technologies (CECTs) at the household level has been low. Studies by George & Gicheru, (2016) and Ndolo, (2017) in Kibera focused only on the adoption of energy sources with no link to the cooking technologies used in the area. This creates a gap in knowledge on the cooking technologies and more specifically clean energy cooking technologies adopted by the residents of Kibera and the factors that influence the intensity of their adoption at the household level.

1.3. Research Objectives

The general objective of the study was to analyse the determinants of adoption of clean energy cooking technologies and energy sources in Kibera, Nairobi.

The specific objectives are;

1. Characterize the clean energy cooking technologies and energy sources adopted in Kibera, Nairobi.
2. Analyse the socio-economic factors that influence the adoption of clean energy cooking technologies among households in Kibera.

1.4. Research questions

1. What are the characteristics of clean energy cooking technologies and energy sources adopted in Kibera?
2. What are the socio-economic factors that influence the adoption of the CECTs at household level in Kibera?

1.5. Justification for the study

The findings of this study are expected to provide more information on household cooking technology adoption behaviour and consumption in the context of a low-income urban setting. This information is expected to facilitate the formulation of policy to increase CECT adoption as well as facilitate the design of strategies to achieve increased uptake of the CECTs.

Adoption of these technologies will directly have an effect on the success of Kenya's Big four agenda; where one of the goals is to improve the health of Kenyans and their wellbeing. The first objective provides an overview of CECT adoption since it serves as a baseline assessment of the adoption level. It also provides a better understanding of the preferences and consumption behaviour of the people so as to facilitate policy development that fits into their behaviour and needs.

The second objective will provide more understanding of the factors that should be keenly considered in policy formulation and program implementation to encourage CECT adoption. It is through the factors identified that the intensity of adoption of CECTs and clean energy sources can be fast-tracked hence bringing the country closer to achieving Vision 2030.

The findings are also expected to facilitate further research to provide better understand energy consumption behaviour in urban areas. The resulting recommendations of the study are meant to jointly facilitate the achievement of Sustainable Development Goals (SDGs) number 3 (Good health and wellbeing), 7 (Affordable and clean energy), 11 (Sustainable cities and communities) and 13 (Climate action) (United Nations Development Programme, 2019).

One of the indirect effects of increased CECT adoption will be improved health and well-being in the household setup since it will reduce the level of indoor pollution. The reduction in emissions in multiple households will collectively result in lower greenhouse gas emissions in the country hence serving as an activity that combats climate change. Through the recommendations provided by this study, the resulting policies and activities are expected to make clean and affordable energy sources and technologies for household use more accessible to the people in low-income areas. The means of bringing clean and affordable technologies and energy sources to the masses can then to be designed in a manner that would lead to the development of sustainable cities and communities for socio-economic growth.

CHAPTER TWO

2.0. LITERATURE REVIEW

2.1. Household energy consumption

The price and income elasticity of demand for energy at the household level is on average inelastic. This is because the energy needs of the household do not change much regardless of their incomes and the price of the energy sources. Households, however, develop coping mechanisms to minimize the general energy cost by using a variety of energy sources in varying proportions at their income levels. The use of an identified energy source is determined by its price and availability together with the consumer's income. This can be related to Neij *et al*, (2009) conclusion on the role of capital and operating cost on the adoption of energy-efficient technologies. This is because the energy source and technology used have a derived demand relationship. It is for this reason that the energy stack model is the best fit to explain household energy consumption (Waweru, 2014).

The commonly used energy sources in Kenya's urban areas are biomass, kerosene, LPG and electricity. Households use these energy sources in varying proportions to minimize their energy expenditure hence respond differently to a price change in each individual energy source. Nyang (1999) found that in the urban areas, kerosene and charcoal were both income inelastic hence their demand was hardly affected by their price. He found firewood consumption to be price inelastic making it hardly affected by price changes. Based on the same attribute, it is income elastic hence its consumption is sensitive to changes in the household incomes. Among the biomass energy sources, firewood can thus be considered to be an inferior source of energy to charcoal since charcoal was found to be income inelastic. Nyang further found that electricity was both price and income inelastic. This can be attributed to the fact that the price for a unit of electricity was determined by the electricity producers and regulatory authorities rather than the market.

Though Nyang (1999) was carried out close to two decades ago, the consumption behaviour expressed reflect what is likely to happen among urban energy consumers in today's society. Changes in the social and economic environment of the country; especially the urban areas, are likely have had an effect on the energy source consumption behaviour at the household level. Innovation and advancement in energy technologies can also be hypothesized to have an effect on the energy choices made at the household level. Increases in the national per capita income and improved access to some of the cooking technologies; together with the restricted use of other energy sources can also be hypothesized to have had an effect on the energy consumption patterns among the Kenyan population. This creates a present need to characterize what energy sources and cooking technologies are currently being used at the household level.

2.2 Clean energy cooking technologies' adoption

These are cooking technologies that have little or no GHG emissions compared to traditional/alternative technologies. As discussed by Inayat (2011), the positive traits of these technologies make them significant to the social, economic and environmental well-being of a household. These benefits include higher energy source efficiency, lower emissions, time-saving properties and overall household cost minimization. The energy sources utilized by each technology vary and this has an effect on the level of cleanliness of the technology. Jain *et al*. (2015) identified a number of clean cooking technologies available in India that this study also seeks to explore in the Kenyan urban context. These technologies are LPG, biogas, electric-based and improved biomass cooking technologies. Though solar-powered cooking technologies are clean technologies, their limitations in design and usability make them less desirable. Their design makes them less desirable for the traditional cooking activities undertaken in the average household (Jain *et al*., 2015). Their dependence on direct sunlight is also a limiting factor since it can only be used on sunny days and cannot be used at night.

The main challenges identified to limit the wider adoption of clean energy cooking technologies are the high cost of acquisition and the lack of awareness on the technology's benefits (Jain *et al*., 2015; Miller & Eil, 2011; Phemelo, 2004). Other cross-cutting factors identified to limit adoption include the society's cultural beliefs and practices, poor marketing strategies, high cost of production of the cooking technology and the dependence on "free" wood. The adoption of the technologies is also limited by the long period it takes for the existing adopter to experience the full benefits of the technologies.

2.2.1. Types of clean energy cooking technologies in the Kenyan market

2.2.1.1. Biomass clean energy cooking technologies

These technologies are also often referred to as improved cookstoves or improved biomass stoves in the literature (Brooks *et al*, 2016; Jagger & Jumbe, 2016; Alamir, 2014; Jeuland & Pattanayak, 2012; Inayat, 2011). Their design and features (portability and combustion system) vary between the various societies due to their ecological, demographic and cultural differences (Jain *et al*. 2015). Their key goal is to reduce the level of GHG emissions from the use of biomass energy sources (firewood, charcoal and crop residue), reduce indoor pollution and improve energy source efficiency in their consumption.

The Kenyan and Indian government have viewed the use of improved biomass cooking technologies as an effective way of reducing deforestation, improving the population's health and combating climate change. Through subsidy programs, the technologies were distributed in India to encourage adoption. Various challenges were faced, key among them being the lack of sustained use of the technologies by the population (Jain *et al*. 2015). Other challenges include poor post-adoption support, limited awareness of the technologies and poor resource allocation due to poor monitoring and evaluation systems in the program.

The Kenya ceramic stove (also identified as the improved jiko/cook-stove) has been produced and marketed locally for over the last three decades. It is one of the first clean cooking options that have been available and more affordable to a majority of the population. This stove often utilized charcoal as an energy source however improvements to the technology have made it possible to use wood and briquettes in the cookstoves. The development of the ceramic cooking *jiko* in Kenya in the early 1980s was one of the first steps taken to encourage the use of fuel and energy-efficient technologies at the household level (Hart & Smith, 2013). The main goal of the ceramic *jiko* was to reduce deforestation in the country by reducing the quantity of biomass energy source consumed. The ceramic *jiko* was a significant improvement from the sheet metal stove which had no insulation against heat loss and the three-stone stove which has no heat-saving mechanism. The ceramic stove was found to have better thermal efficiency by up to 30% compared to the sheet metal stove (Nyang'aya, 1982). According to Hart & Smith (2013), the improved fuel efficiency in the Kenya ceramic stove resulted in fuel-saving by 30% and reduced emissions by 60%. This lowered the cases of respiratory infections among women and children by 65% and 60 % respectively. The improved *jiko* also reduced the time spent on fuel use related activities by 10 hours a month. Involvement of women in the *jiko* value chain was very high especially in the production stage of the ceramic component of the *jiko* and the marketing of the finished *jiko*. The producers were able to generate about US$ 175 annually from moulding the ceramic component, while the technology's distributors were able to make about US$ 200 annually. Female involvement in the jiko value chain evidently increased the level of market penetration of the product while creating opportunities for the women to be more economically empowered. Some of the measures taken included increased awareness of the technology through training and field demonstrations, commercialization of the *jiko* production, increased advertising, improved marketing and distribution channels through women. Similar measures were also advocated for by Phemelo (2004) to encourage adoption of alternative energy sources.

The *jiko* was highly adopted in the Kenyan urban areas but relatively poorly in the rural areas as evidenced by Nyang (1999). This can be attributed to its relatively high price and the fact that it did not me*et al*l the cooking needs of the rural population. The short lifespan of the *jiko* made it less desirable since the user had to replace it every 6 months on average at a cost compared to the more adopted traditional three-stone stove that had no monetary cost of adoption and maintenance.

Over time, there have been further developments in biomass clean cooking energy technologies resulting in clean energy cooking products targeting households that are better than the Kenya ceramic *jiko*. Improvements in the ceramic *jiko*'s design led to its use with other energy sources such as firewood and briquettes. This encouraged its adoption, especially in the urban areas.

The introduction of the new cooking technologies in Kenya has been successful however adoption is still growing since they are new in the Kenyan market. In parts of South Asia where they have been in the market longer, some observations about the technologies have been made through research and hence their positive aspects are being used to encourage their adoption in Kenya.

2.2.1.2. Electrical clean energy cooking technologies

Electric cooking technologies have been widely adopted in the urban areas due to the relatively high connection to the electric grid compared to the rural areas. The adoption is also motivated by the relatively higher per capita incomes of the households residing in the urban areas since electricity is often considered to be an expensive source of cooking energy. According to Jain *et al*. (2015) and Anenberg *et al*. (2017), electric cooking technologies were found to be the cleanest cooking technologies due to the lack of emissions. Anenberg *et al*. (2017), proceeds and considers them to be the most efficient due to their high thermal output per unit of electric input. Electric cooking technologies are also ranked as the safest to use due to their low risk of explosion and low exposure to the heat during cooking. The main challenge to their adoption is its relatively high initial cost of adoption and maintenance making them unaffordable to many (Jain *et al*., 2015; Alamir, 2014; KIPPRA, 2010). Frequent electric shortages among developing countries also limit the adoption of these technologies.

2.2.1.3. Biogas clean energy cooking technologies

Biogas cooking technologies are the cooking technologies that utilize biogas as an energy source. These technologies are specialized to use biogas from a biogas digester as an energy source. The key limitation of their adoption is the high cost of adoption. This is due to the need for specialized equipment and training in order to efficiently use the technology and its energy source. Their dependence on the presence of a biogas digester; which requires high initial capital investment and has a relatively higher maintenance cost, makes these technologies expensive to acquire. The consumption of biogas has however been found to be more efficient in terms of time-saving. In the urban context, the use of biogas is an attractive option. This is because though it has a high cost of adoption when it is used by multiple households it is economically viable; making it an affordable alternative (Ekouevi, 2013).

In Kibera, non-governmental organizations have developed a biogas production system that utilizes human waste. This is part of the community sanitation improvement programs available in the area (Ministry of Energy, 2018). By utilizing the existing public sanitation facilities, biogas is produced and the locals can use it at a lower cost relative to other technologies. This eliminates the high investment costs making it more accessible to those with low incomes.

2.2.1.4. Liquefied Petroleum Gas (LPG) clean energy cooking technologies

The adoption of LPG cooking technologies has been on the rise in Kenya as show by Dalberg Global Development Advisors (2013), especially in the urban areas. This can be directly attributed to the rise in demand for LPG as a cooking energy source since there is an element of derived demand between the two products. This can be partially attributed to the increase in the national per capita incomes, reduction in the price of LPG and its supportive equipment improved access to the technologies and the energy source. The highly specialized nature of LPG cooking technologies is, however, a challenge to its adoption. The relatively high cost of acquiring technology is also a factor that limits its adoption. This is supported by the energy stack model where LPG is considered to be a high-income energy source. Its benefits, however, have played a major role in the increased adoption of LPG cooking technologies. The low GHG emissions with no soot together with its high thermal output and ease of use have made it a popular choice of cooking technology among the Kenyan urban population. Due to the technologies' high cost of maintenance, it is often used for limited cooking functions in the household. It, therefore, serves as a complement for cooking technologies such as the Kenya ceramic jiko. This behaviour is supported by the energy stack model (Kroon *et al*. 2013).

2.2.2. Benefits of CECT use

2.2.2 1. Health benefits of clean energy cooking technologies

The use of traditional steel sheet and 3-stone cooking stoves in the household has been found to have a number of negative effects on the health of its users. Other than the negative economic and environmental implications of using firewood inefficiently, there are also a number of health issues that arise from its use (Vivan *et al*. 2012). The high indoor pollution associated with the use of firewood can be linked to various diseases including asthma, bronchitis, coughing, tuberculosis and pneumonitis. Apart from the mentioned diseases, the exposure can lead to various body irritations such as lung inflammation, respiratory tract and eye irritations. Vivan *et al*. (2012) explained that for pregnant mothers, exposure to the emissions could result in lower childbirth weight and it increases the chances of the child having asthma once it is born. For a growing child, this exposure increases their chances of suffering from pneumonia.

Indoor pollution as a result of the use of biomass and petroleum-based energy sources accounts for 1.5 million premature deaths and 1.6 million deaths of individuals already born. Indoor pollution has also been estimated to account for 2.7 % of global diseases (Adepoju *et al*., 2012; Waweru, 2014).

The use of clean energy cooking stoves (CECT) is part of the solution to the reduction in indoor pollution. Due to their efficiency in energy source consumption and lower particle emissions as explained by Hart & Smith (2013), the CECTs can be used to improve the health of members in the household. Expenses on health matters in the household drain a significant percentage of the household incomes hence the household is not able to improve itself. Though most of the financial burden often falls in the male members in the household (Bloomfield, 2014), the other members are affected in other ways due to the diversion of household income. The challenge of measuring the health benefits of the CECTs is the lack of sufficient baseline data in the health situation of the household.

2.2.2.2. Time and labour-saving properties of clean energy cooking technologies

Due to their inefficient use of fuel, the traditional cooking stoves being used in households have high fuel consumption. This causes the household members to spend a lot of time on fuel collection (Stone *et al*., 2008). The use of time in the activity of fuel collection results in the use of household labour in an inefficient way. The fuel collection is often a laborious process that is often bore by the female members as well as the children in the household.

The use of clean energy cooking stoves offers a reduction in the time spent in the fuel collection since they are more fuel-efficient and consume less fuel to perform a given task in comparison to the traditional stoves (Alamir, 2014; Kanangire *et al*. 2016). This indirectly results in the saving of time and labour in the household hence improving household welfare.

From the summary of studies done in India, Nepal and Bangladesh explained by Bloomfield (2014), the use of improved cooking stoves reduced the time spent in fuel collection by 122 hours per household per year which is about 20 minutes a day. In comparison to the men in the household, women spent 374 hours annually compared to 286 hours annually spent by men; which accounts for 56.7% of the total time spent by men and women in fuel collection. Through the adoption of clean energy cooking stoves, the burden of fuel collection on women was reduced by 70 hours annually. Similar observations in time-saving were made in Dadaab, Geneina together with North, West and South Darfur where women spent less time collecting fuel (Global Alliance for Clean Cookstoves, 2014). These savings of time can mainly be attributed to the fact that the improved cooking stoves have improved combustion efficiency and lower fuel consumption by 28% on average compared to the traditional stoves.

The time saved by the use of the improved stoves was found to be very valuable mainly to the women and children of the household since it created time for the women to engage in other activities that are beneficial to the household. Most of the sampled women responded that they spent their newly found time tending to their children, engaging in agricultural activities, attending community meetings and engaging in recreational activities such as visiting friends, watching television and resting (Global Alliance for Clean Cook-stoves, 2014). All these activities improved not just the community coherence but also the satisfaction level of the women in the households. The time saved had a ripple effect on the household children since the women are able to do most of the household duties and create more time for the children to pursue their education especially for the children in secondary and tertiary learning institutions.

The activity of fuel collection in some cases exposes the participants to a variety of risks ranging from wild animal attacks to human attacks especially in the rural areas. Within refugee camps, frequent cases of gender-based violence against women were linked to the activity of firewood collection in Kenya, Uganda, Ethiopia, South Sudan and Chad (Global Alliance for Clean Cookstoves, 2014). In Uganda, the cases of gender-based violence related to fuel collection were at 41% while in Ethiopia and Chad the cases were at 33% and 42% respectively. The cases were higher in South Sudan at 54% and in Kenya at 60%. This was heavily linked to the distance the women travelled to collect fuel as well as the scarcity of the preferred fuel. The use of CECTs was a tool used to reduce the cases of such violence in the communities since in Dadaab it reduced the risk of rape while collecting firewood by up to 45.2%.

2.3. Clean energy sources used for cooking

2.3.1. Biomass

Biomass is the most adopted energy source in Kenya and Sub-Saharan Africa. Its consumption in Kenya accounts for 68% of the total energy consumption (Wilson *et al*. 2007) and household expenditure on biomass is on the rise as shown by Bacon *et al*. (2010). This is due to the fact that it is easily available at a low price in comparison to the other energy sources. Its dominant use in rural areas is due to the ease of access and the lack of an actual cost being attached to its access in the rural areas. The most commonly used biomass energy sources are firewood, farm residue and charcoal. As of 2000, the per capita consumption of firewood in the country was 741 kilograms and 691 kilograms for the rural and urban population respectively. In the same year, the per capita consumption of charcoal was 152 kilograms for the rural population and 156 kilograms for the urban population (Mugo & Gathui, 2010). Farm residue is also a popular energy source in the rural areas however its consumption is limited in the urban areas. 21 % of the country's population was found to be consuming farm residue as an energy source (the Republic of Kenya, 2000).

The high dependence on biomass as an energy source presents a challenge to the local forest conservation efforts as expressed by Kituyi *et al*. (2001). A number of factors have had a negative effect on the loss of forest cover in Kenya, which has been decreasing at a rate of 5000 hectares per annum (Ministry of Environment, 2018). Key among these factors is increased population in the country given that the annual population growth rate stands at 2.57 % per annum (World Bank, 2017). The population increase results in a constantly increasing demand for timber, land and energy. The timber is mainly used for the provision of housing and the creation of furniture while the land is used for agricultural production (Mugo & Ong, 2006). Illegal production of cooking fuel (charcoal and firewood) has been a major threat to the local forest cover given that 40% of the 2.4 million tonnes of charcoal consumed locally is from the local natural forest cover (Mugo & Ong, 2006). However, as of 2015, the acreage of forest cover was increased by 183 million hectares (FAO, 2015) from the afforestation efforts embarked on by the government and support agencies. Advocation for sustainable production of biomass energy sources is being viewed as the future of sustainable energy supply as discussed by Mugo & Ong, (2006).

2.3.2. Electricity

Electricity is the cleanest form of energy since it produces no emissions when utilized. It has a wide variety of uses which span from domestic uses to commercial uses. Electricity production in Kenya has been increasing due to the increased demand both for commercial and domestic use. This increase can be attributed to increased innovation and investment in improved electricity production technology. Investment in solar, wind, hydro, geothermal, thermal and biomass electricity generation plants have led to an increase in the on-grid electricity supply by 1,493 megawatts since March 2013 to have a total supply of 3,157 Megawatts (MW) up from 1,664 MW (Ministry of Environment And Natural Resources, 2015b). The government's goal is to achieve a production level of 5000 MW of electric power through a sustainable production mix hence lowering the consumers' domestic tariffs from 19.78 cents to 10.45 cents.

The lower electricity prices are often hypothesized to boost economic activities and also increase the use of electricity within households. Cooking using electricity has been low due to the low connectivity in the country together with the high per-unit price of electricity. Pundo & Fraser (2006) found that the use of electricity in Kisumu (which is an urban area in Kenya) for cooking was so low that it was insignificant to the study. However, today's households can take advantage of the continued reduction in electricity prices and use electricity to meet more of their cooking needs.

Development of off-grid solar solutions has also increased the adoption of electricity use in the household however the power is used mainly for lighting and entertainment purposes. This is due to the low electric output that these technologies have hence cannot be used to power heating technologies. The high output off-grid option is often inaccessible to the average consumer due to the high initial investment made to acquire and install the technologies. In Kibera, electricity has been identified as a possible alternative to the energy sources that are less clean in their consumption in an effort to reduce GHG emissions and conserve the existing forest cover in the country and beyond (Aya Yonemitsu *et al*. 2015).

The low adoption of electricity in the study area as a cooking energy source can be attributed to the high cost of legal connection to the grid and the costs of wiring the houses. This high cost of adoption can be hypothesized to have a detrimental effect on the level of empowerment and the standard of living in the area. The households that had adopted electricity in Bangladesh were found to have infant mortality rates lower than the national average by 25-35% at the household level (George & Gicheru, 2016).

2.3.3. Liquefied Petroleum Gas (LPG)

Liquefied petroleum gas is considered to be a clean energy technology due to its significantly lower GHG emission and lack of residue from the combustion process. The only by-products of LPG are carbon dioxide and water vapour. Based on the Kenya Integrated Household Budget

Survey (2006), LPG consumption in the country was still low. Of the nationally sampled population, only 3.5% had adopted LPG; while for the rural and urban samples, 0.7% and 11.9% were found to have adopted LPG respectively (Waweru, 2014). According to Dalberg Global Development Advisors (2013), the consumption of LPG in the country increased by 14 % between 2004 and 2012. This was attributed to the improved market penetration of the technology and its increased ease of access. However, only 5-7 % of the population was estimated to use it as the primary energy source for their cooking.

According to the energy stack model, LPG is viewed as a superior energy source to charcoal and firewood. This makes it more likely to be adopted as an individual's or household's income increases. The majority of the LPG users in Kenya are found in the urban centres which are 21% of the nation's population. However, 60 % of the LPG adopters were found to reside in Nairobi (Dalberg Global Development Advisors, 2013).

The main barriers to adoption of LPG were found to be the high initial cost of acquisition of the technology and recurring operational cost of the technology together with the poor distribution network of the technology. The poor distribution network resulted in the intervention of black-market players to provide substandard LPG products and unfair business practises such as partial refilling of the gas cylinders. This causes lower adoption of LPG due to safety concerns on the LPG quality together with its equipment and lack of trust of the sold products and traders. The relatively lower prices of substitute fuels such as kerosene, wood and charcoal together with their stoves decrease the likelihood of individuals to adopt LPG. Brazil was able to achieve a 98% LPG adoption level at households through government policy. The policies were aimed at improving the LPG distribution infrastructure; making it accessible and provision of subsidies to low-income households to support their adoption (OECD/IEA, 2006).

2.3.4. Biogas

Kenya has been a pioneer in Africa when it comes to biogas adoption with the first digesters in Africa being set in Kenya and South Africa in the 1950s (Amigun *et al*, 2012). Biogas use in the country has been on the rise due to increased awareness of the technology and the reduction in the costs of setting up biogas digesters. The digester's utilization of animal waste makes it sustainable and cost-efficient in the long run however adoption of the technology is done mostly by livestock farmers for livestock waste management. Human waste is also used for biogas production and public toilets are used for the biogas generation. Projects have been developed in densely populated areas to improve the sanitation of the areas while providing cheap clean energy more accessible to the local population. Such a project has been implemented in Kibera (Amigun *et al.*, 2012). The high cost of installation of the digesters, purchase of the complementing apparatus as well as poor design, construction and after-sale services provided are some of the reasons why biogas adoption has been low relative to other cooking sources. (OECD/IEA, 2006; Wilson *et al*. 2007; Mugo & Gathui, 2010; Amigun *et al*. 2012). The other identified reasons include low awareness on the technology, poor management and poor maintenance of the technology among adopters resulting in system failures (Wilson *et al*., 2007). Even with the low level of adoption, it is estimated that the per capita daily consumption of biogas is 0.6 cubic metres, which translates to an annual per capita consumption of 219 cubic metres of biogas (Mugo & Gathui, 2010). Technological advancements and development of innovative ways to improve access to biogas as an energy source are making it more accessible to a larger portion of the population.

There are 19 digesters in Kibera built within proximity to public sanitation facilities by a non-governmental organization in the area. For a fee, the residents are able to cook using biogas and for a separate fee are able to use the public toilets and bathrooms which provide the raw material for the digesters.

2.3.5. Briquettes

The use of briquettes arose from the increasing price of firewood and charcoal in the urban areas and the need for poverty eradication through self-employment, especially in the urban areas. Briquettes are mainly made from a combination of various biomass farm residue material (such as rice husks, maize cobs and stalks, coffee husks), sawdust, waste paper, charcoal dust and in some cases dried cow dung and soil (Ngusale, 2014). These commodities are blended in varying proportions and dried to produce a solid block that is then used as an energy source with high thermal output and low emissions. The briquettes can burn for over four hours, compared to the two and a half hours burning time for regular charcoal (Njenga & Iiyama, 2014) while producing less smoke and carbon monoxide. They are also odourless and leave no soot on cooking pots. Their adoption has been found to improve energy efficiency by over 15% according to Yonemitsu *et al* (2015). Njenga & Iiyama (2014) also found that it costs KSH. 3 to cook a traditional meal of green maize and dry beans (githeri) using briquettes, compared to KSH. 26 and KSH. 45 for charcoal and kerosene respectively Due to its relatively cheaper price and lack of specialized cooking technologies needed for its use, it can serve as a day-to-day alternative to charcoal and firewood. Briquette production has created employment opportunities for a number of women and youth in urban centres (Njenga & Iiyama, 2014; Aya Yonemitsu *et al.*, 2015). Its production has also given farmers and other professionals such as carpenters an opportunity to minimize their wastage while earning earn extra income.

The main challenge to briquette use is lack of awareness on the briquettes and its benefits. The popularity in the use of charcoal and kerosene is also a challenge to the adoption of briquettes as well as lack of a standardization system in briquette quality. This is due to the large presence of informal players in briquette production (Ngusale, 2014). This results in variation in the quality of the products due to variation in the components and proportions of briquette ingredients used by the briquette makers. The consumer is therefore not assured of the same cooking experience when purchasing the energy source from different vendors.

2.4. Review of hypothesized variables that influence the adoption of CECTs

The variables considered for this study were identified based on the literature review carried out on the adoption of technologies with a focus on energy technologies. The variables identified from the literature review are discussed in this section to give a better understanding and context to the analysis. A number of studies have identified these variables as influencing factors to adoption of energy technologies however their influences vary based on the studies. This is due to the differences in the context of the studies and the societies they were carried out in.

1) Age of the individual often involved in cooking

As a factor on the adoption of energy technologies, the effect of age has been found to vary in a number of studies. Lewis & Pattanayak, (2012) could not come to a conclusive agreement that age was a factor in the adoption and use of improved energy sources and cookstoves from their review of 32 studies carried out in various developing countries. Age in the various studies was quantified in different ways hence lack uniformity in the measurements and ultimately results. The comparisons were also done on studies from a number of different areas (Africa, Asia and Latin America) which have varying cultural and ecological traits.

Inayat (2011) and Alamir (2014) got conflicting results on the effect of age on cooking technology adoption with the latter finding it to be statistically significant to adoption and the former finding it not to be statistically significant. The differences in results can be attributed to the difference in the study area as well as the particular cooking technology being assessed. Based on Alamir (2014) analysis younger individuals were more likely to adopt improved cooking technologies for their households. It is therefore expected that younger persons are more likely to adopt the CECTs hence an increase in age would have a negative effect on CECT adoption.

2) Household Size

This effect of household size on cooking technology adoption has been found to vary between studies. According to Inayat (2011), household size was found to be statistically insignificant which was against the study's assumption that a larger household was more likely to adopt improved cooking stoves. Similar observations were made by Alamir (2014).

Contrary to the studies mentioned above, studies by Pine *et al*. (2011) and Lewis & Pattanayak (2012) found that household size had a positive significance to the adoption of improved technologies. This meant that as household size increased, so did the likelihood of adoption of improved technologies. This led to the study hypothesizing that an increase in the number of members in a household would have a positive effect on the adoption of multiple CECTs.

3) Occupation of the household head

Pine *et al*. (2011) found that an individual's occupation has an effect on the adoption of improved technologies. The study was however biased to the technologies that utilized farm residue. The farmer was more likely to adopt a technology that would enable them to utilize the available farm residue as an energy source more efficiently. Oyekale (2018) also found that an individual's primary occupation had a statistically significant effect on the number of technologies they choose to utilize. Ikurekong *et al*. (2009) also found out that an individual's occupation has an effect on the quantity of firewood consumed. Based on the derived demand between the energy source and the technology used, this finding leads to the hypothesis that the more energy demanding and time consuming one's occupation is, the higher the likelihood of them adopting a clean energy cooking technology. Based on the Random Utility model (RUM), individuals are assumed to maximize their utility by minimizing their costs. They are therefore likely to adopt the technologies they considered to be time saving and/or cost-saving. In urban areas, the individual's occupation is hypothesized to have a direct relationship to the daily time allocation, the individual's social network and the income earned. Rogers (1983) identified the effect on occupation on the adoption of technology as a multiphase effect. This is because the occupation of an individual has an effect on their social network, perceptions, preferences and exposure to information.

4) Group involvement among household members

Involvement in groups attests to the individual's social capital and an indicator of the individual's social networks. These networks have an effect on the individual's exposure to information both through formal and informally means which then has an effect on their decision making. Geary *et al*. (2012) found social networks to have a positive effect on the adoption of improved technologies. This can be attributed to the fact that an individual's social network tends to provide information to the individual on the technologies available in the market. The social network however also indirectly applies peer pressure on the individual to adopt specific technologies as opposed to other technologies. Adrianzen (2009) acknowledges the importance of an individual's social capital towards the adoption of technology; giving it similar significance to the household factors. Both the positive and negative experiences of the people around an individual; neighbours and the local opinion leaders do influence the decision to adopt a technology as evidenced by Puzzolo *et al*. (2013).

5) Climate change awareness

Theoretically, awareness of the benefits of a new technology often hypothesized to positively influence the adoption of a technology (Abraham & Sheeran, 2005; Morris *et al*, 2012). For most new technologies in a market, the awareness on their benefits are often low and this serves as a limitation to their adoption. Inayat (2011) concluded that a lack of awareness on the health benefits of improved technologies was one of the barriers to the adoption of the technologies. Given that one of the benefits of CECT adoption is climate change mitigation, it is assumed that the individuals are more likely to adopt the CECTs if they are aware of its benefits. This may however not be the case since the benefits of climate change mitigation may not be directly experienced as the health benefits of clean energy cooking technologies adoption. The motivation to adopt due to climate change awareness is, therefore, more intrinsically motivated than it is extrinsic.

6) Price of the clean energy cooking technology and the cooking energy source

Given that consumers are motivated by cost minimization according to the RUM, the price of the cooking technology is hypothesized to have an effect on the adoption decision. This hypothesis is evidenced by the number of recommendations and interventions to make clean cooking technologies more affordable through subsidy programs and free distribution of the technologies (Anenberg *et al*. 2017; International Energy Agency, 2015; Jain, *et al*. 2015; Iskin *et al*. 2013; Karekezi *et al*. 2008; United Nations Industrial Development Organization, 2006). Based on the cited studies and many more it was found important to investigate the effect of CECT prices on the adoption of multiple CECTs. The study deemed it best to understand the effect of the price of each identified CECT on the adoption of multiple CECTs. The cooking technologies assessed were the Kenya ceramic jiko, the electric cooking technologies, LPG cooking technologies and the improved biomass stove. Since consumers are hypothesized to be utility-maximizing agents and the price of the CECT is the utility measurement tool for this study, it is hypothesized that a high price of a CECT would discourage its adoption.

7) Price of the clean energy source

The relationship between CECTs and the energy sources used is one of derived demand. This is because when an individual's demand to use a specific CECT, he/she is also demanding to use the energy source that is compatible with the cooking technology. Findings by Tembo *et al*, (2015) found that the price increase in one cooking energy source increased the likelihood of adopting another cooking energy source. Among the consumers, this was better than adjusting in the quantity consumed of the already adopted cooking energy source in Zambia. In the context of this study that would mean that the individual would also opt to adopt another cooking technology so as to utilize their preferred alternative cooking fuel.

For this study to effectively capture the effect of the price of energy sources on adoption, the total monthly expenditure on energy sources was used. Though indirectly linked to the CECT adopted, the energy sources were hypothesized to have an independent effect on the adoption of CECTs. This is based on the derived demand relationship between the CECT chosen and the energy source used in which an individual may choose to not use a technology because of the traits of the energy source it utilizes. One of the traits of the energy source adopted is that creates a recurring cost to be incurred by the technology adopter as long as the technology is being used. The price of the energy source speaks to the sustainability of use of the technology hence is expected to have an effect on the adoption of the technology. Highly-priced energy sources are expected to have a positive effect on the adoption of multiple cooking technologies while a lower price of energy source is expected to discourage the adoption of multiple CECTs *ceteris paribus*. This is based on the RUM's assumption of cost minimization among consumers.

8) Safety perception of the cooking technology

Safety on the use of LPG was found to be a concern hence limited its adoption (Dalberg Global Development Advisors, 2013). Safety associated with cooking technologies goes beyond the immediate physical harm it can cause but also the long-term health effects it causes from exposure. The health belief model of technology adoption hypothesizes that individuals were more likely to adopt technologies that would reduce their long term risk toward harm/threats to the individual's well-being (Morris *et al*., 2012). Consumer understanding of the other technologies' benefits beyond their cooking attributes is hypothesized to have an effect on their decision to adopt or not. This understanding is however linked to the individual's exposure to information and their own risk analysis of the technology. The study, therefore, assumes that knowledge on the safety attributes of the CECTs would increase their likelihood of adoption.

2.5. Theoretical framework

The study is grounded on the Random Utility Model (RUM) as developed by McFadden (1981) in which individuals are hypothesized to be utility-maximizing agents. According to RUM, utility is theoretically maximized by consumers through cost minimization. The utility can, however, be maximized by more than cost minimization. This is because utility is influenced by other external factors other than the consumer's extrinsic motivations.

Adoption is described as the mental process in which an individual goes through; from the moment information of the innovation is presented to them, up until the moment of final acquisition and continued use of the technology (Feder *et al*. 1947). Based on the definition, adoption can, therefore, be assessed in two distinct periods; before the acquisition and after acquisition of the technology. Studies that focus on the 'before acquisition' stage are referred to as *ex-ante* studies while those that focus on the 'after acquisition' stage are referred to as *ex-*

post studies. For *ex-ante* analysis, adoption is analysed from a perception point of view and the individual provides the perceptions he/she has towards a hypothetical technology. This is because the individual is yet to adopt the technology, therefore, the traits of the technology and its perceived usefulness according to the consumer are used to assess the likelihood of adoption/intention to use. Adoption models such as the diffusion of innovation (DOI) model (Rogers, 2003) and the Technology Acceptance Model (TAM) (Davis, 1989) use the perceptions and the intent to adopt of the individuals to understand adoption decision making. The *ex-post* analysis focuses on the technologies already available in the market or even already adopted by an individual. The revealed preferences of the adopter towards the technology can then be evaluated to understand the adoption decision. As explained by Greene (2012), the *ex-post* analysis does not focus on forecasting the independent variables' influence since they already can be observed.

This study took an *ex-post* point of view on CECT adoption to assess adopter's utility since the cooking technologies already exist in the market hence the evaluation of the revealed preferences of the consumers. From the assessment of the consumer's social and economic attributes as well as their perception, the factors that influence the cooking technologies' adoption can be determined. This study hypothesized that an individual is bound to adopt multiple clean energy cooking technologies at a given time to maximize their utility through the reduction of household energy expenditure. This behaviour is theoretically supported by the energy stack model of energy source adoption as explained by Kroon *et al*. (2013). The ultimate decision to adopt a cooking technology (or multiple cooking technologies) is dependent on the adopter's attributes and perception on how they consider the technologies will maximize their utility.

The utility function of observation '*n*' having chosen alternative '*i'* can be expressed as:

$U_{in}=V_{in}+e_{in}$ ………………………………………… (1)

where U_{in} represents the utility experienced from the adoption of an innovation

V_{in} represents the observed independent variables that influence the utility derived

e_{in} represents the unobserved independent factors that could influence the utility of adoption.

In the adoption of clean energy cooking technologies, the adopter is hypothesized to maximize their utility by adopting more than one cooking technology.

This adoption behaviour can then be expressed as $U_{in}(y_i) = V_{in} + e_{in}$

where $U_{in}(y_0) < U_{in}(y_1) < U_{in}(y_2) <\ldots\ldots U_{in}(y_i)$ and

y = the number of clean energy cooking technologies adopted, y=0, 1, 2, 3…. i

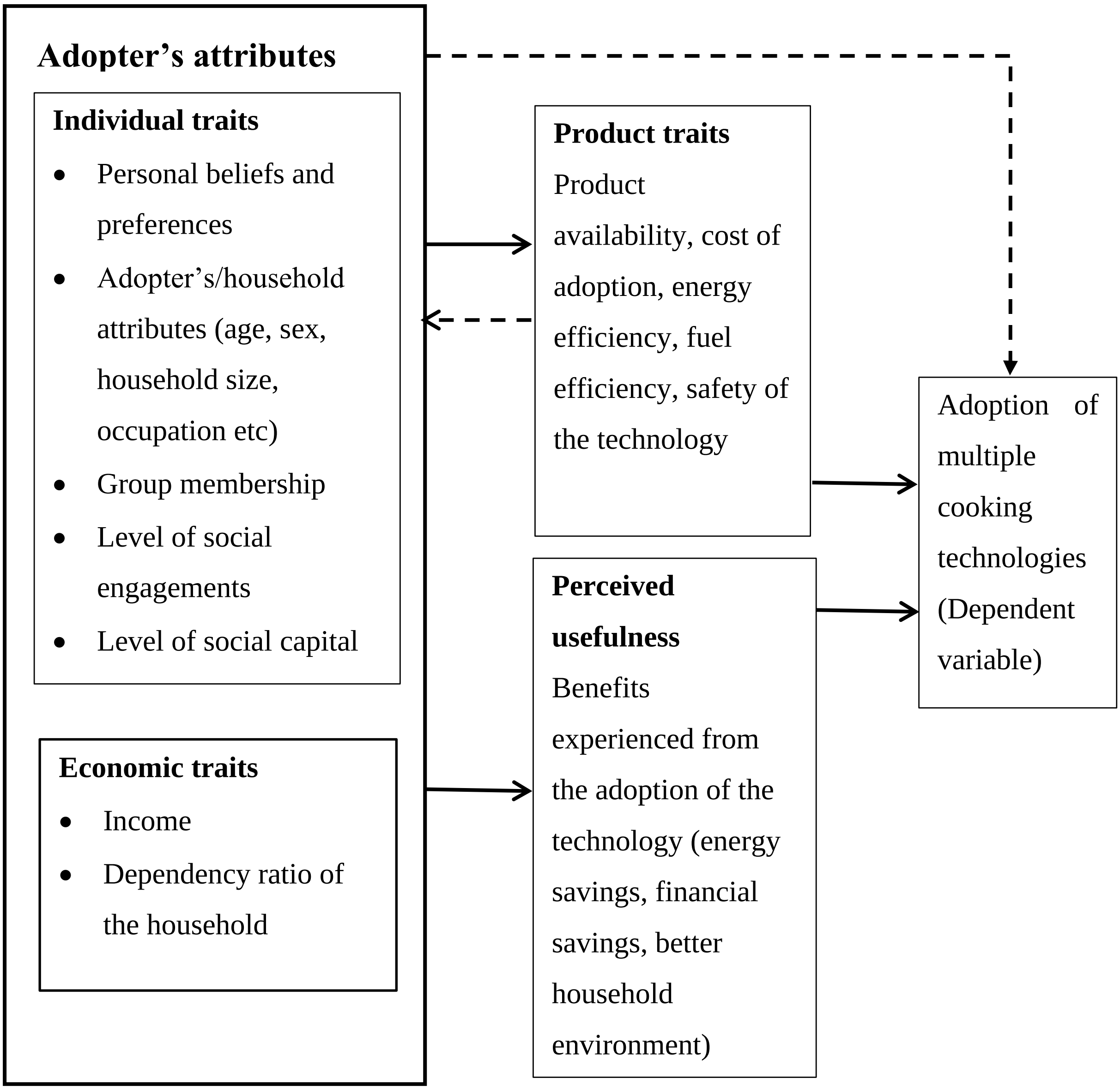
$$V = \sum_{k=1}^{k} \beta_{ik} X_{ik} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where β is the coefficient of the independent variable X_k and k=1, 2, 3, 4….

CHAPTER THREE

3.0. RESEARCH METHODOLOGY

3.1 Conceptual framework



(Dotted line represents indirect relationship)

Figure 1:Conceptual framework of the relationship between the dependent and independent variables in CECT adoption

The adopter is hypothesized to increase their utility by increasing the number of cooking technologies adopted. This behaviour is however subject to a variety of factors within and outside the control of the adopter. These are intrinsic and extrinsic factors. The presence of multiple factors makes technology adoption decision making a complex process for analysis. This is supported by the analysis done by Morris *et al*. (2012) on the theories on technology adoption. However, the conclusion is that technology adoption decision making is based on the adopter's intrinsic values and extrinsic factors (environment). The intrinsic values often affect the perception towards the technology before adoption and the sustained use of the technology after adoption. The extrinsic factors include the socio-economic environment of the adopter and the traits of the product that is adopted.

The adoption decision made to take up a new CECT in the household is based on three main components; the adopter's traits and beliefs, the perceived usefulness of the technology and the product's traits. The three factors work interdependently of each other in the adoption decision making process.

The adopter's attributes can be classified into three main categories; which are individual traits, economic traits and the social traits of the adopter. As evidenced by studies done on how the socio-economic traits of an individual influence their decision making (Inayat, 2011; Njenga *et al*., 2013; Wambui, 2013), the study adopted the assessment of specific individual traits to explain their existing CECT adoption decision. Also given that the existing products in the market cater to the specific cooking need of individuals and households, the adopter's traits have an influence on the design and functionality of the existing technologies. This then means that the adopter's traits and environment have an indirect effect on the traits of CECTs in the market (Zirger & Maidique, 2008).

The adopter's adoption decision is influenced by what he/she perceives would be the benefits of adopting a technology. Some of the key perceptions considered before the adoption can be how much the technology would help the individual save financially as well as time and the environmental benefits of adopting the technology. This perception is influenced by the person's attributes as well as experiences. Perception towards the technology has an effect on the end adoption decision made as expressed in Figure 1. The end decision to adopt is also affected by the adopter's attributes; mainly their social and economic traits.

3.2. Study area

The study was carried out in Kibera area of Nairobi County. Nairobi County covers an area of 696 kilometres' square and has a population of 3,134,265 people based on the 2009 Kenya National Bureau of Statistics (KNBS) census. Kibera is a low-income area in Nairobi about 7 kilometres from the city centre It can be accessed through Ngong road, the Southern Bypass or Langata Road. It has a population of 170,070 households and an approximated headcount of 400,000 people based on the census results (Yonemitsu *et al*. 2015; Yonemitsu, *et al*., 2012) and covers an area of 2.5 km^2. There however exists a number of conflicting reports that estimate the population to be between 235,000 and 2,000,000 people (George & Gicheru, 2016; A. Yonemitsu *et al*., 2014; Cronin & Guthrie, 2011). Due to the low income and high unemployment rate among the residents of Kibera, the housing, road and sanitation infrastructure is poor hence pose significant health risks and reducing the wellbeing of the residents. Various interventions geared towards economic empowerment and welfare improvement have been implemented in the area. Though some of them have been successful, there is a need for further interventions to improve the living standards of the local residents. The study area is also in close proximity to Ngong forest which serves as a haven for wildlife and a diverse range of indigenous plants. It, however, is also threatened by the surrounding population given the high demand for biomass fuels and land for residential and agricultural purposes. Due to the high population density of the area and most of the population being classified as low-income earners, it is expected that the adoption of clean energy cooking technologies would have a more significant positive effect on the people in the area (Mutisya & Yarime, 2011).

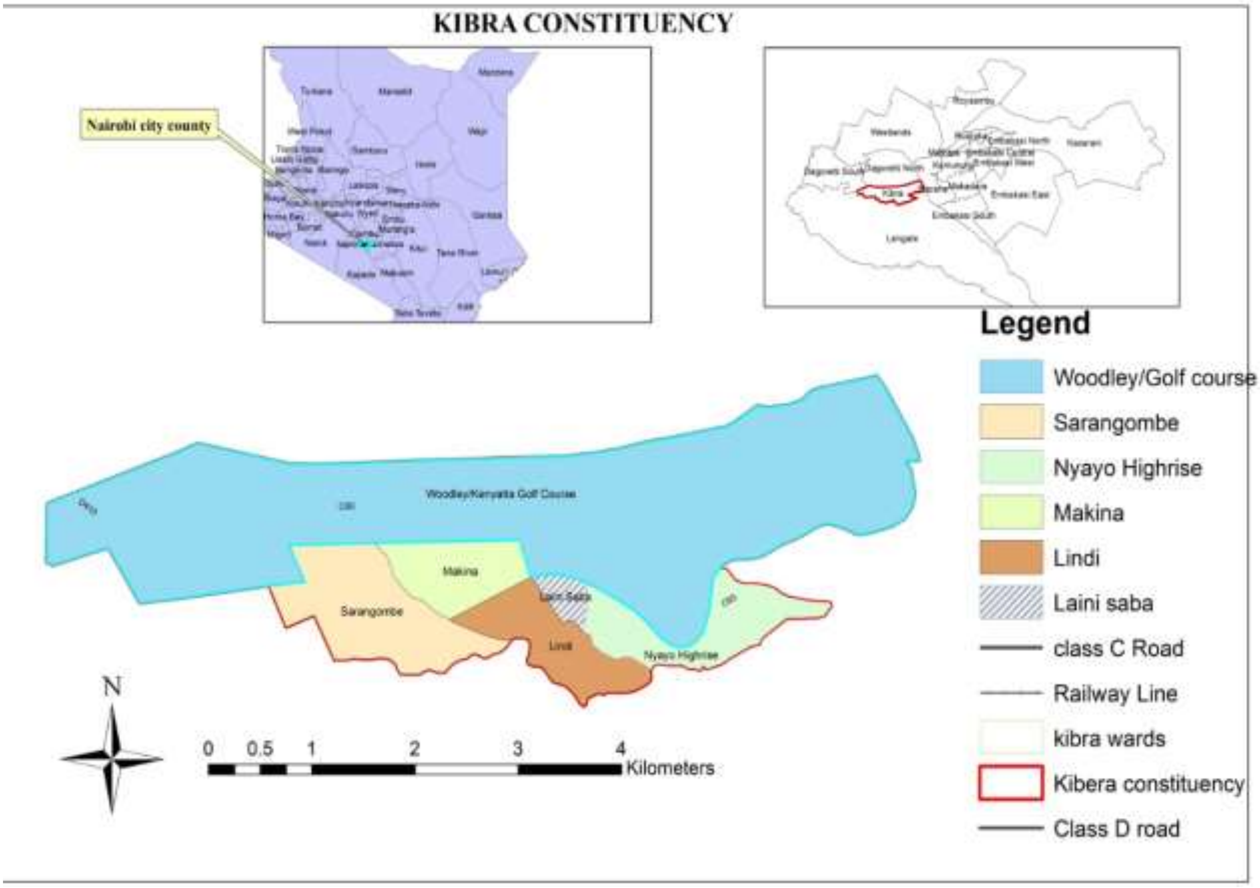


Figure 2: Kibera in Nairobi County

3.3. Research design

3.3.1. Sample size

Previous studies on energy consumption behaviour used various sample sizes due to the difference in the scope of the study and sampling techniques. Aya Yonemitsu *et al*. (2015) used a sample of 200 respondents identified through systematic random sampling. The study identified respondents based on their proximity to a pre-identified road and its diverting roads. Every 5th household from a diversion from the road was identified as a viable respondent. George & Gicheru, (2016) on the other hand used a sample of 449 respondents who were randomly selected on the basis that the population of Kibera was 300,000 people and had 17 villages.

The sample size for this study was determined using the Cochran formula (Cochran, 1977). Based on the 2009 census, Kibera has an estimated population of 170,070 households and a headcount of about 400,000 people. The Cochran formula is often used when the exact population of the study area is unknown. This was the case for the study since there are contradicting reports on the population size of Kibera ranging from 300,000 people to over 2 million people living in the area (Cronin & Guthrie, 2011; George & Gicheru, 2016; A. Yonemitsu *et al*., 2014).

The formula is given as $n_0 = \frac{Z^2pq}{e^2}$ where

n_0 is the sample size

Z^2 is the abscissa of the normal curve that cuts off an area α at the tails

e is the desired level of precision

p is the proportion of the population that is to be investigated

q is *1-p*

Therefore

$$n_0 = \frac{(1.96)^2(0.5)(0.5)}{(0.05)^2} = 385$$

3.3.2. Sampling Procedure

Multistage sampling was used in the determination of the sample. First, the study area was purposively identified due to its geographical positioning within a large city and presence of studies to understand the adoption of cooking technologies and energy sources (Ndolo, 2017; George & Gicheru, 2016; A. Yonemitsu *et al*., 2014). Once the study area was determined the next stage was the division of the study area based on its administrative boundaries. The study area was made up of 3 locations headed by their respective chiefs and all the locations were sampled in the study. Systematic sampling was used to identify the participating households in the study per location. The sample size then was equally distributed among the three locations hence each location had a sample size of 128 households. Field guides were consulted through the local administration in order to get sufficient realistic coverage of the locations. The enumerators would then disperse in different routes and sample up to 3 households on their routes depending on the household concentration in the route. The households were systematically identified given that the enumerators interviewed every fourth household after a sampled household. The dispersion/landmark points per location were distributed in a cross-sectional way to ensure sufficient representativeness of the sample in the study area.

3.3.3. Data collection, capture and analysis

The data was collected using semi-structured questionnaires and was administered by trained enumerators to ensure the data is accurately captured. The enumerators went through a training program to improve their understanding of the questions in relation to the research objectives.

The local administration was contacted in adherence to the researchers' code of ethics and the participation in the study was on a voluntary basis. A pre-test for the questionnaire was done with the enumerators in order to make the enumerators more familiar with the questionnaire and to identify the average interview time for better planning of the data collection process. The pre-test exercise also helped in the refining of the sampling procedure in the study area. The data was collected in the second and third week of January 2018.

The data collected was be managed using Microsoft Excel, SPSS version 22 and all the data analysis was carried out using STATA version 14.

3.4. Data Analysis

3.4.1. Descriptive analysis

To meet the first objective descriptive analysis techniques were used. The results are presented in the form of frequencies and percentages through Tables and graphs.

3.4.2. Econometric analysis

The analysis of the second objective was done using the Poisson regression model. The model was used to establish the relationship between the dependent and independent variables in regard to the intensity of CECT adoption.

Empirical framework

To analyse the factors influencing the intensity of adoption of the clean energy cooking technologies, the Poisson regression model was used to assess the relationship between the dependent variable and the factors identified through literature review. This model was used due to the nature of the dependent variable; which was a count variable of the number of CECTs adopted by a given household. Count data are non-normal hence cannot be sufficiently estimated by Ordinary Least Squares (OLS) regression.

The Poisson regression model was found to be applicable to this study since the number of clean energy cooking technologies available to consumers in the market is more than one. The consumer was also expected to have adopted more than one technology within a time period. Each cooking technology was assumed to be adopted for different purposes as supported by the energy stack model. The model hypothesizes the energy needs of a household are theoretically met by more than one energy source (Kroon *et al*., 2013); and hence more than one technology at the same time. This makes the Poisson model an appropriate econometric tool for this study to assess the intensity of adoption.

The analysis models that can be used for count data are the Poisson Regression model (PRM), Zero Inflated Poisson model (ZIP), Negative binomial regression model (NBRM) and the Zero Inflated Negative Binomial regression model (ZINB) as discussed by Wawire *et al* (2017) and Okello *et al* (2014). And supported by Greene (2012) and Wooldridge (2012). The zero-inflated models (ZIP and ZINB) are recommended for count data analysis with high frequencies of zero observations on the dependent variable; which was not the case for this study. The NBRM is adopted when there is over-dispersion in the data (the variance is greater than the mean for the majority of the modelled variables). The Poisson regression model is more popular for count data analysis due to its assumption that the mean and variance is the same in the variables compared to the NBRM hence the study adopted the Poisson regression model.

The Poisson regression is represented by the density function (Greene, 2012; Wooldridge, 2012)

$$f(y_i \vee x_i) = \frac{e^{-\lambda(x)}\lambda_i(x)^y}{(1+y_i)} \text{ .... (1)}$$

where

λi =intensity parameter, $\lambda i = exp(\alpha + Xi\beta)$ .... (2)

And Xi= independent variables

α *and* β=estimated parameters

y= the number of clean energy cooking technologies adopted

The marginal effects of the independent variables were then determined

$$\frac{\partial \varepsilon(y \vee x)}{\partial xj} = \beta j exp\ (xi\beta) \text{ .... (3)}$$

Where x_i is the independent variable and βj is the coefficient indicating the marginal effect of variable x_i.

The expected effects of each independent variables on the dependent variable based on the literature review are as given in Table 1

Table 1: Hypothesized effect of the independent variables on the intensity of CECT adoption

Variable	**Variable definition**	**Unit of measurement**	**Hypothesized sign**
HHsize	Household size	Number of people in the household	+/-
Sex_mostcooking	Sex of the person who does most of the cooking	Male or Female	+/-
Age_mostcooking	Age of individual who does most of the cooking	Age in years	+/-
Climchange	Climate change awareness of the respondent	Knowledge or lack of knowledge on climate change (Binary variable)	+
HHHead_group	Household head group membership status	Membership lack of membership (Binary variable)	+
Electcost_month	Monthly electricity costs	Cost in Kenya Shillings	+/-
Totalfuelcost_month	Total fuel cost per month	Cost in Kenya Shillings	+/-
Cost_ceramicjiko	Price of Kenya ceramic *jiko*	Cost in Kenya Shillings	+/-
Cost_LPG	Price of acquiring LPG	Cost in Kenya Shillings	+/-
Cost_electricjug	Price of acquiring electric jug	Cost in Kenya Shillings	+/-
Cost_improvedjiko	Price of acquiring improved *jiko*	Cost in Kenya Shillings	+/-
Safety_1	Safety-risk of exposure to hot appliance surfaces	Binary consideration on the risk that the cooking technology poses to the household when used (high risk or low risk)	+/-

CHAPTER FOUR

4.0. RESULTS AND DISCUSSION

In this chapter, the results of the study are presented.

4.1. Socio-economic household characteristics

Of the 378 sampled households, the average household size was found to be 4 people and 79.9% of the households were male-headed. The average age of the household head was found to be 37.54 years with a range of 19 to 77 years and the average number of years of education was 11.03 years. Under the current 8-4-4 education system that is equivalent to getting to form 3 of secondary education. At this level of education, most of the respondents could effectively communicate in English and/or Swahili. In a majority of the households (88.24%), a female member in the household was found to be the person most involved in cooking and the average age of the individual who did most of the cooking was 31.6 years. The average frequency of cooking per day was 3 times. The average age of the eldest female was 32 years while the average age of the eldest female was found to be 10 years.

The group membership among the respondents was found to be 42% of the sample with the average number of groups per person being 2. The group membership among the household heads was at 32.54% with the average number of groups per individual being 2. In both instances, the range on the number of groups was found to be 0 to 5.

Table 2: Household traits

Variable	Units	Mean	Std. Dev.	Min	Max
Household size	Number	3.959	1.827	1	11
Cooking frequency per day	Number	2.718	1.098	1	10
Household head sex	Dummy variable (Male=1, Female=0)	0.799	0.400	0	1
Household head age	Years	37.630	11.174	19	77
Household head group membership	Dummy variable (Yes=1, No=0)	0.328	0.470	0	1
Number of groups household head is in	Number	0.492	0.8777	0	5
Household head years of education	Years	11.042	3.327	2	29
Group membership of the respondent	Number	0.423	.4947911	0	1
Number of groups respondent is in	Number	1.515	0.968	0	5
Age of eldest female	Years	32.396	10.790	15	83
Education of eldest female	Years	10.297	3.249	0	20
Person who does most of the cooking	Dummy variable (Male=1, Female=0)	0.115	0.319	0	1
Person who does most of the cooking age	Years	31.643	10.371	14	77
Person who does most of the cooking years of education	Years	10.371	3.206	0	20
Number of clean energy cooking technologies adopted	Number	1.297	0.6785	0	4

4.2. Characterization of the cooking technologies adopted in Kibera

4.2.1. Cooking technologies adopted in Kibera

Table 3: Cooking technologies adopted

Technology adopted	Adoption level (% from sample)	Average price of acquisition	Average time period of ownership (years)
Kenya ceramic *jiko*	74.34	399.12 (361.99)	3.93
Kerosene stove	43.65	728.21 (563.26)	5.51
LPG	40.21	6346.93 (5970.81)	4.47
Electric burner	10.85	2142.43 (5399.95)	3.20
Improved *jiko*	2.12	3512.37 (435.69)	1.13
Electric jug	3.17	1372.73 (1004.08)	3.77

(Standard deviation in parentheses)

The most adopted cooking technology was found to be the Kenya ceramic *jiko* with 74.34% of the sample adopting it, followed by the kerosene stove at 43.65% as shown in Table 3. Even though the kerosene stove is not a clean cooking technology, its adoption is significantly high at 43.65%. Due to its popularity among urban households; especially in low-income urban settlements, there is a need for further studies to understand the households' kerosene stove use. LPG adoption was also high at 40.21% while the electric stove adoption was relatively low at 10.85 %. The improved *jiko's* adoption was low at 2.12%. From the sample, only one household was found to be using the traditional three-stone stove with firewood being used as the fuel and was also identified as the most important cooking technology in the specific household. The average number of clean cooking technologies adopted was found to be 1 with a range of 0 to 4 clean cooking technologies.

The popularity of the Kenya ceramic jiko can be attributed to its relatively low price of acquisition and the long period of ownership and the same reasons can be given for the popularity of the kerosene stove. The low adoption of the improved jiko and the low period of ownership can be attributed to the fact that it is still a relatively new technology in the Kenyan market compared to the other technologies. The cost of acquisition of the cooking technologies shows that there is low variation from the average costs except for electric burner and improved *jiko*. This is due to the fact that their adoption is relatively low. However, the variation in the types of electric cooking technology adopted is high. The high variance in the price of the electric burner as shown by the high difference between the mean and standard deviation is the indicator of high variation between the highest and lowest value recorded. The price range between the cheapest electric cooking technology adopted and the most expensive was found to be large; ranging between KSH. 150 and KSH 30,000.

4.2.2. Choice on most important cooking technology

Table 4: Most important cooking technology based on the use

Cooking technology	Percentage of sample
Kenya ceramic *jiko*	46.56
LPG	27.25
Kerosene stove	20.37
Electric burner	5.29
3-stone cooking stove	0.53
Total	100.00

The most important cooking technologies were also identified at the household level and the results are presented in Table 4. Though the electric jug was identified as a cooking technology, it was not considered by any household as the most important cooking technology. This is likely because it is often used as a supportive cooking technology rather than a primary cooking technology in the household. It is often used to heat up water for various purposes such as bathing, cooking of traditional meals such as *githeri* (maize and beans mixture) and *ugali*. This is often done to reduce the time spent on the preparation of the meal.

4.2.3. Stacking of cooking technologies adopted

Table 5: Cooking technology combinations

Cooking technology combinations	Percentage adoption by sample
Ceramic *jiko* + Kerosene stove	32.28
Ceramic *jiko* + LPG	25.13
Ceramic *jiko* + LPG + Kerosene stove	9.26
Ceramic *jiko* + Electric burner	6.35

Given that the ceramic *jiko* was the most adopted cooking technology and was considered to be the most important, an analysis of the technology stacking within the households was conducted based on the energy stack model. 32.28% of the sample had adopted both the Kenya ceramic *jiko* and a kerosene stove while 25.13% had a combination of the ceramic *jiko* and LPG as shown in Table 5. Stalking of three cooking technologies was found to be practised by a small portion of the sample at 9.26%.

4.2.4. Reason for the adoption of specific technologies

Table 6: Reason for cooking technology adoption

Technology adopted	**Reason for adoption (% among the technology's adopters)**								
	Ease of use	Ease of access to cooking fuel	Fast cooking time	Low emissions	Ease of acquiring the technology	Cheaper to use	Good cooking quality	House warming	Children safety
Kenya ceramic *jiko*	17.28	8.46	4.04	0.74	4.78	47.79	8.09	8.09	0.74
Kerosene stove	17.65	4.90	39.22	1.96	33.33	-	1.96	-	0.98
LPG	20.67	2.67	62.67	6.67	2.67	4.67	-	-	-
Electric burner	7.5	17.50	32.5	2.50	7.50	27.50	5.00	-	-
Improved *jiko*	-	-	-	62.50	-	37.50	-	-	-
Electric jug	8.33	8.33	83.33	-	-	-	-	-	-

The cost of operation and the fast cooking time were found to be the key motivations to the adoption of the Kenya ceramic *jiko* and the kerosene stove respectively as shown in Table 6. The time-saving properties of LPG, the electric jug and burner made them favourable to a majority of its adopters while the low emissions of the improved stove made it favourable to most of its adopters. Given that the improved *jiko* uses the same cooking fuel as the ceramic *jiko*, it can be concluded that the adopters were interested in using charcoal as the cooking energy source but producing lower emissions.

The findings presented in Table 6 can be used to support the adoption decisions made by the household and preferences revealed (see Table 3). The popularity of the Kenya ceramic jiko can mainly be attributed to its relatively low price of maintenance while the popularity of the kerosene stove can jointly be attributed to its fast cooking time and ease of acquisition. The popularity of the LPG cooking technologies can be attributed to their fast cooking time and the same can be explained for the electric jug. The adoption decision of the improved jiko can then an individual influence to its lower emissions and lower cost of maintenance as expressed in Table 6.

4.2.5. Safety ranking of the adopted cooking technologies

The safety concerns associated with the adoption of each cooking technologies were also evaluated among the adopters of each technology. This was achieved by each household ranking the technologies adopted in the household. The results are as presented in Table 7

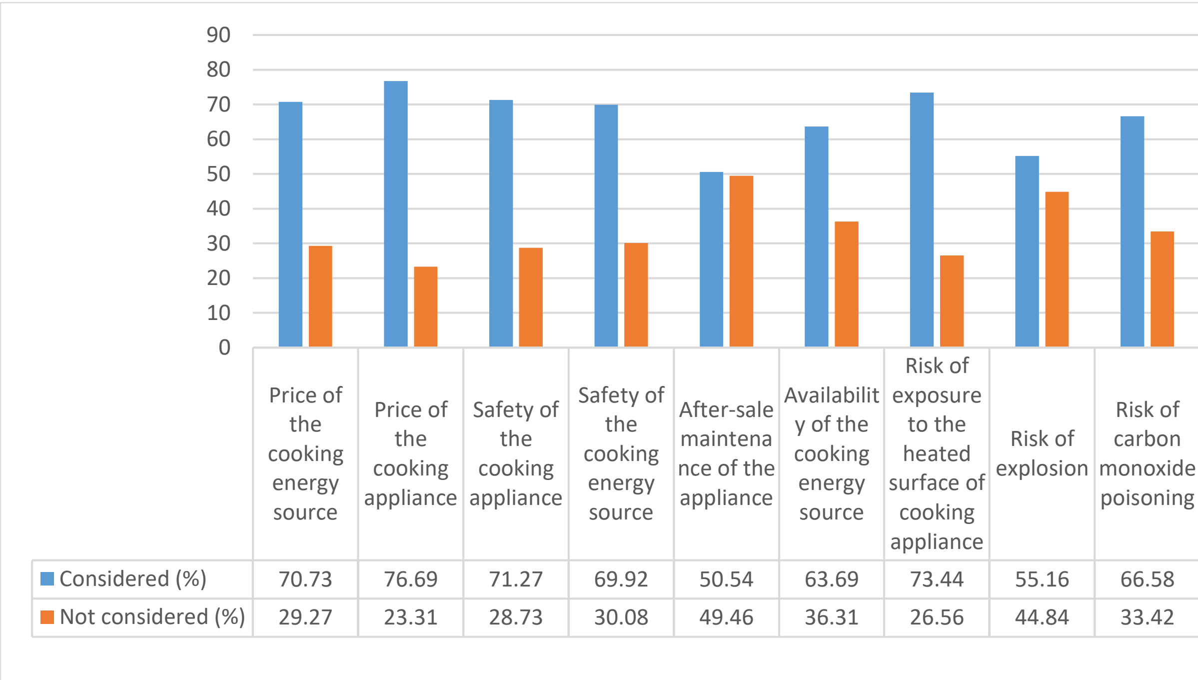
Table 7: Cooking technology safety ranking

Technology adopted	Percentage of sample		
	Rank 1	Rank 2	Rank 3
Kenya ceramic *jiko*	69.18	26.16	3.94
Kerosene stove	34.87	47.37	17.11
LPG	64.24	29.80	3.97
Electric burner	48.78	34.15	12.20
Improved stove	62.50	37.50	-
Electric jug	33.33	41.67	16.67

Contrary to Karekezi *et al*. (2008b) the majority of the electrical technology users; specifically, the electric burner and LPG users considered these cooking technologies to be safest among their adopted technologies. This can represent a shift in the perception of these technologies and their energy sources in society. This can be attributed to safety advancements made in the electrical and LPG cooking technologies available in the markets as well as the increased number of trusted LPG distribution points in the area. Among the improved *jiko* adopters, the majority considered it to be the safest cooking technology they have adopted.

4.2.6. Considerations made in the choice of cooking technologies

A number of considerations were found to be made by the consumers when identifying a cooking technology.



	Price of the cooking energy source	Price of the cooking appliance	Safety of the cooking appliance	Safety of the cooking energy source	After-sale maintenance of the appliance	Availability of the cooking energy source	Risk of exposure to the heated surface of cooking appliance	Risk of explosion	Risk of carbon monoxide poisoning
Considered (%)	70.73	76.69	71.27	69.92	50.54	63.69	73.44	55.16	66.58
Not considered (%)	29.27	23.31	28.73	30.08	49.46	36.31	26.56	44.84	33.42

Figure 3: Considerations made during adoption of a cooking technology

As shown in Figure 3, some of the key considerations made were the price of the cooking technology, risk of exposure to the heated surface, cooking fuel prices and the general safety of the cooking technology. These considerations were made by 76.69%, 73.44%, 70.73% and 71.27% respectively of the sampled households. The price of the cooking fuel was also a key consideration indicating the high interdependence between the cooking technology adopted and the fuel used in the technology in the decision-making process. The availability of the cooking fuel was also considered by 63.69% of the sample. This is due to the risk of a shortage of popular cooking fuels in the area. The relatively least considered factor was the provision of after-sale services by the producers and distributors of the cooking technologies. This is because only half of the sample (50.54%) acknowledged considering it when purchasing a cooking technology. This can be attributed to the fact that a majority of the cooking technologies adopted are developed by the informal sector hence are not regulated and lack after-sale services.

Due to the lack of regulation, these technologies are relatively cheaper hence are adopted by more people. This is well observed in the high range in the prices of the electric cooking technologies, specifically the electric burner which had a price range of KSH. 150 to KSH. 30,000. From an observation of the technologies, the lower-priced electric burners were developed by people employed in the informal sector hence were not monitored or regulated by any regulatory body. This makes them risky to use and less reliable in comparison to the higher-end electric burners. The high-priced electric burners are often produced by established firms that are often monitored and regulated by more than one regulator hence go through a quality assurance process. In addition, the manufacturers often offered a warranty for their products making them more trustworthy to the end consumer.

4.3. Characterization of the cooking energy sources adopted in Kibera

Cooking energy sources adopted

Given that the cooking energy sources are compliments to the cooking technologies, the study also evaluated the adoption and consumption of cooking energy sources. The adopted energy sources by the sample were charcoal, kerosene, LPG, electricity and firewood.

Table 8: Cooking energy source adoption

Fuel used	**Adoption level (%)**	**The average quantity consumed per month**	**The average cost per month (KSH)**	**Distance to the purchasing point of energy source (metres)**
Charcoal	76.46	52.98 kilograms.	1371.73	138.22
LPG	40.21	6.47 kilograms	1004.36	570.61
Electricity	13.49	-	520.39	0
Firewood	0.12	60 kilograms	787.5	262.5
Kerosene	39.68	17.34 litres	764.71	247.89

Given that the ceramic *jiko* was found to be the most popular cooking technology, its complimenting energy source; charcoal, was found to also be the most popular at 76.46% of the sample having adopted it. LPG, electricity and firewood followed respectively at 40.21%, 13.49% and 0.12% of the sample population each as shown in Table 8.

Though kerosene is not a clean source of cooking energy, it was found to be a popular fuel with 39.68 % of the sample adopting in their household. This can be attributed to the ease of acquiring the cooking technology (kerosene stove) together with the technology's fast cooking time.

Electricity adoption as a cooking fuel was found to be relatively low at 13.49%. The average number of units of electricity consumed by the households was unknown to a majority of them since the electricity connections in most parts of the study area are not metered. The illegal connections are carried out by locals in the area and the households are charged a standard monthly fee by the individual who made the connection. The charges range from KSH. 300 to KSH. 500 a month depending on the location. This unsafe but popular activity makes electricity appealing to the consumers as an energy source since the cost of electricity is fixed regardless of the quantity consumed. This is evidenced by the consumers' responses on their choice to use electric cooking technologies. Fast cooking time and the relatively cheaper cost of using the technology were the key drivers to the adoption of the electric technologies.

4.3.1. Revealed preference among the adopted cooking energy sources

Table 9: Rank of cooking energy sources by the adopters

Energy source used	**Preference rank (percentage among adopters)**			
	Rank 1	Rank 2	Rank 3	Rank 4
Charcoal	66.90	29.62	3.14	0.35
LPG	75.17	22.15	1.34	1.34
Electricity	42	46	12	-
Kerosene	33.82	47.06	17.65	1.47

In the ranking of fuels based on preference, a majority of charcoal and LPG adopters ranked them highly at rank 1 while electricity and kerosene were mostly ranked at rank 2 as shown in Table 9. This result can be interpreted to mean that charcoal and LPG are preferred as the main sources of cooking energy at 66.9% and 75.17% of the adopters ranking them at first position respectively. Electricity and kerosene were preferred to play more of a supportive role or a backup source of cooking energy given that they were ranked at second position with 46% and 47% of the adopters respectively.

4.4. Climate change awareness and effect on choices of cooking energy technology

The level of climate change awareness was found to be high since 64.29 % of the sample were familiar with the term 'climate change'.

Table 10: Source of awareness on climate change

Source	Percentage of sample
Media (Television and radio)	42.56
Educational institutions (primary and secondary school)	30.99
Family and friends (Social capital)	22.73
Hospital	2.07
The group that the respondent is a member of	1.24
Seminars and training	0.41
Total	100.00

It was however found that the understanding of the term was not fully representative of its true meaning. For most of the respondents, climate change was understood as a change in the location of residence rather than the weather changes of an area over a long period of time. The understanding of climate change adopted by this study was that defined and explained by UNFCCC (2007). Of the respondents who understood climate change, 14.87 % acknowledged that their knowledge of climate change did influence the energy choices made in their respective households.

The majority of the respondents (42.56 %) identified the media as the place they first came to hear of the term ‘climate change’ as shown in Table 10. Educational institutions and social networks (family and friends) were also found to be key sources of information on climate change accounting for 30.99% and 22.73 % of the sample’s climate change awareness respectively. It was however observed that a majority of the individuals who had a misunderstanding on the term “climate change” got their first understanding of the term from hospitals and clinics.

4.5. A gendered assessment of household decision making on cooking energy technology and energy sources

From the assessment done on the gender influences on cooking technology and energy source adoption, it was found that male and female household members had different roles to play.

Table 11:Gender aspect of household cooking energy decision making

Decision	Male (%)	Female (%)	Joint (%)
What cooking energy source is used in the household	18.7	63.96	17.34
What cooking technology is used in the household	19.29	61.68	19.02
Funds provision for purchase of cooking energy source	50.41	29.00	20.60
Funds provision for purchase of cooking technology	52.03	27.91	20.05

The female members in the household were mostly involved in the decision making on what cooking technology and energy source to use in the household. This is evidenced by the results that female members contributed mostly to the choice of cooking energy source and cooking technology at 63% and 61 % respectively. The male household members who often provided the funds to acquire the cooking technologies and energy source used in the household. This was evident from the result that 50% and 52 % of the households sampled acknowledged that it was the male member who provided the funds to purchase the cooking energy source and cooking technology respectively.

4.6. Factors influencing the intensity of clean energy cooking technologies' adoption

Poisson regression was used to determine the factors that influence the intensity of adoption of these cooking technologies. The number of clean energy cooking technologies adopted was used as the dependent variable and the statistical significance of each independent variable was interpreted using the $P>z$ value (p-value). The marginal effects were also determined to understand the effect of each independent variable on the dependent variable. The results of the regression and marginal effect analysis are presented in Table 12.

Table 12: Poisson regression coefficients and marginal effects of the independent variables

Variable	Variable characteristics (Units)	Coefficients	Marginal effects Coefficient	Marginal effects p-value
HHsize	Continuous (Years)	-0.0094	-0.0105	0.331
Sex_mostcooking	Dummy variable (Male=1)	-0.1467	-0.1559	0.002***
Age_mostcooking	Continuous (Years)	-0.0017	-0.0019	0.963
Climchange	Dummy variable (Aware=1)	0.0237	0.0260	0.477
HHHead_group	Dummy variable (Group member =1)	-0.0094	-0.0105	0.744
Electcost_month	Kenya Shillings	0.1982	0.2229	0.000***
Totalfuelcost_month	Kenya Shillings	0.5211	0.5859	0.000***
Cost_ceramicjiko	Kenya Shillings	0.0001	0.0001	0.038**
Cost_LPG	Kenya Shillings	0.1203	0.1352	0.000***
Cost_electricjug	Kenya Shillings	-0.0002	-0.0001	0.000***
Cost_improvedjiko	Kenya Shillings	0.0001	0.0001	0.001***
Safety_1	Dummy variable (Considered=1)	-0.0260	-0.0294	0.405

Number of observations = 374 Wald chi2(12) = 763.91
Prob > chi2 = 0.0000 Pseudo R^2 = 0.1201
Log pseudo likelihood = -406.3153 Significance levels = 1%*** and 5%**

The monthly expenditure on the electricity, the total expenditure on the cooking energy sources and the cost of acquiring a ceramic jiko, LPG cooking technologies and the improved jiko were found to have a positive effect on the intensity of CECT adoption. This is to mean that the higher the expenditure or cost associated with each of the mentioned items, the higher the likelihood of the household adopting multiple CECTs.

On the other hand, the sex of the person doing most of the cooking as well as the cost of acquiring an electric jug was found to have a negative effect on the intensity of CECT adoption. This means that the likelihood of adoption of multiple CECTs decreased when the sex of the person who did most of the cooking was male and the cost of acquiring the electric jug increased. These findings are all based on the *ceteris paribus* assumption where all other factors are held constant.

The costs and expenditure on cooking energy sources and technologies have been observed by multiple studies to be significant to the adoption of cooking technologies having both a positive and negative influence in adoption (Gaspard *et al*. 2015; Njogu & Kung'u, 2015; Ministry of Foreign Affairs - the Netherlands, 2013; Adepoju *et al*., 2012; Martiskainen, 2007; Troncoso *et al*., 2007; Dzioubinski & Chipman, 1999).

In the households where the person doing most of the cooking was male, were found to be less likely to adopt a variety of clean energy cooking technologies by 15.59%. This observation is similar to Njogu & Kung'u (2015) where female-headed households were found to be more likely to adopt energy-saving cooking technologies compared to male-headed households. This finding is further supported by the observation made by Adepoju *et al*. (2012) and Kanangire *et al* (2016) in which gender played a role in the household energy choices made.

The prices of acquiring the Kenya ceramic jiko, improved jiko and LPG cooking technologies was found to have a positive effect on the intensity of CECT adoption. A unit increase in the price of LPG cooking technologies would increase the intensity of CECT adoption by 13.52% while a price increase associated to the acquisition of an improved jiko would increase the intensity of adoption of CECTs by 0.01%. A similar effect was observed for the Kenya ceramic jiko since a unit rise in its price would increase the intensity of CECT adoption by 0.01%. This can probably be attributed to the increase in income and rise in social status as explained by the energy stack model. Given that LPG cooking technologies utilize a superior cooking energy source, a rise in social status and income would result in its adoption without the full abandonment of the previously adopted cooking technologies.

The relatively lower effect of a unit price change in the Kenya ceramic jiko and improved jiko is likely due to the energy source utilized by this technology; which is charcoal and in some cases firewood. A unit increase in the price of the electric jug was however found to have a negative effect on the intensity of adoption of CECTs by 0.02%. This is likely due to the use of the electric jug as a supportive appliance and not as a primary cooking technology. The electric jug is often found to be used in the fast heating of water to be used for bathing or for the preparation of traditional meals such as *githeri* (maize and beans mixture) and *ugali* hence served as a complement to the cooking technologies adopted.

The monthly expense on electricity was found to significantly affect the intensity of adoption of CECTs as well as the total monthly expenditure on cooking energy source. A unit increase in electricity expenses was found to increase the intensity of adoption of other CECTs by 22.29% while a unit rise in monthly cooking energy source expenses was found to increase the intensity of adoption of CECTs by 58.59%. The effect of increased expenditure on energy source on the intensity of adoption of CECT can be attributed to the need to reduce household cooking energy expenditure through the adoption of more efficient technologies with lower maintenance costs. This results in the adoption of multiple cooking technologies that utilize different cooking energy sources to be used to meet the different cooking needs of households. These findings are soundly similar to observations made by Kituyi *et al*. (2001) and Adepoju *et al*. (2012) where higher electricity cost was found to have a positive effect on the adoption of cooking energy sources and high consumer prices for charcoal had a negative effect on the use of charcoal.

CHAPTER FIVE

5.0. SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1. Summary

The intention of this study was to characterize the use of various cooking energy sources and clean energy cooking technologies as well as assess factors influencing the adoption of multiple clean energy cooking technologies in Kibera. The study area is a low income, densely populated residential area in Nairobi county. Cross-sectional data was collected using questionnaires and data was analysed using STATA-14.

The average household size was found to be 4 individuals and the average number of cooking times per day was 3 times. Cooking was often done by female members of the household and the female members also made most of the decisions on cooking technologies. Financing for the use of the cooking technologies was mostly done by male members of the household. The most adopted cooking technologies were the Kenya ceramic *jiko* and the kerosene stove. Though the kerosene stove is not a clean energy cooking technology, it was found to be a popular cooking technology in the study area. Of the clean energy cooking technologies, the Kenya ceramic jiko, LPG and electric cooking technologies were found to be the most adopted. Charcoal and LPG were found to be the most popular cooking energy sources. The key influencers in the number of CECTs adopted were found to be the sex of the individual who does most of the cooking, the costs of acquiring the specific cooking technology as well as the recurring monthly expenditure on the cooking energy sources adopted.

5.2. Conclusion

The objectives of this study were to first characterize the clean energy cooking technologies and energy sources adopted in Kibera, then to assess the factors that influence the adoption of multiple clean energy cooking technologies. Based on the findings of this study, the Kenya ceramic stove is a key cooking technology among low-income earners due to its low purchasing cost and low maintenance cost. Its adoption results in increased demand for charcoal; making it the most adopted energy source. The second most adopted cooking technology was the kerosene stove; though it is not a clean energy source. Both these technologies and energy sources were adopted due to the low costs associated with their use. The most adopted CECTs were the Kenya ceramic jiko and the LPG cooking technologies with the latter being most preferred for its cost efficiency and the later for its fast cooking time.

The key factors that were considered in the adoption of a cooking technology are the prices of acquiring and maintaining the technology as well as the recurring cost of its maintained use. This is evidenced in the descriptive analysis as well as the econometric analysis of the variables. The safety perception of cooking technology also was found to play a role in the adoption of cooking technologies. However, though consumers may be aware of the effect of their consumption habits on climate change, a small fraction of them actually allow their knowledge to influence their day-to-day household decisions. Gender played an important role in the adoption of CECTs as evidenced by the regression results and the assessment of household cooking energy decision making.

5.3. Policy Recommendations

To encourage adoption of CECTs, there is first need for economic empowerment. This will increase the purchasing power of the people, making them more likely to adopt cleaner cooking technologies. It is through economic empowerment the individuals can be able to afford the CECTs they desire; especially for female members of the household. This is because female members play a critical role in household energy decision making by evaluating and choosing what cooking technologies and energy sources are to be adopted. Their ability to acquire the technologies and energy sources is limited to a degree since they mostly rely on male members for finances to purchase the CECTs and cooking energy sources. Though it is the female members who need most of the economic empowerment, the male members also need to be empowered in the area since it is generally a low-income area with limited opportunities for economic empowerment.

Economic empowerment can be achieved through sustainable entrepreneurship programs in urban areas such as clean energy entrepreneurship programs. The use of clean energy entrepreneurship programs will facilitate distribution of clean energy technologies; both cooking and lighting while generating incomes for the persons involved. Increased female engagement in such activities can further be encouraged since the female members are more likely to encourage each other to adopt CECTs in the respective households. These programs would increase the household's purchasing power, making them more likely to adopt CECTs. By also engaging the local population in the sale of the CECTs as an economic activity, they are able to relate to the needs of the household in the area hence provide recommendations to the CECT manufacturing firms. These recommendations would go into the design and pricing decisions made by the firms so as to make the CECTs more affordable, cost-effective trusted and convenient for the user.

Given that an increase in the price of CECTs was found to positively influence the adoption of multiple CECTs, there is a need for price regulation on the CECTs. This will ensure that the pricing of the CECTs is just high enough to encourage adoption without limiting its affordability to the average consumer of CECTs. The CECTs that utilize electricity and LPG are priced higher than those that consume biomass. There is need for a systematic increment of purchasing power of the people in the area so as to adopt the higher CECTs. This increase in purchasing power will result in the adoption of a second and third CECT which is cleaner than the already adopted technology. As evidenced by the findings the consumers will be motivated to adopt technologies that use cleaner energy sources more even if the price of the cooking technology to be used with the energy source is higher. This is because the advancement from one technology to the next is deemed to be a movement from an inferior good to a superior good.

An alternative approach to increase CECT adoption based on the increase in the price of the technologies is to make them more affordable to the public. Through increased innovation, there is room for the development of CECTs that can cater more to the low-income consumer markets at their income level. As the adoption increases, the more advanced CECTs can be priced higher compared to the first adopted technology; though within the financial limits of the people in the area. This can be achieved through increased research and private-private partnerships since the private sector is the main supplier of CECTs. Investment in the development of cheaper CECTs is also recommended to make the technologies affordable to a wider range of households. This would be of greater benefit to the extremely low-income households

There is a need for more public-private partnerships for better regulation of the technologies and energy sources available in the markets; especially for LPG and electrical cooking technologies. This will increase confidence in the products in the markets and would encourage the adoption of CECTs. Increased involvement of third-party inspections and assurances would improve the trust consumers have in the products they are about to consume. Also, through the partnerships, the actors can work together to increase accessibility and affordability of all CECTs and increase public confidence in LPG cooking technologies to foster increased adoption. Regulation of cooking energy source prices; specifically, LPG and electricity are also recommended since expenditure on energy sources was found to affect intensity of CECT adoption.

5.4. Areas for Further Research

There is the need for further research on the effects of the clean energy technologies available in the market on the climate change mitigation efforts in place, as well as their health benefits in comparison to the traditional cooking technologies in Kenya. There exists a significant gap in data and scientific knowledge on the long-term use of cooking technologies and their socio-economic effects on the people.

There is need research on the measured social, economic and environmental benefits experienced from the adoption of selected CECTs. This is because the products are marketed to improve livelihoods however the information is not sufficiently communicated to the end consumers. It is evidenced by this study that access to information has an effect on the CECT adoption decisions made. It is therefore key that the information from further research on the determined benefits of CECTs is communicated to the consumer in simple ways to encourage their adoption.

There is also a need for long term assessment of consumer behaviour with regard to adoption of CECTs and the supportive decisions that are engaged in the adoption processes. It is evident from this study that the adoption decision of CECTs is not an independent/isolated decision. It would be relevant to understand what other factors could influence the adoption of CECTs in the long run through analysis of time series data on the adoption decisions made by consumers.

There is room for further research on the low adoption of alternative energy sources such as briquettes and biogas. Though the energy sources were found to be available in the study area, their adoption was still low. There is a need to understand why some cooking energy sources are not viable in the context of Kibera and other residential areas such as itself even though they are readily available.

The implications of policy changes on the choices made at the household level need to be further investigated. In the course of the study period, policy changes on charcoal production and its distribution to Nairobi county had a significant influence on charcoal availability and its price. Through continuous monitoring of consumer energy practise and decision making with regard to policy changes, it can be possible to develop clean energy cooking products that will better fit the lifestyle of the consumers and are in line with institutional policy.

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APPENDIX

QUESTIONNAIRE

This questionnaire is part of an academic research conducted by Reuben Omega Amesa under the University of Nairobi and supported by Wangari Maathai Institute for Peace and Environmental Studies. The research title is "*An analysis of adoption of clean energy cooking technologies in Kibera, Nairobi County, Kenya*"

Questionnaire No. ………… Enumerator's Name: ………………………………. …..
Village: ……………………………………...

Respondent Details

Respondent's name: ______________________________Mobile no.: ________________

1 Household Traits

Number of members in the household (individuals who have been living in the household for the last 6 months					
a. Name of Household member	Sex (M/F)	Age (years)	Years of education	Relation to household head	Occupation of the member

Codes

Relation to household head	*Household head=1 Spouse=2 Daughter=3 Relative=4*
Occupation of household member	*0=Unemployed 1=formal employment 2=informal employment…3=student/pupil*

Cooking technologies and cooking fuels

2.1) Cooking technologies used

a. What cooking technology is used in your household? *1-Kenya ceramic stove* *2-Improved biomass stove (specify brand)* *3-Electric burner* *4-Electric jug* *5-Communal biogas burner* *6-Personal biogas burner (specify brand)* *7-LPG cooker* *8-other (provide name)*	What fuel does it utilize as an energy source? *1-Electricity* *2-Biomass* *3-LPG* *4-Biogas* *5-Briquettes*	Rank the cooking technologies based on frequency of use (per week)	How did you acquire this technology? *1-Purchase* *2-Donation* *3-Communal ownership*	For how much did you acquire this technology? (KSH)	For how long have you owned your current cooking equipment?	Please rank the identified technologies in terms of their perceived safety for use.

Provide the brand name of the improved biomass stove adopted. ………………………………………

How frequently do you cook in your household? .... per day

Which cooking technology would you consider to be the most important in your household (provide reason why)?...

What is the sex of the individual who mostly carries out the cooking activities in the household? 0= Female 1=Male

2.2) Cooking fuel used

a. What cooking fuel do you use? *1-Electricity* *2-Charcoal* *3-Firewood* *4-LPG* *5-Biogas* *6-Briquettes* *7-Other(specify)*	What is the monthly cost incurred to acquire this fuel? (KSH)	How far do you have to go to get the fuel from your household? (meters)	Rank the fuels used based on your preference.

2.3) Please rate the following based on their influence on your cooking technology decision making

	1= considered *2= neutral* *3= not considered*
a) Price of the cooking fuel	
Price of cooking technology	
Safety of the technology	
Safety of the fuel	
After-sale maintenance of the technology	
Availability of the cooking fuel	

2.4) Are the following safety concerns about an energy source and technology taken into consideration during the purchase of the cooking technology?

	1= considered *2= not considered*
a) Exposure to the heated surface of technology	
Risk of explosion (applies to LPG)	
Risk of carbon monoxide poisoning	

Group membership

Membership of respondent

Are you a member in any group? ………… (Yes/No) (if no skip to section 4.2)

How many groups are you involved in?..

b.1 On what capacity? (if more than one group, separate respective role in group with commas)
………………………………………………………………………………………….

How long have you been a member of the group(s)? (if more than one group, separate respective periods with commas) ……………………………………………

What is the main goal/role of the group(s)? (if more than one group, separate with commas)
………………………………………………………………………………………………
………………………………………………………………………………………………

How frequently do you meet in the group? (if more than one group, separate with commas)
………………………………………………..

Has (any of) the group been involved in any training on clean energy cooking technologies?

1 = Yes 0 = No (if no, proceed to section 4.2)
f.1. If yes, who/what organization carried out the training? (if more than one group, separate with commas) ……………………...……………….……………………….
What about clean energy cooking technologies did the training focus on?

Topic/issue	Tick appropriately
1. Economic and health benefits of cooking CETs	
Income earning from cooking CETs	
Climate change mitigation traits of cooking CETs	

Since the training have there been any follow-up meetings to it? 1=Yes 0=No
h.1. If yes, when was the last follow up meeting? ………………………………………………

Membership of household head (If respondent is household head, skip to this section)
Is the household head a member in any group? 1=Yes 2=No (if no skip to next section)

How many groups is the household head involved in?....................

On what capacity? (if more than one group, separate respective role in group with commas) …………………………………………………………………………………….
How long has the head been a member of the group(s)? (if more than one group, separate respective periods with commas) ……………………………………………

What is the main goal/role of the group(s)? (if more than one group, separate with commas)
………………………………………………………………………………………………
………………………………………………………………………………………………

Has (any of) the group been involved in any training on clean energy cooking technologies?
1 = Yes 0 = No (if no, proceed to section 5)

e.1. If yes, who/what organization carried out the training? (if more than one group, separate with commas) ……………………...……………….……………………….

f. What did the training on clean energy cooking technologies focus on?

Topic/issue	Tick appropriately
1. Economic and health benefits of cooking CETs	
Income earning from cooking CETs	
Climate change mitigation traits of cooking CETs	

Since the training have there been any follow-up meetings to it? 1=Yes 0=No

If yes, when was the last follow up meeting? ………………………………………………

Social Awareness

Do you participate in social forums around you? 1=Yes 0=No

How frequently do you participate in social forums? …………… per month

Does the household head participate in social forums in the locality? 1=Yes 0=No

Household Decision making

Who is often involved in:

	Male	Female	Joint
a) The decision of what cooking fuel is used in your household			
What cooking technology is used (e.g. cooking stove)			
Provision of funds to purchase the cooking fuel			
Provision of funds to purchase the cooking technology			

Climate change awareness

Have you heard/know of climate change? 1=Yes 2=No (if no, end the interview)

If yes, where did you first hear about it?

1= friends and family 2= a group you are in 3=media advertisement 4=other (specify)………………………………

b. Does your awareness of climate change affect the energy decisions made in the household? 1=Yes 2=No

If yes, please explain how……………………………………………………………………………………….
………………………………………………………………………………………………
………………………………………………………………………………………………

Diagnostic test results

Correlation Matrix

e(V)	hhsize	Sex_mo~2	Climat~a	logel~2c	lo~lcost	hhhead~a	loglp~3e	elecj~3e	impro~3e	logMos~e	Safety~a	jikoprice~3e	cons
hhsize	1.0000												
Sex_most_c~2	0.4232	1.0000											
Climate_ch~a	-0.0846	-0.0652	1.0000										
logelectr~2c	-0.0702	-0.0826	-0.0018	1.0000									
logtot~lcost	-0.0672	0.1701	0.0707	-0.0811	1.0000								
hhhead_gro~a	0.0895	-0.0172	-0.0493	-0.0615	-0.0262	1.0000							
loglpgpri~3e	0.0626	0.0023	-0.2492	-0.0037	-0.3034	-0.0844	1.0000						
elecjugpr~3e	-0.0080	-0.0542	-0.0497	-0.4057	-0.0305	0.0721	-0.0914	1.0000					
improvedj~3e	-0.1007	-0.0033	-0.0107	0.0544	-0.0781	-0.0860	-0.0106	-0.0798	1.0000				
logMostcoo~e	-0.0805	0.0611	0.0653	0.0248	-0.0500	-0.1115	-0.0409	-0.0575	0.0589	1.0000			
Safety_1_4_a	-0.0679	0.0741	-0.1046	-0.1370	0.0599	0.1071	-0.0937	0.0427	-0.0432	-0.1010	1.0000		
jikoprice~3e	-0.1534	-0.0876	-0.1540	0.0748	-0.3434	-0.0152	0.1991	-0.0009	0.1556	-0.0310	0.0085	1.0000	
_cons |	-0.3130	-0.3900	-0.1916	0.0449	-0.5308	-0.0662	0.1191	0.0762	0.0307	-0.5768	-0.2072	0.1587	1.0000