FACTORS AFFECTING THE ADOPTION AND USE OF LIQUEFIED PETROLEUM GAS IN GATANGA SUB COUNTY, MURANG'A COUNTY, KENYA

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A Thesis submitted in partial fulfillment of the requirements for the award of the degree of Master of Science in Environmental Resource Management in the Department of Environment and Natural Resources Management and the school of Science and Technology of Africa Nazarene University

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DECLARATION

I declare that this document and the research that it describes are my original work and that they have not been presented in any other university for academic work.

Kamau Geoffrey

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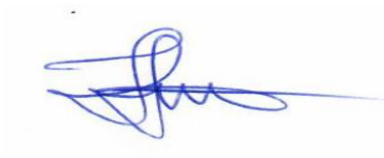

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DEDICATION

This study is dedicated with love to the following:

My Daughters, Ilaria and Ashley,

My wife Faith, and

My father Ngeru Njuguna

ACKNOWLEDGMENTS

My greatest gratitude is to the Almighty God the creator of all earth for enabling me to complete this work. My sincere appreciation goes to my lead supervisor Dr. Sharon Jones, and my other supervisor Dr. David Mugendi for their counsel and guidance without which this work would not have been possible. Their helpful ideas extensively structured my research, and their appropriate comments enhanced my progress during the study and writing of this thesis.

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ABSTRACT

Household air pollution (HAP) emanating from the burning of dirty fuels is the fifth leading risk factor for premature death and disability in low and middle-income countries (LMICs). Additionally, the use of solid fuels such as charcoal and fuelwood continues to exert excessive pressure on the dwindling forest resources in the LMICs. Adoption of clean-burning fuels including liquefied petroleum gas (LPG) can reduce the burden of HAP and pressure on the forest resources. However, Kenya's adoption of LPG remains below Africa's average at about 5%, despite the government exempting LPG from taxation through the Energy Bill of 2016 to lure more Kenyan households into adopting LPG. This research assessed the factors affecting the adoption and use of LPG in Gatanga sub-County. Firstly, the study's research questions addressed the influence of LPG availability on LPG adoption in Gatanga sub-county. Secondly, the study sought to find out the factors influencing LPG use patterns and to assess the potential effects of LPG adoption on the environment, particularly on forest resources. A correlation research design was employed to analyze responses to a structured questionnaire completed by 315 respondents selected through stratified random sampling across six wards of Gatanga sub-county. The relationships between different variables were tested using Pearson's correlation analysis and the Chi-square tests. A paired-samples t-test was used to test for any significant difference in fuelwood consumption before and after LPG adoption ($p \leq 0.05$). The results show that although 49.5% of households have adopted LPG in Gatanga sub-county, only 10.2% use it as their primary fuel for cooking. The findings also showed that a significant positive relationship exists between the distance to LPG depots and LPG adoption. Similarly, the availability of LPG delivery services determines whether a household adopts LPG. Furthermore, household size and household income also influence the choice of a household's primary cooking fuel. The study also found a significant statistical difference in fuelwood consumption before and after LPG adoption. In conclusion, although close to half of the households in Gatanga sub-county have adopted LPG, its exclusive use is limited to a few households. It is therefore recommended that addressing the factors of LPG availability and affordability is critical for the success of the Kenya Vision 2030 Agenda to achieve 35% exclusive LPG use in Kenya. The study further recommends scaling up LPG adoption to achieve the long-term goal of 10% forest cover as a gain from LPG adoption.

DEFINITION OF TERMS

Fuel Stacking: A phenomenon of using multiple cooking fuel combinations within the same household.

Biofuels: Any fuel that is derived from biomass—that is, plant or algae material or animal waste.

Sustainable Development: Development that meets the needs of the present without compromising the ability of the future generations to meet their own."

Awareness: Awareness refers to the degree of knowledge and perception about LPG adoption and use (Lewis & Pattanayak, 2012).

Accessibility: Accessibility of LPG indicates factors impacting a household's ability to procure LPG cylinders and stoves when needed. Factors affecting accessibility include (but are not limited to) distance to rural LPG distribution centers, delivery mechanism of LPG cylinders, and road connectivity from villages to local distribution centers (Jain et al., 2014).

Affordability: Affordability refers to the maximum possible capacity of households to pay for the minimum level of goods and services (Jain et al., 2014).

Adoption: Adoption refers to the initial uptake of LPG (GACC, 2016).

Sustained use: Sustained use shows the degree to which LPG is used and has been integrated into the daily behavior of users (GACC, 2016).

ABBREVIATIONS /ACRONYMS

ANOVA	Analysis of Variance
BCRM	Branded Cylinder Recirculation Model
CCCD	Consumer Controlled Cylinder Model
DRC	Democratic Republic of Congo
ELT	Energy Ladder Theory
ESMAP	Energy Sector Management Assistance Program
GoK	Government of Kenya
GLPGP	The Global LPG Partnership
GWC	Global Warming Commitment
HAP	Household Air Pollution
IEA	International Energy Agency
IEE	Intelligent Energy Europe
KEPTAP	Kenya Petroleum Technical Assistance Project
KNBS	Kenya National Bureau of Statistics
LMIC	low- and middle-income countries
LPG	Liquefied Petroleum Gas
MENR	Ministry of Environment and Natural Resources
MOEP	Ministry of Energy and Petroleum
NORAD	Norwegian Agency for Development
PM	Particulate Matter

SDG	Sustainable Development Goal
UN	United Nations
VAT	Value Added Tax
WHO	World Health Organisation
WLPGA	World LPG Association

CHAPTER ONE

INTRODUCTION

1.1 Introduction

This chapter describes and sets the context of this research project. The background to the research topic, the problem statement, the purpose of the study, and its objectives are provided in this chapter. The chapter further describes in detail the potential contributions that liquefied petroleum gas (LPG) adoption would make towards realizing sustainable development; the study significance, objectives, and theoretical and conceptual frameworks are also addressed in this chapter.

1.2 Background of the Study

Clean fuel provision remains one of the most severe challenges facing humankind, even in the wake of modern technology. In the rural areas of the lower and middle-income countries (LMICs), biofuels such as wood, charcoal, and crop residue are the main fuels used for domestic cooking and heating (Foell et al., 2011; IEA, 2010). Women and teenage girls spend a significant amount of their time gathering solid fuels and processing them for use e.g., chopping firewood (Wickramasinghe, 2011). They also use a considerable amount of time cleaning kitchen utensils which are often engulfed with soot from solid fuels. Consequently, girls end up losing valuable time that would otherwise be used productively doing schoolwork, while on the other hand, older women miss opportunities to take up commercial and income-generating activities (Shashni & Chander, 2014).

The use of non-clean fuels persists worldwide with the uptake of new clean fuel technologies progressing at a slow pace (IEA, 2016). Globally, about 3 billion people rely on biofuels for cooking and heating (Clean Energy Alliance, 2019). About 3.5 million deaths occur globally every year due to household air pollution (HAP) emanating from the burning of dirty fuels such as kerosene, firewood, charcoal, and crop residue (Oseni, 2012). More than 400,000 of these deaths occur in Sub-Saharan Africa where a majority (80%) of the population relies on dirty fuels (IEA, 2016; Rosenthal et al., 2018). Kenya is heavily dependent on biofuels, with 68% of the population still relying on non-clean fuels (IEA, 2016).

The IEA has identified Liquefied Petroleum Gas (LPG) as an inevitable fuel choice for reducing energy-related pollutant emissions (Hsu et al., 2019). LPG is a non-renewable source of energy extracted from crude oil and natural gas. The hydrocarbon-based fuel is comprised of propane and butane and is used for heating, cooking, and transport in developing countries. It is compressed into a liquid for storage in cylinders and can be easily imported and distributed without requiring complex piped natural gas distribution systems (Puzzolo et al., 2019). Despite all the potential environmental and economic gains that LPG adoption presents, LPG adoption is progressing slowly, especially in rural areas (Adeeyo et al., 2022). Studies have shown that LPG adoption is faced with many barriers that would need to be addressed to increase LPG uptake (Singh et al., 2017; Kypridemos, 2020; Wassie et al, 2021). According to Adeyemi & Adereleye (2016), energy transition is faced with various challenges and the promotion of higher levels of education and general economic development may be effective instruments for encouraging rural households to substitute traditional fuels with modern energy fuels.

In 2015, the United Nations (UN) the Member States approved the 2030 Agenda for sustainable development providing a global pathway on an urgent range of sustainable development imperatives (WLPGA, 2019). Within this Agenda are 17 Sustainable

Development Goals (SDGs) which collectively constitute a global action agenda for all countries to work on together. LPG is a clean-burning and portable fuel whose adoption as a primary household fuel is likely to accelerate the realization of all 17 SDGs; either directly or indirectly (Karimu et al., 2016; The Cooking Alliance, 2019). Using LPG for clean cooking, which is the most common use of LPG in developing countries, makes contributions to SDG 7 for affordable and clean energy (Clancy et al., 2013). LPG adoption calls in developing countries are often prompted by the need for climate change mitigation, hence contributing to SDG 3 for good health, especially among women and children (Rosenthal et al., 2018). For long, household energy across Africa has been dominated by the use of biomass resources which remain a common denominator across the continent (IEA, 2019). A total of 135 million people in the Democratic Republic of Congo (DRC), Ethiopia, Ghana, and Tanzania do not have access to clean fuels (WHO, 2019). In all four countries, deforestation is rife, and the use of biomass contributes immensely to the pressure on forest resources (NORAD, 2020). Fuelwood remains the primary cooking fuel for most households in Gatanga sub-county, like most rural areas in Kenya where the uptake of cleaner fuels such as LPG and electricity remains low (Osano et al., 2020). The aim of this study, therefore, is to assess the factors affecting LPG adoption in Gatanga sub-county and deduce the potential contribution of LPG use to sustainability.

1.3 Statement of the Problem

The use of solid fuels for cooking and heating has negatively impacted the livelihoods, the environment, and the health of many Kenyan communities. Demand for firewood and charcoal as a source of cooking fuel continues to exert pressure on the dwindling forest resources in Kenya. Additionally, exposure to indoor air pollution from the burning of solid fuels in homes has contributed significantly to the burden of death and illness, more so among women and children. Continued use of solid fuels is one of the main causes of disparities between girls and boys in rural areas, with girls spending more time fetching and preparing biofuels for domestic use at the expense of doing their schoolwork.

The role of governments is to establish an enabling environment, improve market conditions and develop a value chain to enhance the uptake of LPG (Bruce et al., 2017). Since 2016, the government of Kenya has provided incentives to encourage the adoption of LPG by availing of subsidized LPG cylinders and exempting LPG from taxation. Under the Vision 2030, Kenya seeks to upscale the uptake of LPG as a key fuel of choice to reduce energy-related pollutants to benefit health and climate. However, Kenya’s LPG uptake remains below Africa's average despite many efforts by the government to encourage the Kenyan population to adopt LPG as the household fuel of choice. The slow uptake of LPG may see Kenya lag in realizing her development goals by the year 2030. Additionally, achieving long-term goals such as gender equality under the SDGs may prove to be an uphill task if further interventions are not made to improve LPG adoption and use in the country.

1.4 Purpose of the Study

LPG is a clean fuel, and the government of Kenya has laid out strategies in its Vision 2030 to see at least 35% of Kenyan households adopt LPG as their primary fuel (Mbaka, 2021). However, many barriers are preventing its adoption and use, but there are also several enablers for its adoption and use. Identifying LPG adoption and use factors will guide towards achieving SDG 7 on affordable and clean energy, SDG 5 on gender equality, SDG 3 for good health and well-being, and SDG 13 on climate action. The purpose of this study is to assess the factors affecting the adoption and use of liquefied petroleum gas in Gatanga sub-county, Kenya.

1.5 Objectives of the Study

1.5.1 Broad Objective

To assess the factors affecting the adoption and use of liquefied petroleum gas in Gatanga sub-county, Kenya

1.5.2 Specific Objectives

i. To assess the influence of LPG availability on the adoption of LPG in Gatanga sub-county.
ii. To investigate factors affecting patterns of LPG use in Gatanga sub-county.
iii. To assess the potential effects of LPG adoption on the environment

1.6 Research Questions

The research questions for this study, were as follows:

i. How does LPG availability influence the adoption of LPG in Gatanga sub-county?
ii. What are the factors affecting the patterns of use of LPG in Gatanga sub-county?
iii. What are the potential environmental effects of the use of LPG in Gatanga sub-county?

1.7 Significance of the Study

Over the years, Kenya has implemented various plans and policies to drive incremental adoption and LPG utilization for heating and cooking in households. A transformative-scale adoption and utilization of LPG for domestic cooking would present an opportunity to reduce the country's energy poverty, reduce air pollution, reduce deforestation, mitigate erosion, gain carbon credit, and improve the quality of life (Martinez Gomez et al., 2018). LPG is the most identifiable and highly recommended fuel for household use, with Kenya setting a target in the Vision 2030 agenda to have at least 35% of the households adopt and use LPG as their primary cooking and heating fuel (MOEP, 2016). However, there is a need to assess the progress of adoption and use of LPG in Kenya as this will provide a basis to identify and eliminate barriers to adoption while enhancing enablers of adoption such as subsidies and VAT-free LPG sales.

The findings of this study will therefore help decision-makers in policy formulation, review, and reinforcement of available regulations. Therefore, failure to understand Kenya's status as far as adoption and use of LPG is concerned will restrain Kenya's Vision 2030 and realization of SDGs including SDG 3 for good health, SDG 5 for gender equality, and SDG 13 for climate action. The burdens of environmental effects associated with the use of solid fuels include accelerated degradation, depletion of forest resources, and climate consequences (Ghilardi et al., 2009). Furthermore, this sector is also not sufficiently explored in Kenya, and this study avails crucial literature materials for further scholarly work. Additionally, this study provides relevant information to energy-oriented companies and manufacturing firms in Kenya on the extent to which LPG has been adopted and their role in potentially improving its uptake.

1.8 Scope of the Study

In this study, LPG adoption and use patterns were analyzed. The study was an evaluation of the success in expanding the adoption of LPG and an analysis of factors that should be under consideration in government intervention. The study was carried out in the rural setting of Gatanga sub-county to assess the factors affecting LPG adoption in the Sub-County. Gatanga Sub- County was considered due to its vast endowment of natural resources including natural forests and rivers that form the catchment area of the Ndaka-ini dam which provides about 80% of the Nairobi metropolitan area with clean water (Mwangi, 2021). Therefore, protection of these catchment areas is achievable through LPG adoption, to reduce fuelwood, charcoal consumption, and discourage deforestation. Data collection was conducted between February and March 2022.

1.9 Delimitations of the Study

In developed countries, LPG is not only used at the household level but is being adopted for industrial use as well as in the automotive industry. However, this study and the contents herein focused on the adoption and use of LPG at the household level; seeking to demystify the factors for and against its adoption and use. The study exclusively targeted the rural households of Gatanga sub-county.

1.10 Limitations of the Study

As this study was carried out in somewhat remote rural locations of Gatanga Sub-County, households with no knowledge of the LPG cooking technology were encountered. This necessitated the researchers at times to play the role of creating awareness, which was time-consuming. Additionally, reluctance from the respondents to respond to questions was also encountered. However, this was addressed by seeking consent from the local administration and research authorities to inspire confidence and honesty.

1.11 Assumptions

The research was designed and implemented based on the assumptions that one, the respondent would be cooperative and provide reliable and relevant responses to enable the study to be completed within the set period, and two, the study would assume that the environmental and economic benefits of LPG adoption and use are widely known in the rural Gatanga setting.

1.12 Theoretical Framework

A theory is a bridge between previous experiences and lessons for understanding future behavior, and formulating policies (Fouquet, 2016). The current study adopted two crucial theories, the first one is the theory of sustainability which is concerned with sustainable development and the second one is the energy ladder model which is concerned with the theoretical foundation of the energy transition.

1.12.1 Sustainable Development Theory

The development of humanity over the last few decades has resulted in climate change, natural disasters, and political and socio-economic instability (Gorlach et al., 2014). Unsustainable activities such as over-exploitation and degradation of natural resources and pollution of the ecosystems have negatively impacted the environment, putting future generations in jeopardy. This has contributed to the rationale for efficient management of natural resources to reduce pressure on available resources while also reducing negative environmental impacts.

In 1987, the Brundtland Commission published its report linking the topics of economic development and environmental sustainability. The report provided the most widely accepted definition of sustainable development; “development that meets the needs of the present without compromising the ability of the future generations to meet their own” (United Nations General Assembly, 1987). Elaborating further on the concept of sustainable development, Porter & van Linde (1999) argued that pollution is a sign of inefficient resource use. They surmised that a win-win position can be attained for both the environment and the economy through improvements that reduce pollution in production. Furthermore, sustainable development requires that humanity adopt lifestyles that are within the earth's ecological capacity.

In the energy sector, the use of clean fuel has been emphasized, both in policy and advocacy. In the UN's Sustainable Development Goals of 2015 (SDGs), SDG 7 aims at the provision of affordable and clean energy for all. This goal is aimed at reducing dependence on biofuels and other unclean fuels such as charcoal, firewood, kerosene, ethanol, and coal. The provision of clean energy will reduce the negative environmental impacts of pollution, climate change, deforestation, and ecosystem loss.

1.12.2 The Energy Ladder Model

The energy ladder model is formed as a link between access to a household's fuel of choice and economic growth. According to this theory, household income is the main major determinant of household fuel adoption through a linear hierarchical model that combines household fuel types with improving economic status (Lasisi, 2021). Horst & Horovka (2008) arranged hierarchically from low quality, low technology, and high emission to top quality, higher technology, and low emission with increasing income (Figure 1.1). The hierarchical ordering shows that as households' income increases, the households rise a step higher on the energy ladder and switch to a higher quality non-solid fuel, replacing low-quality and solid fuels.

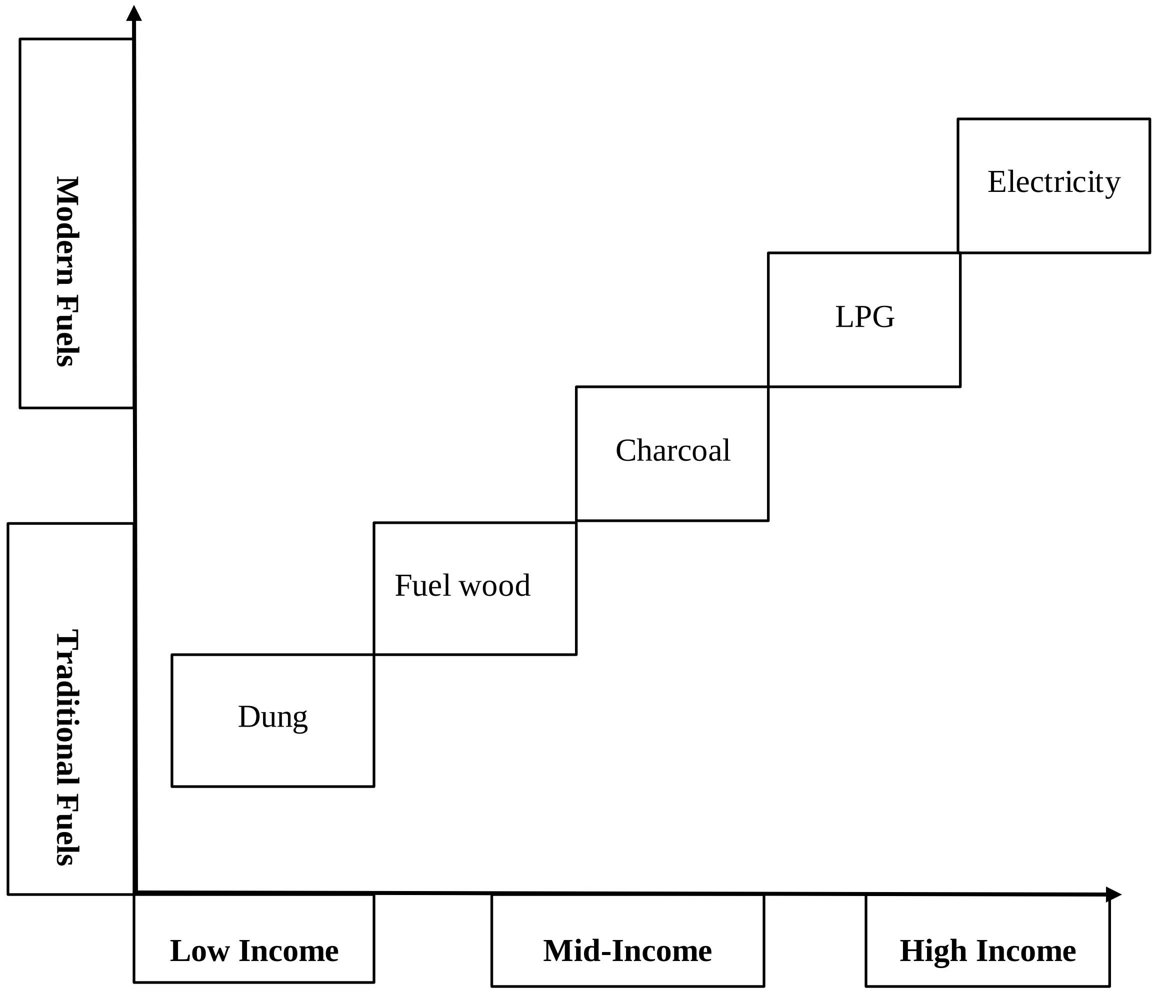

Figure 1.1: The Energy Ladder Model – Illustration of Fuel Shift. Source: Horst & Horovka (2008)

Fuel switching occurs in three distinct phases (Figure 1.2) whereby households move from the use of i) biomass fuel such as dung, and wood to ii) fuels such as coal, kerosene, and charcoal, and then to iii) modern fuels such as LPG, electricity, and other renewable fuels sources (Andadari et al., 2014). According to Hosier & Dowel (1987), the energy transition ladder can be presented in five steps to differentiate between gathered and purchased fuel. Studies have however faulted the energy transition ladder since the factors influencing the choice of cooking fuel may differ across different households (Megbowon et al., 2018; Denis et al., 2017). According to these studies, fuel choice for households is not only a function of household economic status but also other factors such as cultural and technical. Other scholars have agreed that household income is the major factor that positively influences the choice of household cooking fuel (Desalu et al., 2014; Astuti, 2017).

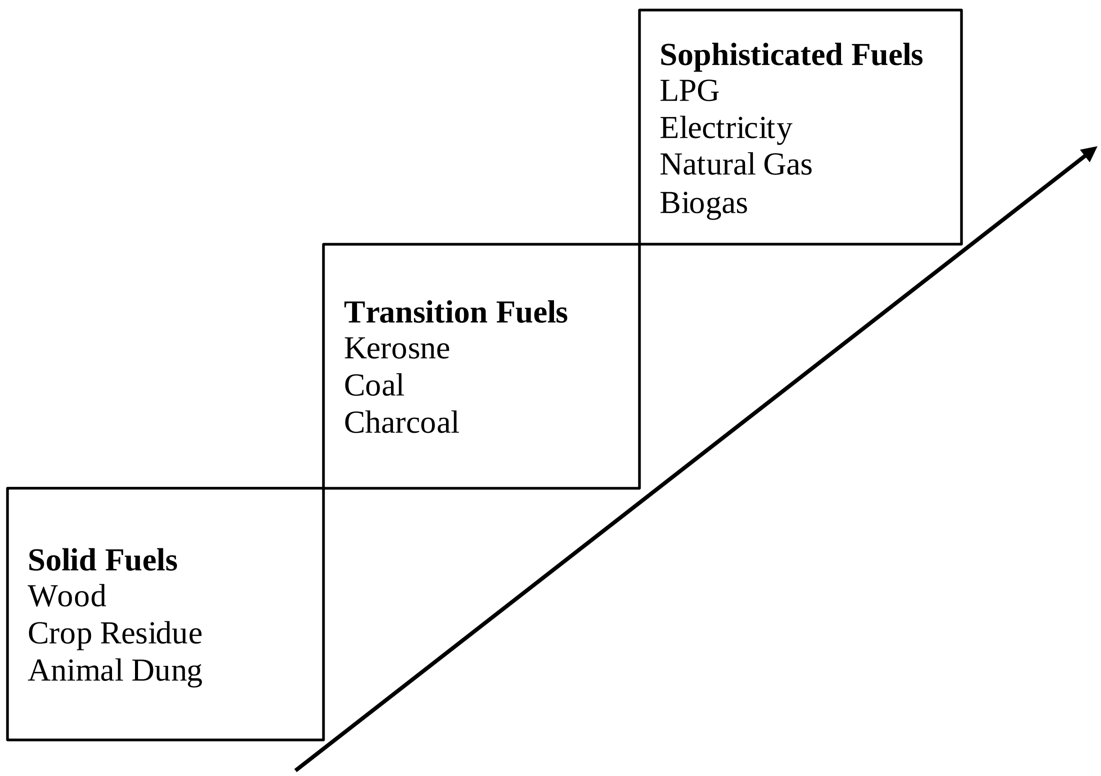

Figure 1.2: The Energy Ladder Model Illustrating Fuel Transition. Source: (Buba et al., 2017)

The theory of the energy ladder model has been acknowledged in this study alongside the theory of sustainable development and other factors of LPG availability, affordability, and accessibility. The study used the energy ladder model to assess the influence of LPG affordability, and accessibility on fuel choice and fuel use patterns in Gatanga sub-county.

1.13 Conceptual Framework

A conceptual framework is a paradigm wherein each concept plays an essential function. It indicates the key elements, constructs, or variables, and posits relationships amongst them (Mite and Huberman, 1994). The figure below shows the conceptual framework that guided this study. Under this conceptual framework, this study assessed the influence of distance to LPG depots and the availability of door-to-door delivery services on LPG adoption in the sub-county. Secondly, this study investigated the factors influencing the patterns of LPG use in the study area. Lastly, the study assessed the potential environmental effects of LPG adoption and use in Gatanga sub-county by comparing daily amounts of fuelwood that was consumed before LPG adoption and after its adoption. Additionally, legal and policy frameworks including the Vision 2030 Agenda and the Energy Bill of 2016 were the main intervening factors.

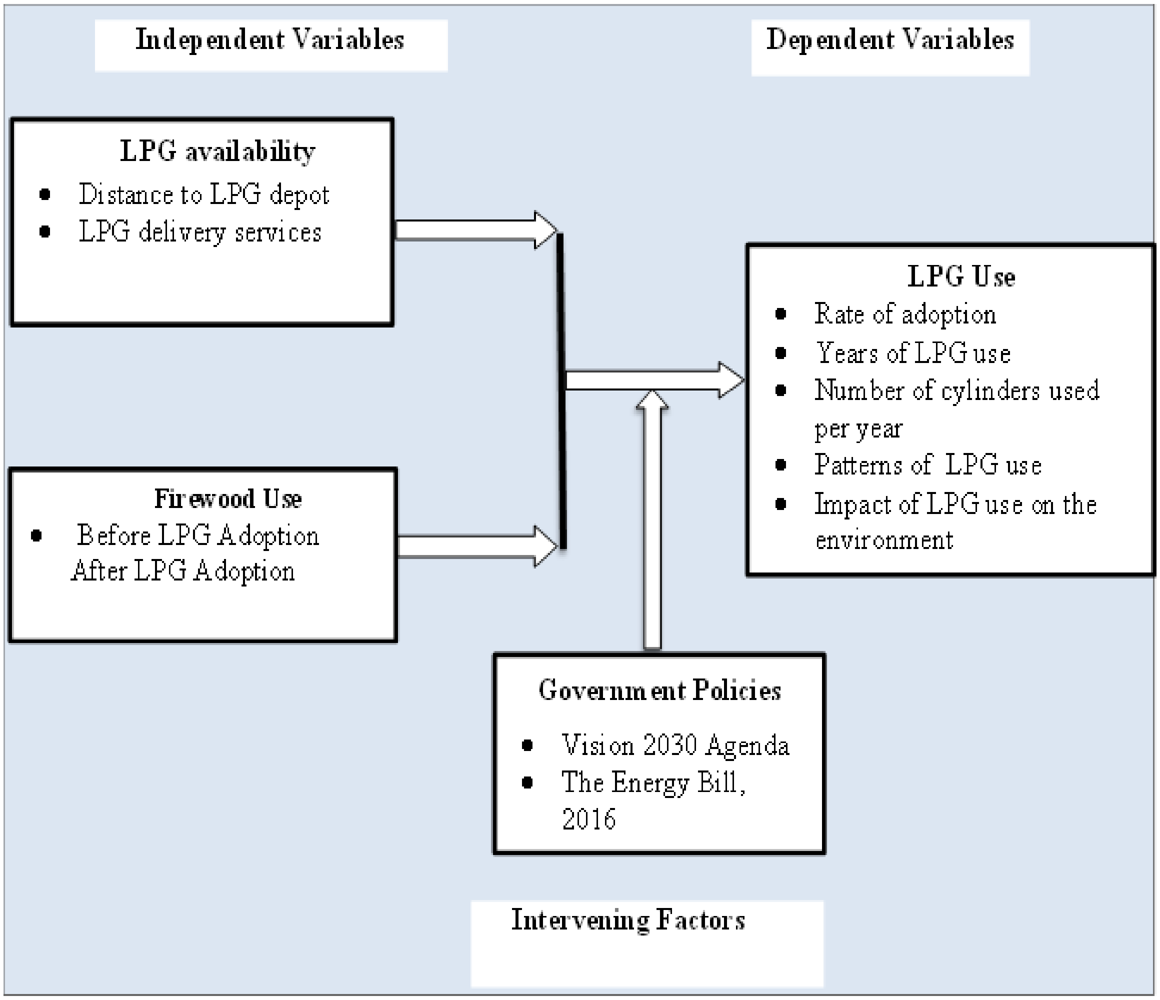

Figure 1.3: Conceptual Framework

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

The chapter reviews relevant literature on the subject under study as has been previously presented by various scholars, authors, and researchers. This review draws from various sources which are closely related to the purpose and the objectives of this study. This chapter reviews the literature on the adoption of LPG as an affordable and clean fuel, typical use patterns and implications of its use on climate and forest ecosystems, and the future of clean cooking.

The following keywords and terms were used to search the literature: energy transition, energy substitution, LPG transition, socio-technical transition, system dynamics, energy models, household cooking, residential energy, domestic energy, transition strategies, sustainability studies, transformational strategies, transition pathways, household fuel choice, impact evaluation, program evaluation, and government policy intervention. These search terms allowed the researcher to access books and scholarly peer-reviewed articles relevant to the topic of study. The literature review built on the work of scholars about household cooking fuel transition in developing countries.

2.2 Affordable and Clean Fuel

The need to transition from the reliance on polluting solid fuels and kerosene as household fuels of choice has led to the development of the concept of clean fuel. For any fuel to be considered affordable and clean, it must burn cleanly and simply, be widely available, and have inexpensive devices with almost no emission of particulate matter (Permadi et al., 2017).Community-wide use of clean fuels is required if air quality is to consistently achieve the WHO final emission rate target for particulate matter ($PM_{2.5}$) (Shen et al., 2017; WHO, 2016). In the transition towards a universal use of clean fuels, countries are seeking to invest in strategies that will address the energy needs of their varied populations over time, involving a portfolio of energy carriers and technologies to meet cooking and other household requirements (United Nations, Department of Economic and Social Affairs, Population Division, 2015).

LPG is used as fuel for thousands of applications, in commercial business, industry, transportation, farming, power generation, cooking, heating, and recreational purposes (Dhanabhakyam and Sumathi, 2014). It is a mixture of hydrocarbon gases. Among the existing liquid and gaseous fuel options, LPG can make an important contribution, with the potential to deliver substantial benefits for health, climate, the environment, and development (Karimu et al., 2016). In Indonesia, replacing the traditional fuel (paraffin) with LPG has reduced infant mortality and the incidence of low birth weight (Imelda, 2020). As a gas, LPG can easily be burned efficiently and has a high energy value for its carbon content (O'Sullivan & Douglas, 2007), making it a relatively low carbon alternative to conventional fossil alternatives. It can be used in simple cooking stoves cleanly and efficiently with a combustion efficiency of about 45-60% depending on the stove used with low pollutant formation (Smith et al., 2005; MacCarty et al., 2010). A study by Budya & Yasir (2011) shows that one liter of kerosene delivers the same energy as 0.39kg of LPG. Additionally, LPG cookstoves heat quickly while providing the user with control over the desired level of cooking power, so users can benefit from time savings through faster and more efficient cooking experiences (Wickramasinghe, 2011).

2.3 Potential Contributions of LPG to Sustainability

LPG has been identified as an efficiently combusting fuel suitable for household cooking and heating, having no residual effects on humanity and the environment (Mbaka, 2021). Its adoption varies worldwide with most developed countries adopting it as their primary household fuel while developing countries especially in the Sub-Saharan region are still experiencing low uptake of this clean cooking technology (Adeeyo et al., 2022). LPG adoption as a clean fuel provides an opportunity to achieve sustainable development, that is, environmental stability and economic development communities (Osano et al., 2020). First, LPG adoption means less time spent fetching and preparing dirty fuels, thus ample time for other activities such as economic advancement, education, and agriculture. Second, LPG use translates to less pressure on natural resources through reduced deforestation, reduced air pollution, and reduced degradation (Karimu et al., 2016). Third, LPG advances SDG 5 for gender equality through the employment of women in the sector, as well as by reducing the burdens of cooking with solid fuels which fall unfairly on women and partially on children (Kariuki & Balla, 2012).

2.4 Influence of LPG Availability on LPG Adoption

Availability and distance to LPG refilling stations have been reported as some of the main factors hindering LPG adoption and use (Oteh et al., 2015; Srinivasan & Carattini, 2016). The availability of LPG for rural households is an even bigger barrier considering that most rural households are located far from retail shops and filling stations where there is limited transportation (Dalaba et al., 2018). Furthermore, rural filling stations and LPG retailers have reported shortages of LPG due to poor accessibility in these areas resulting in inconsistent availability of refilled cylinders (Anderson & Markides, 2007; Oduro et al., 2012). According to Bouzarovski et al. (2017), the availability of cheaper and more readily available biomass may result in low uptake of LPG among low-income households. Elsewhere, studies have shown that supply-related issues are important determinants of fuel stacking (Alem et al., 2016; Choumert-Nkolo et al., 2019). Additionally, in most households, cooking decisions are made based on fuel availability and other supply-related factors (Rehfuess et al., 2010; Shupler et al., 2019).

2.5 Factors Affecting Patterns of LPG Use

A study on the adoption, use, and impact of LPG in rural India by Gould & Urpelainen (2018) revealed that only 4% of households reported not using any solid fuels (firewood, dung, agricultural residue, coal, or kerosene). The prevalence of cooking with firewood was high (83%) and dung (68%) in comparison with LPG (22%) and electricity (1%). About 58% of households used both firewood and dung in cooking and heating. Similarly, primary fuel use was dominated by firewood and chips at 63%. The study implies that LPG was a secondary fuel choice in 41% of households owning LPG. Gould & Urpelainen (2018) further investigate specific dishes cooked in LPG-owning households. LPG is used to cook about 90% and 40% of the dishes in primary LPG and secondary LPG using households, respectively. Elsewhere, despite the deep penetration of LPG cooking technologies in Latin America, fuel stacking still occurs in rural areas (Gould & Urpelainen 2018). Several factors are responsible for household fuel choices across Africa. According to Adeyemi & Adereyele (2016), households with many members prefer fuelwood to LPG and other cleaner fuels. Ahiekpor et al. (2015) reported that low-income households of Ghana tend to adopt more fuelwood as compared to high-income earners.

Similarly, according to Baek et al. (2020), household income and economic status influence fuel choice among Kenyan households.

2.5.1 The LPG Market and Prices

Charcoal, Kerosene, and firewood still dominate the Kenyan cooking fuel market. These fuels are major contributors to respiratory diseases, carbon emissions, and deforestation. The current market for LPG in Kenya is underdeveloped, with 5-7% of households using LPG as a primary cooking fuel (EPRA, 2019). However, LPG penetration remains higher in urban areas at about 21%, with only 1% of rural households using LPG as a primary fuel (EPRA, 2019). Nairobi and its surrounding areas account for close to 60% of the LPG market in Kenya where LPG penetration is 40% (EPRA, 2019). According to Dalberg (2018), the existence of a large consumer segment provides an untapped market for LPG. However, the high prices of LPG compared to other fuels is a key barrier that makes LPG affordability unachievable. Therefore, achieving higher rates of LPG adoption will require a significant lowering of prices to compete with other low-cost unsustainable fuel sources such as charcoal, firewood, crop residue, kerosene, and cow dung.

2.5.2 LPG Distribution Models

There mainly exist two LPG distribution models that also inform the choice to adopt LPG as household fuel for cooking. These models are the Consumer Controlled Cylinder Model (CCCM) and the Branded Cylinder Recirculation Model (BCRM) (Puzzolo et al., 2019). In Kenya, the Consumer Controlled Cylinder Model (CCCM) is the most common LPG distribution system whereby the consumer owns the cylinder and is fully responsible for maintaining the cylinder (Puzzolo et al., 2019). The consumer can also refill their cylinders at any refilling station. In the Branded Cylinder Recirculation Model (BCRM) the LPG marketing company owns the cylinder and is fully responsible for maintaining the cylinder and can only refill the cylinder only at authorized stations of the marketing company. The consumer pays a deposit beforehand, to obtain the first cylinder from an authorized dealer, which is typically set below the cost of the cylinder, and the purchase price of the LPG it contains. Empty cylinders are exchanged for a full cylinder of the same brand for the refill price. The main disadvantage of the CCCM is a decline in cylinder safety, leading to an increased risk of explosion accidents. Additionally, the CCCM is susceptible to illegal market LPG activities by unscrupulous refilling businesses disregarding safety (Puzzolo et al., 2019). On the other hand, the BCRM is often associated with higher-end consumer cost cylinders and refilling and the exclusion of small enterprises from the LPG business.

2.6 Potential Effects of LPG Use on the Environment

Promoting access to cleaner cooking fuels and devices, specifically, LPG would contribute to reducing global air pollution while also promoting climate co-benefits, achieving both environmental and development goals (IEA, 2016). LPG cookstoves have efficiencies of 45-60%, thus emitting fewer Green House Gases (GHG) as compared to other fuel types (ESMAP, 2006; Laan et al., 2010). Afrane & Ntiamoah, (2011) compared LPG, charcoal, and biogas in Ghana and found that LPG performed the same as biogas and had the lowest overall global warming emissions among the three fuels.

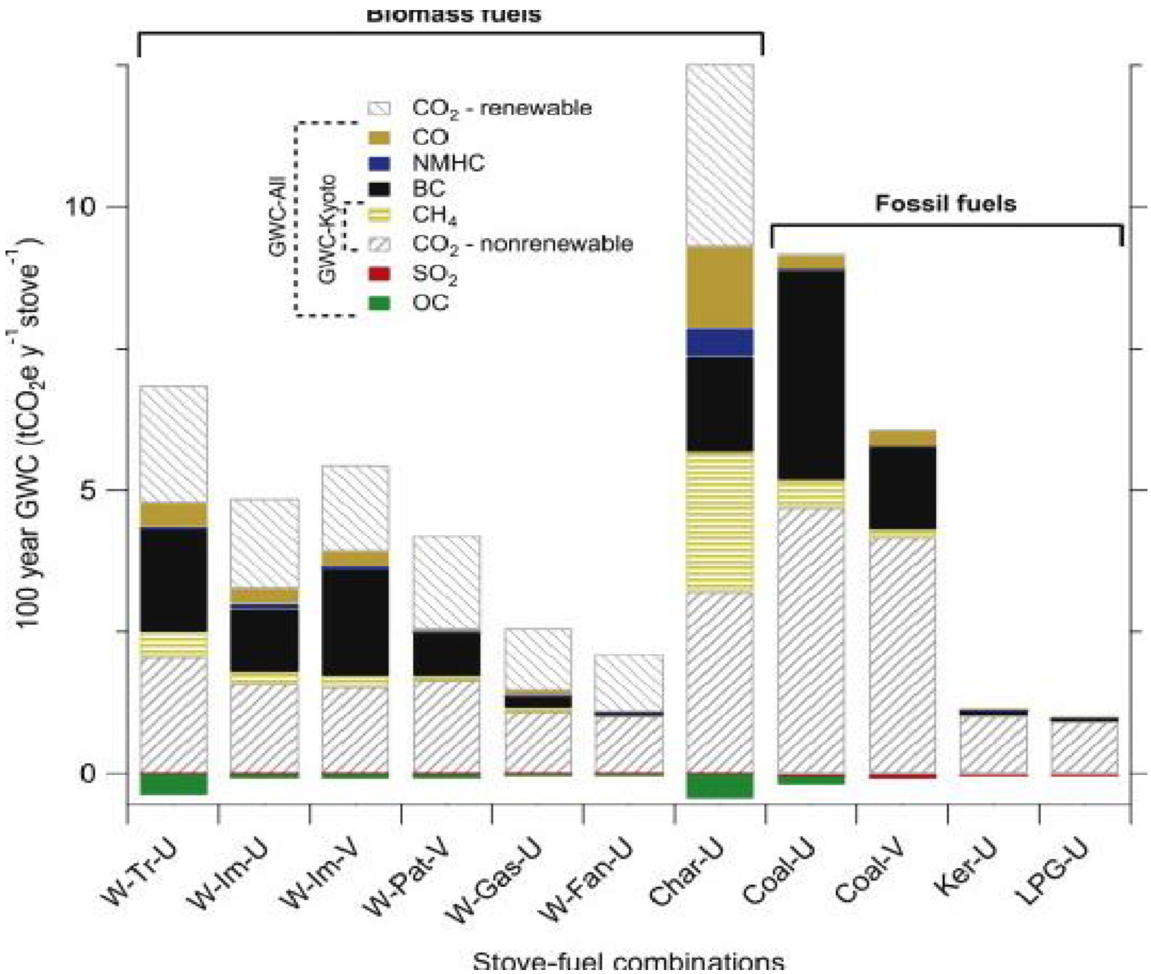

Figure 2.1: Climate impact of stove/fuel combinations estimated using Global Warming Commitment (GWC) over a 100-year horizon. Source: Grieshop et al (2011)

Legend

W-Tr-U: woodstove (traditional) – unvented
W-Im-U: woodstove(improved)–unvented
W-Im-V: wood stove (improved) – vented
W-Pat-V: wood ‘Patsari’ stove – vented
W-Gas-U: wood Karve ‘Gasifier’ stove – unvented
W-Fan-U: Wood ‘Phillips Fan’ stove – unvented
Char-U: charcoal stove unvented
Coal-U: coal stove – unvented
Coal-V: coal stove – vented
Ker-U: kerosene wick stove – unvented
LPG-U: LPG stove – unvented

The Grieshop et al. (2011) study (**Figure 2.1**) shows wide variation in the overall GWC of the different fuel and stove types. The emissions from the climate active pollutants are presented based on estimated annual fuel usage per stove; adjusted for the efficiencies of the various fuel/stove combinations. The highest contributions come from charcoal, although fully renewable, and from coal. The other fossil fuels, LPG, and kerosene, have lower contributions to warming than most wood-burning stoves when 50% renewability is assumed.

Many African governments, Kenya, are concerned about the depletion of forest resources resulting from massive deforestation activities in search of firewood and charcoal. Wood fuel and charcoal are the major forms of biomass energy used in Kenya for household cooking activities. Firewood meets over 64.5% of household energy needs while charcoal meets 7%. (Weismann et al., 2014). Charcoal is the dominant fuel in Kenyan urban households providing domestic energy for 82% of urban households (Ministry of Environments and Natural Resources, 2016). Because of increased urbanization, charcoal will continue to receive considerable economic importance (Githiomi, 2012). Charcoal, which is widely used as a cooking fuel, especially in urban areas of Sub-Saharan Africa, is produced by slow burning of wood under low oxygen conditions and consumes far more forest resources per meal than using fuelwood directly (Zulu & Richardson, 2013). Because of rapidly increasing lower middle income (LMIC) populations and accompanying urbanization, charcoal-driven forest degradation is a fundamental problem in many Sub-Saharan African countries (Chidumayo & Gumbo, 2013; Ahrends et al., 2010). **Figure 2.2** illustrates the alarming increase in charcoal production in the African continent (GIZ, 2014)

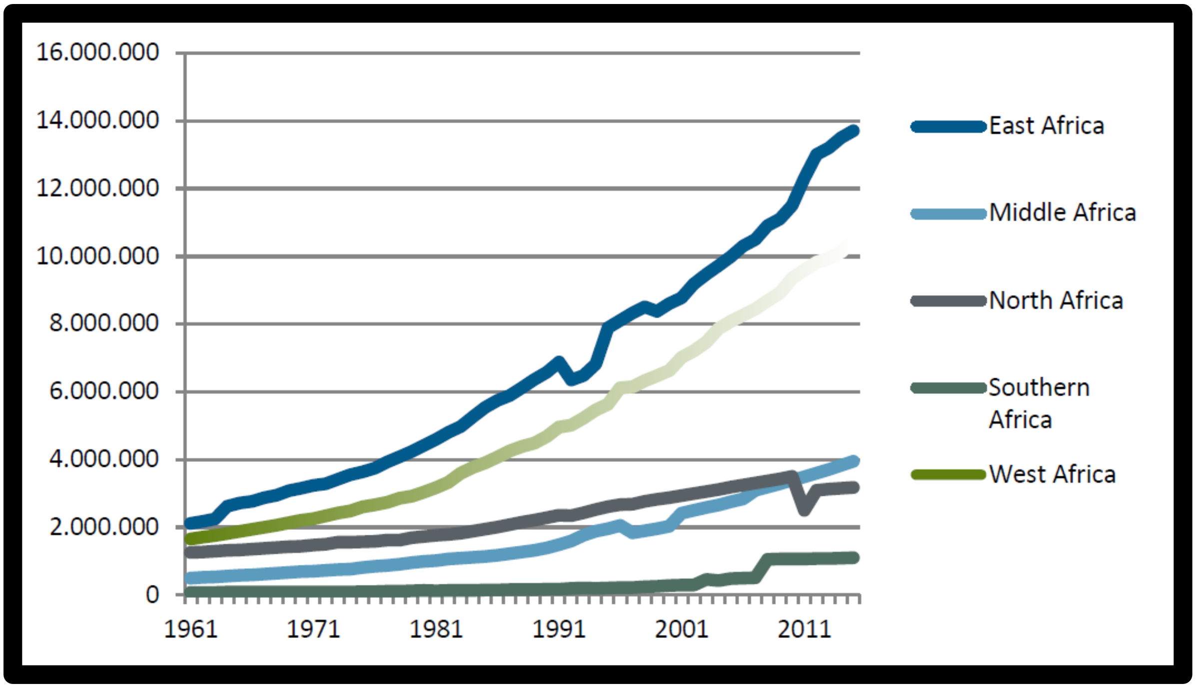

Figure 2.2: Charcoal production trends in African sub-regions up to 2015 (in tonnes), with constituent countries listed below

With a rapidly increasing LMIC population, the amount of charcoal and fuelwood consumed in Africa is expected to rise further if alternative clean and affordable cooking fuels are not made more easily available (Orimoogunje & Asifat, 2015). In a set of studies of villages in the Himalayan region of India, Nautiyal & Kaechele (2008), found out that because of governments action encouraging LPG use, fuelwood use decreased from 475 kg per capita per year between 1980 and 1985 to 46 kg per capita per year between 2000 and 2005. This suggests that LPG can play an important part in forest preservation in low-income countries. Elsewhere, Senegal's increased reliance on LPG as a household fuel of choice in the 1970s resulted in the avoided consumption of about 700000 m^3 of wood per year (Laan et al., 2010).

2.7 The Future of Clean Cooking Fuels

About three billion of the world's population (40%) lack access to clean cooking technologies and therefore rely on solid fuels and kerosene for domestic burning and heating (Van Leeuwen et al., 2017). Sub-saharan Africa's population is projected to double in the next 30 years, which would mean more reliance on biomass fuels (Lindgren, 2020). Many African governments have set their goals for increased or exclusive LPG use with Kenya setting her LPG penetration target at 36% by 2030 (World Bank, 2017). Elsewhere, both Angola and Gabon, which have relatively high levels of LPG usage at 54% and 62% respectively are seeking to achieve universal LPG access by 2025 (Van Leeuwen et al., 2017). Rwanda targets to reduce biomass fuel by 40% by 2024 through LPG promotion (WHO, 2016).

In developed countries such as the Netherlands, the USA, and the UK, the development, and expansion of BioLPG production for use in burning and heating are in their initial stages (Johnson, 2019). Although BioLPG is not sufficiently explored, it is a potential source of renewable LPG (Martinez Gomez et al., 2018). BioLPG in the LMICs is still unachievable at a large scale but is being used at the household level (Johnson, 2019). At the current rate of transition from biomass to clean fuels, the sustainable development goal (SDG7) on clean energy may remain unattainable by 2030, and even by 2050 for the LMICs (Pachauri et al., 2021). Pachauri et al. (2021) further report that this scenario would hinder progress on other SDGs, including those on health for all, gender equality, climate action, and land.

2.8 Research Gap

There exist several gaps in research on this subject. First, there is limited information on the adoption of LPG in the rural areas of Kenya. Additionally, there is no adequate information regarding the attitudes and perceptions of rural communities towards the use of LPG and their willingness to adopt the technology. Finally, most of the LPG used in Kenya is extracted from non-renewable sources such as crude oil and natural gas. There's little information on the development and adoption of renewable LPG in Kenya. According to Johnson (2019), BioLPG is a potential successor to LPG since it is a renewable fuel source produced through the hydrogenation of animal and plant oils, much of those being wastes (Johnson, 2015). BioLPG is chemically like conventional LPG and utilizes the same system, storage, infrastructure, and household equipment. BioLPG could be substituted in all applications of LPG, from cooking and heating to transport and industries (Kallio et al., 2014). BioLPG was first produced in Europe and has become a highly preferred fuel in countries such as the UK, Netherlands, and the US (Johnson, 2019). However, low-income countries are not producing or importing BioLPG, therefore future production of BioLPG for cooking purposes is highly recommended for uptake in developing countries.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter explains and defends the instruments and techniques that were used to collect primary data for the study. It describes the research design that was used, the location of the study, the target population, sampling techniques, and research instruments. The chapter also discusses data collection procedures, data processing, analysis, and legal and ethical issues that were considered during data collection.

3.2 Research Design

To determine the relationship between independent and dependent variables, a mixed methods research design was employed for this study. The mixed methods research design is a procedure for collecting, analyzing, and mixing both quantitative and qualitative research and methods in a single study to understand a research problem (Creswell, 2012). In the study, both qualitative and quantitative data were explored to better understand the research problem. Quantifiable data was collected from participants and analyzed using both descriptive and inferential statistics. Similarly, qualitative data consisting of text was collected from respondents, described, and analyzed subjectively. Using this research design, the effects of numerous factors on LPG adoption and use patterns were determined. Additionally, the potential effects of LPG use on the environment were assessed using quantifiable data.

3.3 Research Site

The research site details the area where the study is conducted as well as the research population in that area. This study was conducted in Gatanga sub-county, Murang'a County, Kenya. Gatanga sub-county was purposely selected due to its rural population and its vast endowment of natural resources. As result, the sub-county is home to the Ndakai-ini dam which supplies 80% of Nairobi metropolitan dwellers with clean water (Mwangi, 2021). Therefore, deforestation through cutting down trees for fuelwood provision and charcoal burning threatens the catchment areas associated with the dam. The sub-county covers an area of 532.3 km^2 and borders Gatundu North sub-county to the South, Kinangop sub-county to the West, Thika West sub-county to the East, and Kandara Sub- County to the North. Gatanga Sub- County is located between latitudes 00^0 45' and 01^0 015^0 South and longitudes 36^0 45' and 37^0 25' East. There are 6 administrative wards in the sub-county with a total population of 187, 989, and a total of 56,430 households (KNBS,2019).

3.4 Target Population

This research targeted the rural households of Gatanga sub-county. The sub county is made up of 6 wards namely, Kariara, Gatanga, Kihumbuini, Mugumo-ini Kakuzi/Mitubiri, and Ithanga. Gatanga sub-county has a population of 187,989 and 56,430 households (Kenya National Bureau of Statistics, 2019).

3.5 Study Sample

3.5.1 Sampling Procedure

A given number of samples are selected to represent the population, such that any statement made about the sample is also true of the population (Orodho & Kombo, 2004). In this research, a stratified sampling technique was used to sample the target population. The target population was divided into strata according to the six administrative wards of

Gatanga Sub county: Kariara, Gatanga, Kihumbuini, Mugumo-ini Kakuzi/Mitubiri, and Ithanga.

3.5.2 Study Sample Size

Gatanga Sub county has a total of 56,430 households in the 6 administrative wards. To determine the sample size, the following formula was adopted from Yamane (1973) with a 95% confidence interval assumed at p=0.05. This formula is suitable to determine the sample size when the target population is above 10,000.

Thus,

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

Where;

n = sample size required

N = population size

e = required sampling error (A 95% confidence level or 0.05 precision level, is assumed)

Substitute numbers in the formula,

$$n = \frac{56430}{1 + 56430(0.05)^2}$$

n =397,

The 397 samples were allocated proportionally in the six strata.

Thus;

Gatanga Ward $n = \frac{13011}{1+13011(0.05)^2}$; = 91

Mugumoini Ward $n = \frac{4328}{1+4328(0.05)^2}$; n= 32

Ithanga Ward $n = \frac{6040}{1+6040(0.05)^2}$; n= 44

Kariara Ward $n = \frac{14209}{1+14209(0.05)^2}$; n= 99

Kihumbuini Ward $n = \frac{8012}{1+8012(0.05)^2}$; n= 56

Kakuzi Mitubiri Ward $n = \frac{10830}{1+10830(0.05)^2}$; n= 75

Households in each stratum were selected randomly, and each household was given an equal chance of being selected.

Table 3.1: Sample Size

Strata/Ward	**Households**	**Samples**
Gatanga	13011	91
Mugumoini	4328	32
Ithanga	6040	44
Kariara	14209	99
Kihumbuini	8012	56
Kakuzi/Mitubiri	10830	75
TOTAL	56430	397

3.6 Data Collection

3.6.1 Data Collection Instruments

The study employed questionnaires to collect data from all the selected respondents. According to Orodho, (2009), questionnaires are advantageous in that they take less time, and energy, and are less expensive to administer to residents distributed over an extensive location. Additionally, questionnaires allow respondents freedom of expression and allow them to make suggestions while maintaining anonymity.

Trained research assistants administered semi-structured questionnaires. This ensured the quality of the data collected since it allowed those respondents that could not read and write to be assisted in completing their questionnaires. Section A of the questionnaire contained questions on demographic data while sections B and C contained data on the extent of LPG adoption and other fuel use characteristics.

3.6.2 Pilot Testing of Research Questionnaire

The research carried out a pilot study before the actual data collection, where forty (40) respondents were drawn from Gituamba ward in Gatundu North Sub- County, Kiambu. This represented 10% of the intended sample size. The area was considered since it has the same demographic characteristics, weather patterns, and culture as the study area. The pilot questionnaire helped in improving the final questionnaire in terms of validity and duration of administration.

3.6.3 Instrument Reliability

Instrument reliability is a test of the consistency of the instrument when used in other studies. This test is done to ensure that it would result in the collection of the same data in repeat operations. The data collected with the questionnaire during the pilot study was measured using Cronbach Alpha α coefficient. Mugenda & Mugenda (2003) recommend that a reliable instrument should have a Cronbach Alpha α coefficient value of at least 0.7. The piloted data produced a Cronbach Alpha coefficient of 0.8 which was acceptable.

3.6.4 Instrument Validity

Content validity was used whereby the validity of the instrument was tested by discussing their content with other colleagues, and further scrutiny was provided by my university supervisors as recommended by Mugenda & Mugenda, (2003).

3.7 Data Processing and Analysis

The study employed a household survey using a questionnaire as the instrument of data collection. A survey using an in-person questionnaire of participants ensured the presence of the same questions in the same order for each respondent. The survey questionnaire helped in collecting data from all willing participants in the sample. The questionnaires were exhaustively checked to ensure data quality. Data analysis for the study employed both quantitative and qualitative methods.

To address the study objectives, qualitative data were coded and entered into the Statistical Package for Social Sciences (SPSS) version 26. Descriptive statistics (frequencies and percentages) were used to show patterns in responses across the various issues as raised through the study objectives. Findings from qualitative data were grouped and presented using tables, graphs, and charts.

Quantitative data analysis was performed on the data using, correlational analysis, chi-square tests, and paired sample t-tests. A Chi-square test was performed to test relationships between distance to LPG depots and the rate of LPG adoption; relationships between LPG delivery services and the rate of LPG adoption; and the relationship between household income and fuel choice. Pearson's correlation analysis was conducted to test for relationships between the distance to LPG depots and the years of LPG use in households; for relationships between household income and the amount of LPG consumed, and relationships between household size and fuel consumption. A paired sample t-test was used to determine differences in firewood consumption before and after LPG adoption.

Table 3.2: Summary of Data Analysis Techniques

Objective	Independent Variable	Dependent Variable	Statistical Test
1.To assess the influence of LPG availability on the adoption of LPG in Gatanga sub-county	Distance to LPG depot	LPG adoption	Chi-square test
	LPG delivery Services	LPG adoption	Chi-square test
2.To investigate factors affecting patterns of LPG use in Gatanga sub-county	Distance to LPG depot	Years of LPG use	Pearson's correlation analysis
	Household size	Annual LPG consumption	Pearson's correlation analysis
	Household size	Daily firewood consumption	Pearson's correlation analysis
	Household income	Annual LPG consumption	Pearson's correlation analysis
	Household income	Household primary fuel	Chi-square test
	Household size	Household primary fuel	Chi-square test
3.To assess the potential effects of LPG on the environmental	Wood Consumption ● Before LPG adoption ● After LPG adoption	Potential environmental impact	Paired t-test

3.8 Legal and Ethical Considerations

As a legal prerequisite, the researcher sought an introductory letter from African Nazarene University before seeking permission to conduct the research from the Murang'a County Government. Further, the researcher obtained a research permit from the Ministry of Education and the National Council for Science Technology and Innovation (NACOSTI) in Nairobi to be allowed to carry out the study.

An explanation was given to the respondent about the study and that the study was intended for academic purposes only. Caution was exercised while administering questionnaires and this ensured trust between the respondents and the research assistants. Additionally, the respondents were reassured of the confidentiality and anonymity of the Information they give concerning their households. Consent, which is the predominant principle of ethics in data collection, was upheld during data collection. Consequently, the study emphasized respect for the participants who were given the freedom to refuse or accept to be interviewed or withdraw from the interview. The study, therefore, complied with the national policy guidelines on basic ethical principles concerning the protection of participants.

CHAPTER FOUR

RESULTS AND ANALYSIS

4.1 Introduction

The fourth chapter of the study provides the presentation and interpretation of the findings derived from the research work. The introduction section is about what the chapter entails. The second section presents the demographic characteristics of the respondents while the third section presents the results of the three research questions in the study. The fourth section entails the findings and attempts to answer the three research questions that the study investigated.

4.2 General Findings

This section presents the demographic characteristics of the households in Gatanga sub-county. The demographic characteristics sought from the respondents in this study included the size of households, age of the household head, education level of the household heads, income of households, and the occupation of the household head. The response rate is also presented in this section.

4.2.1 Response Rate

Response rate refers to the rate of completion and return, which is the product of dividing the number of people who returned the questionnaire by the total number of people in the targeted sample size. A structured questionnaire was used to collect primary data for the current research from a sample of 397 households in Gatanga sub-county. The response rate for all the six different wards (strata) of the sub-county is presented in table 4.1.

Table 4.1: Response Rate

Response	**Frequency**	**Percentage**
Responded	315	79
Not Responded	82	21
Total	**397**	**100**

The study targeted 397 respondents. However, out of the targeted respondent, 315 questionnaires were completed and returned, giving an overall response rate of 79%. According to Mugenda and Mugenda (2003), a response rate of 50% is acceptable while a response rate exceeding 70% is sufficient for analysis and reporting. Therefore, the response rate for this study was adequate and representative and conforms to Mugenda and Mugenda (2003).

4.2.2 Respondents Regions

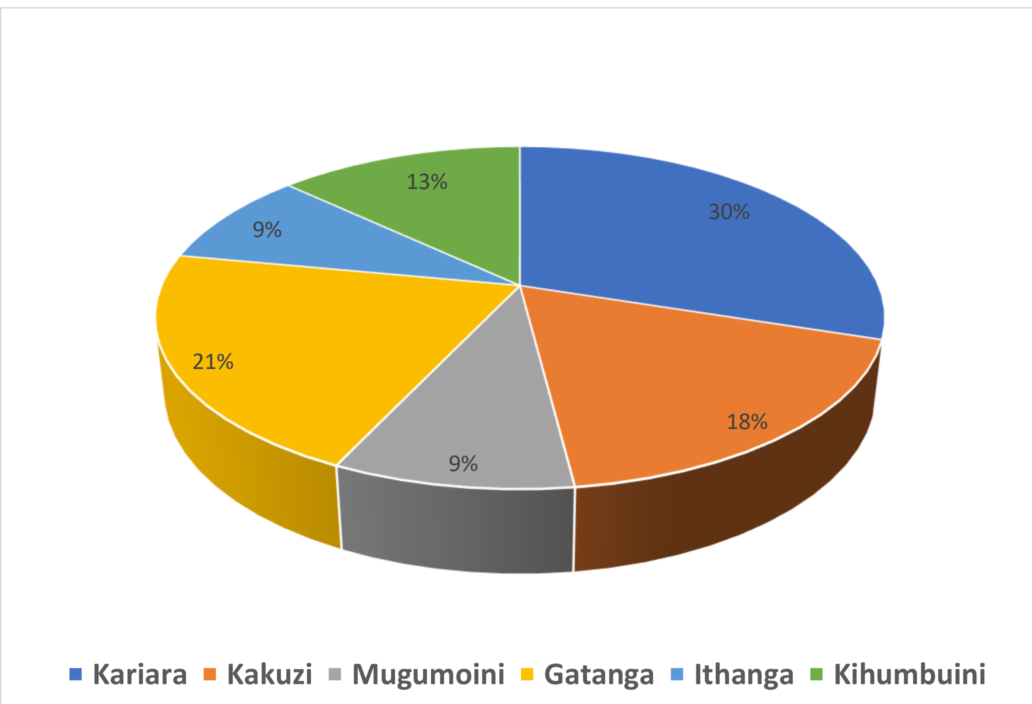

Figure 4.1: Respondents' Regions: proportion of respondents who responded from each ward.

The highest percentage of respondents came from Kariara ward (30%), whereas the lowest percentage came from Mugumoini and Ithanga wards (9%) (Fig. 4.1).

4.2.3 Household Sizes

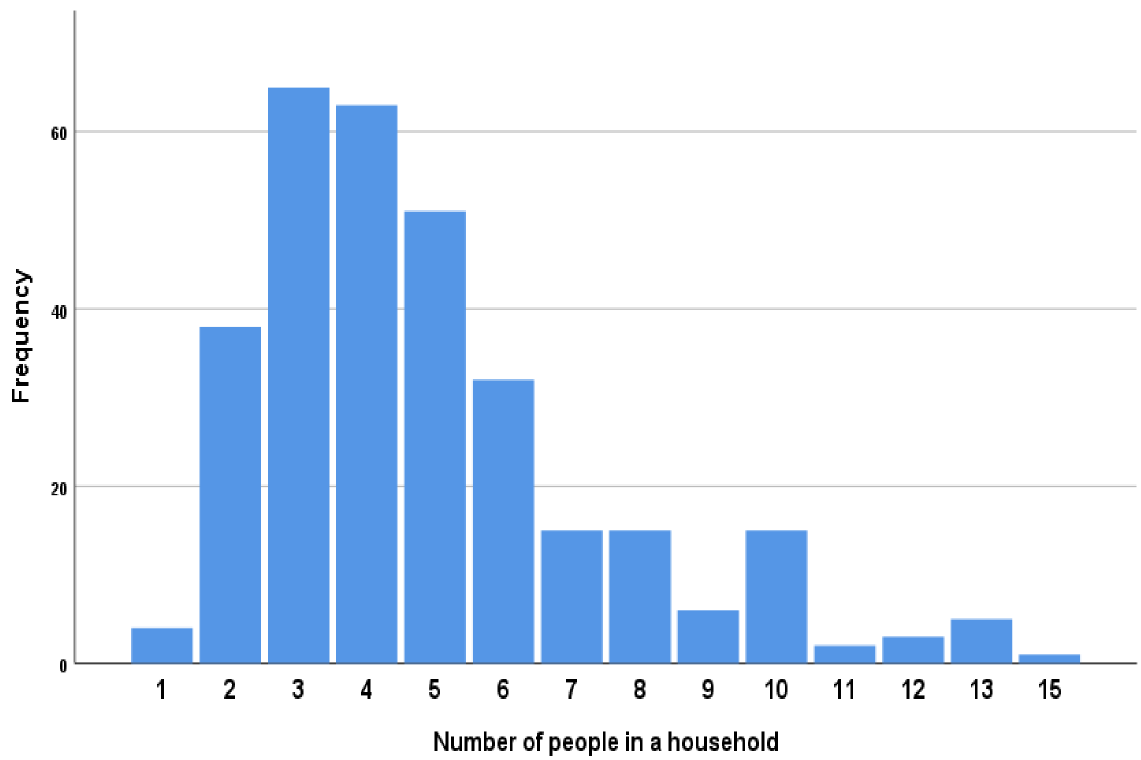

Figure 4.2: Graph: Household Size

The average household size of households in Gatanga Sub- County was 5 members per household. Figure 4.2 shows that the household size in the sub-county ranged from fifteen (15) members to one (1) member.

4.2.4 Age of Household Heads

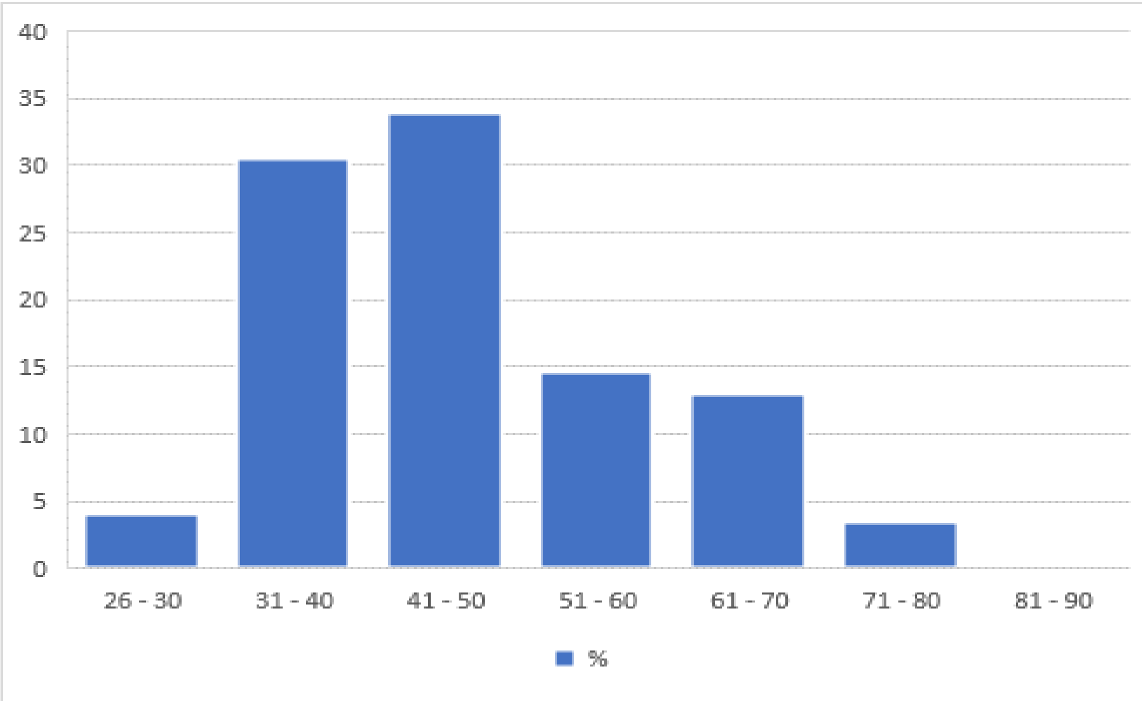

Figure 4.3: Age of household heads

Most household heads in Gatanga sub-county (34) are aged between 41 and 50 years (average age = 48.9 years), while a minority of household heads (0.3%) are aged between 81 and 90 years.

4.2.5 Education Level of Household Heads

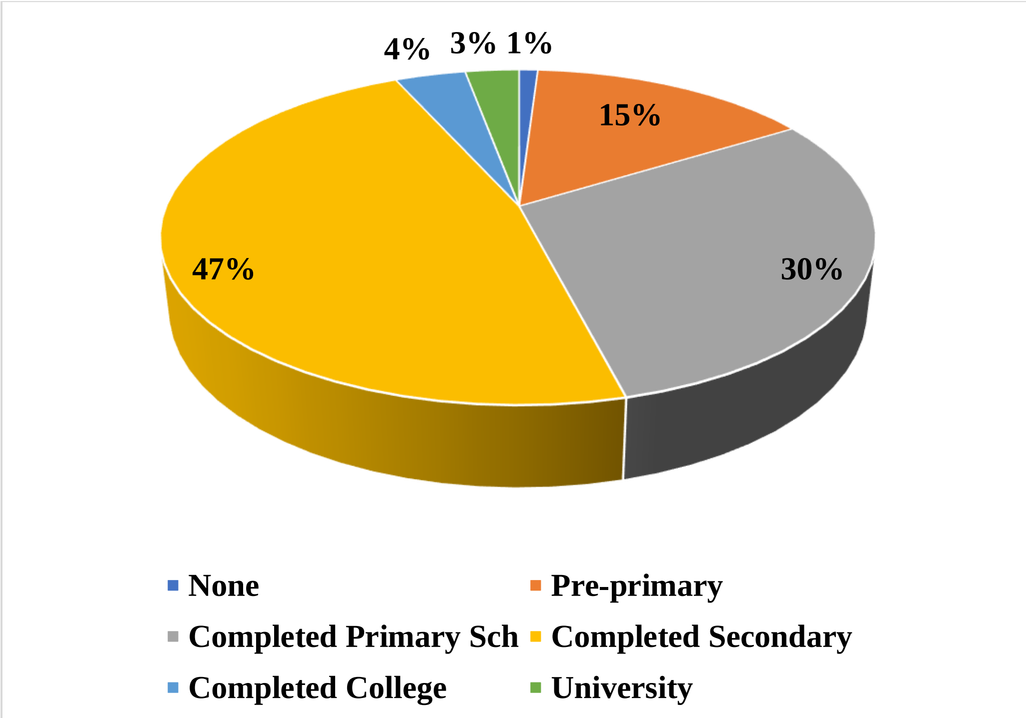

Figure 4.4: Education Level of Household Head

As shown in Figure 4.4, most household heads in Gatanga sub-county (47%) have completed secondary school education, while 1% of household heads did not attend any form of school.

4.2.6 Occupation of the Household Heads

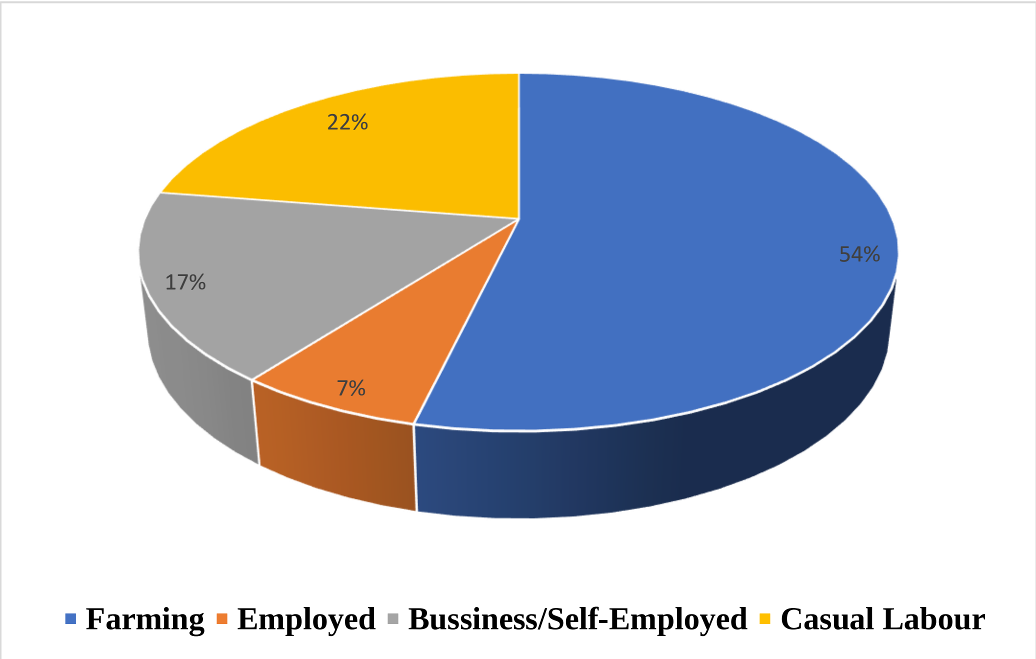

Figure 4.5: Occupation of the Household Head

Figure 4.5 shows that most farmers in Gatanga sub-county (54%) of household heads are farmers, whereas the minority (7%) are formally employed/salaried.

4.2.7 Monthly Income of Household

Figure 4.6 indicates that most households in the study area are low-income households. Around half (52.7%) of households in Gatanga sub-county earn below Kenya Shillings (KES) 15,000 monthly, whereas only 2.2% of the households earn above KES 45,001 per month.

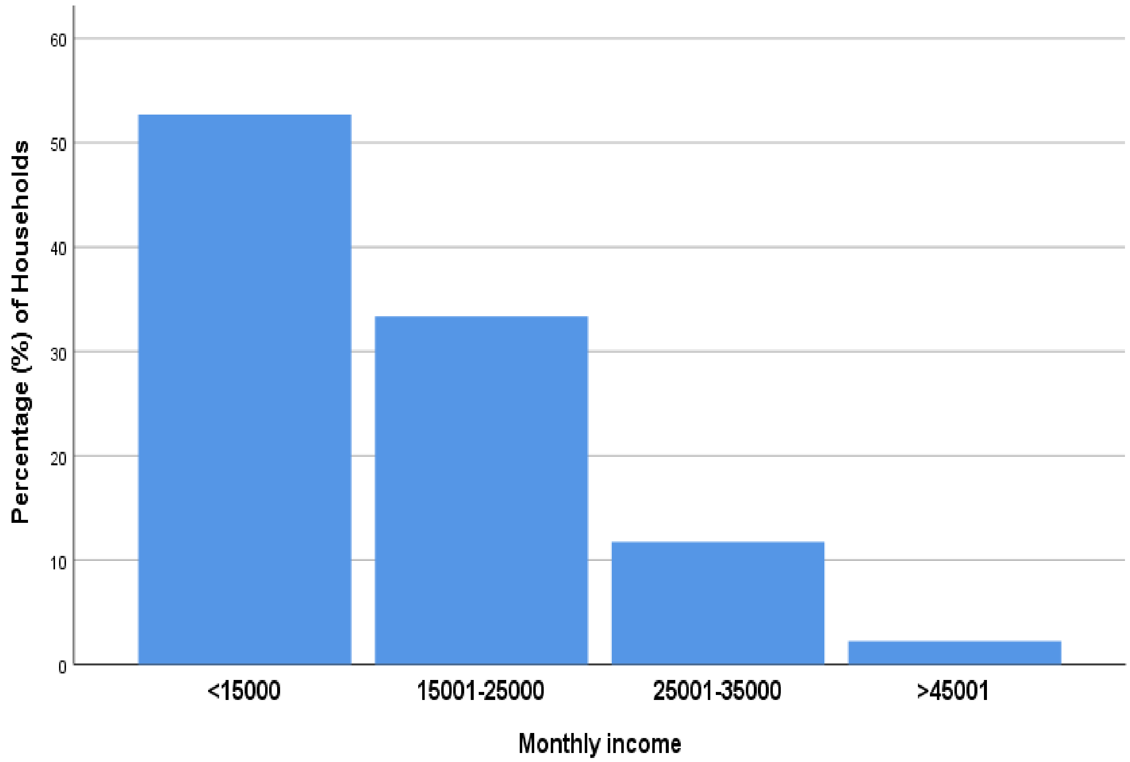

Figure 4.6: Graph: Household Monthly Income (KES)

4.2.8 Rates of LPG adoption in Gatanga Sub- County

The respondents were asked if they had LPG cylinders in their households. Their responses show that 49.5% of households in Gatanga Sub- County have not adopted the use of liquefied petroleum gas (LPG), while 50.5% have adopted the use of LPG. Table 4.3 presents the finding of LPG adoption per each specific ward in Gatanga sub-county. First, In Kariara ward, about 72.6% of households have adopted the use of LPG, while only 27.4% are yet to adopt the use of LPG in their households. In Ithanga ward, 33.3% of the households have adopted the use of LPG while 64.3% have not yet adopted LPG.

Table 4.2: LPG Adoption Per Ward

WARD	RESPONSE			
	YES		NO	
	N	***%***	***N***	***%***
Kariara	69	72.6	26	27.4
Kakuzi-Mitubiri	22	42.3	30	57.7
Mugumoini	10	35.7	18	64.3
Gatanga	30	44.1	38	55.9
Ithanga	10	33.3	20	66.7
Kihumbuini	15	35.7	27	64.3

4.2.9 Fuel Use Patterns

The findings as shown in Figure 4.14 indicate that 81.3% of households in Gatanga sub-county use firewood as their primary fuel for cooking and heating, 10.2% use LPG as their primary fuel for cooking and heating, 8.3% use charcoal as their primary fuel, while 0.3% use electricity as their primary fuel of choice for cooking and heating.

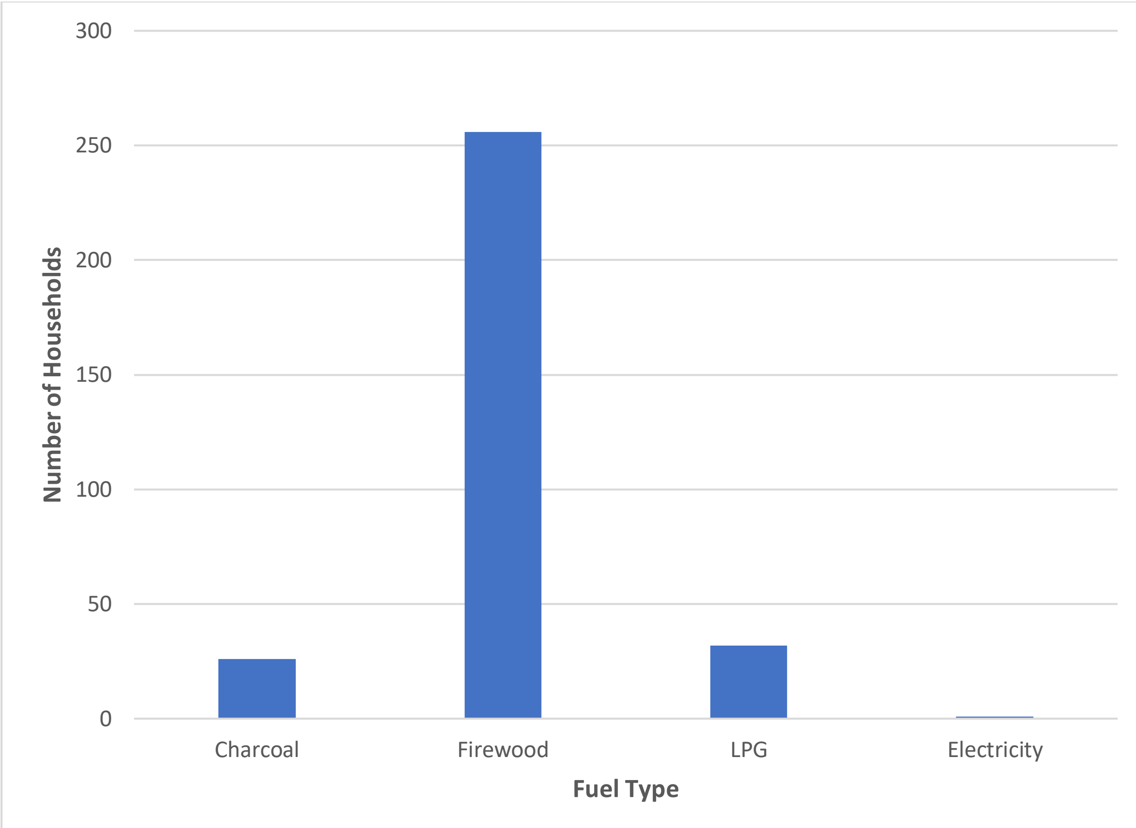

Figure 4.7: Fuel Use Patterns in Gatanga Sub- County

Table 4.3 shows fuel use patterns in the various wards of Gatanga sub-county. The majority (83%; n=256) of households in Gatanga sub-county use firewood as the primary fuel. Electricity is the least used cooking fuel in Gatanga sub-county, where 0.3% of households use electricity as their primary cooking fuel. Furthermore, LPG is mostly used as a primary fuel in Kariara ward (14.7% of households), whereas in Kihumbuini ward, LPG use only constitutes 3.3% of the household cooking fuel.

Table 4.3: Fuel Use Patterns Per Ward. Fuels with the highest percentage of use per ward are highlighted in grey.

WARD	SOURCE OF FUEL							
	LPG		**Firewood**		**Charcoal**		**Electricity**	
	N	%	N	%	N	%	N	%
Kariara	14	14.7	79	83	2	2.1	0	0
Kakuzi-Mitubiri	4	7.7	42	80.8	5	9.6	1	1.9
Mugumoini	3	10.7	24	85.7	1	3.6	0	0
Gatanga	9	13.2	51	75	8	11.8	0	0
Ithanga	1	3.3	25	83.3	4	13.3	0	0
Kihumbuini	1	2.4	2.4	35	6	14.3	0	0

4.2.10 Availability of LPG Delivery services

The respondents were asked to state whether they have a door-to-door LPG delivery in their area. The findings show that 49.4% of households in Gatanga sub-county have access to door-to-door LPG delivery services while 50.6% do not have access to door-to-door LPG delivery services.

4.2.11 Number of Years of LPG Use

This question targeted households that already had LPG. It sought to find out for how many years a household has been using LPG since its adoption. Results in Figure 4.8 show that most households (45%) adopted LPG as a cooking fuel between 6 and 10 years ago, while only a few households (3%) adopted LPG more than 21 years ago.

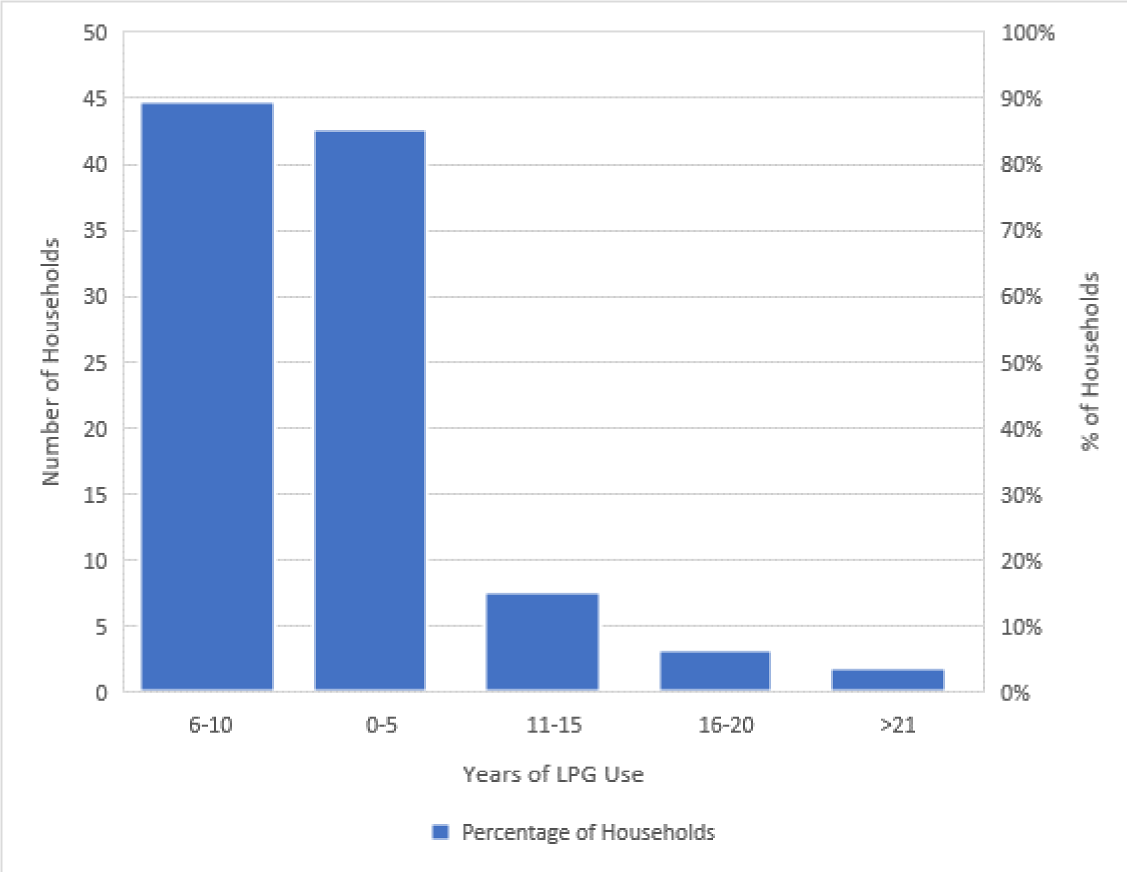

Figure 4.8: Years of LPG Use

4.2.12 Reasons for not Adopting LPG

This question targeted those households without LPG. The question sought to investigate the reasons these households have not adopted the use of LPG. The findings presented in Figure 4.17 indicate that 44.3% of households have not adopted LPG due to the expensive cost of installation, 36.7% have not adopted LPG due to LPG unavailability and long distances to LPG depots, 10.8% have not adopted LPG due to the high cost of refill, 5.7% do not know about LPG, and 2.5% are not interested in LPG and due to safety reasons and cultural beliefs.

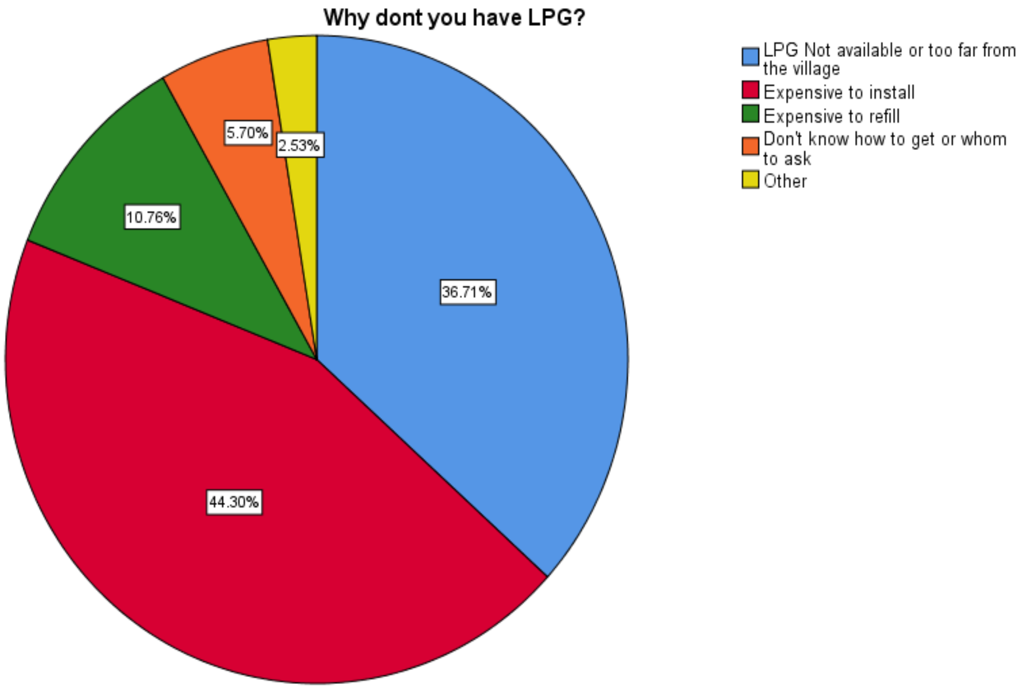

Figure 4.9: Reasons for Not Adopting LPG

4.3 Assessing The Influence of LPG Availability on Adoption of LPG as a Cooking Fuel

4.3.1 Influence of Distance to LPG Depot on LPG Adoption

The respondents were asked the approximate distance to market centers where they purchase and refill their LPG cylinders. A chi-square test was carried out to test if there was any statistically significant relationship between the rate of LPG adoption in Gatanga sub-county and the distance to LPG depots. This relationship was found to be significant X^2 (3, N=315) = 95.03, P=.001 at the $p < 0.05$ level (Table 4.4). Therefore, the adoption of LPG in Gatanga sub-county is influenced by the distance to market centers where LPG depots and retailers are located. Additionally, households nearest to LPG depots are more likely to adopt and use LPG compared to households further from LPG depots.

Table 4.4: Influence of Distance to LPG Depots on LPG adoption

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	95.037[a]	3	.001
Likelihood Ratio	114.503	3	.000
N of Valid Cases	315		

4.3.2 Influence of Delivery Services on LPG Adoption

A chi-square test for independence was conducted to establish if there was any relationship between the availability of LPG delivery services and LPG adoption in Gatanga sub-county. In this case, at $p< 0.5$, the test was significant $X^2 (1, N=315) = 221.99$, $p= 0.001$. Therefore, there was a significant relationship between the availability of delivery services and the rate of LPG adoption in Gatanga sub-county. These test results indicate that households with access to LPG delivery services are more likely to adopt LPG compared to households without access to LPG delivery services.

Table 4.5: Influence of LPG Delivery Services on LPG Adoption

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	225.364[a]	1	.001		
Continuity Correction[b]	221.988	1	.000		
Likelihood Ratio	265.850	1	.000		
Fisher's Exact Test				.000	.000
N of Valid Cases	315				

4.4 Investigating the Factors Affecting Patterns of LPG Use in Gatanga Sub- County

4.4.1 Influence of Distance to LPG Depot on Years of LPG Use

Pearson's correlation analysis was conducted to test whether there was any significant relationship between the distance to LPG depots and the number of years a household has been using LPG. Results of the test show that there exists a negative correlation between the distance to LPG depots and the number of years a household has been using LPG (r = -0.161; p = 0.044) at the level of $p< 0.05$. According to the results of this test, households nearest to LPG depots have used LPG for more years than households located further from LPG depots.

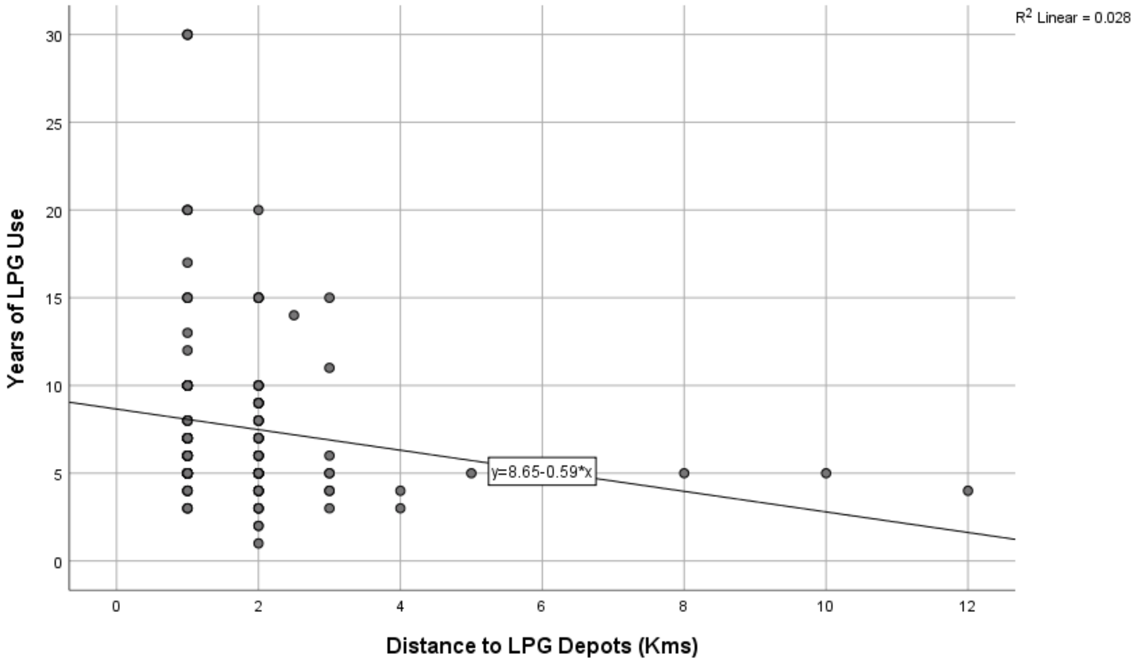

Figure 4.10: Scatter Diagram Showing the Influence of Distance to LPG Depot on Years of LPG Use

Table 4.6: Influence of Distance to LPG Depot on Years of LPG use

		Years of LPG use	One way distance to LPG Depot
Years of LPG use	Pearson Correlation	1	-.161*
	Sig. (2-tailed)		.044
	N	156	156
One way distance to LPG Depot	Pearson Correlation	-.161*	1
	Sig. (2-tailed)	.044	
	N	156	156

4.4.2 Household Size and Annual Consumption of LPG

A correlation analysis was done to test the natural relationship between household size and annual LPG consumption. The test shown in Table 4.7 shows a weak negative relationship between annual LPG consumption and household size (*r* = - 0.042; *p* = 0.602) at the level of $p<0.05$. The test findings reveal that, although large households consume less LPG, there is no significant relationship between household size and LPG consumption.

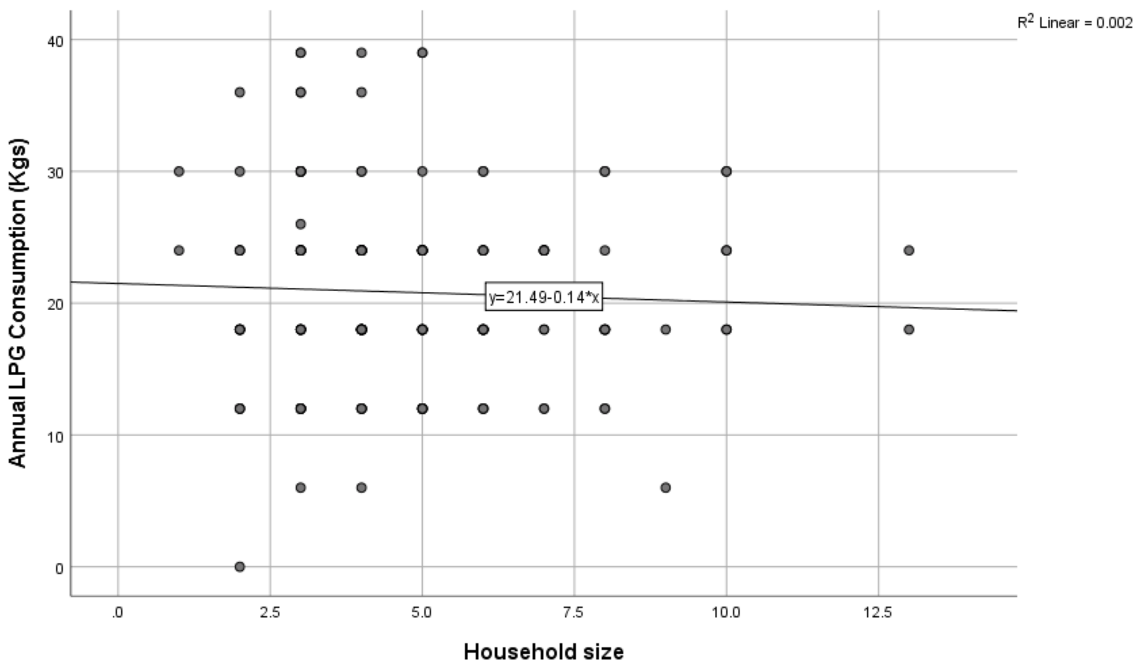

Figure 4.11: Scatter Plot of the Relationship Between Household Size and Annual Consumption of LPG

Table 4.7: Household Size and Annual Consumption of LPG

		Household size	Annual consumption of LPG
Household size	Pearson Correlation	1	-.042
	Sig. (2-tailed)		.602
	N	314	154
Annual consumption of LPG	Pearson Correlation	-.042	1
	Sig. (2-tailed)	.602	
	N	154	154

4.4.3 Household Size and Daily Firewood Consumption

Pearson's correlation test was conducted to find out whether there was a significant relationship between household size and the daily firewood consumption at the household level in the sub-county. The test shown in Table 4.8 revealed a statistically significant relationship (r = 0.25; p = 0.001), implying that household wood consumption increased with an increasing number of household members.

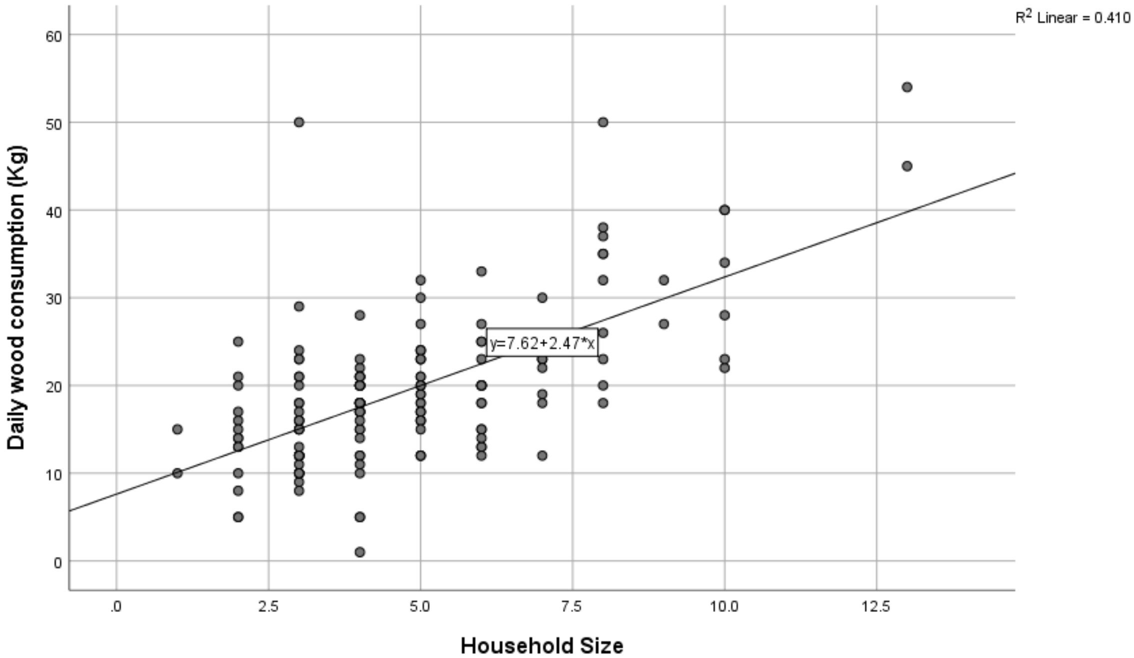

Figure 4.12: Correlation Between Household Size and Daily Firewood Consumption

Table 4.8: Relationship Between Household Size and Daily Firewood Consumption

		Household size	Daily firewood consumption
Household size	Pearson Correlation	1	.624
	Sig. (2-tailed)		.001
	N	314	314
Daily firewood consumption	Pearson Correlation	.624	1
	Sig. (2-tailed)	.000	
	N	314	314

4.4.4 Influence of household Income on Annual Consumption of LPG

Table 4.9 show the relationship between household income and annual consumption of LPG at the household level. The test found a significant relationship between the amount of LPG consumed annually and household income (r= 0.385; p = 0.001). The finding implies that households with higher income consumed more LPG annually as compared to those with lower income.

Table 4.9: Influence of household Income on Annual Consumption of LPG

		Annual consumption of LPG	Household monthly income
Annual consumption of LPG	Pearson Correlation	1	.385
	Sig. (2-tailed)		.001
	N	154	154
Household monthly income	Pearson Correlation	.385	1
	Sig. (2-tailed)	.000	
	N	154	314

4.4.5 Influence of Household Income on Household Fuel Choice

A chi-square test was carried out to test if there was any statistically significant relationship between household income and household fuel choice in Gatanga Sub-County. The test was statistically significant at the significance level, $p< 0.05$, X^2 (9, N =315) = 48.378; P=0.001 (Table 4.10). The presence of this significant relationship between household income and fuel choice indicates that households with lower income are more likely to use biomass fuel types such as firewood and charcoal. On the other hand, higher-income households are more likely to adopt clean fuels such as LPG and electricity.

Table 4.10: Income and Fuel choice Crosstabulation

		Fuel choice				
		Firewood	Charcoal	Electricity	LPG	Total (n)
Income (KES)	< 15000	145	15	0	5	165
	15001-25000	81	11	0	13	105
	25001-45000	27	0	1	10	38
	>45000	3	0	0	4	7
Total (n)		256	26	1	32	315

Table 4.11: Chi-Square Test of the Influence of Household Income on Fuel Choice

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	48.378[a]	9	.001
Likelihood Ratio	41.410	9	.000
N of Valid Cases	315		

4.4.6 Influence of Household Size on Household Fuel Choice

A Chi-square test was performed on SPSS to test if there was any statistically significant relationship between household size and household fuel choices. The test found a significant positive relationship at a significant level of $p < 0.05$, X^2 (9, N=315) = 34.667;

p= 0.00. The presence of a positive relationship implies that large households are less likely to adopt the use of clean fuels such as LPG and electricity as their primary fuels as compared to smaller households who are more likely to adopt LPG and electricity as their primary fuels.

Table 4.12: Chi-Square Test for Relationship Between Household Size and Fuel Choice

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	34.667[a]	9	.000
Likelihood Ratio	41.331	9	.000
N of Valid Cases	315		

4.5 Assessing the Potential Effects of LPG Adoption on the Environment

4.5.1 Comparing Firewood Consumption Before and After LPG Adoption

A Paired samples t-test was used to determine whether the adoption of LPG had any effect on daily firewood consumption by households at the significance level $\alpha = 0.05$. According to the paired samples t-test, the p-value associated with t= -31.441 and degrees of freedom, (n-1) =157 is 0.001 (Table 4.13), at $p < 0.05$ significance level. There is therefore sufficient evidence to conclude that the means of the daily firewood consumed by households before and after LPG adoption were not equal and that LPG adoption positively affected the amount of firewood consumed in households in Gatanga sub-county (firewood consumption decreased with increasing adoption of LPG).

Table 4.13: A Paired Samples t-test Comparing Firewood Consumption Before and After LPG Adoption

Paired Samples Test								
	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95%				
				Lower	Upper			
Wood consumption before LPG adopting - Wood consumption after LPG adoption	-23.375	9.345	.743	-24.843	-21.906	-31.441	157	.001

CHAPTER FIVE

DISCUSSION, SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter discusses the conclusions obtained from the findings of this study on LPG adoption and patterns of use by households in Gatanga sub-county. Discussions of the findings are done objectively to address the research questions and the overall objective of the study. Towards the end of the section, a summary of the researcher's conclusions is made, and recommendations proposed.

5.2 Discussion of General Findings

5.2.1 Transition From Traditional Fuels to LPG

The findings of this study show that the largest transition of households from traditional fuels to LPG use in Gatanga sub-county occurred between 6 to 10 years ago when about 45% of households transitioned from the use of dirty and polluting fuels to LPG. This surge in LPG adoption was a result of the government of Kenya (GoK) anchoring the transition to LPG through subsidies on LPG prices that mostly targeted low-income households. (Mbaka, 2021). The Kenyan policy framework addressed the key challenges related to the supply and affordability of LPG for the poor by exempting the commodity from the 16% value-added tax (VAT). Similarly, Brazil's policy framework aimed at addressing key challenges related to distribution, affordability, and supply led to a 95% transition from traditional fuels to LPG between 1960 and the early 1970s. These scenarios confirm the assertion by Destyanto et al. (2017) that the government is a facilitator, simulator, and coordinator of LPG adoption programs through policy implementation.

5.2.2 Patterns of Fuel Use

The use of LPG as a primary fuel is not widespread within the rural setting of Gatanga sub-county. Only 10.2% of households in the sub-county (n=32) reported using LPG as a primary cooking fuel whereas the majority (81.3%) used firewood. The low LPG usage as a primary fuel in rural settings is well documented in other studies (Lewis and Pattanayak, 2012; Ifegbesan et al., 2016; Wiedinmyer et al., 2017). Other studies have reported that reasons for low LPG use as a primary fuel include the opportunity cost of freely available biomass in the rural setting and relative poverty (Puzzolo et al., 2019; Ronzi et al., 2019). According to Pye et al. (2020), people living in rural areas are significantly more likely to report LPG as being expensive and difficult to obtain. Addressing these barriers will encourage more exclusive use of LPG for clean cooking which is necessary to maximize the gains in forest conservation and environmental management.

5.2.3 Challenges of LPG Adoption in Gatanga Sub- County

About 55% of households without LPG gave reasons related to affordability as their main challenges towards LPG adoption. Such reasons included the expensive costs of buying LPG cylinders and the prohibitive cost of LPG refills. About 42% of households without LPG gave reasons related to the accessibility of LPG within their locality, these reasons included unavailability of LPG due to remoteness and distance to LPG suppliers and depots and unawareness of LPG as modern fuel. These findings agree with Kumar et al, (2020) who while studying the impact of affordability, accessibility, and awareness on LPG adoption in rural poor households of India found out that LPG adoption is associated with the 3A's (Affordability, Accessibility, and Awareness). Kumar et al, (2020) further elaborate those respondents who attended awareness campaigns on clean cooking are 11.8 times more likely to adopt LPG than those who did not attend any clean cooking campaign.

5.3 Assessing The Influence of LPG Availability on Adoption of LPG as a Cooking Fuel

5.3.1 Influence of Distance to LPG Depot on LPG Adoption

The findings show that households near market centers where LPG depots and retailers are located have highly adopted LPG. However, households further away from LPG depots and retailers exhibit lower LPG adoption of LPG. These findings agree with Gould et al. (2020) who studied LPG adoption among various Indian villages with different distances to LPG depots. In the study, Gould et al. (2020) observed less proportion of LPG owning households in more remote villages relative to villages nearer to LPG depots. Similarly, Danlami et al. (2015) note that LPG adoption in most Nigerian households is highly dependent on LPG accessibility. According to Dalaba et al. (2018), availability and distance to LPG depots and filling stations are bigger barriers for rural households in Northern Ghana. Elsewhere, similar studies have shown that availability and distance to LPG depots and filling stations as factors that hinder LPG adoption and use (Oteh et al., 2015; Srinivasan and Corattini, 2016). However, among urban households of Northern Ghana, LPG depots and filling stations are readily available, and therefore, distance to those depots and filling stations do not present any hindrances to LPG adoption (Dalaba et al., 2018).

5.3.2 Influence of Delivery Services on LPG Adoption

The study shows that LPG delivery services in Gatanga Sub- County influence the rate of adoption and use patterns. Households are more likely to adopt and use LPG when there is a door-to-door LPG delivery service in their locality. A study in Ghana shows that LPG door-to-door delivery systems have significantly increased sustained use of LPG and other clean cookstoves (Carrion et al., 2018). Similarly, Ndunguru & Lema (2020) found that various strategies including LPG home delivery services have created an enabling environment for the adoption and usage of LPG by households. Elsewhere, Akter & Pratap (2022) reported that doorstep delivery of LPG cylinders in the rural areas of Bihar, India, increased between 2015 and 2018. In the same period, LPG adoption increased substantially.

The delivery of LPG refills has also been used by retailers and distributors as a strategic marketing initiative (Siringi, 2013). In a study in India, Siringi, (2013) reported that timely refill supply from the distributor has improved the rate of LPG adoption and its sustained use. However, households that did not have access to timely delivery services did not adopt LPG, or those that had adopted LPG and did not have home delivery services did not sustain LPG use. Finally, LPG adoption and its sustained use have been seen as a mechanism to save time for fuel collection, however, this is dependent on the availability of delivery services.

5.4 Investigating the Factors Affecting Patterns of LPG Use in Gatanga Sub- County

5.4.1 Relationship between Household Size and LPG Use

Overall, the amount of LPG consumed by households in Gatanga sub-county is not determined by household size. Therefore, household LPG consumption may be influenced by other factors such as income and social-economic status. Other studies agree with the findings of this study that show no statistically significant association between household size and LPG use. Gould et al. (2020) noted that household size does not necessarily explain the exclusive use of any fuel. According to Gould et al. (2020), household size may play a key part in cooking fuel choice. For instance, larger households require more cooking in terms of frequency and quantity, therefore needing more cooking fuel, which may be expensive. In another instance, a large household may have several income-earning adults, who would contribute to the regular purchase of clean fuels (LPG). Further, Gould et al. (2020) therefore note that some larger households are more likely to cook with solid fuels while others are more likely to use a clean cooking fuel.

The finding contradicts several reports by other scholars (Pope et al., 2018; Mudombi, et al., 2018; Pye et al.,2020). According to a report by Pope et al. (2018) household demographic characteristics, especially household size, level of education, and socio-economic status influence household decisions to adopt and exclusively use LPG. Similarly, Pye et al. (2020) also reported that the number of people resident in a household determines LPG use patterns, as either a primary or secondary fuel. Household size further influences the decision to either or not adopt LPG. Other qualitative studies conducted in Peru (Hollanda et al., 2017; Williams et al., 2020) and Mozambique (Mudombi, et al., 2018) have also reported that large households often refill more, and they may therefore find these frequent refills expensive as compared to smaller households. A study in China (Carter et al., 2019) associated household size with clean fuel adoption and exclusive use.

5.4.2 Influence of Household Income on Annual Consumption of LPG

This study reveals that households with higher income consumed more LPG as compared to households with lower income. Similarly, households with higher income have a higher likelihood of adopting LPG as their primary fuel or using it exclusively. This study, therefore, concludes that LPG affordability is a function of household income. The findings agree with Shupler et al. (2020) who found a seasonal difference in LPG consumption in Kenyan households. During the hot season between January to February, there's usually lower income in Kenya. However, incomes are higher in the cooler months of June and July. LPG consumption was an average of 0.25 kg/capita/month between January and February compared to 1.21 kg/capita/ month, when household incomes had improved (Shupler et al., 2020).

These findings further confirm the findings of similar studies in Peru and other countries that LPG affordability is a critical determinant of transition decisions (Kayode et al., 2015; Kumar, 2017; Pollard et al., 2019). The results are also in agreement with a study by Amoah (2019) who deduces that income and the relative price of fuel are significant determinants of fuel choice. According to Yadama (2013), energy-poor households in rural community's experience frequent shocks which impact their incomes, this presents constraints on the adoption of LPG for such households (Ali, 2007; Yadama, 2013).

5.4.3 Influence of Household Income on Household Fuel Choice

The findings of this study indicate that households with lower income are more likely to use biomass fuel such as firewood and charcoal as their primary fuel, and therefore less likely to adopt cleaner fuel types such as LPG and electricity. However, higher-income households are less likely to use biomass fuels as their primary fuel but are more likely to use clean fuels such as LPG and electricity as their primary fuel. These results provide empirical evidence for the energy ladder model by proving household income is the main determinant of household fuel choice (Horst & Horovka, 2008). These findings are also in agreement with Danlami et al. (2017), who reported income to have a positive influence on the adoption of LPG and electricity as their main cooking fuel. A similar study in Kenya confirms the energy ladder hypothesis (Baek et al., 2020). Further studies on this matter have termed household income and economic status as the most important factors influencing fuel choice, such that increased levels of income result in a decline in the share of biomass fuels in the total household energy consumption (Wuyuan et al., 2008; Osiolo, 2009). Elsewhere, a study in Ghana to assess the determinants of urban household cooking fuel choice deduced that households in the low-income category tend to adopt more firewood, while high-income earners tend to use LPG and electricity (Ahiekpor et al., 2015).

5.4.4 Influence of Household Size on Household Fuel Choice

The findings show that the type of fuel of choice in a household is statistically significantly associated with the total family size of the household. Consequently, households' choice of firewood as the primary cooking fuel increases with an increase in the household size. This finding is consistent with other findings that have reported that the initial increasing trend in firewood preference as the primary fuel is a result of the availability of an abundant supply of labor to collect firewood and prepare dung since the amount of energy needed for large households is quite high so it may be too expensive to purchase and use gas (Rahul et al., 2020; Wassie et al, 2021). Similarly, the findings of the current study confirm with Adeyemi & Adereyele (2016) who deduced that larger households would prefer to use firewood since it is comparatively cheaper to use firewood to cook for many people. Elsewhere, Alem et al. (2016) noted that larger households with many females tend to take advantage of the low opportunity cost of firewood collection.

5.5 Assessing the Potential Effects of LPG Adoption on the Environment

5.5.1 Comparing Environmental Impacts of Wood Consumption Before and After LPG Adoption

Based on the findings of the study, a reduction in fuelwood consumption occurred in most households that adopted LPG. Consequently, there was a significant decline in the general household demand for fuelwood and biomass, which therefore resulted in fewer trees cut to provide firewood. Forests were thus spared from the menace of deforestation as the demand for firewood was not as high as it was before households had adopted LPG. These findings agree with several other reports such as WRI, (2018) which noted that since more than 90% of rural communities in Cameroon cook primarily with fuelwood, Cameroon lost 2.8% of her forest cover between 2001 and 2016. Similarly, Kypridemos, (2020) reported that increasing LPG users in Cameroon would contribute to mitigating the effects of climate change because less fuelwood and biomass would be used for cooking, contributing to forest protection. Transition to LPG can also contribute to deforestation mitigation, by reducing the demand for wood from non-renewable forests for firewood production, in turn positively impacting climate through reduction of CO_2 emissions (Singh et al., 2017).

A study in Tanzania shows that substituting 250,000 tons of fuelwood, and biomass fuels with 80,556 tons of LPG could save 10,000 ha of forests per year (Alem and Ruhinduka, 2020). Therefore, since Tanzania currently consumes about 145,000 tons of LPG per year, close to 18,000 ha of forest are potentially protected from deforestation annually. Consumption of fuelwood and other biomass fuels will continue to increase, especially in Sub-saharan Africa. However, there are clear pieces of evidence showing that substituting fractions of household biomass fuels with cleaner fuels such as LPG would contribute positively to forest protection, and in turn, reduce the effects of climate change.

5.6 Summary of Main Findings

The study sought to assess the factors affecting the adoption and use of LPG in Gatanga Sub- County, Murang'a County. Specifically, the study sought to assess the influence of availability factors on LPG adoption in Gatanga Sub- County; investigate factors affecting LPG use patterns in Gatanga Sub-county and compare the potential environmental impact of the use of LPG versus the use of biofuel, particularly the use of fuelwood in Gatanga Sub-county.

On the factors of availability affecting the extent of LPG adoption, the study established that distance from villages to market centers where they refill or purchase their LPG cylinders influences the rate of LPG adoption. The study also found that households are more likely to adopt LPG when there is a door-to-door LPG delivery service in their area. Therefore, most of the households that have adopted LPG in Gatanga sub-county are located near LPG depots or have access to door-to-door LPG delivery services.

Concerning the pattern of LPG use in the Sub- County, the study found that household income influences whether a household uses LPG as a primary or a secondary fuel. The study also found that household income influences the pattern of LPG use in Gatanga. Households with higher income are more likely to use LPG exclusively, whereas households with lower income are likely to practice fuel stacking, by partially adopting LPG.

Based on the results of the comparison of fuelwood consumption use before and after LPG adoption, LPG adoption would reduce the need for fuelwood in households thus alleviating pressure on the environment through reduced tree cutting. It is therefore imperative that LPG, as a clean fuel, can potentially be used to curtail the menace of deforestation in Kenya. This reduction in overreliance on fuelwood by households would accelerate the growth of the national forest acreage towards the attainment of the 10% forest cover, a long-term development goal for Kenya.

5.7 Conclusion

First, the rate of LPG adoption is influenced by distance to LPG depots/retailers and the availability of LPG delivery services within a locality. Secondly, the study established that LPG use patterns are influenced by household income, the size of the household, and the distance to the LPG depot. Lastly, the study established that scaling up LPG adoption will have a positive contribution toward environmental conservation by reducing deforestation. Protecting forests is critical for Kenya to achieve the global goal of 10% forest cover and sustainable development goal 13 (SDG 13) on climate action.

The study immensely contributes to literature and knowledge that would help other researchers and scholars in related studies. The study provides significant information to energy-oriented firms on the extent of LPG adoption in rural areas. This study provides information to the firms on the various barriers to be addressed and enablers that could be addressed. Therefore, through the information presented by this study, energy firms and dealers can devise measures to upscale LPG adoption and encourage its exclusive use.

5.8 Recommendations

Based on the results, discussions, and conclusion of the study, the following recommendations were made for improvement.

On the first objective, the study found that distance to LPG depots and access to door-to-door LPG delivery services influence the rate of LPG adoption. The study, therefore, recommends availing of depots and suppliers in remote villages, as it will help to reduce the distance traveled to purchase and refill an LPG cylinder. The study also calls for LPG suppliers to avail door-to-door LPG delivery services as a strategy to enhance LPG adoption and thus increase their customer base.

On the second objective, the study found that most households with lower income have not yet adopted LPG. Large households tend to use firewood and charcoal as their primary fuel. This is also mainly due to the comparatively higher costs of purchasing cleaner fuels such as LPG and electricity. The study, therefore, calls for the amendment of the Kenya Finance Bill of 2021 that includes LPG for VAT taxation, consequently increasing the price of LPG products to limits that the rural poor cannot afford.

Lastly, in the quest to achieve the 10% forest cover, the government of Kenya should encourage LPG adoption in rural areas. LPG has the potential to alleviate the overreliance on firewood and charcoal as the household cooking fuels of choice, therefore providing gains in curtailing deforestation. The government further needs to re-introduce subsidies on LPG purchases and refills by zero-rating LPG and exempting it from VAT taxation. This way, the rural poor would be able to adopt LPG and sustain its use.

5.9 Areas of Further Research

The study was only conducted in Gatanga Sub- County, which concentrated on LPG consumers only. Therefore, the views of LPG distributors and suppliers were considered. The study also concentrated on LPG use as a household cooking fuel. However, LPG has also been adopted in the manufacturing and automotive industries.

Further studies are also proposed to assess the potential contribution of LPG use to health and gender equality. A further study is also proposed to assess how the use of LPG contributes to GHG emissions and to compare emissions from LPG used for cooking with corresponding emissions from the use of fuelwood and charcoal.

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APPENDICES

Appendix A: Research Questionnaire

A HOUSEHOLD QUESTIONNAIRE ASSESSING THE ADOPTION AND USE PATTERNS OF LIQUEFIED PETROLEUM GAS IN GATANGA SUB-COUNTY

The interview should be conducted with the wife of the household head or the female household head.

Introduction

Good morning/afternoon. My name is -- sent by Africa Nazarene University to carry out a study in this area on the adoption and use pattern of LPG cooking technology. We met your village chief the other day and he recommended we see you to help us with the questions we have about the cooking practices. All the information given will be treated with confidentiality and be used for the study only. Thank you very much for welcoming us.

For a household with or without LPG: The following must be filled out before the interview:

Serial No______________________________

Date____________________________________

Supervisor's name ________________________

Interviewer's name________________________

Name of respondent (optional)

____

County _______________________________

Sub county______________________________

Ward______________________________

Location____________________________Sublocation___________________________

Beginning time ______________________

End of interview_________________

SECTION A: Household Characteristics

1) **Who is the head of the household?**
   1= Husband, 2 = Self, 3 = others (specify) ___________________
2) **What is the occupation of the head of household?**

1 = Farming, 2 = Salaried/Employed, 3 = Businessman /self-employed, 4 = Part time employed, 5 = others (specify) _________________

3) **What is the level of education of the head of household?**

1 = None, 2 = Can read & write, 3 = finished Primary School,4 = finished Secondary school, 5 = finished College, 6 = Other (specify) __________________

4) **What is your age? (Approximately)__________________________**
5) **What is your highest level of education?**

1 = None, 2 = Can read & write, 3 = finished Primary School, 4 = finished Secondary school, 5 = finished College, 6 = other (specify) __________________

6) **How many people regularly live and eat in the household? Specify numbers. (Define household to include all the people who take meals regularly from the same pot)**

1 = Older people (>64 years) _________________________

2 = Adults (>16 years) ____________________________

3 = Children (<15 years) ____________________________

4 = Total number of household members________________

5 = Total female household members ________________

6 = Total male household members ________________

7) What is the monthly household income (approximately in Ksh)?

1 = <15000

2 = 15001–25000

3 = 25001–35000

4 = 45001+ ____________________

SECTION B: FUEL USE CHARACTERISTICS

1. **Do you use gas (LPG) for cooking?**
   1= Yes, 2= No _________________ (If NO skip to **9**)
2. **How many years ago did your house begin to use LPG? _____________ [YEARS AGO]**
3. **How much did it cost to install the LPG connection? _____________[Ksh]**
4. **What is the one-way distance in kilometers your household typically travels to get LPG? ______ [KM]**
5. **How much does your LPG cylinder cost to refill at the local market? _____________[Ksh]**
6. **Is the domestic gas cylinder delivered to your doorstep?** 1=Yes, 0=No ______
7. **Apart from LPG, which other fuel do you use?** 1= firewood, 2= Charcoal, 3= Electricity, 4= other (specify) _________________
8. **What was your household's average wood consumption per day before LPG adoption? _________________ [KG]**
9. **What is your current daily average wood consumption? _________________ [KG]**
10. **What is your primary cooking fuel?** 1= firewood, 2= Charcoal, 3= Electricity, 4= LPG, 5= other (specify) _________________
11. **How much LPG is consumed annually in your household? ________________[KG]**

SECTION C: FOR HOUSEHOLDS WITHOUT GAS (LPG)

1. **Why don't you have LPG?**

1= not available or too far from your village

2= Expensive to install

3= Expensive to refill

4= do not know how to get or whom to ask?

5= other (specify) _________________

2. **What is the one-way distance in kilometers from your home to the market?** _________________(KM)
3. **Are you interested in getting LPG?** 1=Yes, 0=No _________________
4. **What is your primary cooking fuel?** 1= firewood, 2= Charcoal, 3= Electricity, 4= other (specify) _________________
5. **What is your current daily average wood consumption? _________________ [KG]**
6. **Apart from LPG, which other fuel do you use?** 1= firewood, 2= Charcoal, 3= Electricity, 4= other (specify) ________________
7. **Is there an LPG delivery service in your area?** 1=Yes, 0=No ______

Appendix B: Work Plan

Month	**Oct 2021**				**Nov 2021**				**Dec 2021**				**Jan - Feb 2022**	**March 2022**				**March – April 2022**
Week / **Activity**	1	2	3	4	1	2	3	4	1	2	3	4		1	2	3	4	
Proposal development and Presentation																		
Data collection																		
Pilot testing and equipment validation																		
Data Collection																		
Data processing analysis, and interpretation																		
Report preparation and presentation																		

Appendix C: Approval of Research Proposal

AFRICA NAZARENE
UNIVERSITY

21st February 2022

RE: TO WHOM IT MAY CONCERN

Geoffrey Kamau (19M01DMEV012) is a bonafide student at Africa Nazarene University. He has finished his course work and has defended his thesis proposal entitled: -

"Factors affecting the Adoption and use of liquefied petroleum gas in Gatanga Sub County, Murang'a County, Kenya".

Any assistance accorded to him to facilitate data collection and finish his thesis is highly welcomed.

Rodney L. Reed

Prof. Rodney Reed
DVC Academic & Student Affairs