

**ENERGY POVERTY AND LIQUEFIED PETROLEUM GAS (LPG)
IN KENYA**

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DECLARATION

I declare that this paper is my original work and has not been submitted for the award of a degree in any other university or institution.

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The views expressed in this paper are my own and do not represent the views of any of the named person(s) and/or Institution(s). I solely bear the responsibility for any errors and/or omissions.

DEDICATION

To my family: my dear mother Zilpa Oracha, my precious brother Peter Clever, my wonderful sisters Mercy, Joan, Rita and Emma; and in memory of my Late father Peter Oracha, and brother, Huxley.

LIST OF ABBREVIATIONS

ABE	Advisory Board on Energy
ADF	Augmented Dickey-Fuller
BFI	Buying Frequency Index
CIA	Central Intelligence Agency
DF	Dickey-Fuller
EDI	Energy Development Index
ERC	Energy Regulatory Commission
FGT	Foster Greer and Thorbecke
GDP	Gross Domestic Product
GWh	Giga watt hour
HDI	Human Development Index
IEA	International Energy Agency
KIPPRA	Kenya Institute for Public Policy Research and Analysis
KWh	Kilowatt Hour
LPG	Liquefied Petroleum Gas
MDGs	Millennium Development Goals
MEPI	Multi-dimensional Energy Poverty Index
MoE	Ministry of Energy
OECD	Organization for Economic Co-operation and Development
PQLI	Physical Quality of Life Index
SSA	Sub Saharan Africa
TOE	Tons of Oil Equivalent
UNCHS	United Nations Centre for Human Settlements
UNDP	United Nations Development Programme
UNIDO	United Nations Industrial Development Organization
WHO	World Health Organization

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ABSTRACT

The role played by energy in social, economic and political development of a country is vital. Access to energy encourages development via improvement in education. It also accelerates economic development through mechanization and modernization of communications. Energy poverty continues to be a biting problem in Kenya with an average of 85% of households using traditional fuels for cooking, lighting and heating, and approximately 77% of the total population lack access to electricity.

This study empirically investigates the relationship between LPG consumption and energy poverty in Kenya using time series data for the period 1970 – 2011. Its objectives are to estimate the level of energy poverty in the country, determine the role played by Liquefied Petroleum Gas (LPG) in reducing energy poverty, and to identify measures to enable more households to shift away from solid fuels to LPG.

To measure energy poverty, the study adopts the International Energy Agency's Energy Development Index (EDI). It employs the Error Correction Model to examine the relationship between LPG consumption and energy poverty in Kenya. The results indicate the existence of a negative long-run relationship between LPG consumption and energy poverty. Energy poverty levels in Kenya are disturbing. The study therefore recommends the promotion of LPG consumption as LPG has been seen to play a critical role in reducing energy poverty in the country.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

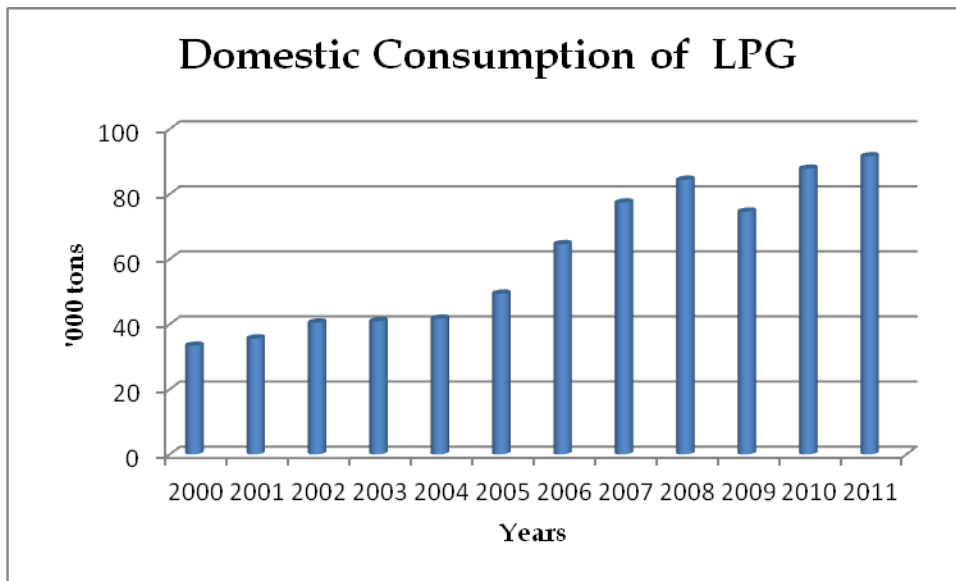
Access to modern forms of energy provides great benefits to development through the provision of reliable, convenient and efficient lighting, telecommunication services, transport, heating, clean water, cooking, healthcare and mechanical power. The international community has long been aware of the close correlation between income levels and access to modern energy.

It has been observed that countries with a large proportion of the population living on an income of less than \$2 a day tend to have low electrification rates and a high reliance on traditional biomass. The IEA also notes that increases in incomes lead to a faster rise in access to electricity than access to other fuels. This is largely because governments give higher priority to electrification, though access to both electricity and clean cooking facilities is essential to success in eradicating the worst effects of poverty and putting poor communities on the path to development (OECD/IEA, 2010).

The United Nations' Sustainable Energy for All Initiative which was launched in 2011 sets as one of its three objectives universal access to modern energy services—electricity and clean cooking and heating systems—by 2030. About three billion people rely on solid biomass or coal for cooking and heating, and smoke from such fuel use is estimated to cause four deaths every minute. The International Energy Agency (IEA) estimates that

more than 40 percent of households newly gaining access to modern household energy by 2030 in the universal-access scenario will do so by switching to LPG, and Kenya is not exempt from this scenario as is evident in the increased consumption of LPG in the country (Figure 1.1).

Figure 1.1: Domestic consumption of LPG in '000 tons, 2000-2011

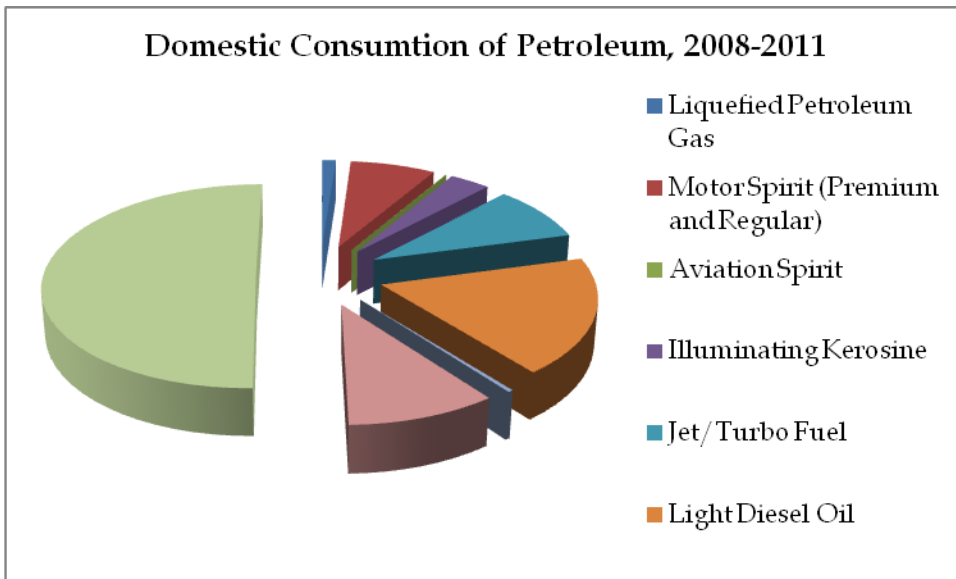


Source: Ministry of Energy

The main sources of energy in Kenya are biomass, fossil fuels, electricity and other renewable energy sources. In 2012, biomass energy accounted for about 70% of all energy consumed while petroleum and electricity accounted for only 21% and 9%, respectively. Petroleum is the most important source of commercial energy in Kenya and petroleum fuels are imported in form of crude oil for domestic processing and also as refined products, and mainly used in the transport sector, industrial sector and the commercial sector.

Trends in the sale of petroleum fuels indicate that retail pump outlets and road transport constitute the single largest customers of petroleum fuels followed by aviation and power generation. Kerosene as a cooking and lighting fuel is equally important especially for the rural and urban poor households and sometimes used as a substitute for wood fuel. The domestic consumption of petroleum products in Kenya from the year 2008 to 2011 is shown in the figure below.

Figure 1.2: Domestic consumption of petroleum for the period 2008-2011



Source: Ministry of Energy

Considered as one of the successors of electric energy by energy economists, LPG affords advantages that set it apart even more from other sources of energy. These benefits, among many others, are that LPG is more economical compared to other fuels and has excellent quality insofar as clean consumption is concerned. Similarly, LPG assists in the efforts to preserve the environment and is also the safest substitute for

firewood and coal, fuels that can pose serious health risks when used to cook food, a fairly common practice in Kenya particularly among low-income families.

Of importance to note is the fact that LPG's portability greatly differentiates it from other fuels since it does not require building gas pipelines in order to supply it to a majority of the Kenyan households, a penetration capability well above those of basic services such as power and running water. Considering the positive aspects of LPG and its broad usage in several consumption segments, it is important to assess its role in relation to energy poverty in Kenya.

1.1.1 Energy Poverty in Kenya

Energy poverty generally refers to a situation where the well-being of large numbers of people is negatively affected by very low consumption of energy, use of polluting or dirty fuels, and too much time spent collecting fuel to meet basic needs. The International Energy Agency specifically defines energy poverty as lack of use of electricity, clean cooking and heating systems, or both (www.iea.org). Researchers and policymakers have increasingly recognized the importance of gas as part of the efforts to attain universal access and reduce energy poverty.

Domestic energy poverty on the other hand refers to a situation where a household does not have access or cannot afford to have the basic energy or energy services to achieve day to day living requirements, the most common being lighting, cooking, domestic heating or cooling. On the measures of the basic energy requirement, many countries have identified the provision of 1 unit of electricity per day per household as a basic

energy requirement, thus it can be seen that in Kenya the units of electricity provided is at a very concessionary rate.

It is estimated that in Kenya 77 percent of the people do not have electricity connections and over 85 percent of the population rely on traditional fuels such as agricultural residues, wood, dung and charcoal for cooking and, to a lesser extent, heating. Many rural households and the urban poor are not reached by grid-based electrical power nor is there adequate distribution of gas or other cooking and heating fuels. Firewood remains the predominant fuel for cooking and nationally, 68.3 percent of all households use firewood as their main source of cooking fuel and over 80 percent of households in the rural areas rely on firewood for cooking compared to 10 percent of urban households.

The lack of access to affordable energy has a number of implications for poor households, and for women in particular including: (i) Women and children disproportionately suffer from health problems related to gathering and using traditional fuel and cooking in poorly ventilated indoor settings. Such include eye diseases and infections, respiratory infections and even cancer (ii) High opportunity costs related to time spent gathering fuel and water which limits their ability to engage in educational and income-generating activities resulting in dramatically different literacy rates and school enrolment levels between men and women; (iii) Lack of electricity in rural areas is a further hindrance to women's access to useful media information such as civic education and important health information.

1.1.2 Factors affecting Energy Poverty

When considering the level of energy poverty in a country, it is clear that accessibility, efficiency, cleanliness and consumption of the various energy services should be looked into. This is because everybody should be having access to improved and efficient energy services; and people should also be able to consume a certain level of clean energy services to meet their basic needs.

A number of energy researchers have focused on the determinants of energy poverty, with Schweizer-Ries (2009) conducting a study on the impact and public recognition of energy poverty in the United Kingdom, France, Germany, Italy and Poland. The study reckons that there exist certain socio-economic indicators that increase a household's risk to being energy poor. These factors are: low income, economic inactivity such as unemployed persons and pensioners, elderly persons, young families/people with disabilities or long term illness, people living alone, low level of education, ethnic minority households and low income single adults.

This is not so different from the conclusions made by El-Katiri & Fattouh (2011), who after investigating energy poverty in Yemen found out that the major factors influencing energy poverty in Yemen include wide spread total poverty, household income, availability of necessary infrastructure and other incentive structures to make use of more costly forms of energy, fuel prices and cost of necessary equipment to use the fuel and individual household preference.

In dividing energy poverty into the two main groups of inadequate supply and no access, with the former focusing on inadequate electricity supply and its various consequences, and the latter addressing various issues concerning the complete lack of electricity access- referring to the situation of the predominantly poor inhabitants of remote, rural areas not connected to the national grid – Onyeji (2010) concludes that to eradicate energy poverty, SSA has to focus on institutional quality to encourage an adequate portion of savings to be channeled towards the electricity sector. This clearly supports the notion that electricity access plays a huge role in determining energy poverty.

The scenario is similar in Ireland. Roinn & Fuinnimh (2010) report that in Ireland, energy poverty can be considered as the product of the interaction between household income, the cost/price of energy and the household's energy consumption pattern.

1.1.3 Energy consumption patterns in Kenya

A study conducted by KIPPRA (2010) reveals that total final energy consumption in Kenya in 2009 was 14,353.8 thousand tons of oil equivalent while the total primary energy supply was 18,215.99 thousand tons of oil equivalent. Petroleum fuels accounted for about 28.57 percent of the total final energy consumption while electricity and combustible renewables accounted for about 3.11 percent and 67.65 percent of the total final energy consumption.

The study shows that the use of LPG at homes, educational and health institutions rose from slightly over 40 thousand metric tons in 2003 to 80 thousand metric tons in 2008. Other products which recorded increased consumption included lubricating oils and

illuminating kerosene, which is the most common fuel for use by households in lighting and cooking, used about 300 thousand cubic meters in 2008 as compared to about 200 thousand cubic meters consumed in 2003.

According to recent data released by the Kenya National Bureau of Statistics, all consumer categories recorded an increased demand in electricity with domestic demand increasing by 10.8 percent, commercial and industrial demand increasing by 7.6 percent, and rural electrification also rising by 3.5 percent. KIPPRA estimates that about 70 percent of the consumers use biomass while 30 percent use other fuels, supporting well known studies that biomass provides 70 percent of the energy requirements in Kenya (Kituyi 2002, Kamfor 2002). The study also revealed kerosene to be mostly used for lighting (52 percent) while biomass was widely used for cooking (60 percent), and with an exception of the transport fuels, average monthly consumption per household was found to be high for electricity (386.01 Mega Joules) compared to the other fuels.

1.1.4 Modern Energy and the Millennium Development Goals

It is important to note that there are unrivaled development benefits to be gained from expanding access to modern energy services as modern energy services enhance the life of the poor in limitless ways. For example, electric energy provides the greatest and most efficient form of lighting thereby extending the day by providing extra hours.

It is also evident that modern cooking facilities have the potential to significantly reduce the daily exposure of households (particularly women and children) to noxious cooking fumes – helping to avoid premature deaths caused by indoor air pollution. They can also

help remove the burden of spending hours every day travelling long distances to collect fuelwood. Modern energy can also directly lessen poverty by raising a poor country's productivity and extending the quality and range of its products – thereby putting more wages into the pockets of the deprived.

The UN Millennium Project (2005)¹ has also emphasized that close links exist between energy and all eight of the Millennium Development Goals (MDGs). Modern energy services help reduce poverty (MDG 1), plays a critical role in improving educational opportunities for children, empowering women, promoting gender equality (MDGs 2 and 3) and the availability of adequate clean energy is vital in reducing child mortality (MDG 4).

Reducing the carrying of heavy loads of fuelwood improves maternal health (MDG 5), inefficient combustion of fuelwood exacerbates respiratory illnesses and other diseases (MDG 6); and fuel substitution and improved stove efficiencies would help alleviate the environmental damage of biomass use (MDG 7). Finally, widespread substitution of modern energy for traditional biomass can be a rallying point for global partnerships (MDG 8). It is therefore clear that modern energy—provided by liquid and gaseous fuels as well as electricity—can greatly assist societies in reducing poverty and hunger and achieving the education, gender, health and environmental rudiments of the Millennium Development Goals.

¹ www.undp.org, Investing in Development: A practical Plan to achieve the Millennium Development Goals, UN Millennium Project, 2005.

1.2 The Research problem

The International Energy Agency (IEA, 2011) notes that energy is a critical enabler and every advanced economy has required secure access to modern sources of energy to underpin its development and growing prosperity. In developing countries such as Kenya, access to affordable and reliable energy services is fundamental to reducing poverty, increasing productivity, enhancing competitiveness and promoting economic growth.

Statistics show that 82 percent of the Kenyan population does not have access to modern energy and 80 percent of the population relies on traditional biomass for cooking. It has also been noted that Kenya's consumption level of LPG is very low, at 1.4 kilograms per capita compared to Africa's average which is 8.3 kilograms per capita². This is owed to inadequate LPG supply and distribution infrastructure.

Of the various modern sources of energy, great emphasis has been laid on electric energy and this is evident on the massive investment in the on-going rural electrification program in the country. Investment will also need to focus on other modern energy sources, including LPG, to help alleviate the widespread energy poverty in the country. Given the light emphasis on LPG energy, the role of LPG in addressing energy poverty in Kenya is vague. The measures that can be taken to enable more households to shift away from solid fuels to LPG are also unclear. This study wants to find out the role of LPG in reducing energy poverty in Kenya and measures in this regard.

² Though this trend is changing, albeit slowly, as is seen in the increased demand for LPG by Kenyan households, especially the urban population

1.3 Research Questions

This study seeks to answer the following questions:

- a) What is the extent of energy poverty in Kenya?
- b) What role can LPG play in reducing energy poverty in Kenya?
- c) What are the measures the government could take to enable more households to shift away from solid fuels to LPG?

1.4 Objectives of the study

The general objective of this study is to investigate energy poverty in Kenya and the role that LPG could play to reduce this poverty.

The specific objectives of the study are to:

- a) Estimate the level of energy poverty in the country
- b) Determine the role played by LPG in reducing energy poverty in Kenya
- c) Identifying measures to enable more households to shift away from solid fuels to LPG

1.5 Significance of the study

The energy poverty situation in Kenya is distressing as statistics show that presently, over 85 percent of the population relies on traditional fuels and approximately 77 percent of the population does not have access to electricity. Specifically, studies carried out by different organizations on LPG Demand in Kenya indicate that in the last decade, there has been a sharp increase in the demand for the domestic cooking gas.

An ERC study carried out by KIPPRA (2010) indicates that the use of LPG in educational institutions, health institutions and homes has risen from slightly over 40 thousand metric tons in 2003 to over 80 thousand metric tons in 2008. Data by the Kenya National Bureau of Statistics also shows that demand for LPG in the country has increased in the last five years by about 78 percent from 49400 tons in 2005 to 87800 tons in 2010.

This study is well-timed and significant. This is because it will not only make a great contribution for policy on the role that LPG can play in dealing with energy poverty in Kenya, but it will also give a more profound understanding of Kenya's energy poverty problem.

1.6 Organization of the study

The next chapter reviews both empirical and theoretical literature on energy poverty, chapter three presents the theoretical framework and gives the various measures of energy poverty. This is followed by chapter four which gives the data and methodology and chapter five discusses the empirical results. Summary, conclusions and policy recommendations are presented in chapter six.

CHAPTER TWO

REVIEW OF LITERATURE

2.1 Introduction

This section has two parts: the theoretical literature review and the empirical literature review. The theoretical literature review provides an economic reasoning on the issue of poverty and gives various theories on poverty. This is then followed by the empirical literature review which provides an analysis, backed with evidence from past studies, on the energy for cooking in Kenya, Access to electricity in Kenya and LPG consumption in Kenya. To wrap up this chapter, there is a general overview of the literature.

2.2 Theoretical Literature Review

Energy poverty is increasingly gaining recognition and policy makers' attention (though theoretical literature on the topic is still limited) because of the notion that any form of poverty in a society is unacceptable. Poverty is multi-faceted and should not only be seen in terms of income. However, several studies that aim at mitigating poverty focus on income and only use non income measures of poverty in the absence of data. One example of the non-income poverty measures is energy consumption, which is increasingly being used to distinguish the poor from the non-poor.

2.2.1. Theories on Poverty

Poverty refers to whether households or individuals have enough resources or abilities today to meet their needs (World Bank, 2013). Economists broadly classify poverty into

two types: Absolute poverty and Relative poverty. Absolute poverty is a level of poverty defined in terms of the minimal requirements necessary to afford minimal standards of basic needs. This approach to poverty can be helpful if poverty is to relate to a basic, fixed level of economic resources which will prevent physical and social suffering due to material deprivation. If incomes or economic resources were to fall below this level (often called the poverty line), then that person would be considered to be poor in absolute terms.

Relative poverty on the other hand, defines poverty as being below some relative poverty threshold and it identifies poor households as those whose incomes (or more broadly, the economic resources they command) fall significantly below the average level of income in the economy. Poverty can also be classified as either cultural or structural. Cultural theories explain poverty in the traits of the poor themselves and assert that it is the valuational, attitudinal, and behavioral patterns of the poor which prevent them from being socially mobile.

On the other hand, structural theories explain poverty in terms of the conditions under which the poor live such as poor health and education, underemployment and unemployment. These definitions and classifications of poverty make it necessary to examine the extent of relative inequality and how it relates to the extent of absolute poverty and also to clearly identify who the poor are and examine their economic characteristics.

2.2.2 Dimensions of Income Distribution

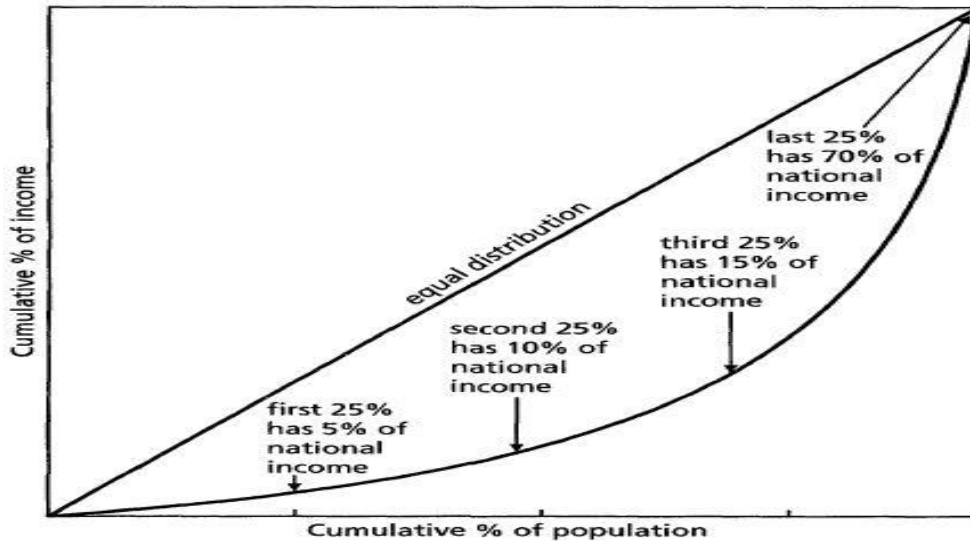
Size Distribution of Income

Is a measure most commonly used by economists and it simply deals with individual persons and the total incomes they receive. This method does not consider the way in which the income was received or the locational and occupational sources of the income. All individuals are arranged by ascending personal incomes and the total population is then divided into distinct groups or sizes such as deciles or quintiles according to ascending income levels. Next, the proportion of total national income received by each income group is determined.

A common measure of income inequality is the ratio of the incomes received by the bottom 40 percent compared with the top 20 percent of the population. This ratio is often used as a measure of the degree of inequality between the two extremes of very poor and very rich in a country.

Lorenz curves are another common way used to analyze personal income figures. This convenient and widely used diagram was devised by Conrad Lorenz in 1905 to show the relationship between population groups and their respective income shares.

Figure 2.1: Lorenz Curve



Source: Todaro, MP 1977, *Economics for a Developing World*, Longman Group Limited, London.

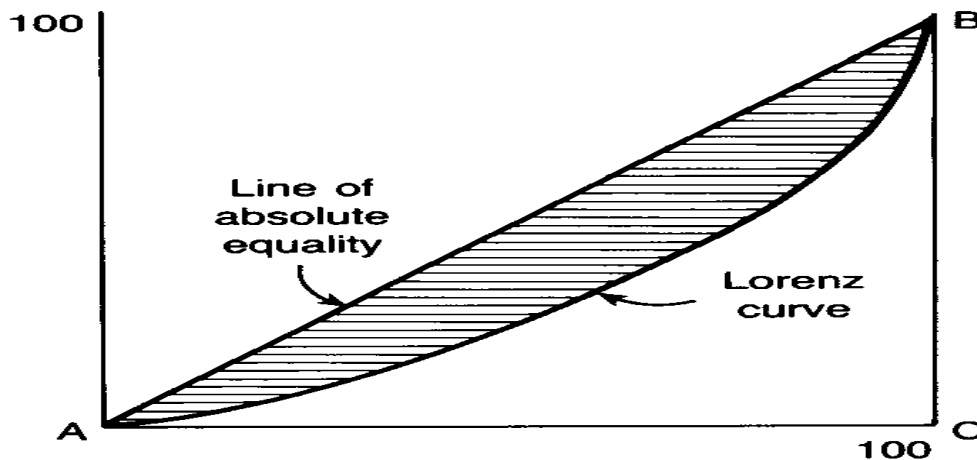
On the horizontal axis is the number of income recipients in cumulative percentages and not absolute terms and the vertical axis portrays the share in total income associated with or received by each percentage of the population. Every point on the diagonal line that runs from the origin to the upper right hand corner represents perfect equality in that the percentage of income received is exactly equal to the percentage of income recipients.

The Lorenz curve shows the actual quantitative relationship between the percentage of income recipients and the percentage of the total income which they did in fact receive during a given period. The more the Lorenz line curves away from the diagonal (perfect equality), the greater the degree of inequality represented. The extreme case of perfect inequality, a situation in which one person receives all the national income while everybody else receives nothing, would be represented by the coexistence of the Lorenz curve with the bottom horizontal and right hand vertical axes.

No country exhibits either perfect equality or perfect inequality in its distribution of income. The Lorenz curves thus usually lie somewhere to the right of the diagonal and the greater the degree of inequality, the more 'bend' and the closer to the bottom horizontal axis will be the Lorenz curve.

The Gini coefficient or the Gini concentration ratio is also another convenient and shorthand summary measure of the relative degree of inequality in a country and it can be obtained by calculating the ratio of the 'area' between the diagonal and the Lorenz curve as compared to the total area of the half square in which the curve lies. Gini coefficient is named after Corrado Gini who first formulated it in 1912 and Gini coefficients are aggregate inequality measures that can vary anywhere from zero (perfect equality) to one (perfect inequality).

Figure 2.2: Estimating the Gini coefficient



Source: Todaro, MP 1977, *Economics for a Developing World*, Longman Group Limited, London.

Figure 2.2 above shows that the Gini coefficient is equal to the shaded area divided by the total area of the triangle *ABC*. Research shows that the Gini coefficient for countries with highly unequal income distributions typically lies between 0.5 and 0.7 while for countries with relatively equitable distributions, it is of the order of 0.2 and 0.35.

Functional Distribution of Income

Also known as the factor share distribution and it measures income distribution by attempting to explain the share of total national income that each factor of production receives. Instead of looking at individuals as separate entities, this theory and measure of functional income distribution inquires into the percentage that labour receives as a whole and compares this with the percentages of total income distributed in the form of rent, interest and profit (i.e. the returns to land and financial and physical capital).

It thus attempts to explain the income of a factor of production by the contribution that the factor makes to production. Supply and demand curves are assumed to determine the unit prices of each productive factor. When these unit prices are multiplied by the quantities utilized on the assumption of efficient (i.e. minimum cost) factor utilization, a measure of the total payment to each factor is arrived at.

Unfortunately, the relevance of the functional theory is greatly vitiated by its failure to take into account the important role and influence of non-market forces such as power in determining factor prices e.g. the role of collective bargaining between employers and trade unions in the setting of modern sector wage rates.

2.2.3 Economic characteristics of poverty groups

Evidence shows that the main causes of poverty are: unemployment or having a poor quality (i.e. low paid or precarious) job as this limits access to a decent income and cuts people off from social networks, Low levels of education and skills because this limits people's ability to access decent jobs to develop themselves and participate fully in society. Large families and lone parent families also tend to be at greater risk of poverty because they have higher costs, lower incomes and more difficulty in gaining well paid employment, (Sachs, 2005).

Research (Iwayemi, 2008) also shows that women are generally at higher risk of poverty than men as they are less likely to be in paid employment, tend to have lower pensions, are more involved in unpaid caring responsibilities and when they are in work, are frequently paid less. Disability or ill-health also increases poverty levels because this limits ability to access employment and also leads to increased day to day costs.

Being a member of minority ethnic groups and immigrants/undocumented migrants also exposes people to poverty as they suffer particularly from discrimination and thus have less chance to access employment, are often forced to live in worse physical environments and have poorer access to essential services. Finally people living in remote or very disadvantaged communities where access to services is worse are also at a higher risk of poverty, (Todaro, 1977).

However, it is important to note that higher levels of per capita income are no guarantee of lower levels of poverty. Some valid generalizations of the poor include the fact that

they are disproportionately located in the rural areas and that they are primarily engaged in agricultural and associated activities.

These characteristics of poverty groups are similar to those identified by energy researchers such as Schweizer-Ries (2009), Onyeji (2010) and Roinn & Fuinnimh (2010) who report that certain indicators such as low income, economic inactivity such as unemployed persons and pensioners, elderly persons, young families/people with disabilities or long term illness, people living alone, low level of education, ethnic minority households and low income single adults increase a household's risk of being energy poor.

2.2.4 Consequences of Poverty

Todaro (1977) notes that repercussions of poverty vary in scale but all have negative effects. Poor people will generally have a low standard of living as they are not able to afford quality education and lack access to health care. This will lead to a low quality of human capital and thus compromise economic growth.

Todaro (1977) further observes that poverty also takes a toll on poor children's development. For example, poverty causes malnutrition which would affect the development of a child's mental thinking and healthy body. Poverty may also lead to political instability increased risk of war, mass emigration of population and terrorism, high annual death rates, increase in hygiene and diet related diseases such as cholera and tuberculosis and increased crime rates as people turn desperate to survive in the face of poverty.

2.2.5 Linking Economic Poverty and Energy Poverty

One of the greatest challenges currently facing man-kind is to find ways to bring a decent standard of living to the majority of the world's population who live in abject poverty; and it is also widely believed that an essential feature of any economic development program aimed at reducing this poverty must be a significant increase in the level of per capita modern energy use.

Energy economists have unanimously agreed that access to a high-quality energy supply makes it possible to improve living conditions substantially, in that it facilitates the fight against hunger and malnutrition through the preservation of food by refrigeration, through higher productivity in the food chain and the development of modern agricultural production modes. It also constitutes an essential feature of sanitary improvement via improved food hygiene and more advanced medical equipment.

Modern energy sources are also less dangerous and their use limits the need to gather wood and seek water from distant sources – tasks which are often physically trying and time-consuming for the populations concerned. The availability of modern energy sources also opens the way to general schooling by freeing time for children to go to school and by facilitating the development of classes and home study in the evening.

Improved living conditions have in their turn a direct impact on the development of economic activity through the quantitative— longer life expectancy and better health — and qualitative — better training — upgrading of the labour force. Better energy supply

opens the way to longer working hours and, where electricity is concerned, to a reduction in periods of forced inactivity resulting from power cuts.

The use of reliable energy sources makes possible a better use of the other components of production, notably machines, and is an absolute condition for the adoption of new technologies capable of promoting diversification. The business environment also benefits directly from the improvements registered in such key sectors as transport and communication, which are heavily dependent on energy supply.

Better energy supply also enables the state to offer education, health and communication services at lower cost and in greater quantity. It also encourages the circulation of information, an essential factor in political decision making. It makes it possible in this way to target populations in need and make an enlightened choice of the policy best suited to the local and national context. Conversely, the circulation of information and improved living conditions promote the development of greater participation on the part of the population in national choices, opening the way to a greater democratization of the institutions. In this way, the authorities are pushed towards greater transparency and responsibility in their decision making.

In conclusion, abundant cheap and highly polluting energy supplies, while providing essential inputs for economic growth in the short term, result in unsustainable local, regional, and global environmental and health effects over the medium and long term; and it is evident that modern energy has strong links with poverty reduction – through income, health, education, gender, and the environment.

2.3 Empirical Literature Review

2.3.1 Energy poverty

Energy poverty is slowly gaining attention from researchers, with Birol (2007)³ including persistent energy poverty among the three main strategic challenges facing the global energy system in the coming decade. The study considers lack of access to electricity and use of traditional biomass in unsafe, inefficient and unstable ways to be the hallmarks of energy poverty.

Kauffmann (2005) conducted a study of energy poverty in Africa and noted that Africa has a vast energy potential that is largely unexploited. The study reports that renewable energy sources are numerous in Africa, for example, the hydraulic basins of central Africa, the Rift Valley fault and the sunshine from which the continent in general benefits, provide sources of solar, hydraulic and geothermal energy which are rarely equaled elsewhere in the world. This fact is supported by Iwayemi (2008) who reiterates that Africa is well endowed with renewable and non-renewable energy resources that far exceed its energy demand requirements for the next century.

Paradoxically, most African countries are still characterized by energy poverty and with current actions to eradicate energy poverty falling short both in terms of scale and pace, the IEA, UNDP and UNIDO (2010) report that the continuation of current trends may mean more people will be without modern energy access in 2030 than currently.

³ This note is based on Fatih Birol's acceptance speech at the IAEE Outstanding Contribution to the Profession Award Ceremony, 4 June 2005, Taipei.

This is evident in parts of sub-Saharan Africa as a study carried out by Practical Action (2010) in Al-Fasher, Darfur, in Sudan revealed that people kept cooking with wood and charcoal despite the fact that the cost of wood and charcoal was three times higher than LPG. This is simply because they could not afford to purchase gas cookers and cylinders and instead had to buy a few kg of charcoal or wood on a daily basis.

A study conducted in India by Jain (Undated paper) also shows that access to electricity is limited to 56 percent of households and about 89 percent of rural households depend on polluting energy sources. Though the paper aimed at linking energy poverty with income poverty and gender inequality, it was of particular importance to this study as it also analyzed measures taken to alleviate energy poverty and recommend regulatory and policy measures as way forward.

2.3.2 Energy Poverty in Kenya

Energy poverty affects many Kenyans and is an important issue for the Kenyan government. A majority of people, especially those in rural areas are hugely dependent on biomass to meet their energy needs. These resources account for over 80 percent (Ministry of energy, 2006) of household energy consumption and the heavy dependence on biomass is concentrated in rural areas but not confined to these areas. Fuelwood and charcoal are also widely used as they do not require a complex and expensive infrastructure to be produced and used as a fuel. In addition, they are relatively the cheapest and usually freely available energy resource for the rural population and urban poor.

Onguru *et al* (2008) investigated energy access among the urban poor in Kenya and the findings of the household survey they carried out revealed that kerosene is the most important modern energy option for the poor for both lighting and cooking. Electricity also appeared to be a relatively important energy option, while biomass in the form of charcoal and LPG appeared to be consumed by a relatively small segment of the urban poor in the selected sample area.

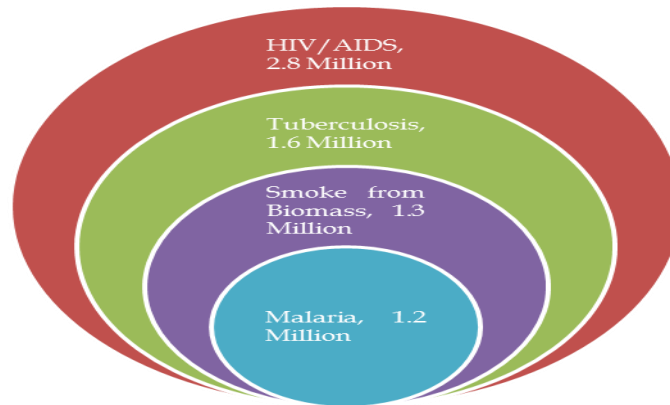
UNCHS/ Habitat (1984) also conducted a study on Energy Requirements and Utilization in Rural and Urban Low–Income Settlements and they report that the use of wood fuel accounts for 50 percent to 90 percent of the total primary energy consumed, particularly in the rural settlements. More than 70 per cent of the wood in developing countries is used for cooking fuel, with cooking being the only use for wood resources in some rural settlements.

The International Energy Agency (IEA 2006) notes that the use of biomass is not in itself a cause for concern. Nonetheless, when resources are harvested unsustainably and energy conversion technologies are not efficient, there are serious and grave consequences for the environment, economic development and health.

Current fuels and technologies used in Kenya have serious harmful effects. Though official data on Kenya is currently not available, global projections by the World Health Organization (WHO, 2004) indicate that 1.5 million premature deaths per year are directly attributable to indoor air pollution from the use of solid fuels. This is more than 4000 deaths every day and more than half of these deaths are children under the age of

five years. From these statistics, indoor air pollution associated with the use of solid fuels is directly responsible for more deaths than malaria, almost as many deaths as tuberculosis and almost half as many deaths as HIV/AIDS (Figure 2.3).

Figure 2.3: Annual Deaths worldwide by cause



Source: WHO Statistical Information System available at www.who.int/whosis

Smith *et al* (2004) also report that solid fuels such as fuelwood produce high emissions of carbon monoxide, hydrocarbons and particulate matter, with women and children suffering most from indoor air pollution because they are traditionally responsible for cooking and other household chores which entail spending hours by the cooking fire exposed to smoke. This is supported by Laxmi *et al* (1999), who carried out a study on indoor air pollution with a focus on gender bias and found out that women and children below five years are among the most affected by pollutants released during the burning of bio-fuels in traditional stoves.

Another effect of traditional fuel use is environmental damage such as land degradation and regional air pollution. Studies (such as Arnold *et al*, 2003) at the regional level

indicate that as much as two thirds of fuelwood worldwide comes from non-forest sources such as agricultural land and roadsides, with charcoal being mostly produced from forest resources.

Studies conducted in Sub-Saharan Africa indicate that in the region, which is heavily reliant on biomass, women and children are responsible for fuel collection, a task which is both time-consuming and exhausting. Specifically, Rwelamira (1999) finds out that the average fuelwood load in sub-Saharan Africa is around 20 kg but loads of 38 kg have also been recorded and with such strenuous work without sufficient recuperation, women risk suffering serious long-term physical damage.

Kenya is no exception to such scenarios as a KIPPRA (2010) study revealed that users of charcoal and fuel wood in Nairobi have to travel on average 0.59 and 6.44 kilometers respectively to access the fuel they need and these challenges are currently being dealt with through the promotion of clean sources of energy for cooking such as LPG and also through the use of improved cookstoves. Pattanayak *et al* (2012) reviewed empirical studies to establish who adopts improved fuels and cookstoves and they concluded that income, education, and urban location were positively associated with adoption in most but not all studies, while the influence of fuel availability and prices, household size and composition, and sex is unclear.

In this regard, it is imperative to assess the electricity access rate in Kenya and review LPG consumption in the country, while paying special attention to factors affecting LPG

consumption in the country. Particular emphasis is laid to electric energy and LPG as they are the widely accepted modern energy sources.

2.3.3 Access to electricity in Kenya

Electricity is the most modern and convenient fuel, ranks highest on the energy ladder, is universally accepted as an enhancer of the quality of life at household level and a stimulator of the economy at a broader level. For households, electricity is the most desired form of energy due to its versatility in use and the fact that it is environmentally friendly, particularly when produced from hydro and geothermal sources (Ministry of Energy/ Ministry of planning and national development, 2006).

In Kenya nonetheless, most people cannot afford electricity because it is expensive compared to the majority of peoples income. Approximately, only 46 percent of urban and 3.8 percent of rural households have access to electricity and nationally this translates to only 15 percent households with access to electricity (Ministry of Energy, 2006). Wood fuel is the cheapest and most accessible form of energy in the country, but as Kenya's population grows, so too does its demand for electricity in the residential sector. Demand already outstrips supply and Kenya's 2010 electricity generating capacity stood at 7501 GWh with the Ministry of Energy forecasting that demand is set to exceed the current 6321 GWh.

Kirubi *et al* (2009) conducted a study in Kenya that lays bare electricity's importance as their study reveals that access to electricity enables the use of electric equipment and tools by small and micro enterprises. This, they report, results in significant improvement

in productivity per worker (100–200 percent depending on the task at hand) and a corresponding growth in income levels in the order of 20–70 percent, depending on the product made. They also note that access to electricity simultaneously enables and improves the delivery of social and business services from a wide range of village-level infrastructure (e.g., schools, markets, and water pumps) while improving the productivity of agricultural activities.

With only 16 percent of the population having access to electricity as at 2009 (World Bank, 2013), electric energy only accounts for 10 percent of total final energy consumption. Roughly 60 percent of all electricity is consumed by the commercial and industrial sectors and only 24 percent is used by households (CIA world FactBook 2013). Even though current electricity demand is still low, it is rapidly increasing and for the period 2005 to 2010 total electricity consumption increased by 27 percent, while electricity consumption in the household sector alone has risen by 35 percent.

2.3.4 LPG consumption in Kenya

In its MDG needs assessment report, the Ministry of Energy (MoE, 2006) notes that LPG is not widely used in Kenya, with only 7.8 percent (23percent urban and 1.8percent rural) households using it due to various constraints. The average mean annual consumption is a paltry 3.6 kg and 9.7 kg for rural and urban areas respectively or a national mean of 5.3kg per household and it is used along with firewood in rural areas while in urban areas it is used as a supplement for electricity.

Presently, LPG demand as estimated by the government far exceeds the annual consumption level of 91000 metric tons (www.data.worldbank.org). A study conducted by the Institute of Economic Affairs (IEA, 2000) noted that the satisfaction of this demand depends on the availability of an import handling and loading facility at the port of Mombasa because there is at present no capacity for such quantities.

The study also found out that the use of LPG has additionally been constrained by the initial cost of acquiring equipment such as cookers and gas cylinders. On their own, such equipment is not inordinately expensive but the modest use is due to the heavy taxation on the equipment itself. For instance, as at April 2000, about 30 percent of the total cost of the simplest equipment was comprised of direct taxation by the government.

These results are consistent with those filed by the Ministry of Energy, in collaboration with the Ministry of Planning and National Development in its MDG needs assessment report in 2006. The report noted that among the reasons why the use of LPG is fairly limited is the fact that LPG based appliances are expensive and regulators are incompatible between different major dealers. This makes it difficult to interchangeably buy LPG from a variety of companies even though this issue is now being addressed (with dealers such as HASHI gas accepting cylinders from competitors).

The report further reveals that transportation and storage facilities for the commodity also present some constraints, making it unavailable in many parts of the country. In fact, even for the few households who have enough income to buy LPG, availability of the commodity in small rural centers cannot be assured.

Factors affecting Household LPG consumption in Kenya

The Ministry of energy's study on Kenya's energy demand and supply in 2001 revealed that there are LPG distributors in residential areas in urban centers and it estimated that 83 percent of LPG consumers in urban centers get their supplies from within a 5 kilometer radius and a majority of these (71 percent) are LPG users of 12-15kg while 17 percent use 6kg and 11 percent use 3kg. The report by the ministry further reiterates that most of the small cylinder users represent new LPG users, most of which are in the low income group and rural areas.

A joint study by EAA, ITDG & KEFRI (2001) reports that despite the huge demand for LPG in Kenya, several factors exist that hinder the widespread use of this relatively safe and efficient fuel for domestic and commercial use. These include: Pricing - LPG is relatively expensive compared to other fuels and prices vary according to retailers and distance from the supply source. There is also the cost of equipment that allows LPG use - High initial costs of LPG appliances (cylinders and cookers) are out of reach for lower income groups. On their own, such equipment is not ordinarily expensive, but the modest use is in heavy taxation

As an imported product, LPG is affected by international fluctuations of crude prices and also relatively low per capita demand makes the unit cost of supply and distribution high. Finally, standardization of valves - LPG sector is devoid of competition because LPG companies compel consumers to purchase separate valves/regulators for gas cylinders. Due to different valves/regulators, the cylinders from different companies are not

compatible with one another. Consumers are therefore unable to compare prices and go for cheaper equipment.

These findings are in agreement with those of Akinyi (2008) whose analysis reveals that in both the long run and short run, household demand for LPG in Kenya is determined by: (i) Urban population – LPG is mostly consumed in urban areas and since urban population is also a measure of urbanization, it drives the demand for LPG (ii) Domestic Revenue – Is the total revenue collected within the domestic economy and it affects budgetary allocations to various sectors such as infrastructure, thereby determining LPG availability (iii) Per capita GDP – This measures the purchasing power of the population and LPG consumers and is also indicative of the level of economic growth, and finally, (iv) Inflation – Which measures macroeconomic stability.

2.3.5 Energy Poverty and LPG consumption

An outstanding study relating Liquefied petroleum gas and energy poverty was carried out by Kojima (2011). The study conducted econometric analysis (using Heckman-type model) of national household expenditure surveys in 10 developing countries to assess the factors influencing LPG selection and consumption. It also examined LPG markets in 20 developing countries, including their regulatory frameworks, pricing and other policies, supply infrastructure, cylinder management, amount of information available to the public, and activities designed to promote household use of LPG.

Finally, it obtained data from households in 110 developing countries about energy choices related to cooking, with information on energy choice by wealth quintile

available in 63 of the countries. The findings of the study reveal that LPG is used predominantly by the upper half of the income groups in low- and lower-middle-income countries. Household income and fuel prices were the two principal determinants of a household's decision to use LPG and how much to consume and response to relative prices indicated that firewood prices would have to rise steeply before a household would consider substituting LPG for firewood.

Interesting to note is the study's revelation that everything else being equal, the higher the education levels attained by household members, the more likely the household was to select LPG. This effect was larger for women than men and once education levels of women and men were separately accounted for, a household headed by a woman was no more likely to favor LPG selection and consumption than a male-headed household, perhaps because male headed households tend to have more assets and access to credit and employment. The conclusion is that educating the public, especially women, about the costs and benefits of fuel choice could promote a switch to cleaner fuels.

Karekezi & Kathyoma (2001) reviewed emerging trends in the rural energy sector of sub-Saharan Africa. The review revealed that for the majority of rural households in the region, biomass fuels will continue to be the dominant fuel of choice and efficient technologies for the use of biomass would, therefore, ensure that scarce biomass resources are effectively utilized, and reduce the negative impacts of biomass use on women and children's health. They conclude that cleaner fuels such as LPG have not

received adequate attention from policy makers and these energy options could significantly reduce energy poverty.

Khandker *et al* (2010) also studied energy poverty in urban and rural India by proposing an alternative measure on energy poverty based on energy demand and using the energy poverty line which is defined as the threshold point at which energy consumption begins to rise with increases in household income. Applying this approach to cross-sectional data from a comprehensive 2005 household survey representative of both urban and rural India, they find out that in rural areas, some 57 percent of households are energy poor, versus 22 percent that are income poor. For urban areas the energy poverty rate is 28 percent compared with 20 percent that are income poor.

Policies to reduce energy poverty would include support for rural electrification, the promotion of more modern cooking fuels, and encouraging greater adoption of improved biomass stoves. A combination of these programs would play a significant role in reducing energy poverty in rural India.

2.4 Overview of the Literature

From the literature reviewed it is evident that energy poverty has not received much of the attention it needs from both researchers and policy makers and it is almost absent from mainstream institution, journal and conference publications. This can be attributed to many factors, particularly lack of adequate information to analyze energy poverty and develop appropriate models. Studies also need to focus on the link between energy poverty and modern energy sources, as this will be of importance to policy on the role of

modern energy in reducing energy poverty. Specifically, literature on Kenya needs to focus on the macro as well as the micro level, and link Kenya's energy poverty crisis to the various forms of modern energy sources.

CHAPTER THREE

THEORETICAL FRAMEWORK

3.1 Introduction

Poverty is an ill and poor people, while they share many other problems with the non-poor, are unique in having a relative shortage of goods and services at their disposal. Poverty in the more restricted sense can be eliminated, and is worth eliminating and will be eliminated more promptly by policies that are aimed at a compact, rather than a diffuse, target. This study developed the concept of energy poverty, taking from the basic model of economic choice the idea of separating preferences from constraints. Associating poverty with extremely limiting constraints, it hinged on the neoclassical model of economic choice.

3.2 Neoclassical Model of Economic Choice

This is based on the idea of economic constraint and is derived from Milton Friedman's theory of permanent income (Friedman, 1957). This model postulates that there is a set of objects of choice which the decision-maker ranks according to his particular, and perhaps peculiar, preferences. Confronted with one or more considerations which limit his choice to a sub-set of these objects, the decision-maker will, according to the model, choose the highest ranking alternative available in that sub-set.

Consider the set of choice objects all to be possible rates of consumption of two categories of consumer goods and services: necessities and luxuries. The decision-

making unit, e.g. an individual or household, has a system of preferences among these objects that may be represented by an indifference map.

Assume that he has a fixed income flow to be spent and can purchase any amount of each good at prices that do not depend upon the size of his purchase, then the combinations available to the decision making unit are constrained. Poverty and affluence provide degrees of constraint on choice with poverty being associated solely with severe constriction of the choice set while affluence corresponds to a much larger area of attainable alternatives.

3.3 Economic measures of Poverty

Headcount Index

Is one of the most used measures of economic poverty and it simply measures the proportion of the population that is counted as poor, often denoted by P_o . The index is

generally given as; $P_o = \frac{N_p}{N}$, where N_p is the number of poor and N is the total population

(or sample).

Poverty Gap Index

This measure adds up the extent to which individuals fall below the poverty line, on average, and expresses it as a percentage of the poverty line. More specifically, the poverty gap (G_i) is defined as the poverty line (z) less actual income (y_i) for poor individuals; the gap is considered to be zero for everyone else. Using the index function,

$G_i = (z - y_i) \times I(y_i < z)$ and the poverty gap index, P_I may be written as; $P_I = \frac{1}{N} \sum_{i=1}^N \frac{G_i}{Z}$.

Squared Poverty Gap (Poverty Severity) Index

This is used as a measure of poverty that takes into account inequality among the poor. It implicitly puts more weight on observations that fall well below the poverty line by

squaring the poverty gap index. Formally, $P_I = \frac{1}{N} \sum_{i=1}^N \left(\frac{G_i}{Z} \right)^2$. This measure may be seen as

one of a family of measures proposed by Foster, Greer, and Thorbecke (1984), which

may be written, quite generally, as $P_I = \frac{1}{N} \sum_{i=1}^N \left(\frac{G_i}{Z} \right)^\alpha$, $\alpha \geq 0$, where α is a measure of the

sensitivity of the index to poverty and the poverty line is z .

Sen Index

Sen (1976) proposed an index that seeks to combine the effects of the number of poor people, the severity of the poor people's poverty, and the distribution of poverty within

the group. The index is given by $P_S = P_0 \left[1 - (1 - G^P) \frac{\mu^P}{z} \right]$, where P_0 is the headcount index,

μ^P is the mean income (or expenditure) of the poor, and G^P is the Gini coefficient of inequality among the poor, with the Gini coefficient ranging from 0 (perfect equality) to 1 (perfect inequality).

The Sen-Shorrocks-Thon (SST) Index

This is a modification of the Sen Index and is defined as $P_{SST} = P_0 P_I^p (1 + G^P)$, which is the product of the headcount index, the poverty gap index (applied only to the poor), and a term with the Gini coefficient of the poverty gap ratios (that is, of the G_n 's) for the whole

population. The said Gini coefficient is typically close to 1, thereby indicating pronounced inequality in the incidence of poverty gaps.

The Watts Index

Is the first distribution-sensitive poverty measure and was proposed in 1968 by Watts (Zheng, 1993). Its discrete version, takes the form W

$$= \frac{1}{N} \sum_{i=1}^q [\ln(z) - \ln(Y_i)] = \frac{1}{N} \sum_{i=1}^q \ln \left[\frac{z}{Y_i} \right],$$

where the N individuals in the population are indexed in ascending order of income or expenditure and the sum is taken over the q individuals whose income or expenditure (Y_i) falls below the poverty line z .

Other Measures

To sum up, there exist other additive poverty measures that are distribution-sensitive and based on Atkinson (1987), one can characterize a general class of additive measures, encompassing the Watts index, the FGT class of measures, and some other measure as

$$P = \frac{1}{N} \sum_{i=1}^N p(z, Y_i). \quad p(z, Y_i) \text{ is the individual poverty measure, and takes the}$$

value zero for the non-poor ($Y_i > z$) and some positive number for the poor, the value of which is a function of both the poverty line and the individual living standard, non-decreasing in the former and non-increasing in the latter.

3.4 Approaches to measuring energy poverty

Ultimately, there are varying levels of energy poverty, depending on the precise approach applied to its definition and particularly its measurement (Roinn *et al*, 2010). It is,

however, a challenge to operationalize the definition of energy poverty and generally, two main approaches to measuring energy poverty have been identified: Expenditure-based approach and the Engineering type estimates.

3.4.1 Expenditure Approach

This includes the actual energy expenditure-based approach in which a household is in energy poverty if it spends more than a fixed proportion of its income on energy. The expenditure approach also involves the required energy expenditure – reflecting energy ‘needs’ approach. It considers a household to be in energy poverty if, in order to maintain an acceptable level of energy services in the home, it must spend more than a fixed proportion of its income on energy.

It is also possible to derive an energy poverty line from a conventional income or expenditure poverty measure and this can be done by determining energy use as a function of income or expenditure, and calculating the average level of energy use corresponding to an amount of income or expenditure specified by the official income or expenditure poverty line. An example of this is in Foster *et al* (2000) who calculated a fuel poverty line using household survey data from Guatemala. In this study, the researchers computed the average energy consumption of households whose overall per capita consumption expenditure level fell within a plus or minus 10 percent range of the official expenditure poverty line and this average energy consumption value was then assigned as the fuel poverty line.

Additionally⁴, there have been attempts to measure energy poverty by looking at energy use at the aggregate national level in relation to other broader measures of poverty such as the human development index (HDI) or physical quality of life index (PQLI). A good number of studies on energy poverty have used this approach to measuring energy poverty, key among them being a recent study in Malawi by Tchereni *et al* (2013) who, using the logit model of energy poverty, revealed that household expenditure on transport, income level, age and education level of head of household, household size and home size, are important factors in explaining the state of energy poverty in South Lunzu Township in Malawi.

3.4.2 Engineering type estimates Approach

This approach uses engineering type estimates to determine the direct energy required to satisfy basic needs. This approach has been used by researchers like Goldemberg *et al* (1987) who aimed at estimating basic energy needs on the basis of engineering type calculations. Their results estimated that the requirement of direct primary energy⁵ per time unit to satisfy basic needs is about 500 watt per person. In addition, Pachauri &

⁴ see Krugman & Goldemberg (1983)

⁵ Primary energy is the energy contained in energy carriers sold by firms or division of firms of the energy extraction sector. This includes coal sold by coal mining firms, crude oil sold by oil extracting companies or, trunks of wood sold by logging firms. It may also include wood and other biomass collected by households directly from the environment, before being transported, stored and dried.

Spreng (2003), in an attempt to look at how access and use of energy are related to poverty, used this approach to measure energy poverty.

More practically, the approach has been employed by the Indian Advisory Board on Energy in its 1984 report on energy demand modeling (ABE 1984). The board uses engineering approach for estimating the basic energy needs for cooking, lighting and heating among households and assumes that a total of some 33 watt of useful energy per capita is required at the household level to meet the three basic direct energy services of cooking, lighting and space heating.

3.5 Measuring Energy Poverty

To measure energy poverty, the International Energy Agency's indicator, the Energy Development Index (EDI), is used. The EDI is calculated in such a way as to mirror the UNDP's Human Development Index and it is adopted by the study because of its relatively broad coverage and its seeking to measure several elements of modern energy development individually and then as a composite index.

3.5.1 Calculating the EDI

Following IEA's assessment of the strengths and weaknesses of different possible indicators to be used in measuring EDI, availability of regular, reliable and robust data, this study uses the following outlined indicators, each capturing a specific aspect of potential energy poverty:

Per capita commercial energy consumption which serves as an indicator of the overall economic development of a country, Per capita electricity consumption in the residential sector which serves as an indicator of the reliability of and consumer's ability to pay for electricity services, Share of modern fuels in total residential sector energy use which serves as an indicator of the level of access to clean cooking facilities and, Share of population with access to electricity which is based on the electricity access rate, and is the percentage of population that has access to electricity.

A separate index for each indicator was then created using the actual maximum and minimum values for the years covered and performance in each indicator expressed as a value between 0 and 1, calculated using the formula:

Indicator = $\frac{ActualValue - MinimumValue}{MaximumValue - MinimumValue}$. The EDI was then calculated as the arithmetic mean of the four values for each year.

3.6 Energy Poverty Metrics

Quantitative assessment of energy poverty has yielded several metrics that have been used by various literature, among them being Foster *et al* (2000) who used three individual measures to quantify it, based on a pre-defined fuel poverty line, Mirza & Szirmai (2010) who developed a new composite index to measure the degree of energy poverty among rural households in rural Pakistan and the International Energy Agency (IEA) which has come up with the Energy Development Index (EDI) as a composite measure of energy use in developing countries (IEA 2010).

In its report ‘Poor people’s energy outlook 2010’, Practical Action (2010) suggests an energy access index based on six essential energy services for which a minimum level of service is prescribed. In parallel, it introduces a hybrid set of indicators that assign a numerical value to qualitative aspects of energy access in three main supply dimensions namely electricity, household fuels and mechanical power.

Nussbaumer *et al* (2011) developed a new metric to measure and report energy poverty, the multi-dimensional energy poverty index (MEPI). This index reflects the multidimensional nature of energy poverty in the choice and structure of its variables which are carefully selected on the basis of their relevance to the issue at hand and measurability. They define the different dimensions of the new energy metric around commonly demanded household energy services to capture various elements as cooking, electricity access and mechanical power.

The MEPI measures energy poverty in d variables across a population of n individuals. $Y = [y_{ij}]$ represents the $n \times d$ matrix of achievements for i persons across j variables. $Y_{ij} > 0$ therefore denotes the individual i achievement in the variable j . Thus, each row vector $y_i = (y_{i1}, y_{i2}, \dots, y_{id})$ represents the individual i achievements in the different variables, and each column vector $y_j = (y_{1j}, y_{2j}, \dots, y_{nj})$ gives the distribution of achievements in the variable j across individuals. A weighting vector w is then composed of the elements w_j corresponding to the weight that is applied to the variable j . They then define $\sum_{j=1}^d w_j =$

1.

For the sensitivity analysis, and by means of capturing some of the uncertainty associated with assigning of the elements w_j corresponding to the weight that is applied to the variable j , weights are defined and probabilistic functions applied to the respective weights. They define z as the deprivation cut-off in variable j and then identify all individuals deprived in any variables. With $g = [g_{ij}]$ being the deprivation matrix whose typical element g_{ij} is defined by $g_{ij} = w_j$ when $y_{ij} < z_j$ and $g_{ij} = 0$ when $y_{ij} \geq z_j$, and in this case the element of the achievement matrix being strictly non-numeric in nature, the cut-off is then defined as a set of conditions to be met. The entry ij of the matrix is equivalent to the variable weight w_j when a person i is deprived in variable j and zero when the person is not deprived.

Following this, a column vector c of deprivation counts is then constructed, where the i^{th} entry $c_i = \sum_{j=1}^d g_{ij} = 1$ represents the sum of weighted deprivations suffered by person i .

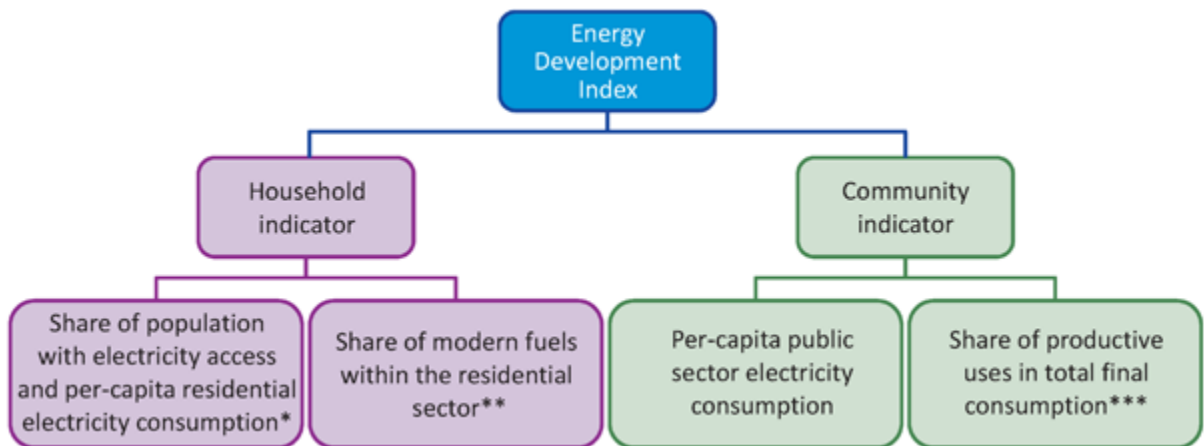
The persons who are multi-dimensionally energy poor are then identified by defining a cut-off $k > 0$ and applying it across the column vector and a person is considered as energy poor if her weighted deprivation count c_i exceed k . Therefore, $c_i(k)$ is set to zero when $c_i \leq k$ and equals c_i when $c_i > k$. Thus, $c(k)$ represents the censored vector of deprivation counts, and it is different to c in that it counts zero deprivation for those not identified as multi-dimensionally energy poor.

Finally, a headcount ratio H , is computed which represents the proportion of people that are considered energy poor. With q as the number of energy poor people (where $c_i > k$) and n the total, there results $H = q/n$, which represents the incidence of multidimensional

energy poverty. The average of the censored weighted deprivation counts $c_i(k)$ represents the intensity of multi-dimensional energy poverty A . A is then formally calculated as $A = \sum_{i=1}^n c_i(k)/q$ and the MEPI captures information on both the incidence and the intensity of energy poverty, and is defined as $MEPI = H * A$.

The International Energy Agency (IEA, 2010) also developed an enhanced Energy Development Index (EDI) that is a multi-dimensional indicator that tracks energy development, distinguishing between developments at the household level and at the community level (Figure 3.1). In the former, it focuses on two key dimensions: access to electricity and access to clean cooking facilities. At the community level, it considers modern energy use for public services and energy for productive use.

Figure 3.1: Components of the Energy Development Index⁶



Source: International Energy Agency, World Energy Outlook 2012

⁶ * The geometric mean of the two variables is taken, ** Electricity is excluded to avoid double counting

*** Includes services, industry, transport, agriculture and other non-specified energy use.

The major indicators for the enhanced EDI include: Access to electricity indicator – This is based on the electricity access rate, which is the percentage of population that has access to electricity, and the per capita residential electricity consumption. The overall access to electricity indicator is then calculated by taking the geometric mean of two variables. Secondly, there is the Access to clean cooking facilities indicator – For this indicator, the IEA uses the share of modern energy use in the total final consumption by the residential sector.

There is also the Access to energy for public services indicator which is represented by per-capita public services electricity consumption. Public sector's share in the services sector is first estimated, and then multiplied by the services sector electricity consumption. To calculate the per-capita public services electricity consumption, the share of the public sector in the services sector is also estimated, by taking the governmental final consumption (percentage of GDP) as a fraction of the share of total services value added in GDP.

The final indicator is the Access to energy for productive use which is given by the share of economic purposes in the total final consumption (TFC). TFC includes the industry, transport, services, agriculture/forestry and fishery sectors, and excludes own use by the energy sector and residential energy use.

To calculate the EDI, the IEA then takes an average across the two household-level indicators and a separate average across the two community-level indicators. The results of these two scores are then averaged to reach a final EDI score. This process means that

equal weighting is applied to each indicator in an effort to leave the methodology neutral to any judgment of whether individual indicators are more or less important than others.

A measure that incorporates energy inconvenience was developed by Mirza & Szirmai (2010). They identified seven energy inconvenience indicators: Buying (collection) frequency, Household Distance covered, Means of transport used, Household involvement, Time spent on energy collection per week, Household health and Children involvement in energy collection.

This measure involves Computing the Inconvenience Index for each Indicator. Inconvenience scores are allocated to each response based on the degree of inconvenience experienced for each indicator and the general formula for the Index is

given as:
$$X_{cij} = \frac{Xi - Xi(\min)}{Xi(\max) - Xi(\min)}$$

Where: X_{cij} = the index for indicator,

$X_{i(\min)}$ = minimum value from sample,

$X_{i(\max)}$ = maximum value from sample

C = capita,

i = the type of inconvenience indicator,

j = the type of energy source,

A buying (Collection) Frequency Index (BFI) which refers to the number of times households buy or collect a given energy source in one week is then computed using the

formula:
$$BFI_j = \frac{BFj - BFj(\min)}{BFj(\max) - BFj(\min)}$$
. The energy inconvenience index at the energy

source level is then computed as $EII_{cj} = \frac{\sum_{i=1}^n Xcij}{N_i}$, where EII_{cj} is the Energy Inconvenience Index (per capita) for a given energy source j in a given household, $\sum_{i=1}^n Xcij$ is the sum of inconvenience index for each inconvenience indicator i for a given energy source j and N_i is the number of inconvenience indicators relevant for a given energy source (i.e. $N_i = 6$ for kerosene and $N_i = 5$ for LPG)

They then compute the energy inconvenience at energy mix level for each household and the inconvenience is controlled for the kilowatt hours produced by a single energy source.

$$TEI_c = \sum_{j=1}^6 \frac{KWh_j}{\sum KWh_j} \times (EII_{cj}), \text{ where } \frac{KWh_j}{\sum KWh_j} \text{ gives the share of energy in kWh and the}$$

sum of energy inconvenience for a given energy mix gives TEI_c (per capita). An energy inconvenience threshold level, which is the cut-off point required for measuring the energy poverty is then defined. Mirza & Szirmai (2010) chose a 30 percent above the sample mean TEI_h (value = 0.249) as the defined threshold level.

Using the value of the TEI , the total energy inconvenience threshold, $TEIT_h$ is calculated as; $TEIT_h = 0.249 \times 1.3 = 0.323$, below which rural households are considered to be at acceptable levels of energy inconvenience. Above the threshold level, the inconvenience is an aspect of energy poverty. Next, they defined the energy inconvenience excess (EIE) at household level and converted the index score differences into percentages; EIE_c

$$= \left[\frac{(TEIT_c - TEI_c)}{TEIT_c} \right] \times 100, \text{ where } EIE_c \text{ refers to the Inconvenience Excess per}$$

capita. *EIE* is expressed in percentages. A negative sign shows that the rural households are in the state of excess of inconveniences whereas a positive sign indicates that households are in the state of convenience.

The Pokharel (2006) threshold level of 1TOE/capita/annum is then used to calculate the energy shortfall (ES) for households using household energy consumption levels. TOE is converted in kwh/week to standardize it with survey data used and all energy sources are converted into kwh using standard energy content (in kwh) for each energy source. $ES_c = \left[\frac{(AEC_c - TER_c)}{TER_c} \right] \times 100$, where AEC_c is the actual energy consumption per capita and TER_c is the threshold energy requirements (in kilowatts) per capita⁷.

Finally, the energy poverty level (EPL) per capita is computed and equal weighting is given to both composite indicators and EPL per capita is computed as; $EPI_c = \frac{1}{2} \times (EIE_c + ES_c)$. The energy poverty index is represented in percentages and positive values indicate non-energy poor individuals, whereas negative values indicate the energy poor.

Tchereni *et al* (2013) used the expenditure approach to measure energy poverty and they did this by adding together all the money-metric costs incurred to fetch energy facilities. These include: Transport cost to and from the place of fetching the energy facility and

⁷ To control for the negative and positive signs and their subsequent interpretation, TER_h is subtracted from AEC_h instead of subtracting the AEC_h from the TER_h . In this way, energy shortfalls per capita are represented by negative values whereas energy excess per capita is represented by positive values.

actual purchase cost of the facility. The formula for this calculation is given by: $EEX_{ij} = ETPT_{ij} + APC_{ij}$, where EEX_{ij} is the total expenditure on energy facility i by household j ; $ETPT_{ij}$ is transport expenses incurred towards the acquisition of energy facility i by household j ; and APC_{ij} is the actual purchase cost of energy facility i by household j .

CHAPTER FOUR

DATA AND METHODOLOGY

4.1 Data Types and Sources

This study uses time series secondary data for the period 1970-2011. The data used was obtained from a variety of sources, among them being the Ministry of Energy, The Energy Regulatory Commission, official country statistical publications including Statistical Abstracts and Economic Surveys. Additional Information will be obtained from The World Bank Data Base, The UN energy database, The International Energy Agency data base and publications such as the World Energy Outlook and the Central Intelligence Agency.

From these data sources, information was obtained to calculate the country's level of energy poverty using the Energy Development Index, and also data to relate the energy poverty to LPG consumption in the country. Such data included data on: Electricity access rate⁸, Per capita commercial energy consumption, Per capita residential electricity consumption, Share of modern fuels in total residential sector energy use, the country's population, population growth rate and percentage of the total population in urban and rural areas, total LPG consumption in the country, electricity tariffs, GDP per capita, gross domestic savings and LPG prices.

⁸ This is proxied by the percentage of population living in rural areas since a majority of the rural population does not have access to electricity and poverty levels are highest in the rural areas.

4.2 The Empirical Model

Let EDI denote the Energy Development Index, which is the study's chosen measure of energy poverty, and consider the following function:

$$EDI=f(PCCEC,PCECRS,SMF,SPAE)..... (i)$$

Where PCCEC is the per capita commercial energy consumption, PCECRS is per capita electricity consumption in the residential sector, SMF is the share of modern fuels in total residential sector energy use and SPAE is the share of population with access to electricity. The development of the EDI is based on the headcount index measure of poverty.

With the EDI having been calculated for each year within the period 1970 – 2011, and based on the previously defined indicators, let *LPGCON* denote the consumption of LPG in the country. This study's theoretical framework does not suggest any particular functional form and thus it uses OLS for all estimations with time series data for 42 years (period 1970 – 2011) for Kenya, in order to examine the extent to which these variables are able to explain the EDI and relate it to LPG consumption for the study period.

Borrowing heavily from structural models in Kimuyu (1988), and the findings of various researchers (from the reviewed literature) on the variables influencing energy poverty, the general equation that was estimated is represented as;

$$EDI=f(LPGCON,LPGPRICE,ELECPRICE,PCGDP,GDS)..... (ii)$$

Where EDI is the energy development index, *LPGCON* is the consumption of LPG, *LPGPRICE* is the real domestic price of LPG per kg, *ELECPRICE* is the price of

electricity (tariffs), PCGDP is the real per capita gross domestic product and GDS is the country's gross domestic savings.

From the general model above, an econometric model is then formulated;

$$\ln EDI_t = \beta_0 + \beta_1 \ln LPGCON_t + \beta_2 \ln LPGPRICE_t + \beta_3 \ln ELECPRICE_t + \beta_4 \ln PCGDP_t + \beta_5 \ln GDS_t + \varepsilon_t \dots \dots \dots \text{(iii)}$$

From equation (iii) above, the variables have been linearized and *ln* refers to natural logarithms; ε is the error term and represents all potential explanatory variables that are not captured in the equation. β_0 is the intercept while β_1 , β_2 , β_3 , β_4 and β_5 are the coefficients of the chosen explanatory variables.

Definition and Measurement of Variables

These are presented in table 4.1 below;

Table 4.1: Definition and Measurement of Variables

Variable	Measurement
Energy Development Index (EDI)	This is the dependent variable. It is a measure of energy poverty level in the country and is measured as defined in section 3.4 of this study.
LPG consumption (LPGCON)	Is measured by the total national LPG consumption in tons.
LPG price (LPGPRICE)	This is the retail price of LPG and is measured in kshs. per kilogram.
Electricity Price (ELECPRICE)	This is the cost of electric energy for households and is measured by the average electricity tariffs in the country.
Per capita Gross Domestic Product (PCGDP)	This measures the purchasing power of the population and is a variable used to measure economic growth and development of a country.
Gross domestic savings (GDS)	This is a measure of the country's savings levels and it is measured as a gross savings as a percentage of GDP.

Technique of Analysis

The data collected was applied to the linear function stated in equation (i) to calculate the EDI and then applied to the log-log model summarized in equation (iii) of section 4.2.1

using regression analysis technique of the Ordinary Least Squares (OLS) method of estimation. This was done with the help of STATA regression software package.

The method of OLS was chosen primarily because it is intuitively more appealing and mathematically much simpler than other estimation techniques (Gujarati (2004)). In addition, it also has some very attractive statistical properties that have made it one of the most powerful and popular methods of regression analysis. However, this is not to say that the method of OLS is devoid of limitations.

The key idea behind the OLS estimation method is to choose values of the coefficients of a functional relationship that minimize the sum of squared errors and this is achieved by assuming that: the explanatory variables are non-stochastic and error free, there is no exact linear relationship between any of the explanatory variables, the error terms are normally distributed with a zero mean and constant variance and the number of observations on the explanatory variables are greater than the number of parameters to be estimated.

Estimation Procedure

Of the steps involved in time series modeling, the first to be performed were the unit root tests and the DF and ADF tests were used. This tested for stationarity (or non-stationarity) of the data. Testing for stationarity was important as the equation requires the use of stationary data in order to derive meaningful results. The Dickey and Fuller (1981) approach was applied by use of the following model:

$$\Delta Y_t = a_0 + a_2 t + \delta Y_{t-1} + \alpha_i \sum_{i=1}^p \Delta Y_{t-i} + U_t \dots \dots \dots (iv)$$

The idea of using many lagged difference terms is to minimize the autocorrelation in the error term. In each case, the null hypothesis was the existence of a unit root while the alternative hypothesis was reversion to stationarity. The test statistic on the parameter δ was then computed and compared to the critical values of τ (tau statistic) in Dickey and Fuller (1981). The null hypothesis was not rejected and the existence of a unit root made it impossible to make any meaningful interpretation of the results of the regression model because it led to spurious regressions.

The next step was to establish co-integration among non-stationary time series variables. The time series were found to have a unit root (non-stationary) and were co-integrated with the same order of co-integration, thus an error correction model was used to estimate the regression model. To test for co-integration, the Engle-Granger co-integration test (Engle & Granger, 1987) was applied and this test was used to test for the long run relationship among variables. Economically speaking, two variables are co-integrated if they have a long-term or equilibrium relationship between them.

The Engle and Granger test is a two-step procedure in which the first step involves estimating the regression equation by ordinary least squares procedure and the residuals from the regression again tested for stationarity. The procedure involved testing whether the regression residuals of the following long-run regressions were stationary:

$$\ln(EDI) = a_0 + a_1 \ln(LPGCON) + u_1 \dots \dots \dots (v)$$

$$\ln(LPGCON)=b_0+b_1\ln(EDI)+u_2.....(vi)$$

Where u_1 and u_2 are error terms assumed to be uncorrelated, with zero mean and constant variance.

The null hypothesis of no co-integration was tested against the alternative hypothesis of co-integration. The null hypothesis of no co-integration was rejected and an error correction model (ECM) was then estimated. According to Granger representation theorem, if two or more variables are found to be co-integrated, then there exists an error correction model between them.

The error correction model captures the short run dynamics of the model with the error correction term containing information about the long run relationship between the variables. The implication is that if the error correction term is significant, then co-integration exists between the variables. The error correction model is constructed by replacing the coefficient with the estimated coefficient from the equation in the first step and can be shown as;

$$\Delta \ln EDI_t = \alpha_0 + \gamma_0 \Delta \ln LPGCON_t + \delta (\ln EDI_{t-1} - \beta \ln LPGCON_{t-1}) + \mu_t.....(vii)$$

Diagnostic Tests

The following diagnostic tests were carried out;

Analysis of Variance Test – Also known as the F test and was used to test the overall significance. The null hypothesis is given as $H_0: \beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = 0$, and is a joint hypothesis that $\beta_1, \beta_2, \beta_3, \beta_4$ and β_5 are jointly or simultaneously equal to zero.

Jarque-Bera (JB) Test for normality – Is based on the OLS residuals and under the null hypothesis that the residuals are normally distributed. If the computed p value of the JB statistic in an application is sufficiently low, which will happen if the value of the statistic is very different from 0, one can reject the hypothesis that the residuals are normally distributed. But if the p value is reasonably high, which will happen if the value of the statistic is close to zero, we do not reject the normality assumption (Jarque & Bera, 1987).

Breusch–Pagan Heteroskedasticity Test - This was used to test for heteroskedasticity.

The Breusch–Godfrey (BG) Test – Was used to test for autocorrelation and it allows for non-stochastic regressors, such as the lagged values of the regressand, higher order autoregressive schemes such as AR(1), AR(2), etc.; and simple or higher-order moving averages of white noise error terms, Godfrey (1978), Breusch (1978).

Ramsey’s RESET Test – This test was used to test for model specification error (Ramsey, 1969).

Akaike Information Criterion (AIC) – This was used to test how the chosen model fits the data in the given sample. One advantage of AIC is that it is useful for not only in-sample but also out-of-sample forecasting performance of a regression model.

Expected signs of Estimated Parameters

The estimation of the econometric model given in equation (iii) was expected to give the below relationships.⁹

Table 4.2: Expected relationship of the dependent variable with the explanatory variables

Variable	Expected Relationship with the dependent variable
LPG consumption(LPGCON)	Positive - LPG being a modern fuel, an increase in its consumption reduces energy poverty and thus the EDI increases.
LPG price (LPGPRICE)	Negative - From the laws of demand, a high LPG price would dampen its demand and subsequent consumption. Being a modern energy source, people will divert to the use of cheaper sources of energy, mostly traditional fuels, and the EDI will fall.
Electricity Price (ELECPRICE)	Negative - High tariffs limit the number of people able to afford electric energy, leading to use of other (usually traditional) energy services. This will increase the levels of energy poverty and as such, the EDI will reduce.
Per capita Gross Domestic Product (PCGDP)	Positive - A high per capita GDP reflects a high level of economic growth and development, which translates to more use of modern energy services, hence the EDI increases.
Gross domestic savings (GDS)	Positive – Increased savings increases investment in modern energy infrastructure and this leads to an increase in the EDI.

⁹ Table 4.2, based on discussions and findings in the reviewed literature

Possible Statistical Problems

Currently, an integrated set of information which combines data on energy use with data on the socio-economic characteristics of households does not exist. This leads to data refinement and without access to up-to-date integrated datasets; it is difficult to accurately measure energy poverty. This means that the estimates of energy poverty may underestimate the extent of the challenge. Also, the application of time series data on the econometric model defined may pre-dispose the estimations to autocorrelation due, primarily, to the time factor.

CHAPTER FIVE

EMPIRICAL RESULTS

5.1 Introduction

In this section, the results from the empirical estimation and their economic interpretations are presented. The section begins by presenting the descriptive statistics of all the variables in the estimable model and then goes further to establish the time series properties of the variables. Finally, the model is estimated in light with the Error correction methodology and post estimation tests conducted on the model.

5.2 Descriptive Statistics

Descriptive analysis was conducted to ascertain the statistical properties of the data, and this is important in giving the estimable model an appropriate functional and mathematical form. The below table gives the mean, standard deviation, skewness, kurtosis, Jarque-Bera statistics and the probabilities of all the variables in the model;

Table 5.1: Descriptive Statistics

Variables	Mean	Median	Standard Deviation	Kurtosis	Skewness	JB Statistic	Probability
lnedi	-1.338037	0.2809413	0.3871391	2.350122	-0.2785066	1.50	0.4715
Lnlpgcon	10.21379	10.1905	0.6023619	2.786734	0.2176851	0.44	0.8035
lnlpgprice	2.631851	2.672878	1.331957	1.547992	0.0062718	18.20	0.0001
lnelecprice	1.899192	1.846267	0.5036127	2.422093	0.291312	1.26	0.5320
Lnpcgdp	10.38008	10.37708	0.0831083	9.745974	-1.95253	24.51	0.0000
Lnngds	2.604725	2.817416	0.4796089	2.222783	-0.630706	4.71	0.0949

Source: Own analysis using STATA

From table 5.1, it is evident that the natural logarithms of all the variables are not dispersed significantly from their mean values as indicated by their relatively small standard deviation values.

The Jarque-Bera test, a statistical test that determines whether the series is normally distributed by measuring the difference of the skewness and the kurtosis of the series with those from the normal distribution, was used to test for normality. Unambiguously, the Jarque-Bera statistic rejects the null hypothesis of normal distribution for LPG prices and per capita GDP. The null hypothesis of normal distribution is however accepted for the EDI, LPG consumption and electricity price at the 1%, 5% and 10% levels of significance and for gross domestic savings at the 1% and 5% levels of significance.

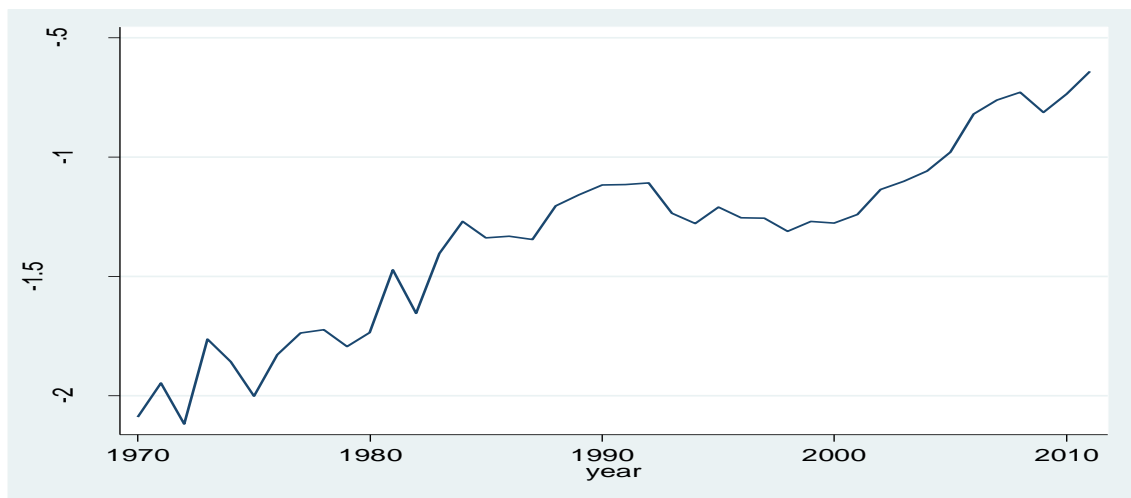
Kurtosis measures the peakedness or flatness of the distribution of the series and the kurtosis statistic shows that EDI, LPG consumption, LPG price, gross domestic savings and electricity price are platykurtic. This means that their distributions are flatter than a normal distribution, with a wider peak and the probability for extreme values is less than for a normal distribution with the values having a wider spread around the mean. Per capita GDP is leptokurtic since its distributions are peaked sharper than a normal distribution, with values concentrated around the mean and thicker tails; this means high probability for extreme values.

As a measure of asymmetry of the distribution of the series around its mean, the statistic for skewness shows that LPG consumption, LPG price and electricity price are positively skewed, implying that their distributions have long right tails. The EDI, Per capita GDP and gross domestic savings are negatively skewed, meaning that the distributions have long left tails.

The EDI shows that the energy poverty levels have been consistently declining since 1970, with the lowest energy poverty levels being recorded in 2011. The energy poverty levels in the country, as measured by the Energy Development Index (EDI), average at 0.28, with a minimum value of 0.12 and a maximum value of 0.52. This implies that the country's consumption of modern energy services is still very low, on average, and is consistent with country statistics which indicate that approximately 77% of the population use traditional fuels.

A trend analysis was conducted to detect the movements in the value of the variables over time and to analyze the causes of such movements. Figure 5.1 shows the movements in real EDI over time, figure 5.2 shows the movements in LPG consumption over time, figure 5.3 shows the movements in LPG prices over time and figure 5.4 shows the movements in electricity prices (tariffs) over time¹⁰.

Figure 5. 1: Trends in EDI

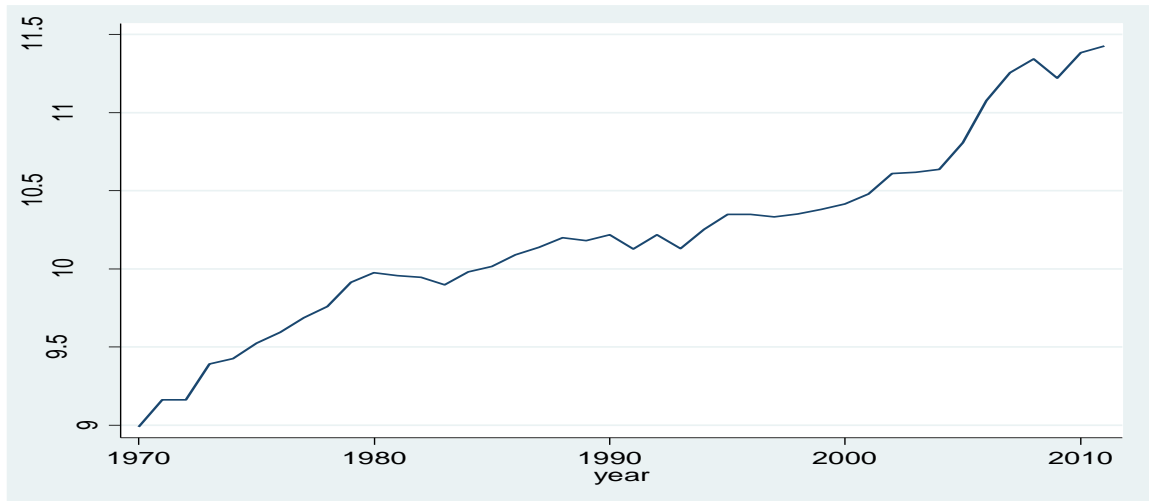


Source: Own graphing from data using STATA

Figure 5.1 shows that the value of the EDI has been increasing over time, declining sharply in mid 1980s, slightly in the mid-1990s and rising steadily since mid-2000 to 2011.

¹⁰ The graphs showing the trends over time for the other variables in the model are attached in the appendix.

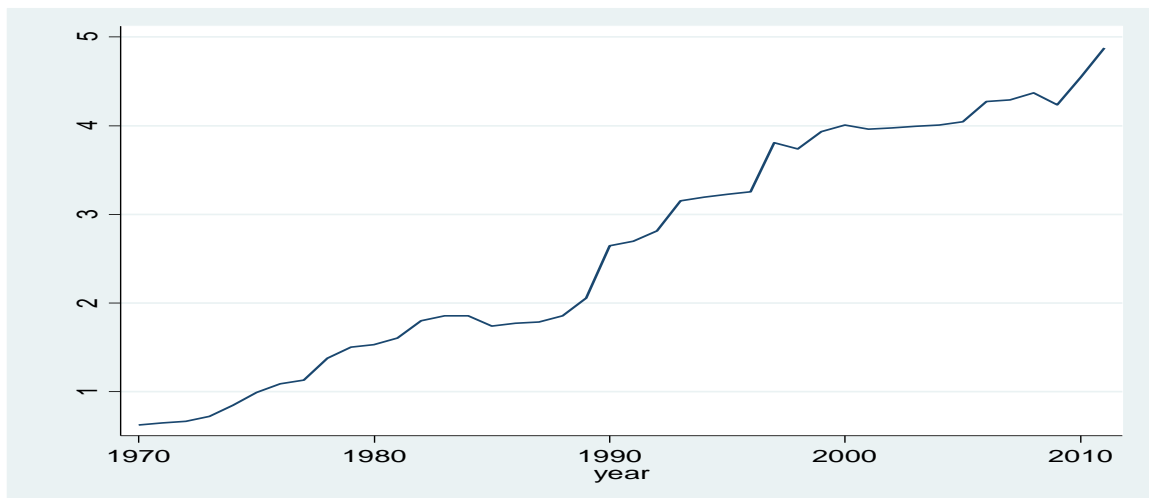
Figure 5.2: Trends in LPG consumption



Source: Own graphing from data using STATA

The above figure also depicts similar trends in LPG consumption, showing a steady rise from 1970 to 2011, with slight disruptions in the early 1990s and late 2000s.

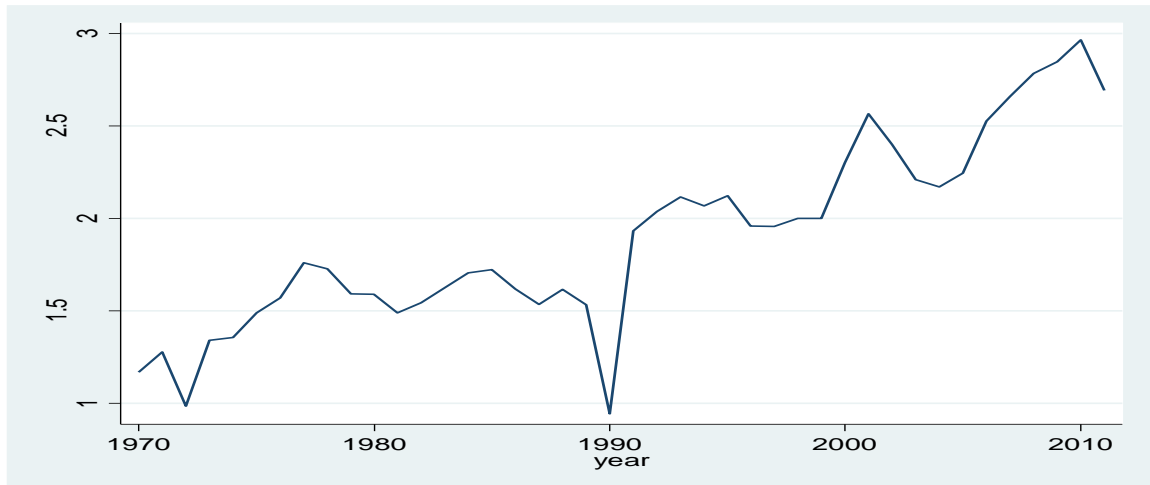
Figure 5.3: Trends in LPG prices



Source: Own graphing from data using STATA

LPG prices have had a general upward trend from 1970 – 2011 with the sharpest rise in 2010 and this is clearly depicted in figure 5.3 above.

Figure 5.4: Trends in electricity prices



Source: Own graphing from data using STATA

Figure 5.4 above shows that trends in electricity prices as measured by the tariffs have been a mixture of high and low movements for the entire study period.

5.3 Test properties of the data

Unit Root Test

A basic assumption of the Classical Linear Regression model is that variables should have a constant mean, variance and the covariance between the values of two time periods should be zero. Violation of this assumption leads to spurious regression. To avoid this short fall, the unit root test was conducted on the variables to ascertain whether they are stationarity or non-stationary.

Several tests can be used to test for unit roots, but the widely acceptable and more reliable Dickey-Fuller (DF) and the Augmented Dickey-Fuller (ADF) tests were employed by the study. If a variable is stationary at level, i.e. without running any differencing, then it is said to be integrated of order zero or $I(0)$ and if it becomes stationary after differencing, then the variable is said to be an $I(d)$ variable, where d represents the number of times it has been differenced.

The Augmented Dickey-Fuller test was conducted with trend and without trend as guided by the graphical analysis. The lag length selection of the ADF test was based on the Akaike Information Criterion (AIC) and the Schwartz-Bayesian Information Criterion (SBIC). Whenever there was conflict between the two information criteria, the SBIC was preferred because it penalizes more. The ADF test results are as shown in the table below.

Table 5.2: ADF Unit Root Test Results¹¹

Variables	Levels		Order of Differencing	Differences		Lags
	Trend	No Trend		Trend	No Trend	
lnedi	-1.873	-0.632	2	-3.566**	-3.629*	4
lnlpgcon	-1.384	-0.061	2	-5.493*	-5.554*	1
lnlpgprice	-2.290	-0.062	2	-3.654**	-3.780*	3
lnelecprice	-3.126	-0.964	2	-5.826*	-5.917*	2
lnpcgdp	-1.776	-1.225	2	-5.799*	-5.551*	4
lngds	-2.978	-0.709	2	-5.348*	-5.402*	3

Source: Own tests using STATA

The above results clearly demonstrate the null hypothesis of each of the time series variables has a unit root that cannot be rejected for the levels since their ADF values are less than critical values at the 1%, 5% and 10% level of significance. It is therefore concluded that EDI, LPG consumption, LPG prices, electricity prices, per capita GDP and gross domestic savings are non-stationary at their levels.

However, the results indicate that the null hypothesis is rejected for the second differences, indicating that the independent variables and EDI are stationary in their second differences. This shows that all the variables under investigation are individually integrated of order two I(2).

¹¹ *, ** and *** imply rejection of the null hypothesis at 1%, 5% and 10% levels of significance respectively

Co-integration

To test for co-integration, the Engle and Granger (1987) procedure, which is based on testing for a unit root in the residuals of the estimated long-run relationship by employing the Dickey-Fuller test, was used. If the residuals are stationary, then it means that the variables are co-integrated.

Table 5.3: Co-integration Test Results

Variable	Trends	Test Statistics	1% Critical Value	5% Critical Value	10% Critical Value
Residuals	Trend	-3.373	-4.242	-3.540	-3.204
Residuals	No Trend	-3.384	-3.648	-2.958	-2.612

Source: Own tests using STATA

The results presented in Table 5.3 above show that the ordinary least square residuals have no unit root at 1% and 5% levels of significance with trend¹² and at the 1% level of significance without trend¹³. The p-values however indicate the non-existence of unit roots at all levels of significance, with and without trend. This implies that the variables are co-integrated, an indication of a long-run relationship.

5.4 Long Run Model

From the co-integrating regression, the results of the long run relationship can be presented as;

$$\ln \text{edi} = -7.9387 + 0.6827 \ln \text{pgcon} + 0.1017 \ln \text{pgprice} + 0.1687 \ln \text{elecprice} + 0.8749 \ln \text{pcgdp} + 0.2344 \ln \text{ngds}$$

(5.02)* (1.89) (1.67) (1.94)*** (2.38)**

¹² P-value of 0.0015

¹³ P-value 0.0051

It is evident that LPG consumption (lpgcon), Per capita GDP (pcgdp) and gross domestic savings (gds) variables are an important determinant of the EDI. The coefficient of lpgcon is both positively signed and statistically significant at the 1%, 5% and 10% levels of significance and those of per capita GDP and gross domestic savings are also positively signed and statistically significant at the 10% level of significance and the 5% and 10% level of significance, respectively.

This means that an increase in LPG consumption by 1% will lead to a long-run increase in the EDI by approximately 0.68%, an increase in per capita GDP by 1% will lead to a long-run increase in the EDI by approximately 0.87% and an increase in gross domestic savings by 1% leads to a long-run increase in the EDI by approximately 0.23% on average.

These results are consistent with those obtained by Kojima (2011), Tchereni *et al* (2013), Onyeji (2010), Onguru *et al* (2008) and Roinn and Fuinnimh (2010). Thus, as the consumption of LPG increases, energy poverty reduces, as per capita incomes increase, energy poverty reduces and as the total gross domestic savings increase, energy poverty also falls. The implication is that any policy that encourages LPG consumption, growth in per capita incomes and growth in gross domestic savings in the long run will have a strong impact on the EDI and thus help in significantly reducing energy poverty.

The prices of LPG and electricity have an unexpected positive sign and also failed to attain statistical significance in the energy poverty function. Thus, there is no empirical support for the view that the reduction in prices of modern energy sources like LPG and

electricity have contributed to the reduction of energy poverty in the country, at least in the long run. The implication is that price reductions of modern energy sources may not bring about an automatic improvement in the energy poverty situation in Kenya.

5.5 Autoregressive Distributed Lag Model (ARDL)

The study estimated the relationship between LPG consumption and energy poverty in the context of the Autoregressive Distributed Lag Model. Before estimating the model, the optimal lag length of each variable in the model was determined in order to ensure that the model was well specified. The Akaike Information Criterion (AIC) and the Schwartz Bayesian Information Criterion (SBIC) were used to determine the optimal lag length and the long run estimates from the model are as shown in table 5.4.

Table 5.4: Autoregressive Distributed Lag Model Results

Variables	Coefficient	Standard Error	t-statistic	p-value
lnlpgcon	0.6262418	0.2190672	2.86	0.008
lnlpgprice	0.0474379	0.1130382	0.42	0.678
lnelecprice	-0.0634754	0.0884949	-0.72	0.479
lnpcgdp	-0.6930358	0.7835685	-0.88	0.384
lngds	0.1305279	0.07242	1.80	0.082
L1lnedi	0.4016828	0.1452912	2.76	0.010
L1lnlpgcon	0.0046295	0.27777	0.02	0.987
L1lnlpgprice	-0.008903	0.1245671	-0.07	0.944
L1lnelecprice	-0.1889742	0.089669	2.11	0.044
L2lnpcgdp	0.195935	0.3073013	0.64	0.529
L1lngds	0.0367686	0.0808624	0.45	0.653
Constant	-2.13422	7.159383	-0.30	0.768
Number of obs. = 40				
F(14, 21) = 52.78				
Prob. > F = 0.0000				
R-squared = 0.9540				
Adj. R-squared = 0.9359				
Root MSE = 0.09213				

Source: Own results from available data using STATA

Table 5.4 above shows that LPG consumption has a positive impact on the EDI and that its impact is statistically significant at the 1%, 5% and 10% levels of significance. Also, electricity price and per capita GDP all have a negative and insignificant impact on the EDI. However, gross domestic savings and LPG price have a positive impact on the EDI, with LPG price having an insignificant impact, while gross domestic savings has a statistically significant impact on the EDI at the 10% level of significance.

The first lag of LPG consumption has a positive sign but is statistically insignificant, while the first lags of LPG price and electricity price both have negative signs, with electricity price having a statistically significant impact on the EDI. The lags of Gross domestic savings and per capita GDP have positive and insignificant impacts on EDI.

The above results also indicate that an increase in LPG consumption by 1% will lead to an immediate increase in the EDI by approximately 0.63% and an increase of approximately 0.01% after the first period. Subsequently, an increase in gross domestic savings by 1% will lead to an immediate increase in the EDI by approximately 0.13% and 0.04% after the first period.

It is however interesting to note that a 1% increase in LPG price will immediately increase the EDI by approximately 0.05% and then reduce it by about 0.01% after the first period, and an increase in per capita GDP by 1% will have an immediate negative effect on the EDI by approximately 0.69% and then increase it by approximately 0.20% after the second period. However, increasing electricity price by 1% will immediately reduce the EDI by about 0.06% and later reduce it by approximately 0.19% after the first period.

The above model describes the dynamic effects of changes of the explanatory variables upon current and future values of the EDI. It postulates that the long run effects of unit changes in the explanatory variables on the EDI are as expected and consistent with previously conducted empirical studies.

5.6 Dynamic Error-Correction Model (ECM)

Estimating a model with non-stationary variables could lead to spurious regression and to solve for non-stationarity, the variables are first differenced and then the short-run relationship estimated. However, estimating a model with differenced variables leads to loss of long-run information and this is curbed by an error-correction model, used to bridge both the long-run and short-run relationships within the context of a single equation. This study's error correction model estimates are presented in table 5.5 below.

Table 5.5: Error-Correction Model Estimates

Variables	Coefficient	Standard Error	t-statistic	p-value
L1D2lnlpgcon	0.1852125	0.2266663	2.82	0.016
L3D2lnlpgprice	-0.0642857	0.1123326	-0.57	0.572
L2D2lnelecprice	-0.0917222	0.0694713	-1.32	0.197
L4D2lnpcgdp	0.7261252	0.8623821	1.84	0.096
L3D2lngds	0.0189807	0.0725322	0.26	0.495
LECM	-0.5723183	0.1762455	-3.25	0.003
Constant	-0.0001677	0.020118	0.12	0.793
Number of obs. = 35				
F(8, 30) = 3.65				
Prob. > F = 0.0084				
R-squared = 0.4390				
Adj. R-squared = 0.3188				
Root MSE = 0.11804				

Source: Own results from available data using STATA

Table 5.5 shows that LPG consumption, per capita GDP and gross domestic savings all have a positive impact on EDI, with LPG consumption and per capita GDP having

statistically significant impacts at the 5% and 10% levels of significance and the 10% level of significance, respectively. The impact of gross domestic savings is however insignificant at all levels of statistical significance, and LPG price and electricity price both have positive but statistically insignificant impact on the EDI.

The results also indicate that the coefficient of the error-correction term (denoted as LECM) for the estimated equation is both statistically significant and negative and thus, it will rightly act to correct any deviations from long-run equilibrium. Specifically, if actual equilibrium value is too high, the error correction term will reduce it, while if it is too low, the error correction term will raise it. The coefficient of -0.5723 denotes that 57% of any past deviation will be corrected in the current period. Thus, it will take a little under two years for any disequilibrium to be corrected.

Furthermore, it is only the LPG consumption and the per capita GDP variables that are statistically significant at the 5% and 10% levels of significance and the 10% level of significance, respectively, indicating that in the short run, it is only growth in income and LPG consumption that have a relationship with the energy poverty levels.

The implication is that short-run changes in energy poverty levels that correct for past deviations emanate principally from changes in LPG consumption and income growth. The coefficient estimate shows that a percentage change in LPG consumption will bring about a 0.19% change in EDI and a percentage increase in per capita GDP will increase the EDI by approximately 0.73%, thus lowering the energy poverty levels.

The other three explanatory variables (lpgprice, elecprice and gds) do not have any short-run impact on the EDI. This result is in keeping with the long-run relationship where over 91% of changes in energy poverty levels are explained by changes in LPG consumption and income growth.

In addition, the adjusted R^2 shows that approximately 32% of the variations in EDI are explained by the model after correcting for degrees of freedom and the F-statistic shows that the estimated parameters are jointly significantly not different from zero.

5.7 Post-Estimation Diagnostics

Ramsey RESET Test

This was carried out to ascertain if the estimated model was properly specified. The Ramsey RESET test, which is based on the null hypothesis of a properly formulated model, against the alternative hypothesis of mis-specification, was used and the results are as shown in the table below.

Table 5.6: Ramsey RESET Test Results

F-statistic	Probability Value
2.97	0.1820

Source: Own results from available data using STATA

Table 5.6 above indicates that the model has no omitted variables and it is well specified, as indicated by the p-values of the F-statistics, at the 1%, 5% and 10% levels of significance.

Shapiro-Wilk Test for Normality

This normality test of the residuals was also carried out in order to ascertain the predictive accuracy of the model and it was conducted on the null hypothesis of normality against the alternative hypothesis of non-normality. The results are presented in the below table.

Table 5.7: Residual Normality Test Results

Shapiro-Wilk W Test	Probability Value
0.95650	0.12702

Source: Own results from available data using STATA

The results in table 5.7 indicate that the residuals from the model are normally distributed at all levels of significance, and this is indicated by the probability values.

Breusch-Pagan/Cook-Weisberg Test for Heteroskedasticity

This was conducted based on the null hypothesis of homoscedasticity, against the alternative of heteroskedasticity and the results are shown below (Table 5.8).

Table 5.8: Breusch-Pagan/Cook-Weisberg Test for Heteroskedasticity Results

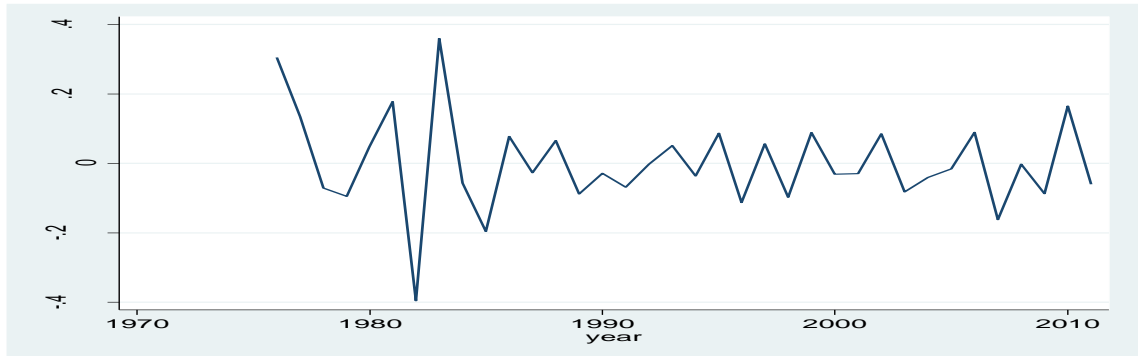
F-statistic	Probability Value
1.61	0.2043

Source: Own results from available data using STATA

The above table shows that the residuals of the model are homoskedastic at the 1% and 5% and 10% levels of significance, as indicated by the p-values. A graphical plot of the

residuals was also examined in order to detect the presence of outliers in the model and the results are shown in figure 5.5.

Figure 5.5: Graphical Plot of the Model Residuals



Source: Own graphing from available data using STATA

The above figure indicates the presence of outliers in the model with second differences and this can be verified by the diagram, showing that the residuals line plot exceed the upper and lower boundaries.

Breusch-Godfrey Test for Autocorrelation

A test for autocorrelation of residuals was conducted using the Breusch-Godfrey LM Serial correlation test and the null hypothesis of no serial correlation was tested against the alternative hypothesis of serial correlation. Table 5.9 below reports the results from the test.

Table 5.9: Breusch-Godfrey Test for Autocorrelation Results

F-statistic	Probability Value
3.353	0.0671

Source: Own results from available data using STATA

From the above table, it is clear that the residuals of the model have no serial correlation, as indicated by the p-values, at the 1% and 5% levels of significance.

Test for Multi-collinearity

This was conducted to ensure that there was no correlation between the variables. The results are as shown in Table 5.10;

Table 5.10: Test for Multi-collinearity Results

Variable	VIF	1/VIF
Lnelecprice	1.46	0.683593
Lnpcgdp	1.46	0.684127
Lnlpprice	1.46	0.686256
Lngds	1.45	0.690315
lnlpcon	1.43	0.697772
Mean VIF = 1.45		

Source: Own results from available data using STATA

Using the variance inflation factor, VIF, and a threshold of 10, the results show that the variables are not collinear and this can also be seen in the tolerance levels, all of which are greater than 0.1.

5.8 Discussion of the Results

The autoregressive distributed lag – error correction model estimates show that LPG consumption, per capita GDP and gross domestic savings all have a positive impact on the EDI. These results are in line with economic theory and they postulate that to reduce energy poverty in the country, LPG consumption should be increased, per capita GDP will also need to increase and the level of savings in the economy will have to rise.

However, there is a negative, yet insignificant, impact of LPG price and electricity price on the EDI. This clearly indicates that in order for the country to eradicate energy poverty, there is need to lower the prices of modern energy sources such as LPG and electricity.

From the regression results, a 1% increase in LPG consumption will increase the EDI by approximately 0.19%, thus reducing the country's energy poverty levels. Increasing per capita GDP and gross domestic savings by 1% each also has the effect of increasing the EDI by approximately 0.73% and 0.02% respectively. On the other hand, increasing LPG prices and electricity prices by 1% each has the effect of reducing the EDI by 0.06% and 0.09% respectively.

The adjusted R^2 shows that about 32% of the variations in EDI are explained by the model after correcting for the degrees of freedom and the model is thus relatively good in explaining changes in energy poverty, as measured by the EDI.

CHAPTER SIX

SUMMARY, CONCLUSIONS AND POLICY RECOMMENDATIONS

6.1 Introduction

This chapter begins by giving a brief summary of the study and then goes ahead to give the conclusions drawn. This is then followed by policy implications of the study and its recommendations and finally, the study's limitations are outlined and areas for further research highlighted.

6.2 Summary of the Study

The study examined the relationship between LPG consumption and energy poverty in Kenya for the period 1970 to 2011. Energy poverty was measured using the IEAs Energy poverty Index (EDI), which was computed using four indicators namely the per capita commercial energy consumption indicator, per capita electricity consumption in the residential sector indicator, share of modern fuels in total residential sector energy use indicator and the access to electricity indicator.

The EDI was the dependent variable and the independent variables included consumption of LPG in the country, the prices of the two main modern energy services namely LPG and electric energy, per capita GDP and gross domestic savings. Pre-estimation tests and statistical, descriptive and graphical analyses were employed by the study, and in addition, time series properties of the variables were established using the ADF unit root test. The ADF test showed that all the variables were non-stationary at levels but

stationary at second differences at the 1%, 5% and 10% levels of significance. Co-integration test was also carried out and it showed that EDI, LPG consumption and the other variables are co-integrated, implying that they have a long-run relationship.

The empirical model was then estimated using the error-correction model and the findings reveal that LPG consumption, per capita GDP and gross domestic savings all have a positive impact on energy poverty, as measured by the EDI, with LPG consumption and per capita GDP having a statistically significant impact. However, LPG price and electricity price had the opposite negative, though insignificant impact on the EDI.

Post estimation diagnostic tests were then carried out and they reveal that the model was well specified as reported by the Ramsey RESET, the residuals from the model were normally distributed and the model showed signs of outliers in the residuals as reported by Shapiro-Wilk W Test. The residuals from the model also had no serial correlation as reported from Breusch-Godfrey Serial correlation LM test and the residuals from the model were homoskedastic, as reported by Breusch-Pagan-Godfrey test.

6.3 Conclusions

The model estimates found that there is a negative relationship between LPG consumption and energy poverty in Kenya. This implies that an increase in LPG

consumption would reduce energy poverty significantly and this is seen in the inverse relationship between LPG consumption and the EDI measure of energy poverty.¹⁴

These results are consistent with those by the two other empirical studies that have tried to link modern energy services and energy poverty. Kojima (2011), in an attempt to establish the role played by LPG in reducing energy poverty, conducted a study across 20 developing countries, Kenya included, and reported that LPG plays a crucial role in eliminating energy poverty in these countries. The other study, though not focusing on LPG but electricity, was conducted by Pereira *et al* (2011) and they too report that rural electrification plays a key role in reducing energy poverty in Brazil.

6.4 Policy Implications and Recommendations

Energy poverty in a country refers to a situation where there is lack of access to clean and efficient sources of energy to the population for their basic activities and it is widely acknowledged that substituting traditional solid biomass or coal with cleaner fuels is one effective way of reducing household energy poverty, which is estimated to kill four people every minute. LPG is a merit good in this context and proper use of LPG can virtually eliminate indoor and outdoor air pollution from fuel combustion, benefiting not only the user but also others in the vicinity.

The negative relationship between LPG consumption and energy poverty in Kenya is a wake up call to the government of Kenya to gear its policies towards improving and encouraging LPG consumption by households. The government needs to take measures

¹⁴ A high EDI means less energy poverty and a low EDI indicates high energy poverty levels.

to alleviate the energy poverty crisis, with such measures incorporating a gradual upward movement of households on the energy ladder, such as moving from usage of biomass to LPG for cooking. Such measures may include strengthening the regulatory and institutional framework, including its pricing and competition policies, developing the appropriate infrastructure and market structure for supplying LPG and minimizing LPG shortages.

More specifically, the government of Kenya can adopt the use of targeted subsidies on LPG, whereby it persuades the segment of households that use traditional energy sources for cooking and spend large portions of their income on energy fuels to use LPG by making sure that LPG is available at a subsidized price to them. The use of targeted subsidies is proposed because the provision of subsidies causes huge financial burden on the government and thus it is necessary that the subsidies should be provided to targeted households only, as mis-targeted subsidies cause wasteful expenditure.

The government may also promote the use of LPG by disseminating information through various means and this has the advantage of not requiring a large budgetary outlay. It can also help LPG marketers make informed decisions about investments and marketing strategies and in addition, promotion programs undertaken can increase awareness of, and interest in, LPG as a household fuel. In addition to these, the government should also subsidize initial infrastructure required for LPG use, such as cylinders and stoves.

6.5 Limitations of the Study

As noted earlier in the review of the literature, currently, an integrated set of information which combines data on energy use with data on the socio-economic characteristics of households does not exist. This led to data refinement in some areas and without access to up-to-date integrated datasets; it was difficult to accurately measure energy poverty. A major limitation is the use of a proxy to measure access to electricity, an indicator in the EDI measure of energy poverty. This means that the estimates of energy poverty may underestimate or overestimate the extent of the challenge and findings may thus be indicative and not conclusive

6.6 Areas for further Study

The key role played by energy in general economic growth and development of a nation calls for more multi-dimensional measures of energy poverty and more research at the household level, linking energy poverty and the modern energy services. In Kenya, particularly, there is need to critically establish and examine the causes of energy poverty.

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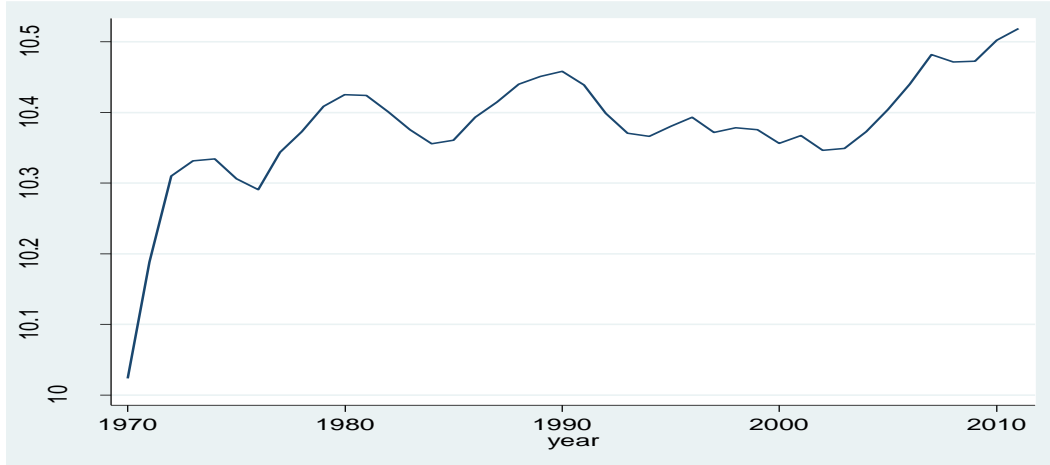
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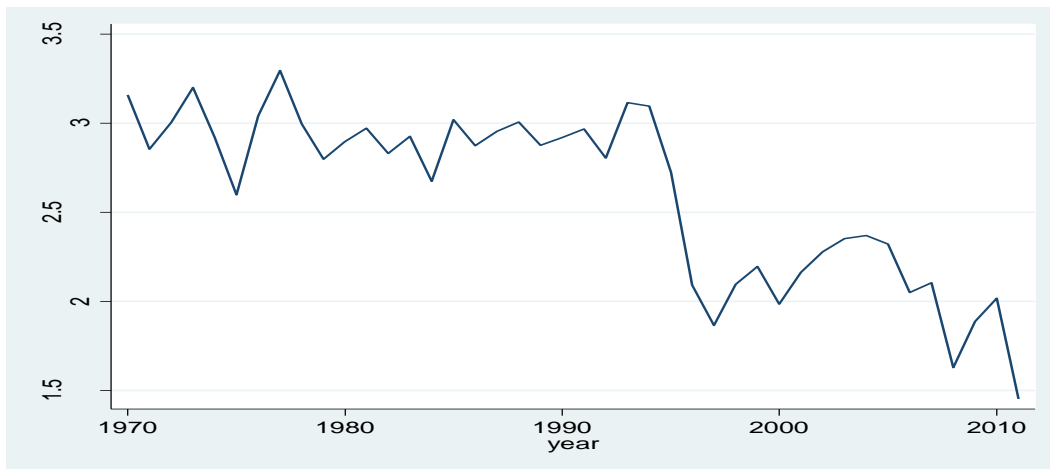
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APPENDICES

Appendix 1: Trends in per capita GDP



Appendix 2: Trends in gross domestic savings



Appendix 3: Correlation Matrix

	d21nedi	d21nlp~n	d21nlp~e	d21nel~e	d21npc~p	d21ngds
d21nedi	1.0000					
d21nlp~n	0.4257	1.0000				
d21nlp~e	0.0496	0.1711	1.0000			
d21nel~e	0.2132	0.0031	-0.3409	1.0000		
d21npc~p	-0.1277	0.0353	-0.1852	-0.1228	1.0000	
d21ngds	0.0984	-0.2176	-0.2154	0.0795	0.1206	1.0000

Appendix 4: Data

Year	EDI	Total LPG consumption	Domestic price of LPG per kg	Electricity Tariff	Per capita GDP	Gross Domestic Savings as a % of GDP
1970	0.123888276	8015	1.87	3.22	22549.34	23.55849
1971	0.142783393	9535	1.915	3.59	26592.28	17.36625
1972	0.120261063	9536	1.945	2.68	30038.05	20.18336
1973	0.171754337	12000	2.06	3.82	30675.38	24.53604
1974	0.156007259	12400	2.34	3.88	30773.93	18.53493
1975	0.135078299	13700	2.7	4.44	29920.09	13.45366
1976	0.160829171	14700	2.98	4.81	29451.11	20.93423
1977	0.176200062	16100	3.1	5.81	31056.19	27.02296
1978	0.178650761	17300	3.974	5.63	31982.15	20.00751
1979	0.16653446	20200	4.508	4.92	33143.79	16.43207
1980	0.176332691	21500	4.632	4.9	33693.54	18.11538
1981	0.229326922	21100	4.972	4.44	33656.58	19.55302
1982	0.1912265	20900	6.05	4.68	32884.22	16.95941
1983	0.245625146	19900	6.412	5.08	32071.88	18.66223
1984	0.280913353	21600	6.399	5.51	31428.3	14.50692
1985	0.262368675	22400	5.71	5.6	31583.75	20.47725
1986	0.264023181	24100	5.893	5.05	32634.47	17.72336
1987	0.26040779	25300	5.984	4.64	33350.54	19.19711
1988	0.299808475	26900	6.4	5.03	34190.45	20.21649
1989	0.314197256	26400	7.82	4.63	34575.85	17.77176

1990	0.327683828	27400	14.129	2.57	34824.2	18.52839
1991	0.327960019	25000	14.843	6.91	34169.55	19.45608
1992	0.330529918	27400	16.643	7.68	32810.51	16.51072
1993	0.290725539	25100	23.388	8.3	31902.03	22.55921
1994	0.278671192	28400	24.454	7.91	31763.17	22.10768
1995	0.298327407	31200	25.2	8.35	32216.13	15.25742
1996	0.285232626	31200	25.956	7.09	32640.58	8.092916
1997	0.285064946	30700	45	7.08	31942.2	6.456646
1998	0.269742459	31300	42	7.39	32158.1	8.133996
1999	0.280969255	32200	51	7.39	32072.45	8.99461
2000	0.278952356	33400	55.11	10	31447.64	7.280189
2001	0.289403352	35600	52.41	13.02	31799.48	8.706657
2002	0.321543861	40500	53.32	11.03	31146.39	9.761489
2003	0.332834547	40900	54.23	9.11	31227.62	10.52351
2004	0.347274698	41700	55.14	8.77	31973.3	10.70601
2005	0.375824651	49400	57.018	9.45	32994.36	10.18888
2006	0.440594243	64600	71.794	12.52	34193.69	7.767719
2007	0.467183801	77400	73.187	14.31	35663.34	8.198508
2008	0.483178259	84400	79.168	16.18	35294.43	5.099124
2009	0.444023477	74600	68.983	17.25	35334.74	6.607656
2010	0.479722164	87800	94.114	19.41	36402.7	7.519125
2011	0.527509513	91600	131.42	14.79	36993.9	4.274788