ANALYSIS OF HOUSEHOLD ENERGY CONSUMPTION IN IBADAN METROPOLIS OF NIGERIA

Oluremi Kayode

PGC(Economics), MSc (Business & Economic Forecasting)

A thesis submitted in partial fulfilment of the requirements of
London South Bank University for the degree of
Doctor of Philosophy

February 2016

I confirm that the work submitted is my own and that appropriate credit has been given where reference has been made to the work of others. This copy has been supplied on the understanding that it is copyright material and that no quotation from the thesis may be published without proper acknowledgement.

Oluremi Kayode

Acknowledgements

I would like to express my special appreciation and thanks to my supervisors Dr Mahtab Farshchi and Professor Andy Ford. I would like to thank you for encouraging my research and for your criticism that has encouraged me to develop and grow as a researcher. Your advice on both research as well as on my career have been invaluable.

I would like to acknowledge the assistance given to me by Professor Tony Day (formerly of London South Bank University) who in addition to supervising my research at the time gave assistance with research materials and the necessary software needed.

I would also like to express my gratitude to Professor John Parkin (formerly of London South Bank University) for the supervision of my thesis for some time. I would like to express my gratitude to all for the constructive comments made, which enabled me to strengthen my arguments in many parts of the thesis.

I am eternally grateful to various people particularly Dr Abel Nyamapfene of University College, London and Professor Adeola Adenikinju of University of Ibadan, Nigeria who throughout the time of this research offered such great support and encouragement at great personal costs. I also appreciate Professor Adeola Adenikinju for offering his time and providing me with feedback after my presentation at the NAEE conference. I take this opportunity to express gratitude to Mr Peter Sanusi (University of Ibadan, Nigeria), who came alongside me to organise the collation of my primary data.

I am also indebted to many friends who encouraged me in this process; Dr Gbenga Babawale, Pst.Fred Esiri, Mesdames Irene Fufeyin, Kumba Doherty, Regina Owence, Toyin Thompson and Ufuoma Agbonifo who not only provided unconditional friendship and support but never stopped believing in my abilities.

Much appreciation also goes to my uncle- Mr A.S.F Atoloye, who not only helped to proof read my work but also whose encouragement and understanding have been a great source of strength. I am also very thankful to members of my family – my husband-Marcus and children: Feyikemi, Fisayo and Feranmi who have supported me throughout this venture. Without their love and understanding, this dream may never have been realised.

I am also indebted to my parents (Late) Hon. Chief Akin Atoloye and Mrs Esther Atoloye and to my siblings- Mr Layiwola Atoloye, Mrs Gbemisola Omojola, Mr Tunji Atoloye and Mrs Funmilola Ayeni for their unceasing encouragement, support and attention. I am sad that my dad is not alive to witness this day that I complete this thesis.

Above all, I thank God for his grace and the sustenance throughout this period of study.

Abstract

Energy including electricity plays a significant role in the economic development of a country as it enhances the productivity of capital and labour. Many of the developing countries are plagued with energy problems: predominantly by their over dependence on low quality, traditional fuel and the over reliance on imported commercial fuel-oil. Some of the problems associated with energy forecasting in developing countries may include lack/insufficient data.

This study was conducted in two phases and begun with the reviewing of literature on energy and the different determinants of energy in a developing nation. Access to electricity is particularly crucial to human development as electricity is, in practice, indispensable for certain basic activities, such as lighting, refrigeration and the running of household appliances, and cannot easily be replaced by other forms of energy. Yet, many developing countries are faced with the challenge of providing adequate and modern energy services to its communities, which in turn is expected to improve the standards of living through increased income and employment generation.

The second phase of this research was developing and modelling demand for residential electricity using secondary data. This task was challenged by the inadequacies in the quality and availability of data on the one hand and the unrealistic assumptions of many existing models used to predict energy consumption in developing countries on the other. The contribution of this thesis here was also to consider a wider set of factors that are traditionally used in energy modelling. Many previous studies had been focusing on income as a determining factor affecting demand for energy (for example, the energy ladder theory).

However, this study found that there are many other factors such as the informal economy (activities within the economy that is not declared or included in the gross domestic product of a nation), urbanisation and transformation from rural to urban areas that may have a significant impact on how energy in the residential sector is demanded.

It was therefore important to exceed beyond unquestioned assumptions of the orthodox belief and to focus on the processes of urbanisation and change as realities facing many developing countries.

In order to develop a deeper understanding and analysis of the residential energy sector, this research offered a thorough examination of the literature on modelling techniques, their underlying theories and assumptions and the choice of variables and measurements. This led to the selection and identification of the factors influencing energy demand and helped determine the modelling techniques finally used in the thesis.

In order to achieve the aims of the study, a mixed method approach was adopted. The use of quantitative (secondary and primary) data as well as qualitative (case studies, face-to-face interviews and semi-structured questionnaires) helped the researcher to test a number of established hypotheses and offer a deeper understanding of the questions in hand.

Through using various statistical techniques the study was able to examine the relationship between different selected variables which can help forecast the demand for residential energy. Furthermore, with the use of a structured questionnaire survey of the households, socio-economic data were collected from 501 households in Ibadan metropolis in Nigeria which provided the premise for understanding factors other than income that are responsible for determining the type and level of energy consumed in households. The analysis involved the use of ordinal regression as households neither use the same fuel in the same combination or at the same level.

In sum the thesis made the following contributions: i) a better understanding of households energy consumption which have implications for a successful energy analysis for households in Nigeria as well as other developing countries; ii) a tested methodology for analysing the determinants of household energy.

The results showed that household income and price of energy do not have a significant effect on the consumption of energy in the household. It was rather factors such as the location of the property, the ownership status of the property and the expenditure spent on energy that seemed to be more relevant in determining the consumption of energy in the households.

The evidence from the study suggests that there is divergence in the energy need of households and hence the different determinants for various fuels. The concept of energy ladder as suggested by earlier researchers was not confirmed by the findings. Instead the study supported the work carried out by Heltberg (2003) and confirmed that income alone may not be sufficient to determine the consumption of energy by a household. It was rather factors such as the location of the property, the ownership status of the property and the expenditure spent on energy that seemed to be more relevant in determining the consumption of energy in the households. This research also highlighted the importance of the various socio-cultural factors that affects the consumption of energy within the household, and in the same vein, it showed that economic contribution is not the sole determinant in the choice of fuel energy.

Table of Contents

List of Tables

Chapter 9

Chapter 10

List of Figures

List of Appendices

Notations and Abbreviations

BPE Bureau of Public Enterprise

BSCF Billion Standard Cubic feet

CEGB Central Electricity Generating Board

DGES Director-General of Electricity Supply

DPR Department of Petroleum Resources

ECN Electricity Corporation of Nigeria

EPIC Electric Power Implementation Committee

EPSRA Electric Power Sector Reform Act 2005

Mmb/pd Million barrels of oil per day

NCP National Council on Privatization

NEPP National Electric Power Policy

NEP Nuclear Electric Power

NEPA National Electric Power Authority

NETA New Electricity Trading Arrangement

NERC Nigerian Electricity Regulatory Commission

NESCO Nigerian Electricity Supply Company

NGC National Grid Company

NNPC Nigeria National Petroleum Corporation

NTS National Transmission System

OFFER Office of Electricity Regulation

PG Power Generation

PHCN Power Holding Company of Nigeria

PPA Power Purchase Agreements

UIS Unesco Institute of Statistics

UNDESA United Nations Department of Economic and Social Affairs

Chapter 1 Introduction

1.1 Background

It is generally recognised that energy, including electricity, plays a significant role in the economic development of a country as it enhances the productivity of a nation when inputs such as capital and labour are considered (Jumbe, 2004; Wolde-Rufael, 2006). In addition, the increased consumption is an indication of an increase in economic activities, and by inference, an improvement in economic development of energy signifies that a country has a high economic ranking.

Energy is only one of the many important inputs for production, conversion, processing and commercialisation in all sectors (FAO, 1992; Popp et al., 2015). Energy cannot be seen but its effects can and although it cannot be made, destroyed or created, it can be converted, redistributed or transformed from one form to another. To understand energy will mean understanding the resources and their limitations especially as the economic development of any nation and improved standards of living will depend, to a great extent, on the availability of energy.

There are two main forms of energy use namely for non-commercial and commercial purposes. The consumption of commercial forms of energy has increased steadily and has been recently marked by especially dramatic growth rates in many developing countries (Ahuja and Marika, 2009). This is because energy is needed to create or produce goods using natural resources, and to provide improved services. Interest in satisfying the derived demand for energy arises from the basic goal of maintaining a certain level of human welfare and improving welfare wherever possible. Energy is also seen as a prerequisite for economic growth and development (Ebohon, 1996, Wolde-Rufael, 2006, Stern, 2011).

Energy demand is important as it affects economy which in turn affects people’s lives by way of their income, health, happiness and their ability to meet basic needs such as infrastructure, education and so on. Energy demand unlike other consumption goods is a derived demand as it is not valued for itself but for what it can do, in other words, it is not wanted for its own sake but rather for the light and heat which it can provide. The ability of any energy form to do so can therefore be regarded as a function of its energy content and the efficiency conversion embodied in the energy using appliances. Hence, energy demand to a great extent is not a function of the usual variables commonly used (e.g. own price, income, price of other goods and tastes) but it is crucially a function of the stock of relevant energy using appliances (Ogbonna, 2008). The energy requirement of an economy is sensitive to the rate of economic growth and energy intensity of producing sectors.

The economy can therefore, be described as a network system of consumers, producers and government – all connected by various laws and financial system and therefore supported by classical economic theory which tends to favour a free market system. Such free economy or society will only require some minor involvement from the government. According to Medlock (2009), the exceptional economic growth and major improvements in standards of living in general over the last few decades have mainly come about because of the replacement of manpower with mechanical power through technological progress.

Energy demand in a developing country has important ramifications for its economy due to the issues of black economy, and growing urbanisation, which exists in such nations. Access to electricity is particularly crucial to human development as electricity, in practice, is indispensable for certain basic household activities, such as lighting, refrigeration and the running of household appliances, and cannot easily be replaced by other forms of energy (IEA, 2002; Akinyemi et al., 2014). Yet, many developing countries are still faced with the challenge of providing adequate and modern energy services to their communities, which in turn is expected to improve the standard of living through increased income and employment opportunities (Reddy, 2000; Reddy and Nathan, 2013).

Prior to the oil crisis in 1973, most governments did not give too much thought to the use of energy as it appeared that there was plenty of fossil fuel and the future of energy in general, looked bright. However, with the oil crisis, all that changed and confidence about the future waned while at the same time many people were becoming more aware of the environmental impact connected with the demand and supply of energy. The increase in oil prices during the oil crisis in 1973/4 for instance resulted in the world experiencing severe inflation, recession, stagnation and huge balance deficits for some countries. Consequently, energy policy became an important issue for both industrialised and developing countries.

The average African still uses less energy than the average person used in England more than a century ago (Davidson and Sokona, 2002). Although there is a disparity in electricity consumption between Africa and the rest of the world, the internal disparity within African countries is even more glaring. For instance, in Ghana 62 per cent of the urban population has access to electricity while only 4 per cent of the rural population has access to electricity (Saghir, 2002 cited in Wolde- Rufael, 2006). Africa has the lowest electrification rate of any major world region (WEO, 2011) and according to the report, the rate of electrification in the sub-Saharan region is only 30.5 per cent compared to the world average of 80.5 per cent. Scarcity of energy or lack of energy resources is not the fundamental problem in Sub-Saharan Africa, according to Wolde-Rufael (2005) rather the critical issue is the management of energy resources including the development of such resources and the utilisation.

A deeper understanding of energy transitions and demands will help in developing energy policies for the poor and promote new energy markets that will improve the household budgets. In Africa, more than 500 million people are still without access to electricity and this includes the 76.4 per cent of the population of Nigeria that is without electricity (WEO, 2011). According to Wolde-Rufael, (2005), improved access to modern energy would not only improve the standard of living of the substantial majority of sub-Saharan African population but can also boost overall industrial and agricultural development.

Nigeria is in the sub-Saharan region with a population of over 174 million in 2013 (UN data, 2013) and a population growth rate averaged at 2.8 per cent as at 2013 compared to Ghana and Togo which averaged 2.1 and 2.6 per cent respectively. The GDP growth rate was less in Nigeria at 5.4 per cent in 2013 in comparison to Ghana with 7.6 per cent and Togo with 5.1 per cent in the same year. As the population grows, it brings about signs of urbanisation, industrialisation and investment. According to the World Bank (2013), the urban population growth rate in Nigeria was 4.0 per cent in 2010 compared to 1.1 per cent in rural areas. Rapid population growth may be a problem for such developing countries as it may result in difficulties for government in providing basic services in health, education and welfare to the growing population, and the need for more rapid growth in GDP to keep up with population growth and maintain living standards.

The general increase in population in Nigeria leads to an increase in the demand for resources and therefore the need for planning for energy for the country. Like other developing countries, Nigeria is faced with the challenge of providing adequate energy services to its communities and with the issue of rapid rate of urbanisation. The rate of urbanisation in Nigeria in 2013 was estimated at 4.60 per cent (World Bank, 2015) but this was not homogenous across the country. This means that as there are different growth and urbanisation rates in the country, there will be differing or varying demands for energy; hence the need for energy planning. The tremendous increase in urbanisation over the years, also resulted in the increase in the proportion of urban residents without electricity.

Energy can be linked to urbanisation as an increase in urbanisation may bring about changes to land use, increase in transportation, industry, infrastructure and use of domestic appliances (see chapter 5 for full discussion). In effect, an increase in urbanisation leads to an increase in energy consumption as the demand for goods and services increases. The rate of urbanisation is therefore important for energy policy and planning and plays an important role in "energy transition" (Leach, 1992). In other words, the rate of urbanisation affects how quickly an area or country can move from a lower inefficient form of energy to a modern fuel. In essence, urban energy planning and urbanisation management will be crucial to creating the right framework conditions for a sustainable energy future. However, there is also the assumption that the current and future growth potentials of urban cities are drastically limited by severe infrastructure constraints due to energy shortages (Ebohon et al, 2000).

Energy management in its widest sense is an important area of study and the tasks of energy planners and energy policy makers are therefore crucial in facilitating strategic national socio-economic planning. The author notices that research in energy management has been dominated by publications that extensively use modelling techniques in their analysis albeit not challenging the logic of the underlying theories.

For Nigeria to achieve sustained economic growth and to establish how this can be facilitated, it should plan and manage its available resources more efficiently. The contributions of this study fill the gap in knowledge.

Review of the literatures on energy demand modelling in general (Bhattacharyya, 1996; Davidson and Sokona, 2002) and in Nigeria specifically (Urban et al, 2007; Ubani, 2013) revealed that existing statistical tools may not offer appropriate methods; nor are the data to run such models are available given the state of economic development in such countries. The use of statistical modelling alone may not enable one to comprehend the unique features of a developing country such as the existence of informal economy. At the national level, statistical categorisations may often appear to be too broad and data even at sectoral level are rarely comparable. A considerable amount of informal economic activity (for instance) takes place but unfortunately, such are not recorded or included in existing classifications of income

Moreover, with the presence of data related issues such as the absence of standardised data categorisations (in relation to household data), and other inconsistencies in data quality, it is important that the data capture includes wider socio-economic factors by using interviews or semi-structured questionnaire surveys instead of using published secondary data. The design of the methodology for this study will therefore challenge the intricacies of the consumption of energy as this methodology will lead to specific type of analysis that would take into account other factors that affect consumption of energy.

From a theoretical standpoint, energy models have been influenced by different theories such as the linear stages of growth, the structural change mode, the international dependent model, the neoclassical counter revolution model and the new growth theory to name a few, while the need for energy planning also brings about the need for identifying the causality and relationship between energy consumption and economic development (Ebohon, 1996; Masih and Masih, 1996; Asafu-Adjaye, 2000; Jumbe, 2004; Oh and Lee, 2004). The question of causality receives a great deal of attention in the literature; most studies have found some level of causality between variables such as economic growth and levels of energy consumption but such findings have remained inconclusive as to whether it is economic growth that influences energy consumption or it is energy consumption that influences energy growth.

The literature in this area can be grouped into different hypotheses such a) *the conservation hypothesis* which argues that a one-directional effect from GDP to cause energy consumption (GDP→EC) (Jumbe, 2004; Akinlo, 2008); b) *the growth hypothesis*, which is in contrast with the above, arguing that energy consumption causes the economy to grow (EC→GDP) (Masih and Masih, 1997; Asafu-Adjaye, 2000); c) *the feedback hypothesis* where there is a bi-directional causality between energy and economic development (GDP↔EC) (Ebohon, 1996), and d) *the neutrality hypothesis* where there is no causal relationship between energy and economic development (GDP─EC) (WolfeRufael, 2006).

Apart from the question of causality and its direction, the literature on modelling energy is divided on the choice of statistical techniques. Most studies are known to have used autoregressive distributed lag (ARDL) models (Bentsen and Engsted, 2001), linear regression method (Mohamed and Bodger, 2005, Enelioglu et al., 2001 and Ubani, 2013) and autoregressive integrated moving average (ARIMA) models (Erdogdu, 2007). The evaluation of such modelling approaches can help us apply the most relevant techniques into the analysis of household energy consumption in Nigeria.

From a modelling perspective the development of independent variables and their measures are also critical. Further review on a sectoral basis indicates that a number of factors are responsible for determining the level and type of energy used in the households. Most studies also included mainly income, the size of household and price of energy (Bentzen and Engsted, 2001;Halvorsen and Larsen, 2001; Heltberg,2004; Ziramba, 2008). The use of the various approaches produces results that centre on one or more combination of the different theories in energy consumption. These include sociological, psychological, educational and economic theories (see Chapter 3 for full discussion).

The overwhelming use of energy modelling in the literature is a manifest of the attractiveness of this approach. Modelling can help us better understand reality with its complexities. Each model may capture the behaviour of an entire energy system by showing how its key elements affect the energy demand trend. The use of energy modelling will also enable such models produced to capture the impact of the energy system on the wider economy. Therefore, energy modelling is important as it provides insights into energy and how this might change over the years.

This thesis also offers challenges to the orthodox assumptions of economics with regard to conditions of perfect competition and perfect information. These are clearly not the case in developing countries where competition is restricted and information is rarely near perfect. The evidence can be found in the existence and size of the informal economy in such countries. In the economic analysis the economy consists of different sectors such as the consumers, producers and government and it is generally expected that such an economy will operate as a free market that requires very minimal or no intervention of the government to support the society as it is a free economy. The consumption of energy is also seen in the light of neoclassical theory (Zachariadis, 2007) which assumes that agents of consumption are rational individuals acting with full information in a market where forces of competition are dominating. As such, there should be no market failure.

However, this does not seem to be the case in Nigeria where the demand for electricity far outstrips the supply. The demand for energy in the household is also associated with the rational choice theory which assumes that an individual has preferences among the available choice alternatives that allow them to state which option they prefer (see discussion in Chapter 3). Although consumers can be assumed as being rational, there cannot be equilibrium in such an economy due to the issues of bribery and corruption and the impact of the presence of informal economy (see Chapter 4). All these buttress the need for energy planning in Nigeria.

On a practical note, the issue facing energy planning in Nigeria includes the availability of data at the national and international levels. The World Bank, International Energy Agency, Central Bank of Nigeria and Power Holding Corporation of Nigeria (PHCN) hold data which spans over 40 years (1971-2011).

Early investigation revealed that some of the variables (such as stock of household appliances, connectivity to the grid, size of flat) used in the reviewed literature are neither readily available in the Nigerian context nor are they available in sufficient quality.

The use of a mixed method approach is perceived to help overcome such barriers as data availability and data quality. Dummy variables can also be used to capture factors for which data are unavailable. The use of an econometrics approach is associated with the application of economic theory (Pindyck et al. 2009). The use of such models requires a long run of quantified historical data in order to function but this may be unattainable in developing countries such as Nigeria. Furthermore, the use of socio-economic analysis via interviews and surveys may help overcome the problem of unobserved components of energy demand, which may be so difficult to capture with traditional statistical and econometric techniques, despite their potential importance in driving energy demand (Dilaver, 2012).

Two dominant approaches in the literature on energy demand are known as the energy ladder and the energy mix models. Here the concepts of consumer preferences and household budgeting processes are considered. These models have argued that income appears to be a predominant factor of energy consumption; the energy ladder theory suggests that people only move onto a more sophisticated form of energy when there is a positive change to their income. This model does not take into account the peculiar characteristics of urbanisation and informal economy in Nigeria as a developing country. With the rate of urbanisation estimated as 3.75 per cent (2010-15 est., Index Mundi, 2011) and between 45 and 60 per cent of the urban labour force in the informal sector, it is worth examining the predominance of income as a factor of energy consumption in the Nigerian context. It would therefore be very important to test the validity of these models and to determine whether the effects of a factor on the consumption of energy by households may differ depending on the associated level of energy consumption for instance when a household is a low, medium or high energy consumer.

It is critically important to highlight various socio-cultural factors that affect the consumption of energy within the households, but in the same vein, it is important to evaluate the contributions of economic factors as the sole determinant in the choice of fuel energy as suggested in the energy ladder approach.

Given the scale of the country, this research will focus its attention on a specific metropolis area in Nigeria-Ibadan. The reason for the choice of Ibadan is the fact that it is the largest city in West Africa with an average annual growth rate of 4.6% during the period 2010-2020 (UNDESA, 2012). In addition, the rate of urbanisation is not as fluid as in the case of some other cities like Lagos and therefore the factors that may attract people to Ibadan can easily be replicated in other cities.

1.2 Research Rationale

Energy is generally accepted to be an important contributor to economic growth (Chapter 2) and therefore the typical focus of energy demand analysis is to identify the factors that might explain energy demand in the past and shape it in the future. Apart from the main economic factors of income and price, there may be other components of energy demand that may be too difficult to capture with traditional statistical and econometric techniques, despite their potential importance in driving energy demand. Understanding the importance of the factors will lead to a better information of the structure of energy demand (Wolde-Rufael, 2006). As such, the accurate evaluation of all sectoral energy demand becomes paramount for a successful energy demand plan.

Due to the nature of most developing countries, and because of the lack of understanding of household dynamics and factors influencing its dynamics, it is difficult to fully identify the impact of insufficient energy consumption on the development of the various parts and sectors of the country and on the standards of living of people. There is difficulty in designing or evaluating policies and programmes intended to address the impact of the use of energy within households. The evidence suggests that there may be a number of factors at work that differ significantly across countries that account for the different directions of causality noted above (see Chapter 2). Being able to detect key factors that can help to explain this inconsistency will enable us to provide an understanding of the relationship between energy consumption and economic development (Soris and Soytas, 2007).

To the effect, this thesis firstly uses factors or variables that were identified from the literature reviewed. The data set used were from 1970 to 2011 because although at that time there was some stability in Nigeria, together with the oil boom of the seventies, it was difficult to get the data for some the variables (such as rate of connectivity to the grid, price of electricity) prior to 1970. Moreover, the electricity board had not been decentralised at the time.

Policies have also changed over the years due to the different government that Nigeria has had. Therefore consideration of the effect of the different policies is very minimal in this research. There is the scope of investigating this as an extension of the research. The focus of this thesis however is on the residential consumers - identifying the underlying factors to the behaviour of consumers on the use of energy.

This research therefore, in particular, focuses on factors that contribute to the demand of electricity (as a form of energy) in the household sector. The household can be considered as a major decision maker in terms of energy use and as such it is important to understand the demand for energy for policy making in sub-Sahara Africa. An understanding of energy transitions and demands will help in developing energy policies for the poor and promote new energy markets that will improve the household budgets.

1.3 Research Aim and Objectives

The research will set out with identifying the above problem (factors that contribute to the demand of energy) following a comprehensive review of the literature. This will include publications dating back 40 years focusing both on developed and developing countries. Initial review of the literature shows that although there had been various studies carried out on energy consumption, a lower proportion of these are on sub-Saharan African countries. Moreover, a fewer number of such publications are on households/ residential sectors which consume the most energy. A great percentage of such studies are based on econometric modelling which required the use of secondary data. Furthermore, most include income as a main determinant of energy as identified in the energy ladder.

To fill these gaps, this research therefore, focuses on identifying various factors that contribute to energy consumption in households since the household sector is considered as a major decision maker in terms of energy use. As such it is important for policy makers to understand the demand for energy for Nigeria. The thesis will consider whether the demand for energy is mainly subject to the impact of changes to the income of the household as portrayed in the energy ladder model. While the importance of understanding the economics of urbanisation and the demand of energy will be examined in detail, it may be difficult or impossible to generate policies that will aid the development of both sectors without such understanding.

Such knowledge and understanding can then be used to plan energy and electricity supply and also to set up policies that will help improve the quality of life of the consumers and enhance the overall development of the country. This study raises awareness that accurate analysis of the household energy sector will be of immense value to the development of a country.

This study aims to investigate the relationship between different factors affecting the energy demand by households in Nigeria and to develop a conceptual framework to analyse and estimate energy consumption by household types.

The objectives will therefore include the following:

1. To evaluate the relationship between energy consumption and economic development.

2. To identify factors affecting energy consumption in the economy in general and in the household sector in specific.

3. To critically evaluate theories of economic development and urbanisation and assess their underlying assumptions in explaining energy consumption in the residential sector.

4. To assess the validity of identified factors in explaining energy consumption behaviour using secondary data.

5. To develop conceptual framework to estimate the behaviour of households using socio-economic factors.

1.4 Scope of the Thesis

This research explores the energy situation in Nigeria, where even though the country is rich in resources, a large proportion of the population do not have access to them. For instance, less than 40 per cent of the population have access to electricity (Sambo, 2010). The research considers the consumption of energy in households in Nigeria and is carried out to establish the various factors that contribute specifically to the consumption of energy in households. This includes the understanding of different economic development theories as the direction of the relationship between energy consumption and economic development is not conclusive.

This research also elucidates on the energy ladder theory in order to establish whether the assumptions of the energy ladder holds true in the Nigerian context. Understanding of the above will help in formulating the appropriate policies and planning for energy use.

The study although limited in regional and sector coverage has a study area that includes five different local government areas comprising of three urban and two rural areas. The combination of these areas allows for a more robust analysis. As this research is unable to cover the whole of Nigeria, due to time constraints, the use of Ibadan as a case study is considered suitable. As a city, some parts of it are rural integrated in shape or forms, also there are various people from other parts of Nigeria that live in Nigeria due to the fact that it is a city of commerce and not as busy as Lagos. It is vital to note that the characteristics of consumers' behaviour to energy do not change drastically and as every Nigerian can be found in Ibadan, the sample randomly selected would give an indication of the overall situation of energy consumption in households.

1.5 Data and Key methods

A comprehensive review of various literature on the energy consumption in the context of developing countries reveals a gap that this study intends to bridge. The gap being the fact that most modelling of residential energy done in developing countries do not take into cognisance the unique features of the country such as the rate of urbanisation and the informal economy that dominates such countries. It will do this through the use of a mixed method (triangulation) research. That is an approach of inquiry that combines or associates both qualitative and quantitative forms. The philosophical assumptions underpinning this research (fully discussed later) encourage the use of qualitative and quantitative approaches. The reason for this is that the overall strength of such a mixed approach is greater than either qualitative or quantitative research. The use of primary data will also provide an account for understanding the behaviour of people in consuming energy.

1.6 Contribution to Knowledge

This thesis makes a number of contributions to the academic literature and policy design. At a theoretical level it seeks to explore the validity and reliability of the current theories on energy demand and modelling. The study also fills a gap by examining the impact of urbanisation and informal economy on the consumption of energy and by using ordinal regression as an approach in analysing the level of energy consumption. Furthermore, the study also aims to break new grounds by empirically testing the energy ladder hypothesis in relation to energy consumption within the household sector using a mixed method or triangulation approach to model the different levels of consumption.

1.7 Structure of the Thesis

The rest of the thesis is presented as follows:

Chapter 2: Theoretical Review of the Relationships between Energy and Development

The review of modelling techniques in relation to energy with the aim of identifying their weaknesses and strengths is the focus of this chapter. The main approaches reviewed include the following: Regression, Auto Regressive Distributed Lag, Error Correction Model /Vector Error Correction Model. The chapter also deals with the reason for modelling and the different hypothesis that are associated with energy-economy nexus.

Chapter 3: Evaluation of Modelling Literature

This chapter mainly deals with the empirical review of literature in relation to energy consumption and aims to provide a better understanding of the existing knowledge on the modelling of determinants of energy in the household. This is further assessed under the main econometric approaches and various theories identified with a focus on the different variables used in energy modelling.

This chapter also explores the development of the conceptual framework for household energy consumption including the concept of the energy ladder and energy mix. It reviews the various assumptions made and evaluates these theories accordingly. The theoretical framework for this study is also developed in this chapter discussing the concept of consumer preferences and household budgeting which are used to support the demand model used for empirical analysis.

Chapter 4: Urbanisation and Energy Consumption

The chapter examines current issues and developments with regard to energy consumption. It expounds on the rationale for the role of urbanisation and informal economy in the context of a developing country.

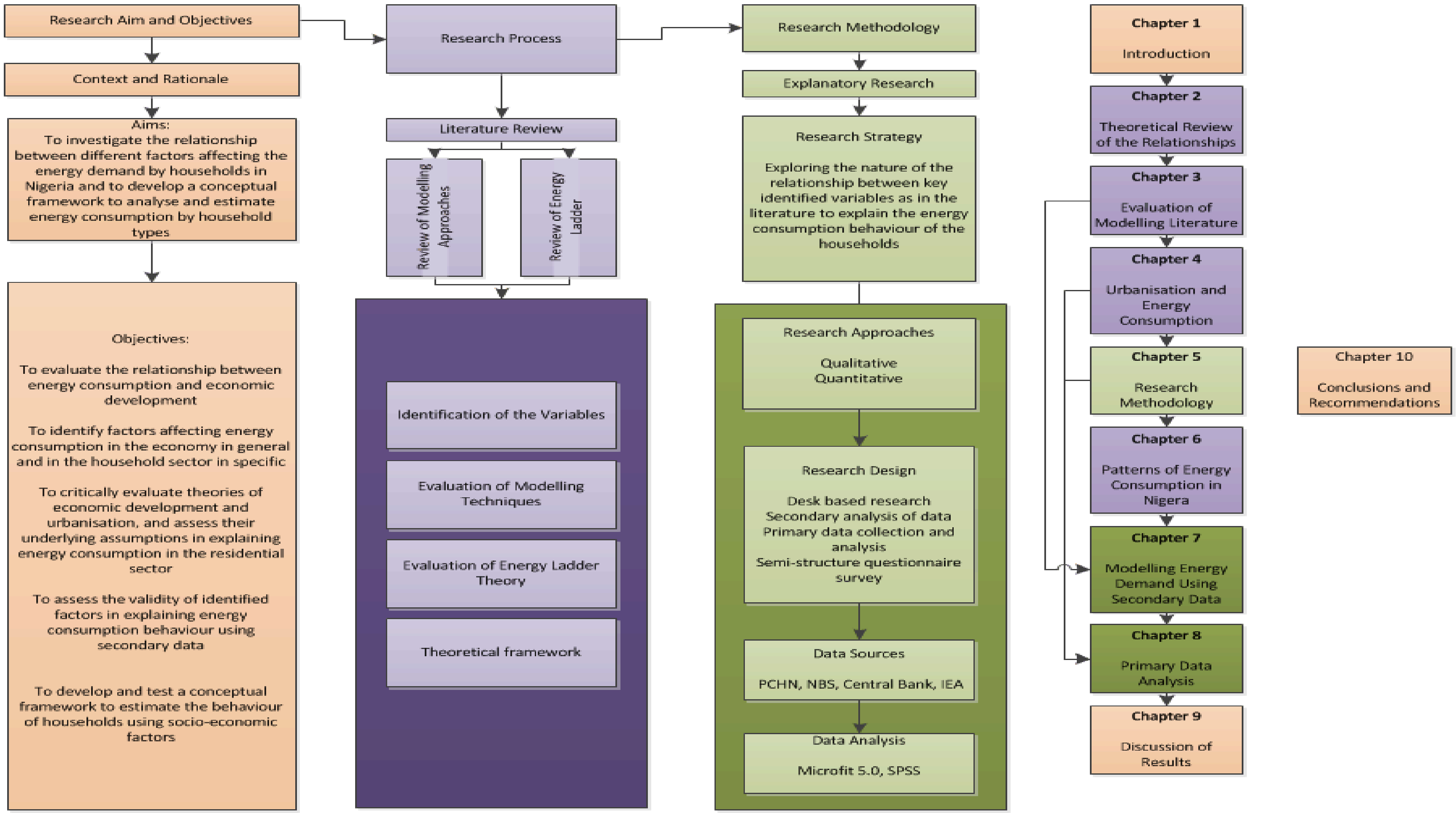
Chapter 5: Research Methodology

This chapter explores the general methodological assumptions underlying the use of the secondary data in quantitative approach and the different philosophies of research methodology whilst centring on the mixed methodology approach that is adopted in this thesis.

Chapter 6: Patterns of Energy Consumption in Nigeria

This chapter includes an overview of energy situation in Nigeria, the production and consumption in the country and provides a historical background to the role of energy, highlighting the various energy resources in the Nigeria and the historical trends of the electricity industry in Nigeria.

Figure 1.1 Theoretical Frameworks



Chapter 7: Modelling Energy Demand using Secondary Data

This chapter deal with analysing factors that contribute to energy consumption and further investigates the rationale for the choice of a particular modelling approach and applying that to a set of data on Nigeria. It analyses the consumption of electricity in Nigeria using secondary data and highlighting the results.

Chapter 8: Primary Data Analysis

The details from the evidence received from the sample area of 501 households is analysed and examined for factors that contribute to the consumption of energy. It uses the empirical evidence as a means of further assessing and attempts to link this with energy ladder hypothesis discussed earlier.

Chapter 9: Discussion of Results

This chapter presents and discusses the results obtained in this research and is in two parts. The first section focusses on the econometric results of the regression modelling that was applied on the secondary data. The second section deals more with the results generated from the survey carried out in the Ibadan metropolis. The factors that influence the consumption of electricity are presented and hypotheses tested.

Chapter 10: Conclusions and Recommendations

The research concludes by revisiting the key objectives and hypotheses of the study. The chapter also gives recommendations for policy design and planning of energy in Nigeria.

Chapter 2 Theoretical Review of the Relationships between Energy Consumption and Development

2.1 Overview of the Chapter

The review of the literature on energy consumption began here by examining the established field of energy modelling over the past few decades. This revealed a range of approaches varying in their type of modelling, countries studied, and various hypotheses being tested. This chapter will cover the following areas and make conclusions:

- Section 2.2 – an overview of the challenges in establishing causality in developing energy models.
- Section 2.3 – an analysis of the key hypotheses tested by the literature and summaries of the finding.
- Section 2.4 – a synopsis on the diverse theories of economic development.
- Section 2.5 – a review of the lesson learnt from energy modelling, forecasting and the theories associated with energy modelling.

2.2 Introduction

A considerable amount of attention in the literature on energy consumption has contributed to establishing the question of causality and the direction of cause and effect. The importance of establishing the causes of energy consumption and factors affecting change in consumption has led this study to focus on the most cited publications in the field with a view to create a synthesis and to identify practical lessons to be integrated in the following chapters.

Studies that model the causality relationship between energy and economic development are useful as they are able to provide suggestions to policymakers with practical ways in developing effective policies to invigorate economic growth and to alleviate carbon dioxide emissions. Nigeria has a population of over 174 million (2012) and an urbanisation rate of 2.8 per cent as at 2011(World Bank, 2015). As a developing nation, the main problem identified in Nigeria (as noted in Chapter 1) has been the rate at which the population is growing. This is because the increase in population is usually associated with an increase in the demand for energy and resources. However, there are other counter arguments that increase in population does not necessarily lead to increase in energy demand. It depends very much on how buildings are constructed and building strategy.

In addition, there are various factors associated with the production and consumption levels of energy which may lead to a high level of unmet demand. Such factors includes underinvestment and poor planning in electricity infrastructure, the vandalisation of gas pipelines feeding major power plants also brought a major reduction in overall electricity generation. It could also be due to the period of low rainfall and near-drought conditions which seriously affected the hydro-generation capacity in Nigeria. The principal problem here is understanding where, how and when the demand for energy will grow or decline, what factors indicate such change and how to plan so that supply can be sufficient for the demand.

The aim of this literature review is therefore to gain a better understanding of the existing knowledge on the causality relationship between energy consumption (EC) and Gross Domestic Product (GDP).

2.3 Identifying the Causality Relationship between Energy and Economy

The use of different energy sources (e.g., wood, coal, oil, electricity, nuclear, etc.) from the beginning of history is an indication of the level of technological and socioeconomic development (Ahuja and Marika, 2009). The most significant change in the use of energy came with Industrial Revolution which affected various aspects of the human life and brought changes in agriculture, manufacturing, transportation as a result of changes in technology. Subsequently, the demand for energy was transformed. Energy is generally associated with productive work and at the beginning of the Industrial Revolution, there was an increase in demand for coal. There was, for instance, an increase in the use of refined coal and an increased need for improved roads and railways as trade was rapidly expanding. Oil, on the other hand, became important around the middle of the twentieth century because of its convenience.

The changes in technology affects production, (moving from a domestic production to a factory production system) the manufacturing industries also resulted in the use was facilitated by the use of steam powered engines and machinery which meant an increase in the use of energy. The birth of the Industrial Revolution changed living standards such that it also resulted in population growth which in turn increased the demand and use of natural and man-made resources as well as energy. It is therefore, easy to understand why most economies practically rely on energy for their growth and development, however, the relationship between economic growth and energy consumption is a deeper question which requires detailed analysis which the rest of this chapter aims to examine.

The review of the relationship between energy and economic growth centres on whether energy consumption causes economic growth or economic growth causes energy consumption. It is important to understand the direction of causality between energy consumption and economic growth as there are direct implications for the formulation of strategic policies. This is because the energy sector is important in the economy as it creates jobs and adds value to the economy by transforming and distributing energy goods. As such, energy can be regarded as a crucial ingredient to the economy. This comprehension enables policymakers to enhance economic growth and also ensures that energy consumption is achieved in a way that enables a reduction in both CO_2 emissions and global warming (Apergis and Tang, 2013).

Economic theories of energy also hold that rates of energy consumption and energy efficiency are linked causally to economic growth. There are of course various factors that may affect the economic growth of a country such as the level of productivity, demographic changes, political institutions and income equality. A summary of the various studies showing the causality relationship between energy consumption and economic growth is presented in Table 2.1.

Table 2.1 Summary of selected papers linking energy consumption and economic growth

Authors	Period	Region/Countries	Causality relationship /hypothesis	Methodology
Masih & Masih (1996)	1955-1990	Asia (India, Indonesia, Malaysia, Pakistan, Philippines and Singapore	GDP →EC[1] (Indonesia)	Cointegration
			EC→ GDP[2] (India)	
			GDP↔EC[3] (Pakistan)	
			GDP─EC[4] (Malaysia, Singapore & Philippines)	
Ebohon (1996)	1960-1984 & 1960-1981	Nigeria and Tanzania	GDP↔EC	Granger causality
Asafu-Adjaye (2000)	1971-1995	South East Asia (India, Indonesia, (Philippine, Thailand)	EC→GDP (India, Indonesia) GDP↔EC (Philippine, Thailand)	Cointegration and Granger causality[6]
Jumbe (2004)	1970-1999	South East Africa (Malawi)	GDP↔EC	Granger causality
Oh and Lee (2004)	1970-1990	East Asia (Korea)	EC→GDP (SR)	Granger causality
			EC↔GDP (LR)	
Altinay and Karagol (2005)	1950-2000	Southern Europe (Turkey)	EC → GDP	Standard Granger causality test
Wolde-Rufael (2006)	1971-2001	17 African countries (Algeria, Benin, Cameroon, Democratic Republic of Congo, Egypt, Gabon, Ghana, Kenya, Morocco, Nigeria, Senegal, South Africa and	GDP↔EG (Egypt, Gabon, Morocco)	Toda Yamamoto's Granger causality
			EC→GDP (Benin, DR Congo, Tunisia)	
			GDP→EC (Cameroon, Ghana, Nigeria, Senegal, Zambia & Zimbabwe)	

		Sudan, Tunisia, Zambia and Zimbabwe)	GDP─EC (Algeria, Kenya, Congo Rep, Sudan & South Africa)	
Yoo (2007)	1971-2002	Southeast Asia (Singapore)	EC → GDP	Standard Granger Causality
Yuan et al. (2007)	1978-2004	China	EC → GDP	ECM
Akinlo (2008)	1980-2003	11 countries in sub Saharan Africa (Cameroon, Congo, Cote d'Ivore, Gambia, Ghana, Kenya, Nigeria, Senegal, Sudan, Togo and Zimbabwe)	GDP→EC (Sudan & Zimbabwe) EC→GDP (Congo) EC↔GDP (Gambia, Ghana & Senegal) GDP─EC (Cameroon, Cote D'Ivoire, Nigeria, Togo & Kenya)	ARDL bounds test
Narayan & Smyth (2008)	1972-2002	G-7 countries (United States, Canada France, Germany, Italy, Japan, and the United Kingdom)	EC→GDP	Panel cointegration and Granger causality
Akinlo (2009)	1980-2006	West Africa (Nigeria)	EC→GDP	ECM
Odularu & Okonkwo (2009)	1975-2005	West Africa (Nigeria)	EC→GDP	Cointegration
Ighodaro (2010)	1970-2005	West Africa (Nigeria)	EC→GDP	Cointegration, granger causality

Ozturk et al. (2010)	1971-2005	51 Countries Low income countries (Bangladesh, Benin, Congo, Ghana, Haiti, India, Kenya, Nepal, Nigeria, Pakistan, Sudan, Togo, Zambia and Zimbabwe)	GDP→EC for low income countries	Panel cointegration and Granger causality
		Lower middle income countries (Algeria, Bolivia, Cameroon, China, Colombia, Congo, Rep., Dominican Republic, Ecuador, Egypt, El Salvador, Guatemala, Honduras, Indonesia, Iran Islamic Rep., Jamaica, Morocco, Nicaragua, Paraguay, Peru, Philippines, Sri Lanka, Syrian,	EC↔GDP for lower middle and upper	

		Arab Republic, Thailand and Tunisia)	middle income countries	
		Upper middle income countries (Argentina, Chile, Costa Rica, Gabon, Hungary, Malaysia, Mexico, Oman, Panama, South Africa, Turkey, Uruguay and Venezuela		
Narayan and Smyth (2012)	1980-2006	Southern Europe (Spain)	EC↔GDP	ARDL

Source: Author's compilation

*See methodology chapter for full discussion of modelling techniques.

The mixed and controversial evidence from empirical research regarding the direction of the causality and the strength of the impact of higher energy access on economic growth could be the result of the different methodological approaches, time periods and country groups examined, as well as the choice of variables (Ouedraogo 2013). The empirical literature has emphasised four possible relationships between energy and economic growth. In other words, in terms of the causality methodology, there are four different type of hypotheses that can be used to describe the relationship between Gross Domestic Product (GDP) and energy consumption (EC). These are as follows:

2.3.1 The conservation hypothesis

This is where changes in Gross Domestic Product (GDP) causes changes in energy consumption (EC) (GDP→EC)[1] suggesting that the economy is not energy dependent and hence as the economy grows energy consumption increases implying that an increase in economic growth increases the consumption of energy. This also means that economic growth cannot be hindered by any form of energy saving. Studies by Wolde-Rufael (2006) and Akinlo (2008) supported this hypothesis as they found unidirectional causality from GDP to energy consumption in countries such as Nigeria, Senegal, Cameroon, Ghana, Zambia and Zimbabwe. The conservation hypothesis can be explained to mean that economic growth may not increase without energy consumption or energy availability. However, contrary literature that do not support this hypothesis is reflected in growth hypothesis, neutrality and feedback hypothesis (2.3.2 to 2.3.4). However, some countries such as Benin, Congo and Tunisia were found to be also unidirectional but in this case it was from energy consumption to gross domestic product (EC→GDP) yet the same study period by Wolde-Rufael showed bidirectional causality (GDP↔EC) for countries such as Egypt, Gabon and Morocco.

2.3.2 The growth hypothesis

Other studies have sustained the fact that changes in energy consumption cause changes in Gross Domestic Product (EC→GDP)[2]. Countries that support such growth hypothesis are energy dependent suggesting that energy consumption plays an

---

[1] GDP→EC, Conservation hypothesis

[2] EC→GDP, Growth hypothesis

important role in economic growth both directly and indirectly in the production process as a complement to labour and capital (Omri, 2014). Therefore, implementing energy conservation policies will have little or no adverse effect on income. Using annual data from 1971 to 1995, Asafu-Adjaye (2000) investigated the relationship between energy and income in some Asian developing countries (India and Indonesia) and showed that in the short-run, there is a unidirectional (Granger) causality from energy consumption to income.

Studies by Masih and Masih (1996) on India, Oh and Lee (2004) on Korea, Narayan and Smyth (2005) on G7 countries, also confirmed this, albeit, in the case of Oh and Lee (2004), this was true only in the short run. However, in examining the validity of the growth hypothesis among 85 different countries, Apergis and Tang (2013) concluded that both developed and developing countries are more likely to support the energy-led growth hypothesis compared to the less developed or low income countries.

2.3.3 The neutrality hypothesis

This is a case where there is no causal relationship between energy and economic development (GDP─EC)[3]. In other words, this hypothesis considers energy consumption to be a small component of overall economic growth and therefore have little or no effect on economic growth (Omri, 2014). As such, any energy conservation policies implemented will have no adverse effect on output. Such was the case of Kenya according to WolfeRufael (2006), Malaysia, Singapore and Philippines as reported by Masih and Masih (1996), Cote D'Ivoire, Nigeria and Togo as reported in the studies by Akinlo (2008). This is due to the fact that neither energy conservation nor expansion policies would have effect on the economic growth.

2.3.4 The feedback hypothesis

This supports cases where there is a bi-directional causality between energy and economic development (EC↔GDP)[4]. In other words, energy and Gross Domestic Product are regarded as complementary and energy consumption and economic growth could be interrelated. Ebohon (1996) ascertained this in the case of Nigeria and

---

[3] GDP↔EC - Feedback hypothesis

[4] GDP─ EC – Neutrality hypothesis

Tanzania, AsafuAdjaye (2000) for Philippines and Thailand, Oh and Lee (2004) for Korea and Jumbe (2004) for Malawi. The lack of a significant relationship between GDP and electricity consumption for many countries (Lutkepohl, 1982 as cited in Wolde-Rufael, 2006) is evident and could be attributed to some omitted variables affecting both economic development and electricity consumption.

2.3.5 Differences in results

There is rich evidence reviewing electricity consumption in various countries, however, the studies show vast variences in country specific conditions. These variations in evidence were noted in the following examples: the extent to which electricity is consumed for economic activities versus human basic activities; the efficiency with which electricity is used; the use of traditional tests of statistical significance with small samples (Khanna and Rao, 2009). Wolde-Rufael (2006) argued that there are possibly a number of factors which may influence the demand for electricity but these differ significantly across countries and can cause the different directions of causality.

Other reasons that have been associated with the mixed evidence obtained from the studies include different datasets used, time periods examined, different variables and methodologies adopted. According to Apergis and Tang (2013), the inconclusive evidence is potentially attributed to model specifications and the stage of economic development of the countries under investigation. This was supported by Omri (2014) who recently conducted an extensive review of the nexus between economic growth and different types of energy consumption. He observed that the results from the studies were mostly sensitive to methodology and type of energy considered. He concluded that the mixture and the non- conclusiveness of the results from previous studies were due to the different countries' characteristics, different datasets, and alternative econometric methodology.

Ozturk et al. (2010) noted though that none of the hypotheses described earlier (2.4.1 to 2.4.4) overrides the other. The econometric analysis used for most of the studies has mainly been co-integration[5] and granger causality[6].

2.4 Economic Development Theories

Energy focused economic theories hold that rates of energy consumption and energy efficiency are linked causally to economic growth. There are of course various factors that may affect the economic growth of a country including the levels of productivity, demographic changes, political institutions and income equality. Many studies show that there is a relationship between economic development and energy but the direction of such relationship is inconclusive (see 2.3). The inconclusive direction may suggest that there are a number of factors at work that differ significantly across countries that account for the different directions of causality. Being able to discover or identify some of these factors can help to explain the inconsistency in results and help to provide a better understanding of the relationship between energy consumption and economic development.

Factors that contribute to economic development such as human resources, natural resources, capital formation, technological development and the social and political factors are complex and based on a host of other interdependencies; thus, the next section will present the development of theories, explanations, arguments and assertions (World Bank, 2000; Todaro and Smith, 2009)) that highlight the multidimensional nature of the subject.

Previously, in the seventies, economic development was considered a good proxy for other attributes of development (Todaro and Smith, 2009) with the World Bank (2011) using GDP as an economic indicator. Although, many developing countries have experienced high growth rates of per-capita income, there has been little change in the living conditions of a large part of the population (Dang and Sui Peng, 2015).

[5] Cointegration is where the variables involved in regression move together and do not drift apart over time.

[6]Granger causality occurs where a time series can be used to forecast another time series as the previous time series have other information apart from its past values that can help predict the latter.

This subsequently led to the expansion of the development goals indicating that although, higher income is necessary, it is not sufficient in terms of quality of life (Sen 1985 as cited in Dang and Sui Peng, 2015). As such, the goals of economic development are now centred on the promotion of wellbeing rather than the promotion of growth. In essence, the growth of gross income and change are central to any developmental strategy. Some of the theories of economic development are outlined below:

2.4.1 Linear stages of growth model

This model identifies five stages of transition for a country to move from underdeveloped to a developed stage and that capital, savings and investment are essential throughout for growth to occur.

The stages include: the traditional society, the preconditions for take-off, the take-off, the drive to maturity and the age of high mass consumption. It was believed that a country has to go through all the stages logically to achieve development.
It was thought that this could only be achieved by increasing the rate of investment and (Rostow's work, 1960 cited in Dang and Sui Peng 2015) like many other accounts of growth, points to the significance of the accumulation of savings to achieve a take-off.

2.4.2 Structural change model

With this, the development process involves the reallocation of labour from the agricultural sector to the industrial sector; thus bringing an increase in economic growth. The model further prescribes that for economic growth to occur, not only should savings and investments be on the increase in the country, but also that there should be a steady accumulation of physical and human capital. It has since been noted by Dang and Sui Peng (2015) that investments in health and education alone do not guarantee development especially as it has been ascertained that in Sub-Saharan Africa, for example, life expectancy and school enrolment rates have increased dramatically in recent decades.

However as a group, the economies in the region have had slow and even negative growth since the early 1970s (World Bank, 2000). There was the assumption that the pattern of development was similar in all countries but Todaro and Smith, (2009 p.120) indicated that the pattern of development differs from one country to another. Furthermore, the development of a country depends on various factors such as the resources available, the government policies, availability of external capital and technology and the international trade environment.

2.4.3 International dependence model

This connotes situations where poor countries are said to be dependent on the developed countries for market and capital. This tends to reflect the capital system of exploitation of underdeveloped countries which cannot be self-reliant. In this instance, developing countries receive a very small portion of the benefits from the dependent relationship established with developed countries. The theory asserts that it is the unequal exchange that brings about exploitation of the less developed countries due to advice from developed countries is often biased and over-complicated. As a result, problems are not dealt with properly leading to an increase in the growth of inequality in the countries.

2.4.4 Neoclassical counter-revolution model

The aim of this model was to counter the international dependence model. Some of the approaches adopting the neoclassical counter-revolution model included the new political economy approach and the free market approach. The model demonstrates that underdevelopment is as a result of the domestic issues arising from heavy state intervention such as poor resource allocation, government-induced price distortions and corruption (Meier 2000) and not due to the predatory activities of developed countries and the international agencies. The development of the Solow neoclassical growth model hinges on the increase in labour, capital and technology as a means of improved economic development. However, this still did not produce expected results in stimulating the economic development in many African countries (World Bank, 2000).

2.4.5 New growth theory

Unlike the Solow model, the new growth theory does not consider technological change as an exogenous factor. The emphasis is that economic growth results from increasing returns to the use of knowledge rather than labour and capital. The new growth model helps to promote the role of government and public policies in complementary investments in human capital formation and the encouragement of foreign private investments in knowledge-intensive industries such as computer software and telecommunications (Meier 2000 as cited in Dang and Sui Peng, 2015).

As such, this model helps to explain the divergence in the growth rates across economies. Nonetheless, there are other factors that provide the incentives for economic growth lacking in most developing countries such as poor infrastructure, inadequate institutional structures and imperfect capital and goods markets (Cornwall and Cornwall 1994 as cited in Dang and Sui Peng, 2015). It is paramount therefore that policy-makers in such countries pay careful attention to all of the factors that determine the changes and their impacts on the aggregate growth rate.

2.5 Summary of the Chapter

In this chapter, the focus has been on reviewing various publications referring to the causality between energy consumption and economic development. Although the causality relationship between economic development and energy consumption is inconclusive, many of the studies reviewed show that the energy demand in any country is expected to be driven by various factors including the state of development of the country in question and both economic and non-economic factors. It must be noted that in this thesis, electricity being a form of energy is used more. A more detailed review of literature which explores different approaches to energy modelling will be examined in the following chapter.

Chapter 3 Evaluation of Modelling Literature

3.1 Overview of the Chapter

Chapter 2 provided a critique of the different causality relationships between energy and economic development. This chapter presents the logic of modelling and further discusses the modelling techniques that are most commonly used in energy modelling and estimation of demand for energy in developing countries. The rest of the chapter is structured as follows:-

- Section 3.3 – a review of the importance of energy modelling.
- Section 3.4 – a review of different studies that have sought to explain the determinants of energy at different levels and in various countries.
- Section 3.5 – a review of different theories associated with energy demand modelling.
- Section 3.6 – a brief examination of the previous studies on energy modelling in Nigeria.
- Section 3.7 – an analysis of the different variables that have been used in the studies considered earlier.
- Section 3.8 – an introduction into development of the conceptual framework for household energy consumption
- Section 3.9 – an analysis of the concept of the energy ladder and energy mix.
- Section 3.10 – the theoretical framework for the study.

3.2 Introduction

Since the 1970s, modelling energy has received extensive attention and many different studies have applied various techniques to predict energy consumption. The rationale for the selection of published paper is to identify the key literature published by international energy development agencies across the world as well as the most influential and reputable journals in this field.

This chapter will review over 40 of those published in various journals such as Energy, Energy Economics, Energy Policy, OPEC Energy Review, Energy for Development Environment & Policy, and Journal of Economics and International Finance.

3.3 The Use of Modelling and Forecasting in Energy Demand

3.3.1 Why modelling?

Energy is an important aspect of the economy and the timely, reasonable and reliable availability of energy supplies is vital for the functioning of a modern economy and so is the accurate analysis of energy demand. Energy modelling involves breaking down energy use and the process of consumption into its key contributing factors in order to create a simpler way to understand the complexity of real life. The main intent of energy modelling is to help explain or predict some of the events in the energy world. Such models can range from explaining simple and direct relationships between two variables or more, to a highly sophisticated analysis of the whole system (Munasighe and Meier, 1993; Bhattacharyya, 1996). Modellers usually refer to an underlying economic theory of how different factors interact with one another and this information helps them to decide the choice of the different factors that are combined to find a meaningful relationship among related variables of energy.

In these models it has been common to use related variables to energy consumption such as income, employment, price, consumer spending and the likes to specify most accurately an economic model which determines parameter values that most closely represent economic behaviour in order to produce accurate forecasts of how changes in one or more of the variables will affect the future course of others.

Although models produced are a simplified description of reality, they contain instinctive approximations that can be used to calculate and predict what might happen in the case that the system continues working in the same given conditions, or when there is a change to the conditions. It is imperative to note therefore that, any predictions made must be considered in light of the subjectivity of the modeller and the randomness of the data used. In sum, the models produced may be used to explain the process of energy consumption and the impact of the various factors to contribute to the consumption.

Energy modelling can also help capture the behaviour of an entire system by showing how key elements affect the energy supply and demand trends. Such models can also capture the impact of the energy system on the wider economy.

The energy industry is known for being highly capital intensive and has an impact on employment. Besides, energy is also deeply linked to other sectors in ways that are not immediately obvious, for example, the amount of energy needed in the production of the food we consume. Moreover, the energy industry significantly influences the vibrancy and sustainability of the entire economy – from job creation to resource efficiency and the environment. However, the energy sector's impact on the economy is greater than the sum of its parts (World Economic Forum, 2012). Most importantly, energy is a core component to nearly every type of goods and service in the economy.

Therefore, energy modelling is important as it provides insights into energy and how this might change over the years. If underestimated, it could lead to potential outages that will have a significant impact on the lives of people and the economy of such countries. Conversely, overestimation would lead to unnecessary idle capacity that translates to wasted financial resources (Kialashaki and Reisel, 2013). The result from modelling contributes to the formulation of policy and strategies that will benefit a nation's energy planning.

There is also the need to improve the understanding of energy demand and this makes energy demand forecasting an essential component of energy planning, formulating strategies and recommending appropriate policies (Bhattacharyya, 2009). Although there are a number of approaches to modelling energy demand, the econometric modelling approach is thought to have a significant advantage in terms of identifying price responsiveness of energy demand and forecasting (Dilaver, 2012).

Furthermore, policy makers will benefit from the use of accurate analysis of energy demand as this will help them to find effective ways to avoid national crises when there are shocks in world oil markets. Such analysis will also be useful in determining the appropriate levels of investment in electric power generation.

This may help countries avoid the economic drain of unnecessary investment and the threats of blackouts.

In their research aiming at the Asian developing countries, Urban et al. (2007) discovered that the use of many models are directed towards industrialised countries as they do not incorporate the main characteristics of developing countries. They advised the need for energy systems and economies of developing countries to be modelled taking account of such factors as supply shortages, poor performance of power sector, electrification and the growing trend of urbanisation. As such, an important goal of developing countries will be to adjust energy models in order to upgrade the quality of energy planning, policy analysis and management. Therefore, in this thesis, a particular econometric modelling approach is used to undertake energy modelling.

3.4 Review of Modelling Approaches on Energy

Several studies reviewed here have shown that while valuable information regarding causality relationship between energy and economic development have been provided for different countries, it is important to note that the results from many of the studies are inconclusive. Also, the results of modelling for different countries have produced varied results due to issues like the availability of data.

Davidson and Sokona (2002) asserted that scarcity of data is one of the difficulties associated with compiling information on the energy situation in sub-Saharan Africa. As shown above a later study by Urban et al. (2007) contended that most energy models for developing countries are biased towards the experience from models used in developed countries. However, there is the need for modelling to take into account the different characteristics of developing countries as the number of factors that influence the type of energy sources used by households in such countries are variant. A key challenge for developing countries is to create a systematic and reliable approach to data collection.

Other than in the cases of establishing the causality relationship (as seen in Chapter 2), there are other variables included in the modelling of energy demand in addition to income or GDP. They include *price* (Haris and Liu, 1993, Beenstock et al. 1999; Amusa et al. 2009), *temperature* (Fatai et al, 2008; Hondrayiannis, 2004; De Vita et al, 2006), *population* (Liu et al.,1991; Rajan and Jain, 1999; and Mohamed and Bodger, 2005), *rate of urbanisation* (Adom et al, 2011), and *education* (Heltberg, 2004 and Khattak et al., 2010) as can be seen in Appendix 3. More details about these and related studies follow below. Table 3.1 presents a synopsis of the literature reviewed while the details of each study is presented in Appendix 1.

Studies reviewed can be classified under four main modelling techniques namely:

- Regression
- Auto Regressive Distributed Lag
- Error Correction Model /Vector Error Correction Model
- Structural Time Series model (STSM)

3.4.1 Use of Regression

Linear regression is a modelling approach whereby the relationship between a dependent variable and some independent variables is determined. This can be a simple regression where there is only one independent or explanatory variable or multiple regressions where there are more than one independent variable. Regression uses the Ordinary Least Square (OLS) method for estimating the model parameters. Regression does not imply causality but rather it is used to estimate relationships between variables and to predict the effect on dependent variable by one or more independent variables.

Many of the studies reviewed here have used different regression approaches including Liu et al. (1993) for *Singapore*; Rajan and Jain (1999) for *India*; Harlvosen and Larsen (2001) for *Norway*; Mohammed and Bodger (2005) for *New Zealand*; Tien and Pao (2005) for *Taiwan*, Louw et al. (2008) for *South Africa*; Egelioglu, (2001) for *Northern Cyprus*; Bianco, (2009) for *Italy* and Kankal et al. (2011) for *Turkey*.

While some have solely used regression e.g. Rajan and Jain (1999), Egelioglu (2001), Louw et al. (2008), others like Liu et al. (1993), Tso and Yau (2007) and Kankal et al. (2011) have compared regression to Artificial Neural Networks which are algorithms that can that can be used to perform nonlinear statistical modelling.

The main benefit of this is that ANN is non-parametric and so was able to produce better results for the model with regard to data fitting and predicting ability hence a viable alternative to the stepwise regression model in understanding energy consumption patterns and predicting energy consumption levels.

Halverson and Larsen (2001) in their examination of the determinants of household electricity demand in Norway used a two-stage least square (2SLS) analysis on annual data (1976 to 1993). Their results showed that an increase in the number of households, the consumption of electricity per household, income, the stock of appliances and the number of rooms, were responsible for the increase in the demand of electricity in households.

Mohamed and Bodger (2005) in forecasting electricity consumption in New Zealand used various economic and demographic variables and applied a multiple linear regression model. They included GDP, electricity price and population as the variables that were most relevant for electricity consumption in New Zealand. The result showed the forecast was very comparable with the national forecast with an accuracy of 89 per cent.

In forecasting the electricity consumption in Italy, Vincenzo et al. (2009) used multiple regression on annual data from 1970 to 2007. They included GDP, price of electricity, GDP per capita and population as independent variables on electricity consumption. They found that price elasticity (i.e. the rate of responsiveness to the change in price) was limited and, therefore, pricing policy could not be used to promote the efficient use of electricity in Italy. On the other hand, changes in GDP and GDP per capita had an effect on electricity consumption.

Al-Salman (2007) in analysing the household demand for energy in Kuwait concluded that rises in price reduced demand for energy.

The research by Louw et al. (2008) in South Africa used income, the price of electricity, the length of grid connection, the number of appliances and the size of households as determinants of the demand for electricity using OLS regression.

They found that there was a cross-price elasticity of demand relating to paraffin, but that this was inelastic. In other words, there was a responsiveness in the quantity of paraffin demanded when there was a change in the price of electricity
This, of course, may have been the case as it is much easier to buy paraffin in any quantity and have it stored more readily than electricity.

In an attempt to analyse and forecast the electricity consumption in Taiwan, Tien Pao (2006) used both linear and nonlinear methods. He analysed monthly data from 1990 to 2002 on national income, population, consumer price index (CPI), GDP and temperature. Price was not included as according to the author, this was fixed by the government and very rarely changed. He maintained that population and national income had more influence on the consumption of electricity than GDP and CPI. Recent studies outlined by Tso and Yau (2007) and Maliki (2011), reported that Artificial Neural Networks (ANN) had better forecasting ability than the linear method (autoregressive–moving-average- ARMAX) because ANN could better deal with sophisticated nonlinear integrating effects.

Ubani (2013) was of the opinion that the problem of electricity supply experienced in Nigeria is as a result of the inability of energy planners to accurately forecast the effects of the various socioeconomic and physical factors that influence the electricity consumption. He undertook a study in which he tried to establish the relationship between electricity consumption and the socioeconomic and physical factors. He used secondary annual data for 21 years and included variables such as per capita income, price per unit of electricity, degree of urbanisation, population density, land area, number of residential units in state per capita, number of banks per capita, number of manufacturing industry per state, households with electricity per capita, employment rate per capita, number of markets per state and distance to the closest functional electricity power generating station.

The data were analysed using multiple linear regression and it was found that only six of the factors (degree of urbanisation, population density, number of manufacturing industries, the number of households with electricity, employment rate and distance to nearest power generating station) contributed to the electricity consumption level.

Liu et al. (1991) in their work in Singapore used multiple regression and compared it to Artificial Neural Networks (ANN). They used annual data for the period from 1960 to 1990 and included GDP, population and the real price of electricity.

The lagged term of the dependent variable was also included in the regression model but not the ANN. They found that ANN was better at fitting past data but regression was better at forecasting the future.

The research by Tso and Yau (2007) in determining the level of energy consumption across Hong Kong found that variables such as the size of the flat, number of household occupiers and ownership of air conditioning had statistically significant impact. They also compared the use of three different modelling approaches and found the use of a decision tree analysis to be more accurate than multiple regression and Neural Network Analysis. However, for nonlinear data this does not perform as well as neural networks. This also confirms that although regression may establish the causality of the relationship between variables; it will never be certain of causality.

This also supported the work by Kankal et al. (2011) who adopted the use of Artificial Neural Networks and, like Liu et al. (1993), and Tso and Yau (2007) compared it to multiple regression in modelling and forecasting energy consumption in Turkey. They used both socio-economic and demographic variables like GDP, import and export volumes and the population for the period between 1980 and 2007. They reported that ANN was better at predicting the energy consumption than regression model and the forecasts were also comparable with the official forecasts.

According to these recent studies, ANN has been useful in instances where the prior knowledge of relationships between inputs and outputs are unknown, however, the inability for such models to provide levels of significance for the parameter estimates is their major drawback. Regression approach has, however, been used as the foundation for the development of other modelling approaches, i.e. further modelling approaches have been developed using regression as a platform.

In the same vein, a more recent study has been carried out by Kialashaki and Riesel (2013) in the United States with a view to forecasting the energy demand in the residential sector. The authors used ANN and compared the analysis to what was obtained by using multiple linear regression using variables such as, GDP, household size, median household income, cost of residential electricity, cost of residential natural gas, resident population and cost of residential heating oil, which were analysed and their trends for the future were forecasted   This forecast had been made based on the historical data from 1980 to 2010 using a regression method.

A further stepwise regression method was also used in order to select the appropriate independent variables for all the possible multiple linear regression (MLR) models that were tested. The results from regression models displayed a decrease with different slopes for the different models for energy demand whereas the results from the ANN models conveyed no significant change in demand in the same time frame. Although the models showed robust outcomes when their R^2 was considered, this was not the case with forecasting with these models. The models showed different trends while their performances were at a similar level of accuracy during the test period. They concluded that there was the need for more research in order to be able to observe the accuracy of the ANN and MLR models developed in the study for predicting the energy demand.

3.4.2 Use of Auto Regressive Distributed Lag

The Auto regressive distributed lag (ARDL) model is a type of Auto regressive integrated moving average (ARIMA) model and in this case, the dependent variable is assumed to be dependent on its past value and the current and past values of some other variables. ARDL is used to capture the dynamic process of adjustment within the variables which may not be flexible to adjust to a new equilibrium in the short-run. ARDL has also been used in recent times to test for the presence of long-run relationships between economic time-series. Although such models can accommodate a general lag structure, it has the problem of not being able to successfully identify the correct relationships between the variables in data that are non-stationary as it tends to approximate the trend that may be in a dynamic data as opposed to modelling the dynamics.

Studies carried out by Bentzen and Ensgtead (2001), Fatai et al, (2003), De Vita et al, (2006), Narayan and Smyth (2005) and Amusa et al (2009) all used Auto regressive distributed lag model (ARDL) in their analysis.

Narayan and Smyth (2005) analysed the residential demand for electricity in Australia. They carried this out using the ARDL bounds testing co-integration approach. They included annual data for 31 years from 1969 to 2000 for income, temperature, price of electricity and price of natural gas in the modelling and found income and price of electricity the most important factors in the long run. The temperature was found to be significant to a small degree but gas price was not significant in the long- run.

Amusa et al. (2009) also applied ARDL approach on data for the period between 1960 and 2007 in their work on South Africa and discovered that the price of electricity had an insignificant effect on aggregate electricity demand but changes in income had an impact. However, they were then advised of the need for pricing policies that ensures that electricity prices are cost reflective and that such policies should also enhance the efficiency of electricity supply and use.

An earlier study by De vita el al. (2006) also used ARDL in analysing the energy demand for Namibia. They used quarterly data and discovered that energy consumption responded positively to changes in GDP but not to prices or air temperature. Specifically, they concluded that there was no cross-price elasticity of demand between the different forms of energy analysed (i.e., petrol, electricity and diesel).

Erdogdu (2007) also carried out a study on electricity demand in Turkey using similar variables as De vita et al. and same frequency of data but Autoregressive Integrated Moving Average (ARIMA) and found that there was limited response to the demand for electricity when there were changes in price and income. The strength of this study lies in the fact that they used local prices as opposed to international prices.

According to a previous study by Griffin and Schulman (2005), the use of international prices may result in a misleading result. This is because according to them, most consumers may not experience the world market prices due to local import duties, consumer taxation and subsidy. De vita et al. also indicated that the growth of rural electricity has no major impact on national consumption.

However, they failed to consider or reflect the impact of the growing population on increased electricity consumption.

Babatunde and Shuaibu (2009) who, in examining the residential electricity demand in Nigeria, used annual data from 1970 to 2006 for income, the price of electricity, the price of substitute and population. As in the case of Narayan and Smyth (2005), income was found to be very significant in the long-run. The price of substitute and population were also very significant in the determination of the demand for electricity, but Babatunde and Shuaibu (2009) found that, contrary to Narayan and Smyth's findings, the price of electricity was insignificant.

Reviewing the studies above showed consistency and confirmed income as being a very important determinant of consumption of energy but the price of energy may not necessarily have a significant effect on the aggregate demand for energy. This caused Ziramba (2008) in his study of residential electricity demand in South Africa to conclude that price increase alone will not discourage increases in residential electricity consumption.

Fatai et al. (2003) also ascertained that ARDL approach has the advantage of reducing potential mis-specification errors and may overlook non-stationarity of times-series data. They further concluded while comparing different approaches to forecasting the demand for electricity in New Zealand that ARDL approach is better at forecasting performance than error correction models or the Fully Modified Least Squares approach. This is due to the fact that ARDL can be applied irrespective of the number of times that differencing needs to be done to make the times series stationary.

3.4.3 Use of Co-integration Error Correction Model

Error Correction Models (ECMs) identify a long-run relationship between variables while allowing for short-run deviations from this relationship. In other words, ECMs estimate how quickly a dependent variable returns to equilibrium after there has been a change to an independent variable. ECM is useful in estimating both long-term and short-term effects of the independent variable on the dependent variable and is an effective way of characterising the dynamic multivariate interactions of economic data.

The use of ECM is to determine if there is a long run relationship between variables. The main advantage of ECM is that it estimates the correction of dis-equilibrium from the previous period and is, therefore, able to provide an adjustment process that avoids errors becoming larger in the long term. ECM is used under the assumption that there is only one co-integrating relationship. In the case of the possibility of there being multiple cointegrating vectors or relationships, the multivariate co-integration approach can be applied.

The study by Holtedahl and Joutz, (2004) in an attempt to understand the electricity consumption in Taiwan used ECM and included price of electricity as a determinant of its consumption, urbanisation (as a proxy variable to capture economic development characteristics and electricity; using capital stocks that are not explained by income), population, income, price of oil and weather. They found that there was an increase in the consumption of electricity and households in towns and cities were these were more likely to be connected to the grid than those in the rural areas. The result suggested that short- and long-term effects are separated through the use of an Error Correction Model.

This supported the finding by Al-Salman (2007) in his study on energy demand in Kuwait as the increase in consumption was also affected by the increase in income. The study also claimed that the relative price of electricity to the substitute petroleum products was inelastic in the long-run. Though their electricity demand studies have important practical applications, both advised on the need to rigorously test the model forecast that was developed. Although, there was a previous study by Bentzen and

Engsted (2001) using Error Correction Model, in Demark, their work like that of Fatai et al. (2008) for New Zealand was to compare the use of different approaches to estimating electricity consumption.

Iwayemi et al. (2010) also employed the use of the Multivariate Co-integration approach in understanding the dynamics of energy demand in Nigeria. The focus was on estimating the elasticity of petroleum products using annual data from 1977 to 2006. They included variables such as GDP, the weighted average price of petroleum products and income.

Examining the price and income elasticity of energy demand at aggregate and by-product levels, they showed that gasoline has the highest income elasticity while kerosene has the highest price elasticity followed by diesel which was more responsive to fuel pump price than to income. Consequently, they concluded that while past consumption of petroleum products has no influence on total energy demand, the previous price of petroleum influenced the aggregate demand for a petroleum product.

The main strength of this study lies in the use of fuel pump prices instead of international prices as this helps to capture the nature of the relationship between the demand for petroleum products and its price. They also took into account the time series properties of the variables used and concluded that prices and income are the major factors influencing the demand for energy in the country.

Abila (2015) also conducted an econometric estimation of the petroleum products consumption, in order to evaluate the impact of the socioeconomic factors on the consumption of same in Nigeria. The models were based on 25 years of annual data using Multiple Regression (OLS). He realised that all the petroleum products contribute significantly to aggregate consumption. This implies that the consumption of petrol, diesel and kerosene will increase along with GDP due to the growth in population and the situation of electricity generation.

Other approaches used include Vector Error Correction model (VECM) by Hondrayannis (2004) for Greece and Vector Auto Regression (VAR) as in the case of Holtedahl and Joutz (2004). A research study carried out by Liu et al., 1993 and subsequent ones by TienPao, 2006; Tso and Yau, 2007, Kankal et al.; 2011 and Maliki, 2011 used Artificial Neural Networks (ANN) in forecasting the consumption of energy. This was compared to other approaches like regression, decision tree, etc. Reports from such studies differ and although ANN and regression were found to be generally comparable (Tso and Yao.2007), most of these studies have suggested that ANN, when trained, is better at forecasting the consumption of electricity (TienPao, 2006, Tso and Yau, 2007, Kankal et al., 2011, and Maliki, 2011).

3.4.4 Use of Structural Times Series Modelling

There have been other energy demand analysis studies that have used Structural Time Series Modelling (STSM). Structural time series models are very flexible and allow for elasticities, together with a trend, which can change over time. In addition, the use of STSM allows for varying coefficients and a stochastic slope, and as such provides a very flexible way to model time-series data. STSMs incorporate stochastic rather than deterministic trend which is more general. Such studies include Hunt et al. (2003), Dimitropoulos et al. (2005) Amarawickrama and Hunt (2007), Sa'ad (2011) and Dilaver (2012).

Sa'ad (2011) in his research on South Korea and Indonesia identified energy security as a main problem with the increase in energy demand in developing countries. Whilst South Korea is an import-dependent country, Indonesia is a leading energy exporter, with the former being smaller both in geographical size and population. He observed that in spite of the co-ordinated policies and programmes by both countries to promote energy efficiency, energy consumption has been on the increase. He applied the use of Structural Times Series Modelling (STSM) on annual data set for 35 years (1973-2008) with a proxy for the underlying trend of energy demand (UEDT) in modelling energy in both countries (both for the whole economy and the residential sector).

The use of UEDT helped to reflect the different rates of technical progress, energy efficiency and the progress of other social, economic and cultural changes that may exist. He asserted that the use of a proxy for UEDT suggested that there was a wide variation of factors that affected the energy saving technical progress and he also established that energy demand is more responsive to income than price.

Broadstock and Hunt (2010) investigated the relative importance of the factors that affect the demand for transport oil in the UK, using a longer set of data than Sa'ad, (2011) (annual data from 1960 to 2007 and STSM approach). They also maintained that UEDT was very important in determining UK transport oil demand.

Similarly, Dilaver (2012) in his thesis made an attempt to explain the determinants of energy in Turkey and employed the use of Structural Time Series Modelling (STSM) on the data from 1960 to 2008. The use of STSM helped to capture the underlying trend of energy demand (UEDT) as the demand for energy is thought to be dependent on the efficiency of the appliance and the capital stock.

The UEDT is used to capture the technical changes and the efficiency of the capital stock and according to Hunt et al. (2003), the UEDT will also capture other exogenous variables that are not normally used in traditional methods and can include consumers' taste and preferences, demographic and social structure. Non-inclusion of such factors may result in biases in the estimated price and income. Dilaver noted that the STSM was able to distinguish the structural changes of demand behaviour and concluded that although the previous year's electricity consumption has an effect on current consumption, the impact of changes in prices and income in the short-run are limited.

There are other studies that have been carried out in recent times using the concept of UEDT and applying STSM approach. These includes studies by Hunt and Ninomiya (2003); Dimitropoulos et al (2005); Amarawickrama and Hunt, (2008) and Agnolucci (2010)), Broadstock and Hunt (2010) and Chitnis and Hunt (2011) but very few of such studies have been on developing countries.

The review of various studies on energy modelling shows that whilst some studies have employed monthly data in modelling energy (Haris and Liu, 1993; Halicoglu, 2007; Yan, 1998; Tso and Yau, 2007; Louw et al., 2008), some have used quarterly data (De Vita, 2006 and Erdogdu; 2007). Liu et al. (1993), Narayan and Smith (2005), Ekpo et al. (2011) and Adom and Bekoe (2012) used annual data in determining the level of energy consumption in Singapore, Australia, Nigeria and Ghana respectively. Only Tso and Yau (2007) and Louw et al. (2008) obtained primary data by carrying out surveys in collating information and used less than 30 data points in their analysis. Most data sets reflected in this review are quantitative in nature.

It is expected that this thesis will contribute to the development of a Nigerian energy policy as any estimated model generated will take into account other factors that are not normally included in energy demand modelling. This should in turn generate better forecasts that can be used for generating and distributing companies in establishing long term investment decisions.

3.5 Theories of Energy Demand Modelling

The study of energy demand modelling is of importance in identifying the factors that influence the demand and consumption of electricity. There are however various approaches to energy use and modelling, all of which are underlined by one or more of the theories below. They include sociological theory, psychological theory, educational theory and economic theory. Each of these is discussed briefly below.

Sociological theory (S) ascertains that the use of energy can be determined by physical appliances available, social norms and comfort preferences. The theory implies that people use and prefer a particular type of energy because they have ideas of what comfort and status can be achieved whereas in terms of **psychological theory (P)**, the use of energy can be affected by stimulus and according to Fischer (2008), behaviour pattern becomes more relevant the more a person can link energy consumption to specific appliances and activities.

On the other hand, the belief in **educational theory(Ed)** is that energy use is a skill that needs to be taught and learnt as this will help people take better control of the usage of energy. Energy users are of mixed ability in learning. This will, therefore, result in them having different levels of skills and understanding of the use and consumption of energy.

With **economic theory (E)**, generally, energy is considered as a commodity and price has a great impact on the demand for energy. According to this theory, the use of financial incentives may have some impact on energy-using behaviour and energy-related investments, with the size of incentive affecting the scale of response. Specifically, consumer theory tends to explain the relationship between consumers' purchasing choices and income. In this case, individuals tend to make choices under income constraints while taking into account the value placed on the consumption of energy.

There are several approaches used in the modelling of energy that have incorporated Neoclassical theory (see section 4.5.2) by suggesting that the individual's or household's taste and demand are the primary economic variables in determining the demand for goods or service. The demand for such is further influenced by the income of an individual or household and the price of the good or service.

Existing studies that are examined in this section relate mainly on the modelling of energy demand and attempts to examine factors that influence the demand for energy using variant models. The review also shows the inclusion of different data sets and the use of different variables in energy modelling; all of which influence the outcome of the modelling. Many have been found to incorporate economic theory in their modelling. A summary of the theories and associated studies are in Table 3.1.

A close observation of the studies shown in Table 3.1 suggests that about 23 per cent of the studies reviewed were purely based on economic theories while only 7 per cent were rooted in sociological theories. None of the studies solely used educational or psychological theories but a total of 86 per cent included economic theory. However, over half of the studies reviewed (52.4 per cent) were based on socio-demographic and economic factors such as income, employment status, dwelling type, size, home ownership, household size and so on (see Appendix 3).

The review of these various studies suggests that energy consumption in households is strongly impelled by sociological and economic theories. In essence, the demand for energy within households is influenced mainly by socioeconomic factors. This also indicates the interconnectedness of the different theories involved. About 12 per cent of the studies reviewed included more than two theories in their modelling.

Table 3.1 Summary of some of the studies carried out in relation to energy demand

Modelling technique	Studies reviewed			
Regression	**Author**	**Year**	**Theory**	**Type of data**
	Liu et al	1993	S,E	Annual
	Yang	1998	S	Monthly
	Beenstock et al	1999	S,E	Quarterly
	Rajan & Jain	1999	S	Monthly
	Englegiolu et al	2001	P,E	Annual
	Halvorsen & Larsen	2001	S,P,E	Annual
	Heltberg	2004	S,E.Ed	Monthly
	Mohammed & Bodger	2005	S,E	Annual
	Tien Pao	2006	S,E	Monthly
	Tso & Yau	2007	E	Monthly
	Louw et al	2008	S,E,P,Ed	Monthly
	Bianco et al	2009	S.E	Annual
	Khattak et al	2010	S,P,E,Ed	Monthly
	Kakal et al	2011	S,E	Annual
	Adom et al	2011	S	Annual
	Ubani	2013	S,E	Annual
	Abila	2015	S	Annual
	Alam	2015	S,E	Annual
	Halverson & Larsen	2001	S,P,E	Annual
Auto Regressive Distributed Lag	Dimitropolous et al	2005	E	Annual
	Bentzen & Engsted	2001	E	Annual
	Fatai et al	2003	S,E	Annual
	Narayan & Smyth	2005	S,E	Annual
	De Vita	2006	S,E	Quarterly
	Erdogdu	2007	E	Quarterly
	Halicoglu	2007	S,E	Annual
	Ziramba	2008	E	Annual
	Author	Year	Theory	Type of data
	Babatunde & Shuaibu	2009	S,E	Annual
	Amusa et al	2009	Ed	Annual

	Odularu & Okonkwo	2009	S,E	Annual
	Iwayemi	2010	E	Annual
	Ekpo et al	2011	S,E	Annual
	Kankal	2011	S,E	Annual
	Adom et al	2011	S	Annual
	Dilaver	2012	P,E	Annual
	Adom and Bekoe	2012	S,E	Annual
Error Correction model	Kulshreshtha & Parikh	2000	E	Annual
	Bentzen & Engsted	2001	E	Annual
	Fatai et al	2003	S,E	Annual
	Holtedahl & Joutz	2004	S,E	Annual
	Hondrayiannis	2004	S,E	Monthly
Artificial Neural Network	Liu et al	1993	E	Annual
	Tien Pao	2006	S,E	Monthly
	Tso & Yau	2007	S,P	Monthly
	Kakal et al	2011	S,E	Annual
	Adom and Bekoe	2012	S,E	Annual
	Kialashak & Riesel	2013	S,E	Annual
Structural Times Series model	Hunt & Nimoniya	2003	E	Quarterly
	Amarawickrama & Hunt	2008	E	Annual
	Dilaver & Hunt	2009	S,P	Annual
	Agnolucci	2009	E	Quarterly
	Khattak et al	2010	S,P,E,Ed	Monthly
	Dilaver	2012	S,P,E	Annual
	Sa'ad	2011	P,E	Annual

Source: Author’s compilation

.

3.6 Previous Energy Modelling Studies on Nigeria

The modelling of energy for Nigeria is generally carried out on an aggregate basis (Babatunde and Shaibu, 2009; Odularu and Okonkwo, 2009; Iwayemi et al., 2010 and Ekpo et al., 2011) and few have been aimed at the consumption of energy at the household/ residential level. Modelling tools from IAEA (International Atomic Energy Agency) such as Model for the Analysis of Energy Demand (MAED) and Model for Energy Supply Strategy Alternatives and General Environmental Impact (MESSAGE) are models that have been used in projecting the demand for energy in Nigeria on a scenario basis (Sambo, 2009).

MESSAGE combines technologies and fuels to construct “energy chains", making it possible to map energy flows from supply (resource extraction) to demand (energy services). Such a model can help design long-term strategies by analysing cost optimal energy mixes, investment needs and other costs for new infrastructure, energy supply security, energy resource utilisation, the rate of introduction of new technologies (technology learning), environmental constraints, and so on.

The application of MAED requires detailed information on demography, economy, energy intensities and energy efficiencies. MAED allows the breakdown of the country’s final energy consumption into various sectors: households, services, industry and transport and within each sector a further breakdown into individual categories of end-uses. Sambo (2009) established that the breakdown helps in the identification of the social, economic and technical factors influencing each category of final energy demand and that economic growth and structure of the economy are the major driving parameters in the modelling of energy. Future energy needs are linked to the production and consumption of goods and services; technology and infrastructure innovation, lifestyle changes caused by increasing personal incomes; and mobility needs. The importance of modelling to assist with forecasting of energy cannot, therefore, be over-emphasised especially as this will enable proper planning for the demand for energy by policy makers.

3.7 Variables in Energy Modelling

Energy models have been formulated using different variables such as price and Gross Domestic Product (GDP) as significant in determining the demand for electricity (Atakhanova, 2007; Narayan et al., 2007). Others have included population (Liu et al., 1993; Mohamed and Bodger, 2005) and domestic exports and population (Fung and Tummala, 1995), while yet other studies have included climatic variables (Yan 1998, Rajan and Jain; 1999, Haris and Liu; 1993). Other variables that have also been used in modelling electricity consumption include income, the price of a substitute, and length of grid connection, appliances and size of household (Louw et al., 2008).

Studies by Holtedahl and Joutz (2004) for Taiwan included urbanisation as a proxy for electricity-using equipment and Azam (2015) in his study on factors that affect energy consumption for ASEAN countries included urbanisation, foreign direct investment, human development index and real growth rate. Heltberg (2004) included education, size and composition of household, income, distance to suppliers and availability of natural resources as factors that influence the choice of fuels for households. Prasad (2006) on the other hand included the cost and availability of suitable appliances while Adom et al. (2012) considers real per capita GDP, industry efficiency, the degree of urbanisation and structural changes in the economy as other important factors that influence decisions on the use of energy). Generally, the variables that have been used in energy modelling can be grouped into two main categories- endogenous and exogenous as seen in Table 3.2.

Table 3.2 Summary of factors determining household energy choice

Factors determining household energy choice	
Categories	Factors
Endogenous factors (household characteristics)	
Economic characteristics	Income, expenditure
Household size, gender, age, household composition, education, labour	
Behavioural and cultural characteristics	Preferences (e.g. food taste), practices, lifestyle, social status, ethnicity
Exogenous factors(external conditions)	
Physical environment	Geographical location, climatic condition, Policies
Public policy, energy policy, subsidies, market and trade policies	
Energy supply factors	Affordability, availability, accessibility, reliability of energy supplies
Energy device characteristics	Conversion efficiency, cost and payment method, complexity of operation

Source: Author's compilation

3.8 Energy Ladder Model

Understanding household energy consumption, fuel choice and fuel switching behaviour are of vital importance in the search for policies to support a transition process. In developing a conceptual framework, attention is given to characteristics of households and models of energy consumption in developing countries. The framework uses energy ladder hypothesis as a starting point. With this hypothesis comes the view that fuel substitution takes place in households. The framework facilitates the estimation of household demand for energy.

Energy demand in households in developing countries is generally based on the concept of energy ladder or fuel substitution. According to Hosier and Dowd, the 'energy ladder' is a concept used to describe the way in which households will move to more sophisticated fuels as their economic status improves (cited in van der Kroon; 2013). The concept of the energy ladder model is one that shows how improvement in energy use correlates with an increase in the household income.

In essence, the energy ladder is a concept used to describe the way in which households will move to more sophisticated fuels as their economic status (incomes) improves (Reddy, 1994). This is because it is assumed that as income increases, the energy types used by households would be cleaner and more efficient, but more expensive as moving from traditional biomasses to electricity. A synopsis of the energy ladder indicates that there is a positive relationship between socio-economic level and modern fuel uptake, that fuel preferences are ordered by physical characteristics and fuel costs and that there is an assumption of complete substitution of one fuel for another.

According to the World Health Organization, over three billion people worldwide are at these lower rungs, depending on biomass fuels, crop waste, dung, wood, leaves, and coal to meet their energy needs and a large number of such are in Africa and Asia. However, as their incomes rise, it is expected that households would substitute to higher quality fuel choices, especially if in coming up the economic ladder, they use products that have technologies that use only electricity.

In addition, whilst demographic changes, economic growth, technological shifts, policies and lifestyles are among the most commonly agreed drivers of energy use and green gas emissions (IEA, 2009), the rate of fuel switching/energy demand in the households will depend more on other factors like reliability, cost of the appliance, access and availability, income and fuel prices and cultural preferences (Pachauri, 2012). With increasing disposable income and changes in lifestyle, households tend to move from the cheapest and least convenient level (fuels) to more convenient and usually more expensive ones (Dzioubinski and Chipman, 1999).

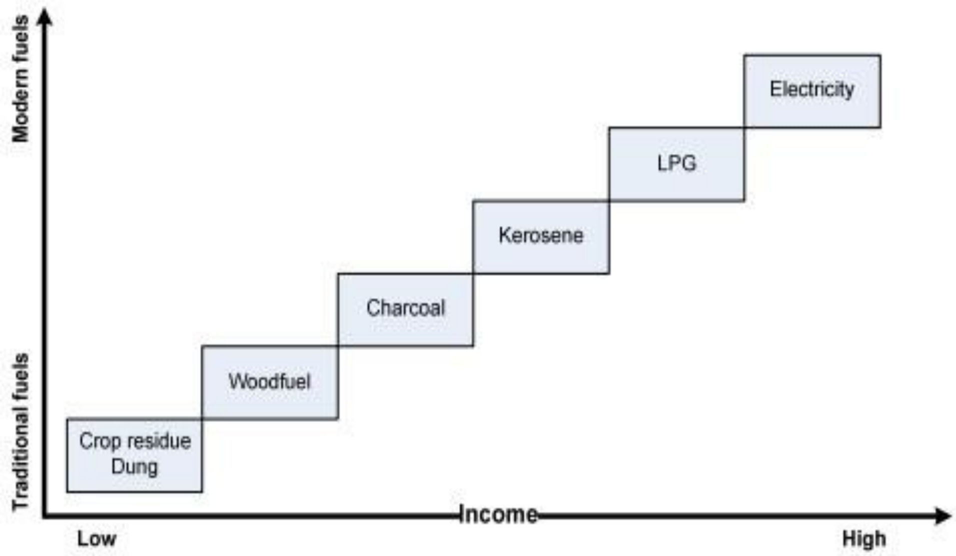
Moving to higher quality fuel will among other benefits help reduce the air pollution within the household and consequently translate to an improvement in the health of the household. This is because the reduction of air pollution within the household has the positive impact on the potential to have a direct effect on the respiratory system of the household. As such, there will be an increase in productivity with household adults missing fewer days of work and children missing fewer days of school.

The concept of energy ladder also connotes that the differences in the pattern of energy use in households vary with their economic status. Each step of the ladder corresponds to different and more sophisticated energy carriers. This relates to the underlying assumption of the energy ladder model in that it is inferred that households are faced with an arrangement of energy supply choices in order of increasing technological sophistication.

In essence, households have a disposition of energy supply choices ranging from traditional fuels such as crop waste, dung waste, fuel wood to electricity. The step to which households climb up the ladder depends on household income and the level of substitution affected by the preferences of consumers for modern fuel. The concept relies on the microeconomic theory of rational choice. This will be discussed in details in section

The concept of the energy ladder is closely connected with urbanisation and according to Montgomery (2008), urbanisation and its associated changes in energy use and consumption patterns are currently a dominant force for land use change. The shift from rural to urban lifestyles is generally accompanied by reduced reliance on traditional forms of energy. Traditional fuels are disproportionately consumed in urban areas of most developing countries. Hence the rate at which households move up the energy ladder may be as a result of urbanisation amongst other reasons. Urbanisation and energy use is discussed in more details in chapter 4 as improved insight into urban energy use is increasingly important.

Figure 3.1 Schematic illustration of energy ladder hypothesis



Source: Adopted from Holdren and Smith, 2000

Essentially there are three steps in the energy ladder;

- The universal reliance on biomass in the form of wood, dung and agricultural residues.
- The use of transition fuels for example switching to fuels such as kerosene and coal.
- The third and final phase is the adoption of fuels such as LPG, natural gas, electricity or other 'clean' sources of energy (Heltberg 2004).
- At the top of the list is electricity, while at the low-end of the range are fuel wood, dung and crop wastes. Figure 3.1 shows the relationship between income level and energy type. There is also the assumption that the energy ladder model operates both at the micro and macro levels. According to Hosier and Dowd, households at lower levels of income and development tend to be at the bottom of the energy ladder, using fuel that is cheap and locally available but not very clean nor efficient.

Hence, at the macro level, energy consumption increases with development and accompanies higher reliance on modern fuels (cited in van der Kroon et al., 2013). Cross-country comparisons also reveal a positive correlation between economic growth and modern fuel uptake, suggesting that as a country progresses through the industrialisation process, its reliance on petroleum and electricity increases and the importance of biomass decreases (Van der Kroon et al., 2013).

In addition, other factors that may influence the choice of fuels in households have been considered, given that income alone is not sufficient to determine the household consumption of a particular energy type (Heltberg, 2003). The choice of fuel for a particular use will depend on other issues not only on the price of the fuel or the income of the household but also on the availability of the fuel and the prices of the substitutes, the appliances and the efficiency of the fuel used.

3.8.1 Literature on energy ladder

As discussed above the energy ladder is a concept used to describe the way in which households will move to more sophisticated fuels as their economic status improves. According to Leach (1992), the energy ladder model (ELM) process is strongly dependent on urban size and, within cities, on household income, since the main constraints on the transition are poor access to modern fuels and the high cost of appliances for using them. The energy ladder model portrays wood as an inferior economic good, suggesting that it is a fuel for households with a lower income. Thus implying a strong correlation between income and fuel choice.

Hosier and Dowd in their earlier study (1987) on energy ladder hypothesis in Zimbabwe , using the Multinomial Logit technique discovered that contrary to the assumptions of energy ladder, households do not move away from the lower end of the energy ladder to a sophisticated form of energy (i.e., from wood to kerosene and electricity) as their economic status improves but rather that a large number of other factors such as the particular household characteristics and environment are important in determining household fuel choice. In the Tanzanian cities of Dar es Salaam and Mbeya, Hosier and Kipyonda (1993) found that neither fuelwood consumption nor the percentage of households using fuelwood varied significantly by income category.

In the study carried out reassessing the energy ladder in household energy use in Maun, Botswana, Hiemstra-van der Horst and Hovorka (2008), it was shown that consumers do not follow the energy ladder model. They do not simply switch from one fuel to another as their income improves. Instead they use multiple energy sources because the different fuels that they use are not entirely inter–substitutable. In fact, the results of the survey indicated that despite the nearly universal use of commercial alternatives, fuelwood was chosen by households across the income spectrum as a strategic energy source important for particular applications.

Odihi (2003) too in a recent study of the deforestation in Sub Saharan area used Maiduguri, which is the biggest city in the northern part of Nigeria as the study area and observed that fuelwood was preferred over other energy forms by "all members of the different classes". He further noted that there were other factors such as availability, affordability and provision of alternative energy source that contributed to the decision of a consumer to shift to another form of energy and that such decision was not solely on based on the income level.

Similarly, in Zimbabwe, Campbell et al., (2003) conducted two questionnaire surveys of fuel use by low-income households in four small towns and discovered that "even the poorest households used electricity if they had a connection" which, in some towns included "almost 100 per cent of households in all income groups". They also realised that fuel prices were not a significant variable in explaining households' choices of main fuel, but rather household incomes were significant (Leach, 1992). This means that the ability to afford fuels was not the sole reason for the difference in household choice across the income spectrum. They identified the important factors as availability and price of electricity appliances.

Masera (2000) used a four year data set obtained from a survey to evaluate the energy model in a village in Mexico and noted a pattern of household accumulation of energy options. This is contrary to the "energy ladder" model that suggests that increasing affluence brings about a progression of consumers from traditional biomass fuels to more advanced and less polluting fuels. It was also pointed out from the study that families desire to move up the energy ladder was not just to achieve greater fuel efficiency or less direct pollution exposure, but also to demonstrate an increase in socioeconomic status".

The results from the study by Farsi et al (2007) in modelling fuel choices and patterns of cooking fuel use in urban Indian households showed that although insufficient income is one of the main factors that deters households from using cleaner fuels, they concluded that several socio-demographic factors such as education and sex of the head of the household are also important in determining household fuel choice.

3.8.2 Evaluation of the energy ladder model

The energy ladder model although noted mainly for its ability to explain the income dependency of fuel choices, has been criticised as being insufficient to represent actual energy consumption dynamics (Foster, 2000). This is due to the complexities of switching process as economic aspects are linked with social and cultural issues. The energy ladder model is, however, based on certain assumptions as outlined below:

- Economic factors determine energy consumption;
- Unidirectional movement in energy consumption;
- Linear progression of energy consumption;
- Movement due to improvement in the economic situation;
- Energy consumption depends on fuel preferences.

Assumption 1: *Economic factors determine energy consumption*

Generally, economic factors such as income is used to determine and influence the consumption of energy and although the energy ladder model suggests that consumption of modern fuels are caused by increase in incomes, results obtained in this study (see Chapter 6) shows that for a developing country, this may not necessarily be the case. Social and cultural factors may also influence consumers' behaviour pattern. Other factors such as education and fuel subsidy were found to affect the level of energy consumption. The issue of other factors being responsible for household consumption has not been accounted for in the energy ladder model. Atanassov (2010) in his work on household cooking energy choice in Mozambique also asserted that fuel choice is not just determined by income but rather by a combination of different factors including socio cultural factors such as life styles, attitudes, behaviour and religion.

Figure 3.2 Energy Ladder Transition

Energy transition in developing countries: Two alternative frameworks for analysis 2013 International Energy Workshop (IEW) Source: Treiber, M. (IEA, Paris, 19 - 21 June) International Energy Agency

Assumption 2: *Unidirectional transition in energy consumption*

The model also assumes that the movement to different forms of energy is unidirectional and that it is usually as a result of improved economic circumstances. Masera (2000) advocates that the process in energy ladder model be seen as a process resulting from the interaction of various factors that tend to pull households towards the use of modern fuel and away from biofuel. It is possible though for there to be a downward movement on the ladder if for instance there is an increase in the cost of the sophisticated fuel or if there is a drop in the household income. It is important that such be taken into consideration in using the energy ladder model. Fuel scarcity is also an important consideration when discussing about energy ladder.

Assumption 3: *Linear progression of energy consumption*

The model also portrays the dynamics of energy consumption as a simple linear progression from inferior fuels like crop residue to sophisticated fuel like LPG. This is not usually the case in a developing country as households tend to use several forms of energy at the same time depending on a number of factors. They can, for instance, use electricity for lighting and kerosene for cooking family meals. In reality, energy consumption for most households will involve the partial adoption of several fuels at the same time and consumers will not necessarily choose a fuel in order to completely abandon the previous one used.

Findings by Masera et al. (2000) on a study done in Mexico confirms this as families began to use additional technology without completely abandoning the old one. Barnes and Floor (1996) declared that the model leaves little room for multiple fuel use. Such behaviour helps the families to avail the benefit of the different energy fuels at their disposal. The underpinning assumption here is the wider availability of fuels.

Assumption 4: *Movement due to improvement in economic situation*

The energy ladder model also assumes that the same path is used for going up and down the ladder. It suggests that movement in households or societies to better fuels is due to improving economic circumstances and the ability to purchase the appliances that can be used which may be costly financially. Chambwera (2004) cited Hosier and Dowd (1987) as suggesting that ELM assumes that although households behave in a manner consistent with neoclassical theory of consumer behaviour, the model is flawed as in the assumption that households move to more sophisticated energy carriers as incomes increase without being specific on the status of abandoned fuels.

Assumption 5: *Energy consumption depends on fuel preferences*

Consumers are assumed to regard some fuels better than others and this is seen as they move up the energy ladder. This is contrary to reality as households tend to keep fuels for preferred uses and at the same time continue to use other fuels. This is in order to spread the risk that may be associated with the one form of energy in terms of its availability and costs.

The energy ladder model has a strong emphasis on the role of income in determining the choice of fuel and hypotheses that as households gain socio-economic status, they tend to move away from technologies that are cheaper and start using modern technologies (Masela et al., 2000).

As above, the energy ladder concept relies on the microeconomic theory of rational choice. It assumes that all forms of fuel (traditional to modern) are available, that there is a universal set of fuel preferences, and that households will choose to move up the ladder as soon as they can afford to do so.

As above, the energy ladder model according to Heltberg (2003) also has a misleading implication that moving up to a new fuel is simultaneously moving away from fuels used. A study by Heltberg has also found that income alone is not sufficiently able to determine the household consumption of a particular energy type.

3.9 Energy Mix Model

Energy mix refers to the distribution of the consumption of the different energy sources available to a country, nation or household and therefore to meet its energy needs, each uses the energy available to it in differing proportions. The same is true for households. The energy ladder hypothesis has not been able to account for the fact that households may be using several fuels but in different proportions at any point in time.

Several studies pertaining to households' choice for cooking fuels conducted throughout the globe have disproved its applicability claiming that the observed behaviour of the households of the developing economies conforms to fuel stacking rather than fuel switching as postulated by the energy ladder model (Sengupta, 2013). This too was confirmed in the work of Kebede et al (2000) in Ethiopia when he established that location of households in addition to income levels, the infrastructure in different urban centres, availability of fuels, climate and other characteristics that vary across the urban centres may explain some of the variations in the energy demand of households and hence causing households to use multiple fuels.

Thus, instead of moving up the ladder step by step as income rises, households choose different fuels as from a menu. They may choose a combination of high-cost and low-cost fuels, depending on their budgets, preferences, and needs (World Bank 2003, Mekonnen and Köhlin; 2008). This led to the concept of fuel stacking (multiple fuel use), as opposed to fuel switching or an energy ladder (Masera et al. 2000; Heltberg 2005).

Soussan et al.(1988) in their earlier work in Mexico implied that the energy ladder model only provides a limited view of reality in households and that the issue of multiple fuel use constitutes the rule rather than the exception in many urban and rural areas of developing countries (cited in Masera et al, 2000). Masera et al (2000) also reported that households follow a multiple fuel approach or fuel stacking process as opposed to simple linear progression or switching fuels portrayed in the energy ladder model.

The energy mix has been mostly from fossil fuels and differs for each region or country. The composition of the energy mix depends on the availability of usable resources on its territory or the possibility of importing these, the extent and nature of energy needs to be met, the economic, social, environmental and geopolitical context and the political choices resulting from the above. The propensity though is for energy mix composition to change over the years due to the rate of demographic growth, changes in consumption behaviour and the rate of economic growth which may result in changes in energy needs. Households also tend to use different fuels for various tasks. They do so in order to reduce risk, spread costs or to cater for periods when particular fuels are unavailable.

Like in the case of the energy mix for a country, the energy mix for households will be dependent on a number of factors such as the availability of the different fuels, the price of the fuels, income of the household and characteristics of the household. Therefore, it is important that any framework used for estimation must reflect the fact that the amount of the different fuels used in households may be dependent on factors (such as availability of appliances (which may be determined by the availability of fuels, the cost of appliances and the price of the individual fuels) other than income.

The estimation of the demand for electricity would, therefore, be carried out within the context of the other types of fuels that are consumed by households.

Generally, people with limited income tend to purchase a group of goods or services from which they can achieve a level of satisfaction. The same is true in the case of energy where customers, following the concept of utility theory will use a combination of fuels that will give optimal satisfaction subject to the constraints of income.

The framework of the energy mix model shows that households will therefore always allocate their disposable income among the different goods or combination of goods that will maximize utility (economic theory). As disposable income is a constraint for most households in developing countries, it means that the households will determine how much of its income will be spent on energy and, in addition, will determine the amount to be spent on each of the fuels and likewise the quantity of such fuels. Couture et al (2012) studied the profile of households in France with regards to wood as a potential source of energy. They modelled the use of wood as the main source of heating energy, combined with others (fuel, electricity, gas) or as a back-up energy source and discovered the choice of the energy mix by household determines the consumption level of each type of energy. The decision to use a certain type of energy is determined by other several factors including energy prices, income and some characteristics of households such as the profession of the head of the household.

There are different combinations of fuels that make up the total energy consumption of the various households and correspondingly, the energy mix model presents the different expenditure on the different fuels. This combination may change from time to time for the different households depending on the income and other determinants of energy. In other words, this model has the advantage of allowing consumption and expenditure of energy in real terms. The model also allows changes in energy consumption to be estimated if or when there are changes to household circumstances. This enables the estimation of demand for both total energy and individual fuels.

3.9.1 Assumptions for using energy mix model

In using the energy mix model, the following assumptions are made:

- All households use a combination of different fuels/ energy use equipment over a period of time.
- Energy is a compound commodity and comprises the different sources of energy such as kerosene, liquefied petroleum gas, electricity and firewood;
- Households also allocate part of their income or expenditure to energy and further decide on how much of this expenditure will be put towards the different sources of energy.

As stated earlier, the priority of households in assigning any expenditure to the different energy sources combination is to ensure that they have maximum utility. A household expenditure may consist of three main categories namely: Food expenditure, clothing expenditure and energy expenditure. The energy expenditure is further broken into the expenditure associated with the different forms of energy: kerosene, Liquefied petroleum gas (LPG) and electricity.

The characteristics of the energy ladder model and the energy mix model provide a basis of which a framework for household energy consumption in Nigeria can be built. The energy mix model is assumed in this research as a framework to analyse and estimate the demand for electricity in Nigeria.

3.10 Theoretical Framework of Energy Consumption

3.10.1 Introduction

In this section, the theoretical framework for this research is developed and forms the basis for the analysis of energy consumption. The theory set out in this chapter aims to capture the intricacies that are involved with choices that households make in energy consumption taking into account the various socioeconomic factors that may affect such choices. It is the behaviour of consumers that determine the combination of fuels that they use and the quantities of such. The purpose of this section is therefore to develop an understanding of how consumers behave with respect to energy consumption in general and electricity in particular.

3.10.2 Concept of consumer preferences

Traditional consumer theory is concerned with how a rational consumer would make consumption decisions. Such decisions are based mainly on income constraints and the availability of the goods. In understanding the consumers' behaviour, the study is able to predict how changes occur to consumption of energy when there is a change to the consumers' social, economic environment.

The basic hypothesis is that a consumer chooses a vector of goods from a set of alternatives and does so in such a way that he maximises utility subject to budget constraint. Such consumer behaviour is presented in terms of preferences and possibilities. These preferences provide justification for the existence of demand functions (Deaton and Muelbauer, as cited by Chambwera, 2004). Under the consumer theory, the consumer is assumed to be rational and therefore in choosing the preferences is guided by some properties.

In general, neoclassical economics from which the consumer theory is derived is basically an approach in which the economy is depicted as a collection of profit maximising firms and utility-maximising households interacting through perfectly competitive markets (Godwin et al., 2013). It focuses on the determination of prices, outputs, and income distributions in markets through supply and demand. This shows that neoclassical economics operates on the basis of three main assumptions which include the fact that people have rational preferences of outcomes that can be identified and associated with values; that whilst firms tend to maximise profits, consumers maximize utility and the fact that people act independently on the basis of full and relevant information.

However, neoclassical approach regards the economy as a closed system and the theory assumes that only firms and consumers make up a system and that they interact in perfectly competitive markets where firms maximise their profits from producing and selling goods and services, and consumers, are assumed to maximise their utility from consuming goods and service. In other words, the variables of a system adjust within given constraints in such a way that a balance is produced.

The issue of consumers being rationale is a major critique of this approach and modern research in behavioural economics has suggested that the neoclassical rationality axiom does not stand up to tests of logic, experience, or the needs of society (Godwin et al, 2013).

3.10.3 Properties of consumer preference ordering

a) Reflexivity: it is assumed that any bundle is at least as good as itself i.e. for each bundle,
$X_1 \geq X_2$
b) Completeness: it is assumed that any two bundles can be compared such that for all X_1 and X_2 in X, either $X_1 \geq X_2$ or $X_2 \geq X_1$ i.e. the individual can order any two bundles. This means that individuals are able to make choices and rank their preferences for different goods and services.
c) Transitivity: the assumption here is that if $(X_1, Y_1) \geq (X_2, Y_2)$ and $(X_2, Y_2) \geq (X_3, Y_3)$, then one can assume that $(X_1\ Y_1) \geq (X_3\ Y_3)$. This ensures the consistency of preference ordering and shows that individuals are rational in the choices they make.
d) Non Satiation: In this case, it is assumed that more is preferred to less. This implies that given any set of two bundles, if one of them contains at least as much of all goods and more of one good than the other, then the first bundle will be preferred to the second.
e) Convexity: that is, any combination of two equally preferable bundles will be more desirable than these bundles. In other words, consumers prefer averages to extreme as the more you have of a particular good, the less satisfaction you receive with additional consumption of that same good.

A utility function (max U = *f*(X, Y)) will exist where these attributes are present in a consumer's preference ordering. Consumers behave to maximise utility which infers that consumers will make choices between sets of goods that will satisfy their budget constraint and yet bring about maximum utility.

The budget constraint is represented as below:

$$X=\sum_{I=1}^{n} piqi \text{ ....} 3.1$$

Where the sum of the products of price and quantities must be equal to the total expenditure X. This budget constraint combined with the principles of consumer preferences results into the utility maximization problem.

Max U (q) will be subject to Σpiqi= X.

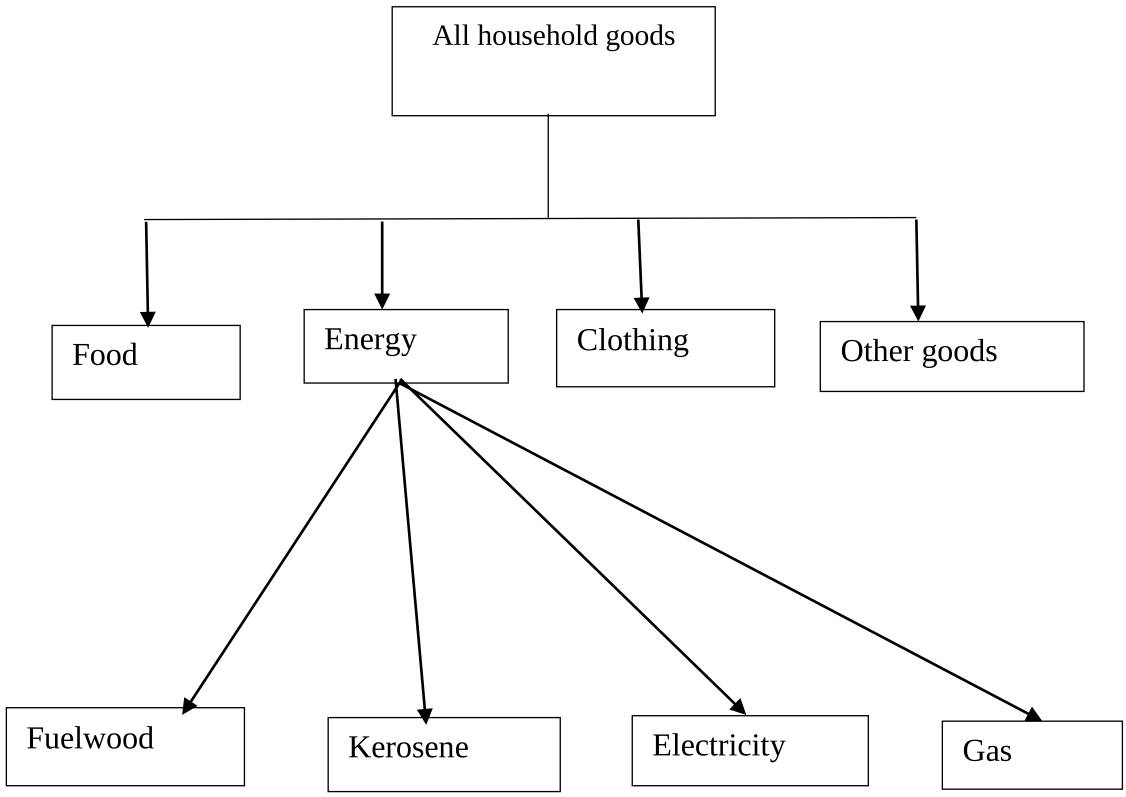
This is further reduced to Marshallian demand functions in which utility from consumption of a good or set of goods is maximised subject to expenditure and prices.

$$Qi = gi\ (x, p) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.2$$

3.10.4 Household budgeting process

This section deals with the conceptual framework developed earlier in this chapter and can be used as a basis for specifying the empirical model that will be estimated. Households usually utilise the concepts of separability and multi-stage budgeting in maximising their utility.

Figure 3.3 Concept of separability and consumer preferences



Source: Author’s compilation

Here it is assumed that just as it is possible to consume different items within the same group (e.g. bread, milk, rice, fish, and meat within the food category), it is also possible to allocate expenditure to subgroups.
In other words, there is the concept of separability of preferences where items consumed in households are put into different categories- food, clothing, energy, and other goods. The expenditure allocated to each broad group can also be sub allocated to specific commodities within the group. This multi stage budgeting helps households to determine how much of their income is to be allocated to specific items within each group and households and this can be done on the preferences of the items within the commodity group.

Traditional consumer theory is concerned with how a rational consumer would make consumption decisions and it has its particular structure which allows for economically meaningful results to be obtained. Consumer's choice sets are assumed to be defined by certain prices and the consumer's income or wealth. It analyses how consumers maximize the desirability of their consumption as measured by their preferences subject to limitations on their expenditures, by maximizing utility subject to a consumer budget constraint (Levi and Milgrom, 2004).

The intrinsic properties of particular goods are however omitted from the theory and therefore as all goods are the same to all consumers, as the taste or preferences of consumers do not come into play (Lancaster, 1966). Accordingly, Lancaster criticises the fact that consumer theory is incapable of dealing with complementarity, substitution, independence and neutral want association within the conventional framework. Goods are therefore according to Lancaster (1966), not the direct objects of utility but instead it is the properties or characteristics of goods from which utility is derived. The assumption therefore is that the characteristics possessed by a good or combination of goods are the same for all consumers and it is these characteristics that brings about the utility that is derived. It is only by moving to multiple characteristics can the intrinsic qualities of individual goods be incorporated.

In the energy mix model examined, energy is taken as one of the household consumption goods and this energy can then be further divided into the different fuels. In the first instance, households decide what amount of their income to allocate towards the energy component of their consumption and a further decision is made as to how much of their energy budget to be allocated to the individual fuels. It can be assumed that households use a two-stage budgeting process (see Figure 3.2) based on the energy mix model considered in this study. These decisions are made in line with the consumer demand theory described above.

The different fuels or food combination are chosen with the aim of maximising the utility derived from such combination whilst still being subject to a budget constraint. The demand for electricity is, therefore, considered in a system that includes other sources of energy.

3.11 Summary of the Chapter

Most of the literature reviewed in this chapter used the econometric approach to modelling. Nearly all the literature reviewed with reference to Nigeria have found mainly income and price of energy as important contributors to the demand for energy. Some of the studies have included and found other variables such as consumer price index, the price of a substitute, population, industrial output and employment useful in determining the level of energy consumption. Clearly, as seen, most of the modelling approaches considered have limited the inclusion of determinants of energy to economic factors as indicated by the different theories that influences energy modelling.

However, only very few of the studies have been able to capture the effects of non-economic factors including the efficiency of appliances used in the case of a developing country like Nigeria. This is usually accommodated by the stock of capital in models looking at energy consumption from this perspective. As noted by Odularu and Okonkwo (2009), energy efficiency is an indispensable component of any effort to improve electricity productivity and it will also bring about a reduction in the energy necessary to provide energy services such as lighting, cooking, heating, cooling, transportation and manufacturing.

Furthermore, Ekpo et al. (2011) ascertain that because electricity products have special characteristics, there is the need to use special models for estimation and forecasting. Part of the motivation for this research is, therefore, to identify the effects of the different factors on household energy demand and, therefore, this thesis will investigate efficiency as a part of the underlying factors that contributes to the consumption of energy within the household sector

A detailed analysis of secondary data using an identified modelling approach (including some of the variables identified in the various studies reviewed in this chapter) will be discussed in Chapter 8.

It is, however, important to examine alternatives to approaches that are economically based on the fact that the use of econometrics approach is associated with economic theory and the use of models requires a long run of quantified historical data in order to function. Obtaining such data may not be easy as identified in the case of Nigeria. More so, there is no doubt that econometrics is subject to important limitations, which stem largely from the incompleteness of the economic theory and the non-experimental nature of economic data. Two of such alternative theories are the focus of the latter part of this chapter. This includes the conceptual framework using the energy ladder model.

Following this, the approach of energy mix model has evolved to show electricity as a part of the household mix with other sources of energy being considered. Furthermore, the household energy mix is seen to be influenced by different factors such as household size, income, the price of fuel, availability and so on. The various hypotheses generated from both the energy ladder model and the energy mix will be considered in the methodology chapter.

Chapter 4 Urbanisation and Energy Consumption

4.1 Overview of Chapter

It is vital to understand the dynamics of energy consumption in both the semi-urban and urban areas in Nigeria in order to manage the demand for energy and minimise the energy crises that occurs in this developing African country. According to the World Bank (1993), the causes of the energy crisis in Nigeria, in particular, has been attributed to factors such as the inadequacies of the energy supply, distribution, improper energy pricing policies and the inconsistent planning system.

This issue is also associated with the fact that the peculiar characteristics such as the rate of urbanisation and the existence of informal economy of the country are not taken into account in the course of analysing the demand for energy. As such, analytical tools for energy policies in developing countries have not been successful in achieving their goals.

This chapter sets out to:

- Section 4.1 – examine urbanisation process and its impact on energy consumption
- Section 4.2 – offer an understanding of urbanisation in relation to energy use
- Section 4.3 – examine the role of the informal economy in the consumption of energy

The lack of sufficient reliable data is also an issue that has contributed to the inconsistent planning of energy use. As such, against the background that households are the largest consumers of energy in the Nigerian economy, it is expected that a framework for household energy demand is developed.

4.2 Urbanisation and Energy Use

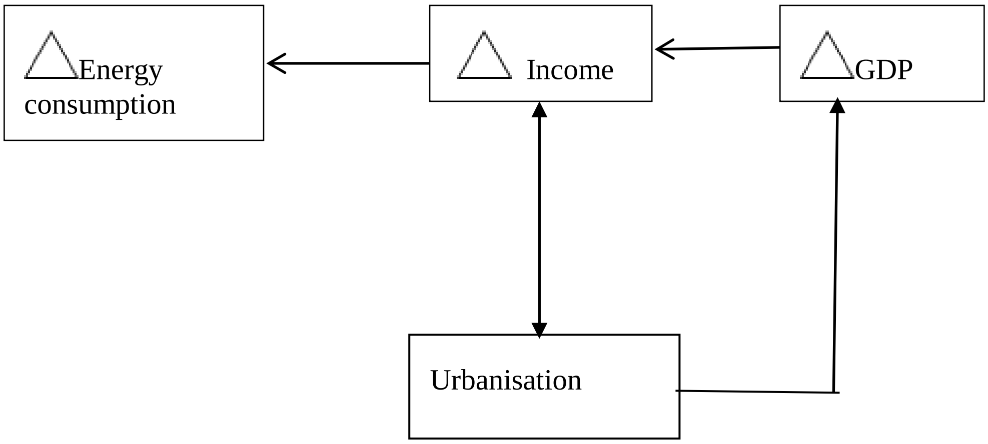
Urbanisation, which is the process of rural settlements becoming urban reflects aggregate population growth in cities through either natural population increase or migration and is inextricably linked with development (Galea and Vlahov, 2005; Glaeser, 2013). Developing country cities are growing far more rapidly than those in the developed countries and urban population growth is generally far more rapid than total population growth (Todaro et al, 2011).

Urbanisation which may be driven by local and global economic and social changes is according to Montgomery (2008) a major demographic trend in much of the world. It is generally a product of modernisation and industrialisation and as reported by Hardoy et al., 2001 citied by O'Neil, 2012) it potentially has major consequences for the wellbeing of consumers, development and the environment. Yet it is only beginning to be explicitly incorporated into long-term scenario analyses of energy and emissions. Urbanisation itself increases energy-use (Couture et al., 2012) and, therefore, knowing more about how urbanisation affects energy-use can give some ideas about where energy policymakers could focus the attention. In some instances, though, urbanisation per se may not necessarily worsen energy consumption or demand. It very much depends on the policy response direction of urbanisation.

Therefore, in order to estimate the impact of urbanisation on energy demand, Madlehar and Sunak (2011) advised of the need to identify the different processes and mechanisms of urbanisation that substantially affect urban structures as well as human behaviour. They indicated that various mechanisms of urbanisation within the different sectors of the economy led to a substantial increase in urban energy demand and to therefore to a change in the fuel mix in some instances.

Therefore, urbanisation, when accompanied by economic development and increasing incomes, tends to lead to a change in consumer needs, (Figure 4.1) which results in increasing energy consumption.

Figure 4.1 Relationship between energy use and urbanisation



Source: Author's compilation

Their analysis also shows that income effects on urban and rural household consumption patterns are crucial to understanding the evolution of household energy demand, and demand for other good. With urbanisation, as the city population grows, the demand for goods and services increase thereby causing prices of such to increase. This increase may cause an increase in the GDP of the country as more money is used to purchase goods and services provided. An increase in GDP may also lead to further development of the nation which in turn requires more energy consumption for the development (see conservation hypothesis discussed earlier in 2.3.1).

Consequently, this may lead to increase in the income available for households to spend on suitable appliances for the consumption of electricity. This in turn brings about significant economic and environmental effects on cities and surrounding areas. The impact of urbanisation is also an important factor that affect the change of total energy consumption. (Liu, 2009).

It is also important that there is a better understanding of the relationship between urbanisation and energy consumption as this will also enable decision makers at various levels to address energy security and sustainable development.

Urbanisation is, therefore, important for energy policy and planning and plays an important role in "energy transition" (Leach, 1992).

The observation suggests that the process of economic development is generally accompanied by a shift within developing country households and towards an increasing use of modern fuels and decreasing reliance on biomass. Urbanisation is a major contributor in energy consumption, and as O'Neil et al. (2012) found that its effects are primarily due to the influence on economic growth and that there was a rapid transition away from traditional fuel use as incomes grow.

This currently may not be the case in sub-Saharan Africa, where only 46 per cent of the urban population uses electricity in comparison to 15 per cent of the world urban population that still lack access to electricity (IEA, 2010). Ebohon et al (2000) also stated that the increasing rate of urbanisation in sub-Saharan Africa has stretched its energy infrastructure to the limit. Furthermore, approximately, 70 per cent of those in developing countries use liquid fuels such as kerosene or bottled gas for cooking and heating (UNDP/WHO 2009).

In exploring the relationship between urbanisation and energy consumption in China, Liu (2009) found that there exists only a unidirectional Granger causality running from urbanisation to total energy consumption both in the long run and in the short-run. The concern according to Pachauri (2012) is that continuing urbanisation might result in growing numbers of urban poor without access to modern forms of energy and deterioration in the quality and reliability of energy services available to them. Furthermore, uncontrolled urbanisation, as evident in many developing countries exerts considerable pressure on land, housing and social and physical infrastructure leading to the spread of slums, only if is unanticipated and planned for.

Consumption of energy is also according to Adegbulugbe and Akinbami, (2009) expected to increase with the increase in population and urbanisation and, therefore, the need to have information on the utilisation pattern and factors driving consumption of urban household energy. According to Ebohon et al, (2000), one of the unique features of the influence of urbanisation on energy consumption is in the fuel use pattern where clear shifts from traditional energy to modern or commercial fuel have occurred because of the suitability of such fuels for specialised urban facilities.

The growth rate of urbanisation in Nigeria between 1970 and 1980 was between 16 and 20 per cent but by 2011, about 49.6 per cent of the total population was estimated to be living in urban areas while the rate of urbanisation is estimated as 3.75 per cent (2010-15 est., Index Mundi, 2011). The average weighted regional urbanisation rate in West Africa is greatly influenced by Nigeria which accounts for half the region's total population. Although there has been a tremendous increase in urbanisation over the years, the proportion of urban residents without electricity has also increased. Between 1970 and 1990, the number of urban inhabitants without electricity in Africa increased from less than 40 million to 100 million as reported by Karekezi and Majoro (2002).

There are different factors that contribute to the urbanisation of an area such as economic growth, policy changes. According to O'Neil et al. (2012), population, household size, household structure and the age composition of the population were found to be significant factors in determining energy use. However, changes in urbanisation have a less than proportional effect on aggregate emissions and energy use. This is due primarily, to an economic growth effect driven by the increased labour supply associated with faster urbanisation. However, they also acknowledged that income has a strong influence on household energy consumption and this stipulates a rapid transition to household consumption of modern fuels like electricity and gas from traditional fuels. Normally, this would be the case but the transition is often exaggerated owing to scarcity of modern fuels.

They also inferred from their study that the effects of income on household consumption patterns is crucial to understanding the evolution of household energy demand, and demand of other goods. These effects have particularly important consequences for the potential speed of the transition away from traditional fuels and toward modern fuels.

There are however inter-country variations in the energy transition process which as asserted by Arimah and Ebohon (2000) are due to the level of urbanisation and the extent of forest and woodland resources. Furthermore, in their study relating to energy transition effects on sustainability in Africa, they informed that whilst the nature, pattern and factors that affect energy transition in some regions like Southeast Asia are known with a high degree of certainty, this is not the case of those in Africa. Nigeria, of course, for example is considered as a net exporter of energy and therefore, may have comparative advantage in the development of commercial sources of energy, resulting in faster transition to use of commercial fuels.

Although energy use patterns in developed and developing countries differ considerably, the evidence on urban energy use in developing countries suggests that it is common practice for poor urban households to use a mix of fuels for different end uses and to switch when fuel prices or household incomes change (Pachauri and Jiang 2008).

4.3 Informal Economy and Energy

The informal sector according to Sparks (2010) was "discovered" in the early 1970s and represents the dominant share of many sectors across the continent, especially in manufacturing, commerce, finance and mining. The informal sector manifests itself in different ways in different countries, different regions within the same country, and even different parts of the same city. It was not until 1993 that the ILO (International Labour Organisation) provided a statistical definition of the informal sector suggesting that "The informal sector may be broadly characterized as consisting of units engaged in the production of goods or services with the primary object of generating employment and incomes to the persons concerned."

The economic impact of the informal sector is hard to measure because of the difficulty in defining and analysing the phenomenon owing to the limited available information outside the macro-economic regulation of the government. The informal sector is the part of an economy that is not taxed, monitored by any form of government, or included in any gross national product (GNP), unlike the formal economy. In developing countries, some 60per cent of the potential working population earn their living in the informal sector.

The informal economy refers to all economic activities by workers and economic units that are not covered or are insufficiently covered by formal arrangements and includes barter of goods and services, mutual self-help, odd jobs, street trading, and other such direct sale activities (Akintoye, 2006). Usually the income generated by the informal economy is not included in Gross Domestic Product calculation as the income is often not recorded for taxation purposes. Charmes (2000) argues that informal economy continues to grow as the bulk of new employment in recent years, particularly in developing countries and transition countries.

Indeed, reports from African Development Group Bank (2013) suggests that the informal economy comprises half to three-quarters of all non-agricultural employment in developing countries and it contributes about 55 per cent of Sub-Saharan Africa's GDP and 80 per cent of the labour force. The sector accounts for about 21 per cent of total employment in Sub-Saharan African countries (ECA, 2005).

4.3.1 Characteristics of informal economy

The informal sector is continuously expanding in developing countries and characterised by a lack of protection in the event of non-payment of wages, compulsory overtime or extra shifts, lay-offs without notice or compensation, unsafe working conditions and the absence of social benefits such as pensions, sick pay and health insurance (Onyebueke and Geye, 2011). Generally, the main reasons for participating in the informal sector range from pure survival strategies undertaken by individuals facing a lack of adequate jobs, unemployment insurance or other forms of income maintenance, to the desire for independence and flexible work arrangements and, in some cases, the prospect of quite profitable income-earning opportunities, or the continuation of traditional activities.

Although the informal sector presents the opportunity for the workers to generate income, this is not secured for most workers who are often without employment benefits and social protection.

Ncube (2013) identified that the prevalence of informal activities is closely related to an environment characterised by weaknesses in three institutional areas, namely taxation, regulation and private property rights. This is because of higher taxes and complicated registration process, limited access to technology, poor infrastructure, and lack of training which prevent informal sectors from formalising their activities.

However, the energy use of the informal sector is limited by capital limitations and as established by Hosier (1991) in his study of the informal sector in Tanzania, energy efficiency follows capital intensity in the formal sector to a certain extent. He also identified that the energy-use patterns of the informal sector differ in the same way as the overall energy consumption patterns. The government must indisputably find ways to encourage the development and growth of the sector providing better access to financing and improving access to information.

Specifically, there is the need to establish an enabling environment and supportive regulatory framework that help provide access to appropriate training, improve basic facilities, amenities and infrastructure, increase the ability to obtain property title and access to credit, and improve national databases and establish uniform standards (Sparks and Barnett, 2010).

4.3.2 Informal economy in Nigeria

The informal sector in Nigeria refers to economic activities in all sectors of the economy that are operated outside the confines of government regulation. Nigeria has the largest informal sector in Africa; this stems from its stupendous population and decades of high unemployment rate. An attribute of the informal sector in Nigeria is the fact that the sector has a broad spectrum of activities that cuts across the entire segment of the economy. Such activities include: manufacturing, construction, repair of cars and cycles, transportation whole sale and retail among others.

As reported by Nwaka (2005), information on the size and employment structure in the informal sector is hard to obtain, but estimates suggest that the sector accounts for between 45 per cent and 60 per cent of the urban labour force with job creation in the informal sector may be averaging 25,000 to 35,000 a year (Fapohunda, 2001).

Activities within the informal sector in Nigeria had been on the increase since the Structural Adjustment Programme (SAP) in 1986. According to Magbagbeola, this sector may be invisible, irregular, parallel, non-structured, backyard, underground, subterranean, unobserved or residual (as cited in Folawewo, 2006). Nevertheless, informal economic activities in Nigeria encompass a wide range of small-scale, largely self-employment activities and is found in the productive, service and financial sectors.

These include financial and economic endeavours of a subsistence nature, such as retail trade, transport, food section, repair services, financial inter-mediation and household or other personal services. About 50 per cent of the informal sector economy comes from wholesale and retail, but the informal sector in Nigeria has also been noted to have age and gender differences. The construction sector, for instance, is dominated by male (65 per cent) while in the manufacturing sector (food, beverages), the predominant workers are female (58.5 per cent). In addition, Abumere et al, (1998) in their work asserted that the dominant age cohort in the sector accounting for over 50 per cent of the workforce is the 20 - 40 year group (as cited in Onyebueke and Geyer, 2011). The sector constitutes 38 per cent of the Gross Domestic Product (GDP) in Nigeria (FOS, 1999) and comprises about 69 per cent of all informal manufacturing activities. This sector may be invisible, irregular, parallel, non-structured, backyard, underground, subterranean, unobserved or residual.

Informal economic activities in Nigeria encompass a wide range of small-scale, largely self-employment activities. Most of the informal sector activities are traditional occupations and different methods of production (Akintoye, 2006). Though Nigeria does not, at present, have accurate statistics on the proportion of the labour force in the informal sector, the CBN/NISER/FOS survey of 1998 indicates that informal manufacturing enterprises are small (Onwe,2013).

The activities in the informal sector in Nigeria although are difficult to measure, but are highly dynamic and contribute substantially to the general growth of the economy. The sector can be seen as better placed to absorb unutilised resources which the public sector and the organised private sector are not willing or able to use.
The informal sector contributes significantly to the national economy in terms of output and employment and therefore, it is vital that the government encourages and empowers the informal sector through the provision of conducive policy and physical conditions.

As reported by Onwe (2013), the informal sector has the potential to provide the needed incitement for employment generation as a result of the ongoing economic and financial crisis that characterises the economies of Nigeria and many other African countries. As such, Yusuff (2011) has advised of the need to integrate informal economy in the equation of economic development despite the limitations on data collection in developing countries as qualitative analysis of the informal economy is plausible. The development of the informal sector as suggested by Nwaka (2005) follows closely the general pattern of urban development in Nigeria. In essence, each phase in the development of Nigeria's cities and the economy has its own dynamics in informal sector development. It is relevant therefore to have an understanding of the behaviour of consumers in their energy use, particularly in light of the findings that highlight the relevance of urbanisation and the contribution of the informal sector to the economy.

4.4 Summary of the Chapter

The issues of urbanisation and informal economy have been discussed especially as the informal economy contributes over 35 per cent of the country’s GDP and almost 60 per cent of the urban labour force. Studies have also shown that income effects on urban and rural household consumption patterns are crucial to understanding the evolution of household energy demand, and demand for other goods. These will be seen to contribute to the understanding of the linkages between economic activity and the energy environment.

The rest of this study will, therefore, concentrate on exploring the energy use and demand within a developing country and making an analysis of household energy demand and consumption within the context of the conceptual and theoretical framework developed in the last chapter.

Chapter 5 Research Methodology

5.1 Overview of the Chapter

In this chapter, the issues about the methodology used in this thesis are discussed. This methodology relates to the data selection, the procedure in selecting the sample and the actual sample itself.

The chapter describes the general methodological assumptions underlying the use of the secondary data in quantitative approach and highlights the difficulties of obtaining detailed and reliable secondary data in the case of Nigeria. To overcome the shortcomings of secondary data the thesis offers the need of using a mixed approach. A combined approach is adopted, where the aim is to provide explanation and prediction while checking the results against what actually happens. In addition, the overall strength of such a mixed approach will be greater than either qualitative or quantitative research.

The rest of this chapter covers the following:

- Section 5.2 – offers a discussion of the various theoretical approaches
- Section 5.3 – narrows down the approaches to the ones that are appropriate to this study
- Section 5.4 – reviews the use of a mixed approach this thesis and the benefits of such outlined.

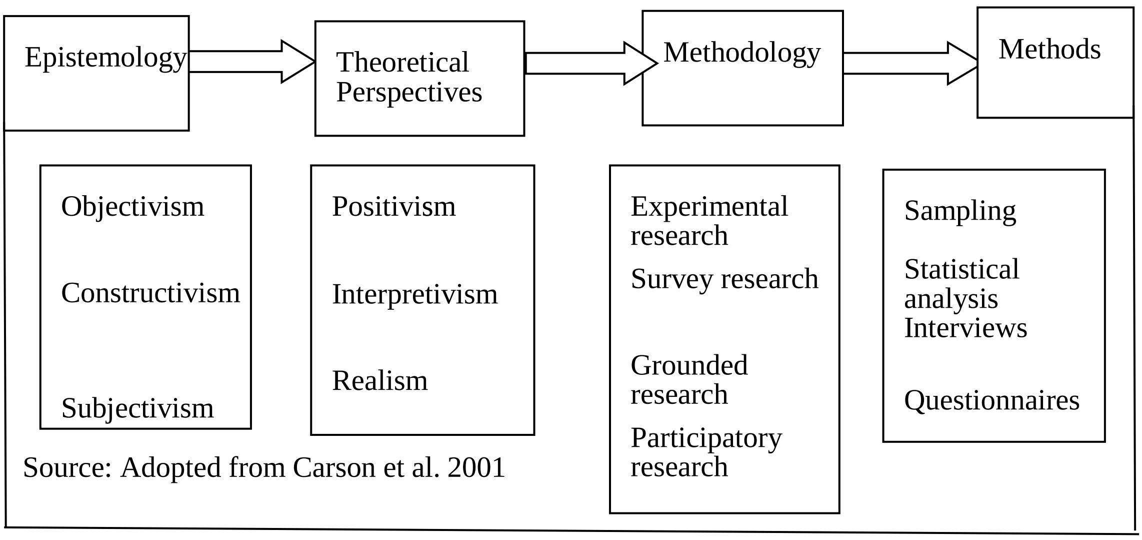
5.2 Introduction

The research was set out to develop a coherent and sustained way of analysing energy demand in developing countries. The research involved the study of the trends and patterns in energy demand and consequently identifying the factors that cause or influence the consumption of energy in households. The studies for the research were carried out using a variety of tools which included both quantitative and qualitative approaches and primary and secondary data. Energy data collection and analysis were then identified and reviewed to assess the impact of such information on consumption of energy. As seen in Figure 5.1, the methodology chosen in a research depends on what theoretical perspective of the researcher.

It is, therefore, the aim of this research, to formulate a methodology that aids in identifying the various factors that contribute to energy consumption in households. The objectives will, therefore, include the following:

- To evaluate the relationship between energy consumption and economic development.
- To identify factors affecting energy consumption in the economy in general and in the household sector in specific.
- To critically evaluate theories of economic development and urbanisation and assess their underlying assumptions in explaining energy consumption in the residential sector.
- To assess the validity of identified factors in explaining energy consumption behaviour using secondary data.
- To develop a conceptual framework to estimate the behaviour of households using socio-economic factors.

Figure 5.1 Theoretical approaches in Methodology



Source: Adopted from Carson et al. 2001

5.3 Philosophies of Methodology

5.3.1 Introduction

Undertaking a research process usually requires engaging with theoretical perspectives at some stage. It also involves examining the range of theoretical perspectives in order to determine which one is most appropriate for this research. The table 5.1 shows the relationship between epistemology, theoretical perspectives, methodology and research methods.

Characteristics of the two main philosophies - Positivism and Interpretivism from the theoretical perspectives (as seen in figure 5.1) will be considered in this study as they relate to this research.

Positivism is seen in this research in the use of secondary data from various publications which are then analysed statistically in order to determine the factors that contribute to the consumption of energy in the household (see 7.2.4). In order words, the research partly focuses on the use of positivism philosophy whereby the model obtained by using the determinants will show a pattern of cause and effect. On another hand, the research uses the opinion of interpretivists as unstructured interview and questionnaires are used to obtain information from consumers. These information presents the opportunity to understand and interpret the meaning in human behaviour (see 8.4-8.5).

Epistemology in a sense brings about the grounds of knowledge and relationship between reality and research. It is the philosophy of knowledge or of how we come to know. The Epistemology and methodology are intimately related: the former involves the *philosophy* of how we come to know the world and the latter involves the *practice* (Gray, 2014).

Within epistemology are two main theoretical approaches:

5.3.2 Positivism

Positivism is of the opinion that social interaction is based on unpredictability, action and consciousness and therefore, any inquiry should be empirical (Gray, 2014). In this sense, the inquiry will be based on quantifiable observation that results in statistical analysis. It assumes a scientific approach to the development of knowledge.

This assumption underpins the collection and understanding of the data. Positivism also attests to the essence of having general patterns of cause and effect that as such can be used as a basis for predicting and controlling natural phenomena. The goal is to discover these patterns with the purpose of simply being to adhere to what can be observed and measured.

5.3.3 Interpretivism

Interpretivism, on the other hand, is concerned with the collection of data and uses methods such as unstructured interviews and participant observation that provide the sort of data required. In this way, it is claimed that the behaviour or a pattern can be established. It is crucial though according to Carson et al (2001) for the interpretivist researcher to be empathetic. Accordingly, interpretivists tend to avoid rigid structural frameworks such as in positivist research but rather adopt a more flexible research structures which are receptive to capturing meanings in human interaction (Black, 2006) and make sense of what is perceived as reality (Carson et al., 2001).

Therefore, the goal of the interpretivist research is to understand and interpret the meanings in human behaviour rather than to generalize and predict causes and effects (Neuman, 2000). In other words, the research focuses on the human interpretations of the meanings perceived in phenomena and events, rather than the events themselves.
A summary of the various theories and the analytical framework considered in this thesis can be found in Table 5.1 below:

Table 5.1: Analytical Framework: Methodology and Theory

Dependent variable:			
	Economic	***Energy Ladder***	***Socioeconomic***
	Underlying Theory	Underlying Theory	Underlying Theory
Residential electricity consumption	Chapter 7:-Consumer theory Purpose: to identify the determining factors of electricity consumption	Chapter 8:- Energy ladder model Purpose: to see if changes to fuel consumption responds only to economic factors	Chapter 9:- Purpose: to see how well energy consumption can be predicted by the responses to questions
Independent variables	-GDP, price of electricity, price of gas, price of kerosene and fuel subsidy	Income, wealth and price of fuel	Income, price of electricity, price of kerosene and price of gas
Non-Economic/Social factors			
	Rate of connectivity to the grid		Age, number of appliances, education, gender, ownership status, housing type and household size
Exogenous factors			
	Location of property ,reliability of fuel and availability of fuel		

Method of analysis	Quantitative: Multiple regression (Chapter 7)	Qualitative: Survey (Chapter 8)	Quantitative: Ordinal regression (Chapter 9) Qualitative: Survey (Chapter 8)
Hypotheses testing	Chapter 4:- ***Hypothesis 1*** Relationship between energy consumption and factors must be statistically significant.	Chapter 5:- ***Hypothesis 1*** The move to cleaner and more sophisticated fuel is solely dependent on the positive change in income of households.	Chapter 10:- ***Hypothesis 1*** Coherence of the households' consumption of energy operations is positively associated with various socioeconomic factors
	Hypothesis 2 Consumer chooses a vector of goods from a set of alternatives and does so in such a way that utility is maximised subject to budget constraint	***Hypothesis 2*** Assumption of complete substitution of one fuel for another. ***Hypothesis 3*** Movement to different forms of energy is unidirectional.	***Hypothesis 2*** The effects of any explanatory variables are consistent or proportional across the different thresholds.

Source: Author's compilation

5.4 Mixed Method Approach

The methodology focuses on the specific ways that methods are used to understand issues better. The approaches in this study are categorised as using a survey/questionnaire to obtain primary and secondary data using econometric modelling methods. This study investigated the use of different approaches to estimate energy demand in developing countries. Although, either of the approaches (Positivism and Interpretivism) discussed has its own advantages and disadvantages, both approaches have become associated over time with specific data collection techniques and ideas regarding the purposes of empirical research.

This study has adopted the use of the triangulation research-a combination of both approaches. That is an approach of enquiry that combines or associates both qualitative and quantitative forms to ascertain philosophical assumptions. The reason for this is because the overall strength of such a mixed approach is greater than either qualitative or quantitative research (Creswell and Clark, 2007). In addition, any research method chosen will have inherent defects, and the choice of that method may limit the conclusions that can be drawn. It is, therefore, important to obtain substantiating evidence from an array of methods.

The next section describes the various modelling approaches that are generally used in instances such as the one in the thesis.

5.5 Modelling Approaches

Various models have also been employed in predicting energy consumption. Such models have been classified using different criteria. Two main types of analytical classification include the top-down approach and the bottom-up approach (Swan and Ugursal, 2009). There are major variations between these main approaches.

The top-down approach focuses on an aggregated level of analysis and applies econometric techniques and macroeconomic theory to historical data. In other words, the top-down approach evaluates the system from the use of aggregate economic variables. This approach is essentially the breaking down of a system to gain insight into its compositional subsystems.

This approach tends to capture market interaction and economic feedback between the energy sector and other economic sectors but does not capture changes in technology (Kung, 2012).
The bottom-up allows for simultaneous investigation of component parameters to energy demand and deals with micro level data. This approach identifies the homogeneous activities or end-uses for which demand is forecast (Bhattacharyya and Timilsina, 2009).

The bottom-up modelling approach captures technology and provides a detailed description of the energy system. The approach assumes that although there may be an interaction between the energy sectors and other sectors of the economy, such interactions are negligible. Bottom-up models usually concentrate on the demands for the different energy services to piece together of systems to give rise to more complex systems.

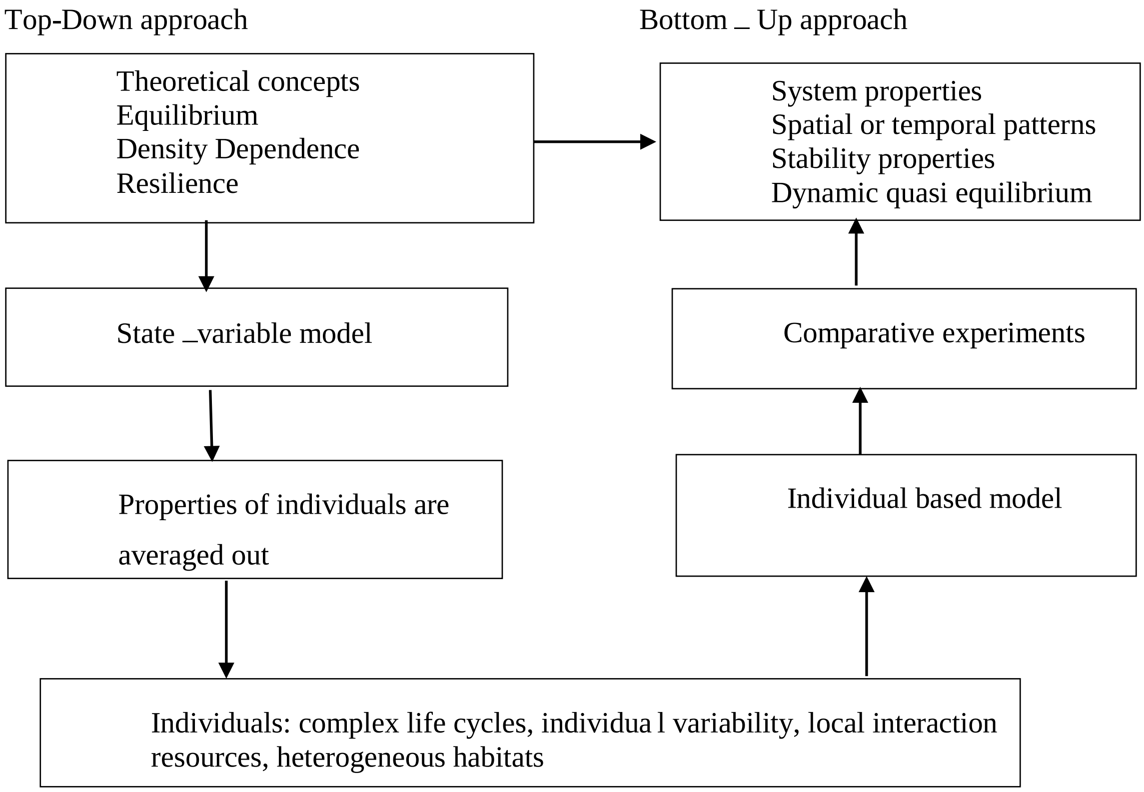
According to Ryan and Plourde (2009), there is no single correct approach to energy demand modelling. The three main groups used in energy demand are discussed below and includes the end-use (engineering) approach, econometric modelling approach and hybrid approach. A summary of these features is outlined in Table 5.2.

5.5.1 End use approach

The end use approach is based on estimating energy demand in various sectors using the information obtained through energy surveys, technical papers and energy audits. According to Bhattacharyya and Timilsina (2009), the end use approach does not rely on focusing on the determination of goods, outputs, and income distributions in markets through supply and demand (neo-classical economic theory) but rather it uses recent structural and technological developments that have occurred. This approach includes the evaluation of the social, economic and technological factors in order to identify the interrelationships between such factors. This approach also tends to be more generic in nature (Bhattacharyya, 2011).

The main strength of this approach is that it is easy to incorporate anticipated changes in technology and policies as the model represents end uses and associated technologies.

Figure 5.2 Top-down vs. Bottom-up approach to modelling energy



Source: Adopted from Wainwright and Mulligan, 2013

Another advantage of this approach is that these approaches are relatively easy to develop based on the limited information provided by macroeconomic indicators. One of the weaknesses of this approach is the use of limited data which means that the level of disaggregation is often not supported by data. The other downside of the end use approach is the fact that it does not generally account for the influence of price changes in energy models.

5.5.2 Econometric modelling

Econometric modelling is defined as the application of statistics to economic theory, for example it gives the empirical verification of economic theory (Gujarati, 2004) and is able to quantify the relationships among variables by using available historical data.

Econometric modelling uses the methods of statistics to measure and estimate quantitative economic relationships and has a close link with consumers and production theory. An econometric model is a set of equations, representing the behaviour of the economy that has been estimated using historical data. This type of empirical model generally aims to analyse statistical relationships between dependent and independent variables. Furthermore, the approaches will have coefficients that determine how dependent variable changes when an input variable is introduced. The relationship determined can then be used for forecasting by considering changes in the independent variables and determining their effect on the dependent variable.

The purpose of the econometric modelling approach is to predict the future as accurately as possible with the use of measured parameters and relies on data that have been measured previously. Although according to Hyman (2009), no econometric model is ever truly complete; rather all models contain variables that cannot be accurately predicted because they are determined by forces "outside" the model. The strength of the econometric approach though, lies in its use of theoretical background based on economic theory and the use of models to validate the economic rules empirically (Bhattacharyya and Timilsina, 2009).

This is the main reason why this approach may be preferable to others, such as input-output approach (Dilaver, 2012). This technique also requires a long-run of quantified historical data in order to function. This particular requirement for data limits the use of this technique in many developing regions, where such data are lacking in sufficient quantity and quality. However, the simplicity of this approach gives it an advantage as a forecasting tool.

There are various forms of econometric modelling approaches that have been used in energy demand modelling. The main ones considered in this thesis are Multiple Regression, Auto Regressive Distributed Lag (ARDL), Co-integration (includes

Engle-Granger Error correction model and multivariate co-integration) and Structural Times Series Model.

These were discussed with the relevant studies in 3.3.

5.5.3 Hybrid approach

This approach allows the combination of two or more models. The use of hybrid approach helps overcome the limitations that may be in individual approaches and as a result, are able to achieve a better result. Hybrid energy system modelling approaches usually combine at least one macroeconomic model with at least one bottom-up model for each final energy and conversion sector (Herbst et al. 2012); there still remains the challenge that such combined models are theoretically consistent and empirically valid. It may be difficult to classify any particular model into a specific category as the hybrid approach attempts to bridge the difference between the end-use and econometric approach (Bhattacharyya, 2011).

Table 5.2 Summary of the different modelling approaches

	End use approach	**Econometric approach**	**Hybrid approach**
Features	Estimates energy demand in various sectors using the information obtained through various means e.g. surveys. It does not rely on neoclassical economic theory but rather relies on scenario building approach. .	Uses statistical methods to measure and estimate quantitative economic relationships. Has a close link with consumers and production theory. May lack transferability.	Allows the combination of two or more models.
Strengths	Easy to incorporate anticipated changes in technology and policies. Requires less skills due to their accounting approach.	Its use of theoretical background based on economic theory and the use of models to validate the economic rules empirically. Generally, unable to capture non price related issues.	To achieve a better result as able to overcome the limitations that there may be in individual approaches.

Weaknesses	The level of disaggregation is often not supported by data due to the use of limited data.	Requires a long run of quantified historical data in order to function.	Combined models produced may not be theoretically consistent.

Source: Bhattacharyya, 2011

The next section describes the general concepts and methodological assumptions underlying the use of the secondary data in the quantitative analysis. While the survey, sampling techniques for the survey, the tools and materials for the respective studies and the procedures adopted are presented in section 5.6. Most of the study tools like questionnaires, letter of consent, participant's information sheet are attached as appendices.

5.6 Quantitative Analysis

The study used multiple linear regression analysis on a variety of data. The use of quantitative approach resulted in providing a general picture of the research. It exhibited the factors that contribute to the consumption of electricity within households. Firstly, statistical association was used to determine the correlation between variables and establish a suitable econometric model that was subsequently used to forecast the demand for residential energy. Although, it is possible to notice correlation between two variables, it does not imply that one causes the other is not possible to observe causation but rather to infer it.

5.6.1 Data collection

The econometric analysis was carried out using annual data for the period from 1970 to 2011 for Nigeria. As suggested by McAvinchy, (2002), the use of annual data in forecasting energy usually results in parameter estimates that are valid both in the estimation sample span and outside it and this also improves the forecasting performance of the equation systems investigated.

The empirical study used the time series data from secondary sources and data on various indicators were considered. They included education indicators (i.e. education, secondary enrolment) and energy consumption data (i.e. energy demand, electricity generation, electricity loss during transmission and distribution, residential energy consumption, petroleum motor spirit consumption, dual purpose kerosene production, gas production, gas utilization and rate of connectivity to the grid).

Other data used included data on growth measures (GDP, consumer price index, and inflation), income variables (includes price of kerosene, average load demand, price of electricity, gas price, and fuel subsidy), health variables (life expectancy), and population growth (i.e. population, rate of urbanisation, labour force).

In this study, the real GDP is expressed in terms of US dollar (constant 2005) while electricity consumption and generation are expressed in terms of Megawatts per hour. The data on inflation and consumer price index (CPI) were obtained from the Central Bank of Nigeria's (CBN) various statistical bulletins. The data on the price of electricity, fuel subsidy, average load of electricity demand and kerosene were obtained from Power Holding Company of Nigeria (PHCN) while the data on dual purpose kerosene (DPK) was obtained from Nigerian National Petroleum Corporation (NNPC) and Federal Office of Statistics (FOS). Other sources of data used include International Energy Agency (IEA), African Development indicators (ADI) and the World Development Bank (WDB). The data used which spanned over 40 years were transformed into natural logarithms in order to improve the interpretability of the data as they all are measured in different units.

5.6.2 Data analysis

Various forms of equations were tried and an alternative approach to consider a linear relationship among log-transformed variables was used. This is a log-log model where the dependent variable and all explanatory variables were transformed to logarithms. With this form, it was possible to specify an equation of a linear relationship among the variables. The use of this form of model was also able to provide an approximate description of some economic behaviour. These multivariate non-parametric regression models were estimated using Microfit 5.0 software.

Multivariate linear regressions are widely used in the energy sector as they are simple to implement, fast, reliable and provide information about the importance of each predictor variable and the uncertainty of the regression coefficients. The decision for a particular model chosen was based on the inference from using the different functional or unit diagnostic tests associated with output from Microfit 5.0 such as the R2, serial correlation and heteroscedasticity. The different results obtained are seen in Appendix 2.

5.7 Qualitative Analysis

The development of the statistical association was followed by the use of interview/ survey to identify other variables that may have not been determined in using secondary data. One of the aims of using the qualitative approach was so as to understand the experiences and attitudes of energy consumers. The analysis using qualitative approach therefore on its part helped to refine and explain the statistical results by exploring the participants' views in more depth (Creswell, 2002). The qualitative approach used a cross-sectional survey design to help identify variables that affect the consumption of energy but which were not identified in using secondary data in the quantitative approach.

Generally, the surveys were conducted to investigate the choice of energy for households and the way of consumption- what factors affect people's behaviour and to try and capture other details that secondary data may not have captured. The data collected from the survey was then analysed to provide information about residential energy demand and use within Nigeria (see 1.1). The survey focused on four different areas of residential energy demand and use. The first section of the questionnaire was centred on household demographics and included questions on gender, household size, age, education level, employment status and income category. Other questions were on energy usage, energy efficiency and household appliances which help to identify the range of household appliances owned by different households and the rate of consumption within the households. These questions generally provide a linkage between energy sources, household characteristics, income levels, appliance ownership and energy consumption.

Checklists and interviewer's guide (Appendix 10) were developed to help facilitate the work and the gathering of information.

In the use of qualitative analysis, a survey was conducted using questionnaires. The questionnaires were issued after sampling was done. The use of qualitative method allows one to test the theoretical formulations or hypothesis in place for energy consumption; in this case, the energy ladder and the energy mix theories. The stages involved includes: Sample collection, instrumentation, validation of questionnaires, distribution, data entry, coding and analysis.

5.7.1 Sample collection

Data were collected mostly through face-to-face contact using questionnaires. This was either 'self-completed' or 'interviewer- assisted' completed. The latter being the preferred method in order to ensure reliability of the selections of the answers. Those that were involved with the interviewing were given basic training on the use of the questionnaire and the interpretation on some of the questions involved. They were mostly Post- graduate students who had previous knowledge of carrying out a survey of similar nature. Prior to this, the permission of the participants were sought in pre-survey visits where the date and timing of the interview was set.

A pilot study was carried out using a sample size of 30 to test the reliability and validate the effectiveness of the instrument, and to ensure that the values of the questions were sufficient to obtain the required information. This also gave the opportunity to correct any problems with the instrumentation or other elements in the data collection technique (questionnaire). There were some slight modifications made to the questionnaire based on the experience gained from conducting the pilot survey. The sample selected as a representative of the areas was carefully chosen so that it reflects the characteristics, opinions and attributes of the complete group that was under study.

5.7.2 Study area

The area used for the study was Ibadan in Oyo state which is the third largest metropolitan area, by population, in Nigeria. It is located in the South-western part of the country and is situated about 128km (78 miles) inland from Lagos. The city covers a total area of 3,080 km^2 (1,190 square miles) and is made up of 11 local government areas-five urban and six are semi-urban. Ibadan has a total population of about 3.2 million (2011 estimate) and it also houses the first university in Nigeria-University of Ibadan.

The economic activities of Ibadan include agriculture, commerce, handicrafts, manufacturing, and service industries and it has the tropical dry and wet climate. Five of these local government areas were used in this study. These includes: Akinyele, Ibadan North, Ibadan North-East, Ibadan South-East and Ido (See Figure 5.3). The urban areas used include Ibadan North, Ibadan South-East and Ibadan North-West.
Although all three urban areas were created in 1991, their population and sizes differ. Ibadan North has a population of almost three times the size of Ibadan South-East but with half the land mass area. The former has a population of over 850,000 with a landmass area of 420 km^2 whereas the latter has a population of over 250,000 with a landmass area of 805km^2. Ibadan North-West is the smallest of the three and has only a population of 152,000 and a landmass area of 283km2. Akinyele and Ido were created in 1976 and 1989 respectively and are regarded as semi-urban areas.

The city is projected to increase to about 5.03 million inhabitants by 2025, considering an average annual growth rate of 4.6% during the period 2010-2020 (UNDESA, 2012). Five of the LGAs are located in the metropolitan core of the city, while the remaining six are either predominantly peri-urban or rural settlements. The sub-urban city comprises a mix of neighbourhoods some of which are well-defined and better planned residential areas than the core areas while many are mixed agglomerations which cannot be clearly defined on the basis of socio-economic class or residential density. Nevertheless a pattern of haphazard development is still evident especially in the newly developed and peripheries of the city.

The target population included those that are heads of households, home owners, tenants and spouses of the heads of households. All these participated in completing the questionnaire. A sample size of about 560 households was selected and this allowed for a representative subset of the population. Table 5.3 shows basic information about the selected areas.

Figure 5.3 Geographical position of the study area

Table 5.3 Local Government areas in Ibadan used for the study

	Local Government	Headquarters	Year of creation	Number of wards	Area population *	Landmass area km²
1	Akinyele	Moniya	1976	12	211359	575
2	Ibadan North	Agodi-Gate	1991	12	856,988	420
3	Ibadan North East	Onireke	1991	11	152,834	238
4	Ibadan South East	Mapo	1991	12	266,457	805
5	Ido	Ido	1989	6	103,261	986

Area population * as at 2006 census

Source: National Bureau Statistics

5.7.3 Sampling Frame

In this instance, a probability sampling technique was used as it allowed samples to be gathered in a process that gave all the individuals in the population equal chances of being selected. Probability sampling also helps us to make statistical inferences and assesses the confidence of such inferences.

This was achieved by randomisation. One of the reasons for using probability sampling is that it is particularly effective at helping to minimise sampling bias compared with nonprobability sampling. Due to the large size of Ibadan, it was difficult to carry out a simple random sampling at the initial stage and therefore cluster random sampling was used. Cluster random sampling requires that a number of identified areas be selected randomly within the boundary area set. This led to the selection of five Local Government Areas (LGAs) within Ibadan metropolis- Akinyele, Ibadan North, Ibadan North East, Ibadan South East and Ido. Participants were randomly selected within these areas (see table 5.3).

In this study, the area sampling, which is a version of cluster sampling, was adopted. Specifically, a two-stage cluster sampling was used. Firstly, certain numbers of clusters were selected and then simple random sampling was used to further select clusters within the already chosen clusters i.e. subset of elements within selected clusters were randomly selected for inclusion in the sample. A list of the elements of the entire household or population sampling frame was not feasible in this survey because of the irregular pattern of streets and of houses without number or difficulties in describing some residences.

Cluster sampling has been found to be quicker and more reliable in controlling the uncertainty related to estimates of interest. Another reason for the choice of cluster sampling was the fact that it was difficult to obtain a complete list of the people of the Ibadan population that was needed for the study. It was also envisaged that the increased sample size that will be obtained by using cluster sampling would be sufficient to offset the loss in precision.

There were some problems that I encountered in the process of collecting the data.

The main issue was being able to collect information from the consumers even though they had agreed to participate in the study. This meant getting to their homes earlier than normal so that I could get the survey questionnaire complete and at other times, it meant travelling to the participant's workplace or business place to collect the completed questionnaire. Other problems encountered are highlighted in 8.2.2.

A pilot test using about 5 per cent of participants were randomly selected from a list of the addresses in the chosen areas until a minimum of thirty addresses are chosen. It resulted in a good cross section of participants in terms of gender, age, and type of accommodation. These were also used for instrument validation and to test the reliability of the questionnaire. Once the pilot testing had been done, the questionnaire was revised accordingly and these participants were excluded from the major study.

5.7.4 Instrumentation

The instrument used to collect the data was a questionnaire drawn up by the researcher (Appendix 9). The design of the questionnaire was based on the perception of the researcher on what affects the demand for energy in a developing country, how best to obtain such information from participants (particularly on the issues of income and expenditure) and on the hypotheses being considered in the study. The questionnaire was designed to represent the population at both the urban and rural area. The houses were randomly selected choosing hundred houses in each LGA. The questionnaire provided information on demographics; education, expenditure on various energy fuels, ownership of various appliances; and other sources of household income.

5.7.5 Data processing

A card of introduction (Appendix 6) was placed in people's houses with basic information about the research. Prospective and interested participants were advised to leave the card outside their doors if interested in participating. This was followed by issuing a written consent form (Appendix 7) and participation information sheet (Appendix 8) to the participants.

The primary technique for collecting the quantitative data in this instance was a self-developed questionnaire, containing items of different formats: multiple choices, asking either for one option or all that apply, questions that require dichotomous answers like “Yes” and “No”, self-assessment items, measured on the 5-point Likert type scale.

The questionnaire consists of four main sections including household economic status, energy consumption, electricity usage and energy services and efficiency. Both forms of direct and indirect administration were used as the questionnaires administered were either self-completed by the participants or with assistance from the researcher where the interviewer records the answers given by the interviewee. There was no participant at risk or any disadvantage from the study. An informed consent form was part of an opening page of the survey. Participants had to tick the sentence “I agree to complete this questionnaire”, thus expressing their acceptance to participate in the study.

5.7.6 Data screening

Data screening was carried out on the information received before the statistical analysis of the results. This includes the descriptive statistics for all the variables, summarised in the text and reported in tabular form (see Table 8.2). The various valid per cent for responses to all information was done by carrying out a frequency analysis. Frequency Tables and descriptive statistics were constructed to display results obtained. The analysis was done using Statistical Package for Social Sciences software.

5.8 Summary of the Chapter

In this chapter, the various theoretical and econometric modelling approaches for energy demand were considered. The econometric models tend to create a statistical relationship between various factors that determine energy. The purpose of this chapter also includes describing the research methodology, explaining the selection of the sample, how the instruments were designed and the procedure for collecting the data used in this study.

The quantitative method included the use of secondary data of forty years in an econometric analysis. The qualitative process covered the use of 501 household respondents and the method included door to door survey in the form of semi-

structured questionnaires. These were used to collect data on socio-economic, demographic and housing characteristics.
Questions such as household size, type of fuel, amount of fuel used, expenditure on energy, usage of electrical appliances etc. were asked.

In effect, the choice of the areas was made to reflect the trend in other places. As earlier mentioned in section 1.1, different people from across the nation live in Ibadan, therefore the sample chosen should reflect to an extent the behavioural pattern on energy consumption. This trend of movement does have an impact on the rate of urbanisation which tends to lead to an increase in the consumption of energy. The method of triangulation was also adopted in this study so as to have a better understanding of what happens in the real world for energy demand. Triangulation is a way of ensuring the validity of the research. However, the purpose of using triangulation in this research is capture the different dimensions of energy consumption. Triangulation is also not merely aimed at validation but at deepening and widening one's understanding of the various factors that contribute to energy consumption in households.
Such knowledge and understanding can then be used for energy planning and setting up of policies that will help to improve the quality of life of the consumers and enhance the overall development.

It is important too that data for relevant variables needed for the residential electricity demand model are carefully chosen as a reliable energy demand collection framework is the potential for one of the tools for proper energy planning in developing regions. Forecasts are important for the Nigeria energy sector as this will help the electricity generating and distribution companies to establish their long-term investment decisions. Therefore, before investigating the electricity demand functions, it is paramount to understand the history and development of energy in Nigeria. This is discussed in the next chapter.

Chapter 6 Patterns of Energy Consumption in Nigeria

6.1 Overview of the Chapter

This chapter gives a review on the development of energy in Nigeria. It identifies the current situation of the various energy resources that are being produced in Nigeria and the different sectors that are regarded as energy consumers (sections 6.2 and 6.3). Section 6.4 then gives an overview of a modern form of energy- electricity, delving into the historical trend of its generation and consumption.

6.2 Introduction

The energy supply and consumption system in Nigeria consists of the energy supply sector and the energy end-use technologies such as refrigerators, cookers, light bulbs, computers and transportation. The energy system is made up of a set of chains that are often connected. The purpose of the energy system is to deliver energy services but there are a number of factors that interplay. Energy services result from a combination of different technologies, labour, materials and energy sources which are combined to provide different services such as lighting, cooking, cooling and each input to the service is subject to change.

6.3 Overview of Energy Situation in Nigeria

Nigeria is in the sub-Saharan region with a population of 162 million and has a GDP growth rate averaged at 6.8per cent (from 2005 to 2012). Like other developing countries, Nigeria is faced with the challenge of providing adequate and regular energy services to its communities. This energy in this instance refers to the use of electricity and Liquefied Petroleum Gas (LPG) as opposed to the use of firewood, charcoal or crop residues for cooking and lighting. Relatively low-income levels in rural areas make the provision of modern energy services unaffordable to most communities, thus, denying them access to clean water, sanitation and healthcare and the provision of reliable and efficient lighting, heating, cooking, mechanical power, transport and telecommunications services (World Outlook, 2010). Poor access to energy in turn has not allowed improvement in people’s standards of living because of low income and slow employment generation.

The energy sector in Nigeria is described by Ebohon (1992) as being underdeveloped and characterised by shortage and supply constraints and as stated by Iwayemi (2005), the low level of energy consumption evident in the low level of electricity consumption per capita is an indicator of energy and income poverty.

6.3.1 Energy production in Nigeria

Nigeria is endowed with natural resources like oil, gas and hydro resources- with oil reserves of 37.2 billion barrels and natural gas reserves of 187 trillion cubic feet in 2011, but in spite of this advantage to natural energy resources, accessibility of the population to electricity is low and irregular. Friends of the Earth (FoE) (2005) confirm that biomass, which consists of mainly fuel wood dominate the composition of energy consumption in Nigeria.

6.3.2 Energy resources in Nigeria

- Introduction

Nigeria is a vast country and has the benefit of abundant and diverse energy resources such as crude oil, natural gas, coal and lignite, and renewable energy resources such as solar, hydro, and wind. These energy resources can be used for electricity generation. Nigeria has 36 states and the Federal Capital Territory (FCT). With a population of 162 million and a population growth rate of 2.55per cent (World Bank, 2012), Nigeria is a leading producer of crude oil and has been a member of the Organization of Petroleum Exporting Countries (OPEC) since 1971. The country Nigeria had an oil reserve of 37.2 billion barrels in 2011 and a large natural gas reserve of 187 Trillion cubic feet (Table 6.1). Nigeria is the largest oil producer in Africa and ranks 11th in the world and in 2012 she was the world's 4th leading exporter of Liquefied Natural Gas. If the resources are harnessed properly, they will have a positive impact on the level of development of the nation. The various energy reserves can be seen in Table 6.1.

- Coal

Coal is the oldest commercial fuel in Nigeria and was first discovered in Enugu in 1909. Coal production increased greatly until the late 1950s when oil was discovered.

Although it has the lowest energy density of 24MJ/kg (mega joules per kilogram), coal has the greatest pollution potential.

Coal is the country’s largest source for the generation of electricity. The Nigerian Coal Corporation (NCC) was established in 1950 and had the task of exploiting coal reserves. Unfortunately, the civil war in Nigeria between 1967 and 1970 affected coal production as many of the mines were closed. The monopoly of the NCC ceased in 1999 when the government at the time allowed private investors to jointly operate coal fields with the NCC. Nigeria, however, still has a coal reserve of about 2 billion metric tons. The government has since placed a priority in utilising coal to increase electricity generating capacity. The plan is to expand power generation by attracting companies to develop these large coal resources and construct coal-fired generating plants that will connect to the country’s electrical distribution grid.

Table 6.1 Energy Reserves in Nigeria

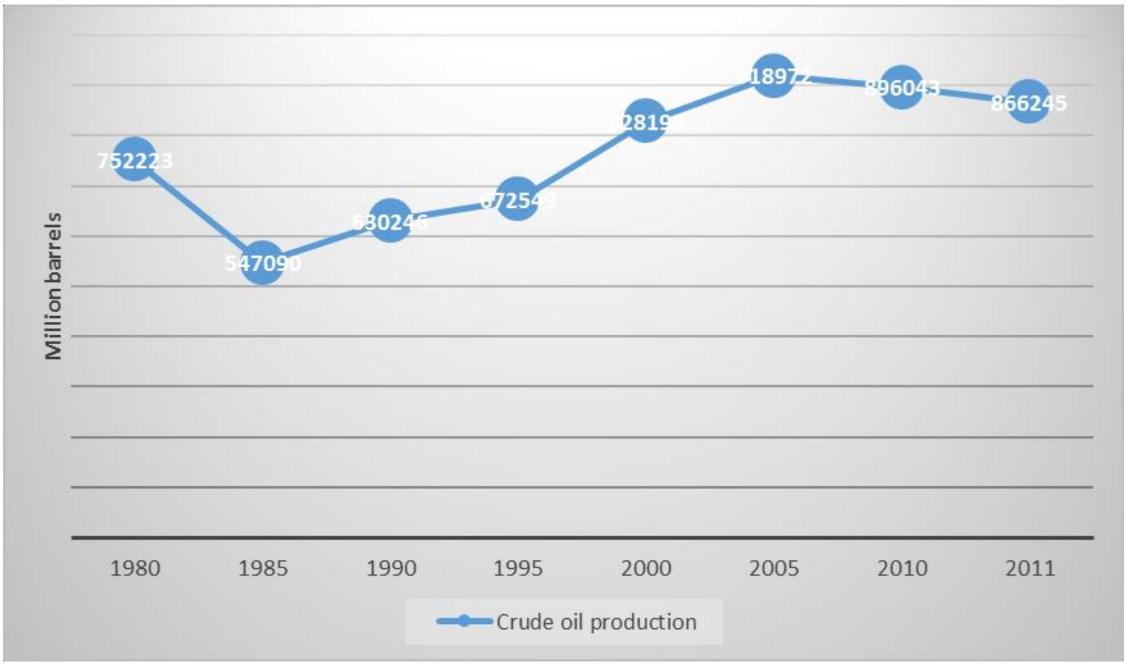
Resource Type			Estimated Reserves
Fossil resources	Crude oil		37.2 billion barrels
	Natural gas		187 trillion SCF
	Coal and Lignite		2.7 billion tonnes
	Tar Sands		31 billion barrel of Oil equivalent
Renewable resources	Large Hydropower		11,250MW
	Small Hydropower		3,500MW
	Solar radiation		3.5- 7.0KWh/m2/day (485.1million MWh/day using 0.1per cent Nigeria land area
	Wind		2- 4 m/sat 10m height
	Biomass	Fuel wood	11 million hectares of forest and woodland
		Animal waste	211 million assorted animals
		Energy drops & Agriculture residues	72 hectares of agricultural land

Source: Energy Commission of Nigeria (2010)

- Oil

Oil is produced from deceased sea organisms and when used has many social, health and environmental impacts. Crude oil was first discovered in commercial quantities in Nigeria in 1956, while actual production started in 1958. Nigeria produces only high value, low sulphur content, light crude oils such as Antan Blend, Bonny Light, Bonny Medium, Brass Blend and Escravos Light to mention a few. These have contributed an average of 25 per cent to the GDP of the country. The Bonny Light oil is a light crude oil produced in Nigeria in great quantity. Nigeria produced about 91,128,721 barrels of bonny light oil in 2010 making it 10.47 per cent of the total oil produced (NNPC, 2011). This oil has low specific gravity and therefore is moderately volatile, less evaporative and moderately toxic. As a result, it is highly desired due to its low corrosiveness. Although, Nigeria is a net oil exporter of Bonny Light crude oil, energy shortages marked by power interruption and fuel shortages are common. This is due mainly to many factors such as, inadequate or out of date infrastructure, lack of spare parts, manpower shortages and inefficient management. Reserves of crude oil still stand at 37.2 billion barrels (ECN, 2010).

Figure 6.1 Crude oil productions in Nigeria



Source: NNPC, Annual Statistics Bulletin, 2011

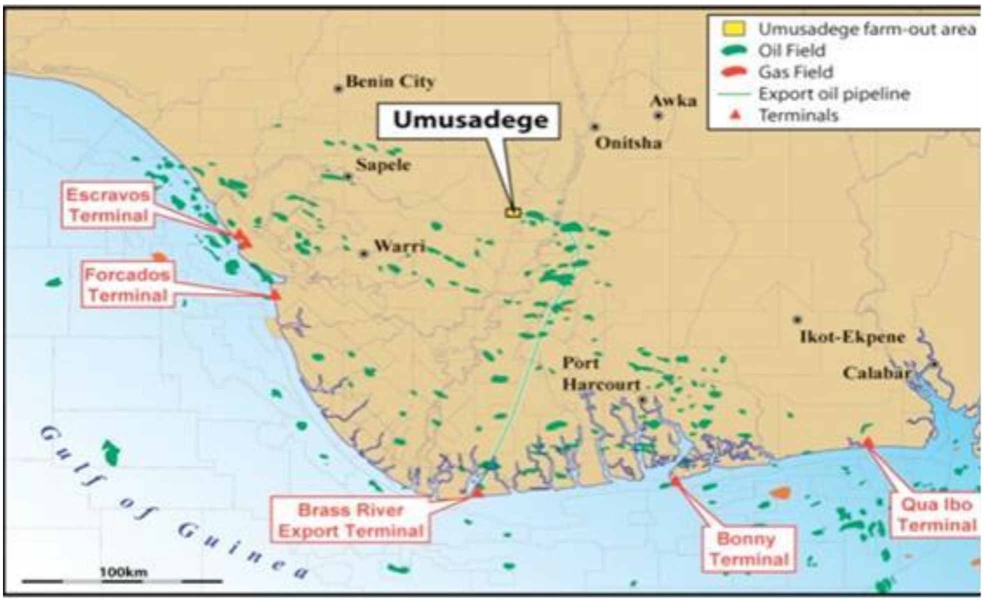
The Nigerian National Petroleum Corporation (NNPC) was created in 1977 with the aim of overseeing the Nigerian oil industry. It was divided into 12 subsidiaries in 1988 in order to manage the industry better. The subsidiaries covered areas including exploration and production, gas development, refining, distribution and engineering and commercial investments. The industry is currently regulated by the Department of Petroleum Resources (DPR). The first exploration dates back to 1956 in the Niger Delta with a production rate of 5,100 barrels per day. The production of crude oil has increased over the years (Figure 6.1).

Nigeria produced about 3.3 per cent of the world's oil output production in 2010 (IEA, 2011) and the total crude oil production in 2011 was 866 million barrels at an average of 2.37mb/pd (IEA,2011) which was about 3per cent less than the previous year's.

Increase in pipeline vandalism is a major reason for the reduction in oil production (NNPC, 2012) as it led to spillage, pipeline fires and explosions. Between 2010 and 2012 a total of 2,787 lines breaks were reported on pipelines belonging to the Nigerian National Petroleum Corporation (NNPC), resulting in a loss of 157.81mt of petroleum products. It presents the single biggest threat to the smooth operation of the petroleum industry in Nigeria and has grave consequences on the entire economy of the country. NNPC reported that there were 16,083 pipeline breaks of which 2.45 per cent was due to rupture and the remaining 97.5 per cent were due to activities of vandals. Nigeria proved reserves at the end of 2011 is equivalent to 41.4 years of current production and 2.25 per cent of the world's reserves (BP, 2012). McPhail (2000), Akinlo (2012) asserts that although crude oil makes significant contribution to the economic development of Nigeria as it generates sizeable revenues, creates jobs and business opportunities, and brings new roads and access to water and power to the isolated rural areas in which they are typically located, it has none the less had a negative impact on manufacturing.

NNPC has three refineries, at Kaduna, Port Harcourt and Warri, with a combined installed capacity of 445,000 bpd and approximately 80 per cent of the crude oil produced is exported while the remaining is refined for domestic consumption. According to the International Monetary Fund (IMF), the Nigerian economy is claimed to be heavily dependent on the oil sector, which accounts for over 95 per cent of export earnings and about 40 per cent of government revenues. The energy sector is therefore important in enhancing the competitiveness of the Nigerian economy.

Figure 6.2 Gas and Oil fields in Nigeria



Source: http://www.martresources.com/news-events

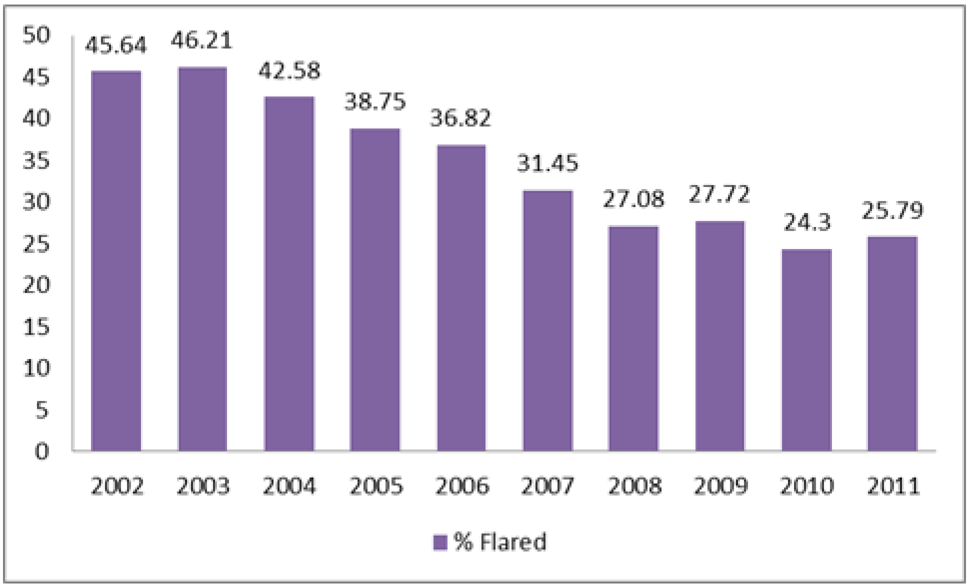
- Gas

The gas sector is also managed by the NNPC and production is closely associated with crude oil production. The process extracts a mixture of oil, gas and water from the well which is then separated at the surface. Nigeria had a reserve estimate of 185 trillion cubic feet (tcf) of natural gas in 2010, making Nigeria 8th natural gas endowed country in the world and the largest in Africa. In 2011, a total of 2,400.40 billion standard cubic feet (bscf) of Natural Gas was produced by sixteen companies. Unfortunately, due to lack of infrastructure, a great proportion of the annual production is flared as seen in Figure 6.3.

About 26 per cent of this was flared in 2011 and shows a slight increase of 0.37 per cent when compared with 2010 production (NNPC, 2012). This is due to the broken promises from companies like Shell to stop flaring as reported by Friends of the Earth international (FOEi, 2010) and the fact that there are no measures in place in Nigeria for oil companies to report on the significant negative impacts of their business operations and to provide local communities affected by oil companies' flaring operations with a statutory right to seek redress. Iwayemi (2008) affirms that the persistent flaring of oil-associated gas is partly due to the reluctance of multinational oil companies to invest in the gas gathering facilities for domestic use and their willingness to pay the low penalties for flaring gas.

About 70 per cent of the natural gas produced is used by Power Holding Company of Nigeria (PHCN) to operate electricity generating gas plants (Sambo, 2008). As already indicated, the demand for energy will continue to increase and it is therefore vital that there is a focus on developing technologies for cleaner fossil fuel use and developing the exploitation of renewable energy sources.

Figure 6.3 Percentage of gas flared in Nigeria over 10 year period



Source: NNPC, 2012

- Hydro

The use of small hydro power has been identified as one way of providing convenient and uninterrupted energy to those in the rural areas of Nigeria. This will enable development to take place by establishing industries, creating employment and income generating opportunities; thus alleviating poverty and improving communication and better health for such communities. Improvement in living conditions will reduce the rate of moving to the urban areas.

The first hydropower plant was built in 1968 in Kainji. There are two other plants in Shiroro and Jebba. All three have a combined installed capacity of 1930 MW. According to IEA (2010), hydroelectric power production in Nigeria increased from 3 billion kilowatts in 1980 to 8 billion kilowatt in 2006 but then declined to 6.31 in 2010 (IEA, 2011). As at 2009, hydropower accounted for about 23 per cent of the electricity production (World Bank, 2010).The development of hydro power will reduce the use of diesel in generating electricity or use of kerosene in providing light. It will also reduce the cost of transporting fuel from cities to rural areas and the level of deforestation in order to obtain wood for cooking and lighting.

6.3.3 Energy consumption in Nigeria

- Introduction

Energy use in a society is connected to a large number of diverse activities undertaken by different sectors which may conveniently be divided into three: commercial, industrial and residential sectors. Generally, there has been an increase in the demand of energy in almost every sector of the country especially in the transport and residential sectors. The consumption of oil increased from 245.56 Thousand barrels per day (tbd) in 2000 to 286 tbd. The analysis carried out by Sathaye and Goldman (1991) indicated that an increase in energy demand in Nigeria is due to the increase in economic activity and the high rate of population growth. Much of the development in energy demand in the country has in turn been accompanied by increases in oil demand and use of fossil fuel.

There have been various reasons identified for the increase in use of energy in developing countries. They are as follows: (a) people are gradually turning from the use of time consuming and difficult fuels such as wood and crop residues to cleaner, commercial fuel; (b) Nigeria, like some other developing countries has over the years been involved with the building of infrastructure which requires more energy intensive materials; and (c) there has been an increase in the rate of urbanisation which tends to result in an increase in the transportation of raw materials and food from the agricultural areas to urban areas. This is because most of these food and raw materials are produced in rural farm areas that are far from the cities and towns where the final products and food are consumed. The effect of urbanisation has also led to an increase in the consumption of electricity as households are more easily connected to the grid leading to an increase in the use of existing appliances and the purchase of new ones.

- Industrial Sector

Irrespective of the level of material and human resources, technological innovation and industrial capacity are considered the major ways by which a nation can achieve sustainable economic growth and development. The industrial sector consists mainly of the primary (agriculture) and the secondary (manufacturing) industries with the manufacturing sector being usually the basis for determining the nation's economic level. In Nigeria, the subsector is responsible for about 10 per cent of total GDP annually (NBS, 2010). This industrial sector includes the industries that use a lot of energy and produce goods such as food, bulk chemical, refining, glass, cement, steel and aluminium. Although the sector grew by 1.3 per cent in 2011 (CBN, 2012), prior to then, there was a decline in the sector due to the reliance on the oil sector and hence a reduction in its contribution to the economy. The main problems facing the manufacturing sector are the issue of inadequate infrastructure and lack of power supply. Most industries have either installed generators or moved out to countries where power supply is regular and constant. This invariably results in high costs of production which are subsequently passed on to consumers.

- Commercial Sector

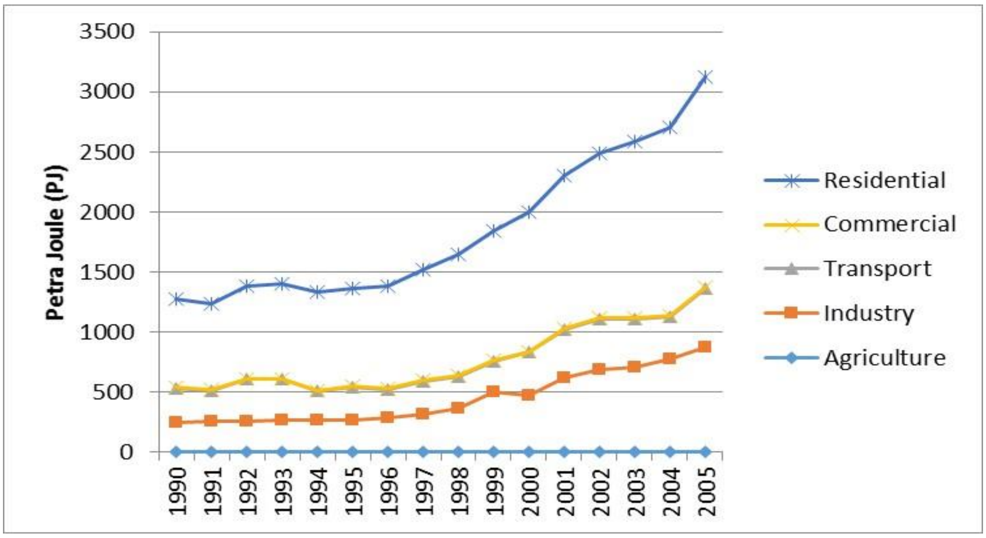
The commercial sector includes organisations that operate for profit. It includes the service sector and transportation. The commercial sector also includes schools, hospitals, offices, stores and restaurants. Transportation accounts for a rising share of energy use in Nigeria as many cars and light trucks that have been imported into the country are less fuel intensive. A good transport system allows for access to places of employment, education and health facilities and proper functioning of these contributes to the development of the sector and the country. The growth in the use of energy in this sector in Nigeria has been due mainly until recently on the subsidised energy prices.

- Residential Sector

The residential sector consists mainly of use of energy by households. This includes energy for cooking, heating and lighting. Generally, the residential sector is the highest consumer of energy. This has consistently accounted for over half of the energy consumption in Nigeria.

Most households seem to make choices among energy carrier options on the basis of both the household's socioeconomic status, attitudes and the attributes of alternative carriers (Reddy, 2000). They use a combination of kerosene, Liquefied Petroleum Gas (LPG) and electricity for different activities. The energy demand in the residential sector may depend on various factors such as prices of the fuel, appliances, the disposable income of the households, and availability of the fuel and appliances.

Figure 6.4 Energy demands of various economic sectors



Source: Energy Commission of Nigeria, 2009

6.4 Overview of Electricity

The use of electricity is growing worldwide and it is generally used for lighting, cooking, heating and cooling. Other uses include for irrigation, pumping, telecommunication, purification and sanitation. It is also useful for medical care like refrigeration of medicines and generally contributes to improving the quality of life. The increase in the use has been due mainly to its convenience, an increase in population, urbanisation and the fact that it gives less environmental pollution compared to other fuels and end use technology. Improved working and living conditions, increased productivity are some other benefits of using electricity.

Although it is not an energy source, it is a good transporter of energy. Electricity is also the largest and the fastest-growing source of energy-related carbon-dioxide emissions as it is mainly generated via fossil fuels (IEA, 2011). Its main advantage over other forms of lighting is the fact that it does not produce smoke and is less of a fire hazard. Although it is a convenient way to transport energy, about 1.6 billion people in the world are without electricity (OECD, 2011). World electricity generation rose by an average of 3.6 from 1971 to 2009 and came from sources such as coal, oil, gas, nuclear and hydro. The increase was due to the development of electrical heating in many developed countries and of rural electrification programmes in developing countries. According to Ebohon (1996) and Rosenberg (1998), increasing electricity use has been identified as an important source of productivity improvement in developed countries and it is the sector that is currently fuelling the 'new digital economy'.

In addition, Economic Commission for Africa (ECA) in 2004 found that there is a significant correlation between export diversification and per capita electricity consumption and production per worker in Africa.

6.4.1 Electricity in Nigeria

Nigeria is a populous nation of 162 million and has a land area of 923,768 sq. km. Nigeria is made up of 36 states and the Federal Capital Territory (FCT). Access to energy, and specifically electricity, is a driving force behind economic and social development. Energy exists in various forms and has its sources such as coal, oil and gas.

Electricity, on the other hand, is an efficient, safe and easily distributed energy transporter. Dependable and affordable access to electricity is essential for improving public health, providing modern information and education services, and saving people from subsistence tasks, such as gathering fuel.

Electricity is widely consumed in the residential, industrial and commercial sectors in Nigeria but the sector is characterised by power shortages and poor quality supply of low voltage. Although, consumption has been on the increase over the years, partly due to the convenience of use and population growth, the supply has been inadequate. Krizanic (2007) pointed out that one importance of power supply is the fact that is has become equally indispensable to food supply, and food is a basic necessity for all life forms. Similarly, energy is also a necessary condition for an economy to thrive. In both situations, consumption will increase productivity and, therefore, growth is achieved.

Electricity in itself is not an energy source but can be used to transport energy from one point to another using the grid. Electricity as one of the commercial energy forms in Nigeria is inadequate to meet the demands of the ever increasing population. It currently constitutes less than 1 per cent to the country's GDP (CBN, 2012) and the demand for electricity is more than the supply. Sambo (2010) states that less than 40 per cent of the population has access to electricity and the power sector suffers from high energy losses (30-35 per cent) and a low collection rate of money owed to the power supplier. This is due mainly to ageing and broken equipment, vandalisation of equipment and poor management associated with public enterprises in Nigeria. Another problem has been the fact that the low prices of energy (due to subsidies from the government) has to an extent made energy affordable but has also resulted in inadequate revenue to cover costs and finance expansion of supply.

Although, electricity is provided from two major sources – conventional thermal power plants (which provide 48 per cent of electric power) and hydroelectric power plants (which provide 52 per cent), the unreliability of energy supplies brings about an economic burden on the nation (Olaopa et al, 2009). Furthermore, interruptions in electricity supplies often force many industries to operate far below capacity utilisation or incur huge additional costs in procuring off-grid energy supply equipment such as electric generators (Ebohon et al, 2000). In addition, because electric supply is generally of poor quality, it discourages the use of efficient technologies that are usually dependent on high quality energy supplies.

As a result, most goods manufactured tend to be more expensive and as identified by Ikeme and Ebohon (2005), the erratic and epileptic power supply has disrupted economic expansion leading to closure of businesses that are unable to sustain the huge cost of maintaining private electric generating plants.

6.4.2 Historical trends and background of electricity generation in Nigeria

Electricity supply in Nigeria dates back to 1886 when two 30 kilowatt generating sets were installed to serve Lagos city. In 1951, the Nigerian Electricity Supply Company (NESCO) commenced operations as an electric utility company with the construction of a hydroelectric power station at Kura, near Jos. In 1972, the Electricity Corporation of Nigeria (ECN) which was established in 1951and the Niger Dam Authority (NDA), established in 1962 were merged to form the Nigerian Electricity Power Authority (NEPA). This was done with a view to generating, transmitting and distributing electricity to consumers throughout Nigeria under a single management structure. Within the first twenty years, there was a tremendous growth in the electricity industry.

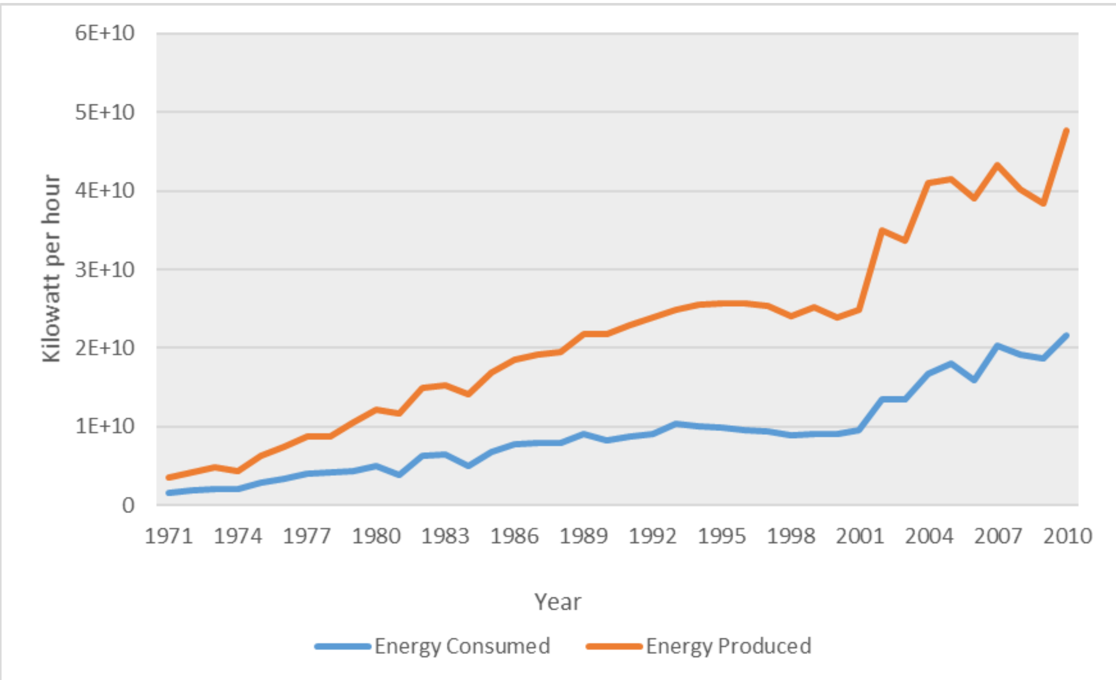
The electricity industry was, however, limited by different problems that occurred in the late 1990s leading to a crisis. The problems included the mishandling and vandalising of various pipelines in the country, insufficient generation from plants, lack of maintenance of installed generators and other generating equipment. Others were the insufficient flow of water into the reservoirs for the hydro-generating stations and the low level of technology. This also affected the reliability and security of the industry. Power from the electricity distribution grid is supplemented by numerous small but expensive diesel powered generators resulting in suppressed demand for electricity.

The Electric Power Reform Implementation Committee (EPIC) recommended the privatisation of the electric power sector and the need for a market trading method, new rules, codes, processes and the establishment of a regulator sector. Consequently, the government bought in Electric Power Sector Reform Act in 2005 and the control of the sector was handed to the state-owned Power Holding Company of Nigeria (PHCN) in 2005. This was done in order to enable private companies to participate in electricity generation, transmission, and distribution.

The Electric Power Sector Reform (EPSR) Act of 2005 provides the legal and regulatory framework for the development of this sustainable electric power supply and delivery system for the shift from a state-dominated system to a private-sector dominated system.

With this reform, distribution companies buy power directly from generators, making the transmission company a pure electricity "transport and dispatch" company. Adoption of this reform resulted in the former National Electric Power Authority (NEPA) to be divided into 18 companies, including six generators, eleven distributors and one Transmission Company.

Figure 6.5 Electric power produced and consumed in Nigeria



Source: Energy Commission of Nigeria, 2009

In addition, the Act made provision for the reform to occur in phases. The reform, which allowed the unbundling of the electricity industry into generation, transmission and distribution, has also initiated an upward review of the tariffs and if the reform is properly designed and implemented, it will promote the flow of both domestic and foreign investment and manpower resources into the sector. Olaniyi et al, (2011) expect that the reforms will bring about an increase in power generation and distribution and also increase in residential electricity demand in Nigeria. It is also expected that in general, the energy sector reforms will lead to improved access to affordable energy services by businesses and companies.

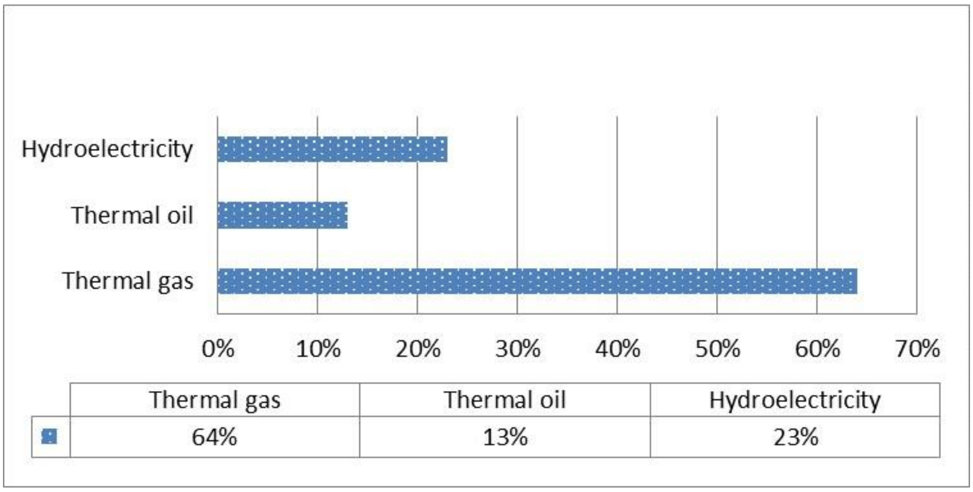
The National Bureau of Statistics (NBS, 2010) notes that not only is electricity generation in Nigeria characterised by excess capacity and inadequate supply, but that peak demand is often about one-third of installed capacity. The inadequate supply is mainly because of the non-availability of spare parts and poor maintenance of the system. Another reason is the fluctuation in water level powering the hydro plants.
The transmission network is overloaded, with poor voltage resulting in low current in most parts of the network. Sambo et al. (2010) also confirms that, the technologies used generally deliver very poor voltage stability and profile.

Figure 6.6 Nigeria electric grid map

Source: Source: http://www.nigeriaelectricityprivatisation.com

Thermal power plants generate 77 per cent of electricity, with two-thirds from natural gas and the rest from oil as shown in Figure 6.7. The hydroelectricity constitutes 23 per cent but according to IEA (2010), the amount generated reduced from 8.2 billion KWh in 2002 to 4.5 billion KWh in 2009. This has been due to the general global climatic change leading to fluctuation in the water level.

Figure 6.7 Total installed electricity net generation in Nigeria by type, 2009



Source; IEA, 2010

There was, however, an improvement of 1.8 per cent in the electric power generation in 2011compared to 2010 attributed to increased gas supplies to the thermal stations (CBN, 2011). The increased supply from the generating stations allowed for the increase in electricity in the same year. The electricity generation in Nigeria from 2007 to 2012 is shown in Table 6.2.

Table 6.2 Electricity generation in Nigeria

	2007	2008	2009	2010	2011	2012
Hydro	7776	7645	7645	7416	6658	6455
Gas	15410	13852	13373	17604	21034	23117
Total	23186	21497	21018	25020	27692	29572

Source: PHCN Generation and Transmission Grid Operations 2007- 2012 Annual Technical Reports

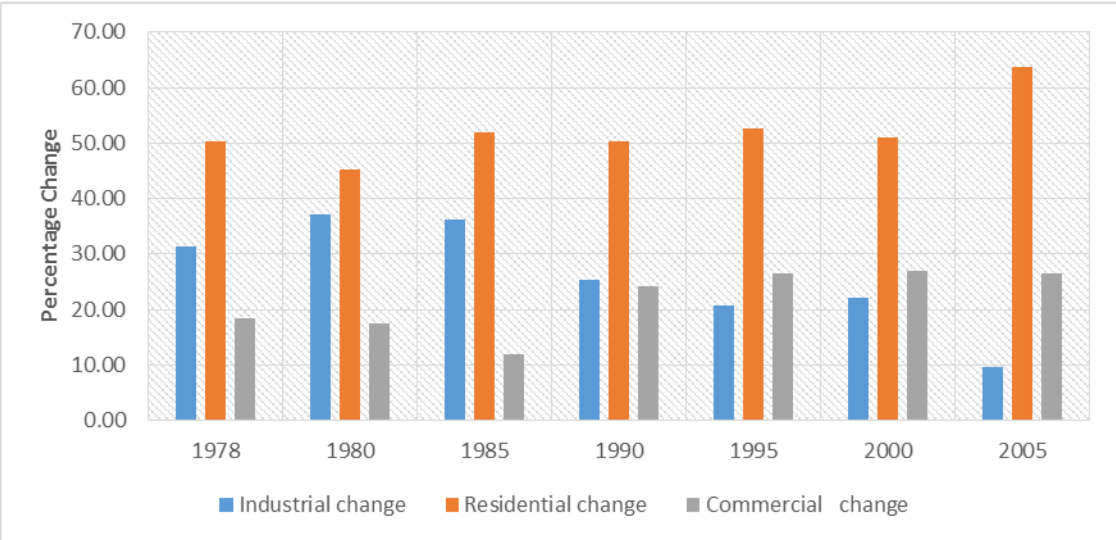
The Nigerian government has since increased foreign participation by commissioning independent power projects (IPPs) to generate electricity and by selling to the Power Holding Company of Nigeria (PHCN). IPPs currently account for approximately 20per cent of installed capacity; Nigeria currently has fourteen generating plants, half of which are over 20 years old. As reported recently, the federal government plans to bring sustainable electricity supply to about 75 per cent of Nigeria's total population by 2025 and it is expected that at least 10per cent of the electricity will be generated from renewable energy sources.

There are, however, some problems with the transmission of electricity in the country as the grid structure is unstable and allows for illegal connection. There are also zoning issues where in some cases, a property has been zoned for residential purposes but could be used for industrial purposes which often use more energy. This can overwhelm the grid and cause a transformer to explode.

6.4.3 Trends in electricity consumption pattern

In the case of Nigeria, the demand for electricity in all sectors has increased over the years with the residential sector having the highest consumption level of energy. This is followed by the commercial sector and the industrial sector.

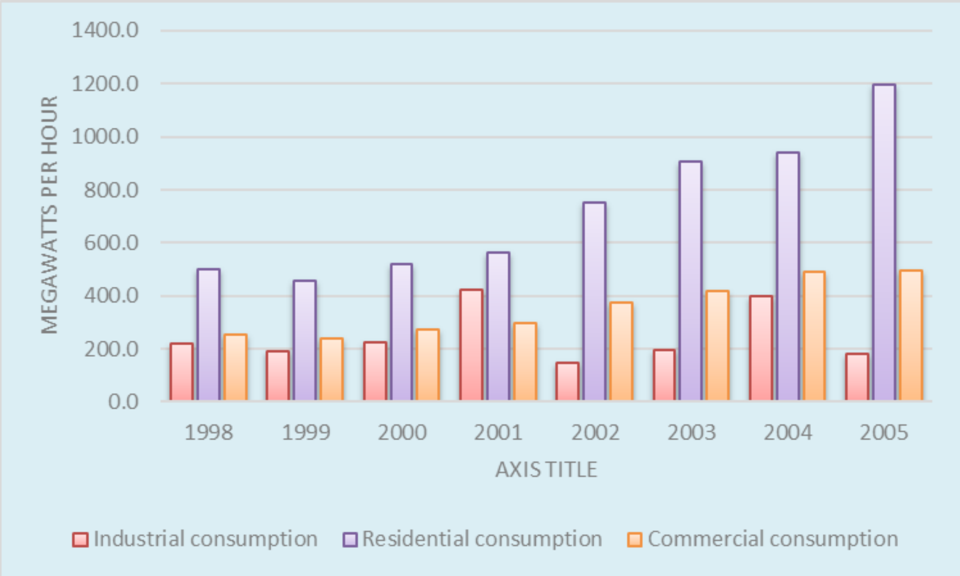
Figure 6.8 Changes in electricity consumption by the different sectors in Nigeria



Source: Central Bank of Nigeria (2009)

Prior to 1978, the industrial sector had the highest consumption level. However, since then the residential sector has been the largest consumer of electricity in the country. According to the data obtained from the Central Bank of Nigeria (2009) as shown in Figure 6.8, there has been fluctuation in the amount of electricity consumption within the three main sectors. Even though, an increase is recorded in the total consumption of electricity in the country since the late 1990s as reflected in Figure 6.8, the trend is not the same for all the sectors where there have been fluctuations.

Figure 6.9: Electricity demand by the different sectors in Nigeria (MW/h)



Source: Central Bank of Nigeria, 2009

Table 6.3: Percentage of consumption of electricity of the different sectors

Year	Percent Industrial consumption	Percent Residential consumption
1975	62.90	37.10
1985	36.20	51.90
1995	20.80	52.60
2005	9.70	63.80

Source: PHCN, 2005

The consumption level of the industrial sector had been on the decline mainly due to the fact that the electricity supply in the nation has been irregular and very erratic.

This has led most industrial firms to purchase private generating plants which generate electricity for them and reduces their dependence on public electric supply.

This was confirmed by Iwayemi (2008) who reported in his studies that the manifestation of poor electricity supply has resulted in Nigeria being the largest importer of generators in the world. In addition, most manufacturing companies have also been involved with self-generating electricity or moved out to neighbouring countries where electricity supply is steady. On average therefore, according to Ekpo et al. (2011), about 97.1per cent of industrial business firms in Nigeria own private generating plants.

6.5 Summary of the Chapter

Energy which comes from different sources is needed in the economic and social development of any nation. While it is important, the access to modern energy services is also necessary as this will contribute to the economic growth and improved quality of life. This chapter has explored the various energy resources in Nigeria, the production and consumption and a more in-depth examination of the trend of electricity in the country.

It is important therefore that access is improved especially in a developing country like Nigeria where it is hoped that the energy reforms that are being implemented will bring about improvement and increase in the generation and distribution of electricity. The next chapter will, therefore, focus on the details of the results obtained by using secondary data.

Chapter 7 Modelling Energy Using Secondary Data

7.1 Overview of the Chapter

This chapter deals with energy modelling for Nigeria. It begins with a general view of the energy system and its purpose in Nigeria (7.1). This proceeds to energy modelling in Nigeria and an initial model for consumption of energy households in this study is proposed using one of the methods reviewed in chapter 3, with the findings expounded (7.2). The previous studies on modelling energy in Nigeria are the focus in section 7.3. The conclusion is in 7.4 and clearly identifies the need for a different method of modelling energy consumption for a developing nation in order to be able to include the relevant factors that contributes to the consumption of energy.

7.2 Introduction

This chapter deals specifically with identifying if there is any relationship between electricity consumption in households and socio economic variables. In order to achieve this, the electricity demand function for the residential sector was estimated using an econometric approach (multiple regression analysis) as outlined in the chapter 3. Annual data for the period 1971-2011 was used and the relationship identified was then used to produce a forecast for the residential sector.

As earlier discussed in chapter 2, energy is an important aspect of the economy and the timely, reasonable and reliable availability of energy supplies is vital for the functioning of a modern economy and so is the accurate analysis of energy demand. In other words, for sustainable economic growth, robust and reliable demand forecasts of Nigerian electricity demand are vital for the development of appropriate energy policies. Therefore, there is the need to test the various drivers of the demand.

The aim of this chapter, therefore, is to analyse factors responsible for electricity demand using one of the econometric methods already identified in chapter 3 within the Nigerian context. This will explore the use of multiple regression in terms of modelling electricity, estimating the elasticities, and forecasting future electricity consumption.

The motivation for this chapter is in the fact that the use of a modelling method like regression analysis would allow for a focus on all economic and exogenous factors that have been identified from various literatures to contribute to the consumption of electricity.

7.3 Energy Modelling in this Study

Following on from the literature reviewed in chapter 3, this section focuses on the initial modelling carried out in this study. The modelling adopts the economic theory in general, (chapter 3) where energy is considered as a commodity and price as one of the determinants of energy consumption. Specifically, the demand for energy is supported by the consumer theory which is concerned about how a rational consumer makes consumption decisions (3.10). This is because the consumer's choice sets are assumed to be defined by certain prices and the consumer's income or wealth. The consumer will, therefore, choose the set of goods that maximises their utility. In essence individuals tend to make choices under income constraints while taking into account the value placed on the consumption of energy.

The demand for a form of energy can be expressed as the function of its own price, income, the price of substitute and price of appliances. The demand includes both economic and non-economic factors in order to determine if either of these have an effect on the demand for electricity as they may also contribute to the unmet demand within the households in a developing country. Generally, as earlier stated in the methodology chapter, it is usually assumed that the relationship for electricity demand is given by:

$Et=f(Y_t,P_t, \varepsilon_t)$

where:

E_t = electricity demand (industrial, residential or aggregate);

Y_t = income;

P_t = real electricity prices and εt = error term

Following the identification of the possible econometric models, the preliminary modelling proposed an econometric model that will be described in the rest of this section. The modelling will also investigate how electricity consumption should be specified.

Preliminary modelling was undertaken at an aggregate level to reflect only consumption level within the households.

7.4 Data for Modelling

All the data were transformed into natural logarithms in order to improve the interpretability of the data and linearity. In other words, the interpretation is given as an expected percentage change in Y when X increases by some percentage. Such relationships, where both Y and X are log-transformed, are commonly referred to as elastic in econometrics, and the coefficient of log X is referred to as elasticity. The choice of explanatory variables was based on prior expectation which is in line with some of the previous studies that were reviewed.

In attempting to decide on a model in this study, various factors that were found significant in numerous studies carried out in different countries for household energy consumption including developing countries were considered (see Chapter 3). These include GDP, the level of education, the price of electricity, the rate of connectivity to the grid, the price of kerosene, fuel subsidy, life expectancy at birth and population (as seen in Table 7.1).

Different functional forms were tested to determine which form of modelling best captures the behavioural response in electricity consumption to changes in the various factors. The fit of the model to the data is an important consideration for all models, but particularly so when such model is to be used for forecasting. The modelling also investigates how electricity consumption should be specified. The preliminary modelling was narrowed down to reflect only consumption level within the households.

7.4.1 Independent variables used in initial modelling

The variables used in this case are continuous in nature as they have a number of different values between two given points.

However, the measurements were rounded off so that it was easier to work with the data obtained. Data for all variables are in Appendix 3. These include:

Gross domestic product (GDP) is used to represent the sum of value added by all its producers and in this instance is used to represent the income to the economy as an economy's growth is measured by the change in the volume of its output or in the real incomes of its residents. The GDP (constant 2005) is used in this case as the use of the base year represents normal operation of the economy. To obtain comparable series of constant price data for computing aggregates, the World Bank rescales GDP and value added by industrial origin to a common reference year. Because rescaling changes the implicit weights used in forming regional and income group aggregates, aggregate growth rates are not comparable with those from earlier editions with different base years (World Bank publication, 2010). Rescaling may result in a discrepancy between the rescaled GDP and the sum of the rescaled components.

Education[g] as a variable in this study is represented by secondary enrolment level (percent gross). The gross enrolment ratio is the ratio of total enrolment, regardless of age, to the population of the age group that officially corresponds to the level of education shown. This as at 2010 was 44 per cent (UNIS, 2010). This is used as a proxy for education. In this instance, a proxy for education- paper qualification was used as this cuts across all the different consumers. The role of education about energy is also important in a practical sense as the knowledge will assist consumers in understanding the benefits of the use of the various forms of energy and as such will help them to make better choices. Education can empower people particularly women by providing them with better economic opportunities.

Population[h] in this study includes all residents regardless of legal status or citizenship except for refugees not permanently settled in the country of asylum, who are generally considered part of the population of their country of origin. The values shown are midyear estimates. The quality and reliability of official demographic data are also affected by public trust in the government, government commitment to full and accurate enumeration, confidentiality and protection against misuse of census data, and census agencies' independence from political influence. Any substantial

[g] Definition of education given World Development Indicator

[h] Definition of population as given in World Development Indicator

increase in population, whether as a result of immigration or more births than deaths, can place pressure on the country's sustainability through impacts on many natural resources and social infrastructure. Irrespective of whether urbanisation is as a result of rural-urban migration or accelerated birth rate, if there is not adequate infrastructure in place to match the population growth, then the infrastructure will be stretched. If however, urbanisation is managed properly, then it will bring about a positive effect.

Likewise, a significant increase in population will negatively impact the availability of land for agricultural production, and will put increased demands on food, energy, water, social services, and infrastructure.

Fuel subsidy[i] is a measure that keeps prices for consumers below market levels, or keeps prices for producers above market levels. In this instance, subsidy is defined as money that is paid by a government or an organisation to reduce the cost of services or of producing goods so that their prices can be kept low. Within the Nigerian context, fuel subsidy means to sell petrol below the cost of importation. The introduction of the fuel subsidy in 1992 was to give the average Nigerian access to cheap petroleum products, reduced transport and production costs. Furthermore, the generation of electricity is pivotal to the availability of electricity for energy consumption and although, there are several medium for the generation of electricity, the bulk of this in Nigeria is through the use of petroleum product or fuel.

Also, almost every home and business is powered by generators fired by subsidised petrol while kerosene is still considered complement to the use of electricity for some activities, especially domestic uses. Therefore, a great proportion of the country benefits from fuel subsidy and the removal of such would cause untold hardships on the poor and an adverse effect on the standard of living of the people, since fuel is essential for the transportation of major Nigerian commodities, such as agricultural produce and other market products. This is in line with the claim by Nwachukwu and Chike (2011) that there is a significant relationship between the fuel demand and fuel subsidy factors.

---

[i] Definition according to OECD (Wikipedia encyclopaedia)

7.4.2 Analysis of data

In order to examine the impact of the other factors on energy demand, various multiple regression analyses were carried out using the data seen in Appendix 3. Table 7.1 shows the relationship between the dependent variable total electricity consumption and several economic and non-economic variables in the Nigerian context. Although, most of the output suggests that combination of the various factors could explain the variation in residential energy consumption, the diagnostic test reveals that there were problems with the functional form.

Table 7.1 Energy consumption: A review of variables with Total electricity consumption as dependent variable

Variable	**Standard coefficient**	**T ratio**	**P**	**Remark**
Gross Domestic Product	0.153	0.417	0.680	Not significant
Education	0.185	0.851	0.402	Not significant
Price of electricity	1.513	1.845	0.075	Not significant
Connection rate	-0.960	1.467	0.153	Not significant
Price of kerosene	0.005	0.098	0.922	Not significant
Fuel subsidy	-0.072	-1.432	0.162	Not significant
Population	1.019	1.135	0.265	Not significant
Life expectancy at birth	3.115	0.730	0.471	Not significant

Source: Author's compilation

The initial regression analysis using the variables above is seen in Table 7.1. The analysis suggests that none of the regression parameters is significant in determining the energy demand for Nigeria. In other words, none of the variables is significantly different from zero although the value of R^2 (0.96573) and its adjusted version (0.95659) are both very high, to the extent that, taken as a whole, the regression seems to indicate a good fit. It is not possible to draw conclusions about the correctness of the regression function solely using the residual sum of squares.

Since a sufficiently complex regression function can be made to closely fit virtually any data set, further study is necessary to determine whether the regression function is in fact useful in explaining the variance of the data set. Typically, however, a smaller residual sum of squares is ideal

Collectively, the relationship between the variables seemed to be able to explain about 96 per cent of the variability in energy demand. There may be multi-collinearity in this case where the individual regressors are very closely related, so that it becomes difficult to separate the effect of each individual variable on the dependent variable.
Further specific regression analysis was done with regard to the residential sector using a combination of variables from (1970-2011) including GDP, consumer price index, the level of education (EDU), fuel subsidy, the price of kerosene, the price of premium motor spirit, the price of electricity, the rate of connectivity to the grid and amount of dual purpose kerosene consumed. The choice of these variables as previously mentioned was based on logic and the fact that some of these variables were significant when used in earlier studies by different researchers.

Although, most of the output suggests that combination of the various factors could explain the variation in residential energy consumption, the diagnostic test reveals that there were problems with the functional form. As the residual plot pattern was not random, both the independent and dependent variables were transformed and after conducting another regression analysis using the transformed data, the residual plots were found to be random.

The use of double log involves applying natural logs to both the dependent and independent variables; as such helps to transform the data into its linear form. The linear transformation neither increases nor decreases the linear relationship between variables rather it preserves the relationship. Consequently, it enables the interpretation of the regression coefficients to be straightforward. The coefficients in a log-log model represent the elasticity of the dependent variable with respect to the independent variables.

In other words, the coefficient of a variable in such instance is the estimated per cent change in the dependent variable for a per cent change in the independent variable. A log-log model was used for regression in order to improve the interpretability of the data as they all are measured in different units.

The coefficients determine the impact of the independent variables on the residential electricity consumption. The use of a double logarithm for regression showed that some of the variables tested earlier such as GDP, price of electricity, the level of education, and the lag value of fuel subsidy were highly significant in determining the amount of electricity consumed in the household sector while the level of connectivity to the grid was not significant. Prior to this, various other regression analyses were done to include the lag values of different variables and various cross-correlation plots of pairs of variables before arriving at the decision to use a double logarithm and to use the lagged value of fuel subsidy. This is also because the effect or benefit of the fuel subsidy may not be realised in the current year.

Furthermore, the coefficients in this log-log model also represent the elasticity of the residential electricity consumption variable with respect to the independent variables. The regression output for the model can be seen in Table 7.2 and expressed in the equation below:

$REC = f\,[GDP, EDU, Pe, FS_{(-1)}, Con]$………………………………………………… (7.1)

Where REC is the residential electricity consumption level (MW)

GDP - Gross Domestic Product (constant 2005 US $)

EDU - Secondary enrolment level (per cent gross population)

Pe - Price of electricity (Kobo)

$FS_{(-1)}$ - Amount of fuel subsidy- lagged value (Kobo)

Con - Rate of connectivity to the grid (per cent)

All data are transformed to log.

The econometric model can therefore be written as:

$log(REC) = \beta_0 + \beta_1 log\,GDP + \beta_2 log EDU + \beta_3 log\,Pe - \beta_4 log\,FS_{(-1)} - \beta_5 log Con + \varepsilon t$………(7.2)

The result in Table 7.2 shows that about 96.8 per cent of the variation in energy demand can be explained by a combination of the level of GDP, education, price of electricity, the amount of fuel subsidy from the previous year and the rate of connectivity to the grid. A one per cent increase in GDP, for instance, will bring about 0.63 per cent increase in the demand for electricity whereas a one per cent increase in the level of education will bring about 0.56 per cent increase in energy demand providing all other variables are held constant. An increase in the price of electricity does not indicate a fall in the level of consumption. This may be because of the outstanding benefits of using electricity in households such as the provision of lighting at evening for studying, instant provision of energy and less environmental pollution.

This implies that an increase in the price of electricity may not be a hindrance to increasing domestic consumption so long as the supply of electricity is constant and reliable. The increase in GDP may help to accommodate the price increase. The result of the impact of pricing on electricity consumption further confirms the economic theory of monopolistic pricing and the reality on the ground in the Nigerian context, which was eluded to in the earlier pages.

This certainly shows that in Nigeria any increase in the consumption of energy will be brought about by an increase in a combination of the various factors. The rate of connectivity to the grid was also found to be partially significant. All these are on the assumptions that the Gauss Markov assumptions for OLS regression hold, that the coefficients are statistically significant and that the other independent variables are held constant while only one of them is varied at any point in time. On the other hand, one per cent increase in fuel subsidy may cause a slight reduction in the consumption of electricity about 0.07 per cent.

The generation of electricity which is an important factor in national growth and development is mainly through the use of fuel or petroleum product. An increase in fuel subsidy will help to reduce the prices of the different fuels and therefore making such more readily available to consumers.

The increase in the level of consumption of such fuel like kerosene will cause a reduction in the level of electricity consumption; albeit at a very low amount.

The government officials in Nigeria have argued that removing the subsidy, which is estimated to cost $8bn a year, would allow the government to spend money on badly needed public projects across Nigeria, which include damaged roads, inadequate electricity and a lack of clean drinking water for its inhabitants . Siddig (2014) has noted that although a reduction in fuel subsidy generally results in an increase in Nigerian GDP, the removal of the subsidy, without accompanying it with other economic palliatives, will negatively affect private household income.

Table 7.2 Regression output of residential electricity consumption (Model 1)

Model 1			
Dependent variable is LREC			
39 observations used for estimation from 1971 to 2009			
Regressor	Coefficient	Standard Error	T Ratio [Prob]
CONST	-27.8928	4.1694	-6.6899 [.000]
LGDP	.6368	.1801	3.5351 [.001]
LEDU	.5695	.1437	3.9628 [.000]
LPE	2.3695	.5583	4.2436 [.000]
LFS1	.07368	.03460	-2.1295 [.041]
LCON	-.77783	.64668	-1.2028 [.238]
R-Squared	.97228	R-Bar-Squared	0.96808
S.E of Regression	.14427	F-Stat. F(5,33)	231.5160 [.000]
Mean of Dependent Variable	5.9879	S.D. of Dependent Variable	0.80755
Residual sum of squares	0.68687	Equation loglikelihood	23.4251
Akaike info Criterion	17.4251	Schwarz Bayesian Criterion	12.4344
DW-statistic	1.2854		
Diagnostic Tests			
Test Statistics	LM Version	F Version	
A:Serial Correlation	CHSQ(1) = 4.1497[.042]	F(1,32) = 3.8103[.060]	

B: Functional form	CHSQ(1) = .25586[.613]	F(1,32) = .21132 [.649]
C: Normality	CHSQ(2) = .51316[.774]	Not Applicable
D: Heteroscedasticity	CHSQ(1) = 1.3464[.246]	F(1, 37) = 1.3231[.257]
E: Predictive Failure	CHSQ(2) = 1.8887[.910]	F(2,33) = 0.94436[.910]
A: Lagrange multiplier test of residual serial correlation		
B: Ramsey's RESET test using the square of the fitted values		
C: Based on a test of skewness and kurtosis of residuals		
D :Based on the regression of squared residuals on squared fitted values		
E: A test of adequacy of predictions (Chow's second test)		

Source: Output generated from using Microfit 5.0

The model 1 in (ii) above can be re- written as

$$\underset{(4.170)}{LREC= -27.89} + \underset{(0.637)}{0.63LGDP} + \underset{(0.144)}{0.56\,LEDU} + \underset{(0.558)}{2.36\log Pe} - \underset{(0.035)}{0.07LFS1} - \underset{(0.647)}{0.77LCON} + \varepsilon t \ldots \quad (7.3)$$

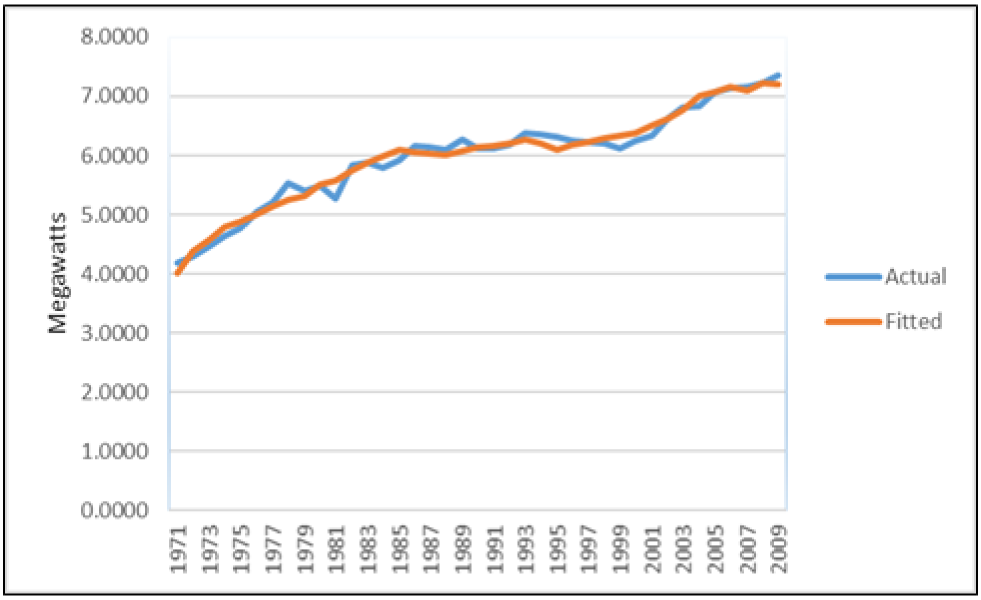
Table 7.3 show a positive relationship between each of the variables chosen and the level of electricity consumption (REC). The price of electricity (Pe) has the strongest correlation with residential electricity consumption whilst GDP was the least correlated with the dependent variable.

Table 7.3 Estimated correlation matrix of variables

	LREC	LGDP	LPE	LEDU	LFS	LCON
LREC	1.0000					
LGDP	0.7775	1.0000				
LPE	0.9656	0.7827	1.0000			
LEDU	0.9347	0.5776	0.8987	1.0000		
LFS	0.8142	0.7650	0.9122	0.7050	1.0000	
LCON	0.9426	0.8698	0.9581	0.8638	0.8785	1.0000

The data highlights that a close relationship between the variables and an increase in each of the variables individually, will generally lead to an increase in the residential electricity consumption. That is the data is sufficiently correlated to justify the regression. This could also imply that if there is a high level of multicollinearity, the linear regression is unlikely to allow reliable estimation of parameters. The graph below (Figure 7.1) shows the actual and fitted values of residential electricity consumption using the equation (iii) above. This observation can also be seen in Appendix 4.

Figure 7.1 Actual and Fitted values of Residential electricity consumption



Source; Author's compilation based on regression output from Microfit 5.0

The value of the DW-Statistics (1.2854) indicates that there is no autocorrelation as although the value falls within the lower (1.128) and upper limit (1.789), it is still higher than the lower limit at 5per cent significance level. The null hypothesis of no autocorrelation is therefore accepted in this instance. The model was, however, used to produce a forecast as seen in Figure 7.1.

Further stepwise regression analysis was carried out in the process of building a model by successively adding or removing variables based solely on the t-statistics of their estimated coefficients. It was important to include as few variables as possible as each irrelevant regressor would have reduced the precision of the estimated coefficients and predicted values.

Also, the presence of extra variables would increase the complexity of data collection and model maintenance. The goal of variable selection therefore becomes one of parsimony that is achieving a balance between simplicity (as few regressors as possible) and fit (as many regressors as needed). In this instance, the variable (connection to the grid) was excluded. The exclusion of the rate of connectivity from the regression model had very low impact on the analysis. The model can therefore be written as:

Model 2

$$LREC = -24.99 + 0.48LGDP + 0.48LEDU + 2.18LPe - 0.08LFS_{(-1)} + \varepsilon t \ \ldots\ldots\ldots.. \ (7.4)$$

$$\quad (0.129) \qquad (0.125) \qquad (0.540) \qquad (0.034)$$

A summary of this model and other regression can be seen in Table 8.4 while other details about the different models are in Appendix 2. Of the various types of analysis that were tried, the only ones reported in Table 7.4 are conventional multiple regressions. From a combination of different variables, the regression gave different results. The best specification that resulted was a matter of trial and error, and there is no guarantee that an optimal combination of independent (right-hand-side) variables has been yet selected.

Table 7.4 reports three different models of multiple regression. All of them had the residential electricity consumption from 1971 to 2009 as the dependent variable and used the model to forecast from 2010 to 2011. This allowed for comparison between the forecast and the actual values obtained.

A comparison of models in Table 7.4 revealed that many of the parameter estimates have similar magnitudes. A comparism of models was done using the diagnostic table. The $\mathbf{R^2}$ only give some information about the goodness of fit of a model; that is how well the regression line approximates the real data points. The higher it is, the better. However, other diagnostic information were considered in identifying which of the variables is to be included or removed from each model. The T-test which measures the likelihood of the actual value of each parameter not being zero is high in the models for all the variables thereby resulting in each variable being significant. However, this is not the same when DW-statistics which is used to detect the presence of autocorrelation in residuals is considered.

Table 7.4 Regression models for Residential electricity consumption

Dependent variable	Residential electricity consumption	Model 1		Model 2		Model 3	
		Coefficient	T-Ratio	Coefficient	T-Ratio	Coefficient	T-Ratio
Independent variable	Gross Domestic Product	0.6368	3.535**	0.4836	3.744**	0.5395	3.387**
	Education level	0.5695	3.962**	0.4816	3.866**	0.4126	3.173**
	Price of electricity	2.3695	4.244**	2.1816	4.043**	0.8293	2.157*
	Fuel subsidy	0.0736	2.129*	-0.0837	2.140*	-	-
	Rate of connectivity	0.7778	-1.203	-	-	-1.0376	-1.887
	Lag residential electricity consumption	-	-	-	-	0.511	4.019*
Intercept		27.890	-6.690	-24.996	-7.296	-14.759	-3.863
N			39		39	39	
R^2			0.968		0.967		0.975
F-stats			213.516		285.280		305.000
DW-statistics			1.283		1.272		2.250

Source: Author's compilation

In general terms, it can be assumed that there is positive serial correlation in models 1 and 2 as DW-statistics is less than 2. However, when considered in detail using the DW statistics table in Appendix 5, it is unclear as to whether there is autocorrelation within the dataset used or not. Reading off the DW-Statistics Table, when the number of observation (n) =39 and number of parameters K=4, (as in model 1) at 5 per cent level of significance, the lower value (d_L) =1.273 and upper value (d_U) = 1.722, whereas the DW-Statistics from model 1 is 1.2854. On the other hand, when K=5 and n=39, (model 2) d_L=1.128 and d_U=1.789 whilst the DW-Statistics is 1.2725.

The presence of autocorrelation would result in an infringement of the OLS assumption, thereby leading to incorrect estimates of the standard errors of the estimated coefficients. It was therefore important to eliminate the presence of autocorrelation in the model. Another regression was carried out using the lagged value of residential electricity consumption dependent variable (REC-1) as one of the dependent variables.

The use of the lagged variable i.e. REC (-1) in the model (3) will help to make the variables stationary and give certainty that the correlation between all variables are stable over time. In addition to being used to get rid of autocorrelation, the inclusion of lagged dependent variable is also used to capture the dynamics that may occur in the past. In other words, the use of lagged dependent variable also helps to incorporate feedback over time. This resulted in the OLS estimation seen in Table 8.4 and a better forecast produced. (Figure 7.2)

7.4.3 Forecasting residential electricity

Linear regression analysis shows that there is a statistically significant linear relationship between logged lagged values of residential electricity consumption and lagged values of GDP, price of electricity, education and rate of connectivity to the grid. In addition, the probability for each of the diagnostic tests consents that the model can be deemed reliable.

Model 3 is written as

$$LREC = -14.75 + \underset{(0.128)}{0.51}LREC_{(-1)} + \underset{(0.160)}{0.53}LGDP + \underset{(0.130)}{0.41}LEDU + \underset{(0.384)}{0.83}LPE - \underset{(0.549)}{1.03}LCON + \varepsilon t \quad \text{….(7.5)}$$

where $REC_{(-1)}$ is lagged value of residential electricity consumption

GDP is Gross Domestic Product

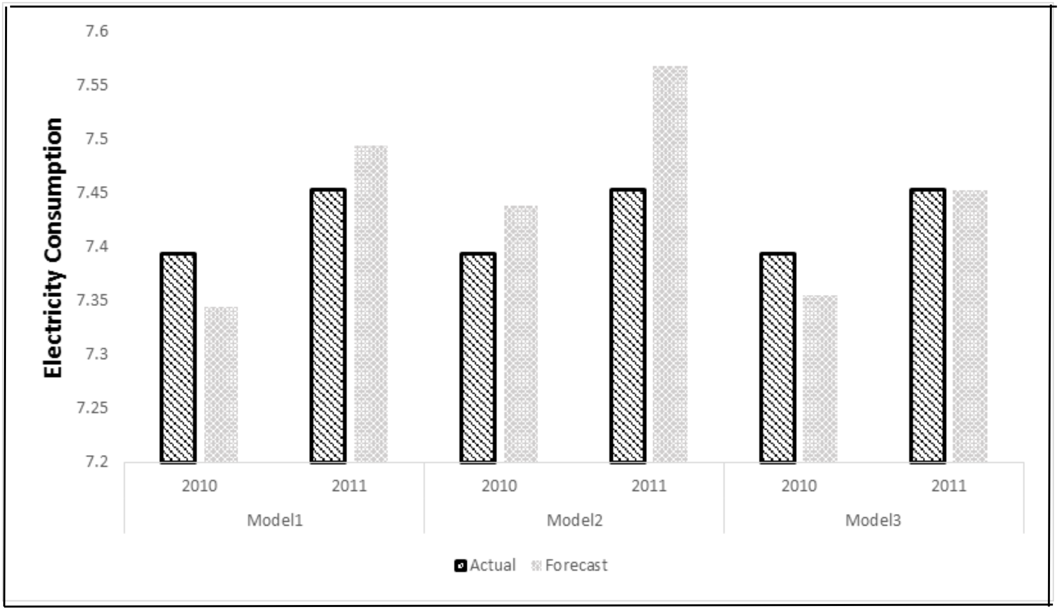
EDU is level of education (secondary school enrolment)

Pe is price of electricity

CON is rate of connectivity to the grid

As the model now has the lagged dependent variable, the use of DW-statistic is no longer relevant in checking the presence of autocorrelation. However, the reading based on LM multiplier test for serial correlation confirms that there is no serial correlation. This also shows the model produces a better forecast as in Figure 7.2 than the two previous one with the average standard error being 0.1567 which is less when compared to the previous model 1 (0.1791) and model 2 with 0.1659. The standard deviation measures how concentrated the data are around the mean; therefore the more concentrated, the smaller the standard deviation.

Figure 7.2 Actual residential electricity consumption vs forecasts



Source: Author's compilation based on output from Microfit 5.0

7.4.4 Summary of statistical findings

The study so far shows that the data on GDP had risen steadily over the years and the inclusion of education and GDP is significant in determining the consumption of electricity in households in Nigeria. This also shows that these factors and others like consumer price index, the rate of connectivity to the grid, the price of substitute or complement may not be adequate to determine the energy demand in Nigeria.

Model 3 performs considerably better than either of models 1 or 2. First, the adjusted R-squared (R^2) is larger than for the two preceding models, at .975. Along with this, the F-value in the final row is substantially larger than in models 1 and 2, thirdly, all the key variables entered turn out to be highly significant and possessing the 'expected' signs and lastly, the errors obtained between the actual and forecast values were less compared to the other two models.

7.4.5 Choice of software package

Microfit 5.0 was used in carrying out the analysis of the secondary data in 7.4.2. The use of the software package is mainly due to the user friendliness of the programme. I found the programme easy to use having used it previously during my Msc programme. The F-statistic is also provided as part of the summary statistics for a regression model. Microfit 5.0 is an interactive, menu-driven program with a host of facilities for estimating, hypothesis testing, forecasting, data processing, file management, and graphic display. It is a major advance over Microfit 4.0 and offers a unique built-in interactive, searchable econometric text. It provides users with technical, functional and tutorial help throughout the package, and can be used at different levels of technical sophistication. It also provides a large number of diagnostic and non-nested tests not readily available on other packages and can run regressions using up to 102 regressors and allows 5,000,000 observation data points (Peseran and Peseran, 1997).

7.5 Issues of Energy Modelling in Nigeria

There are few studies that have been carried out on energy demand in the residential sector and these have used mainly econometric models. The main problem identified with the existing energy models is that most econometric models used, take only into account the impact of economic factors on the demand for energy in the household sector of a developing country. Many do not account for other factors that may influence the demand for energy especially as energy is a derived demand. Generally, such models have also not considered the prevailing characteristics of such developing countries: issues such as the informal economy, the rate of urbanisation, the structural changes that may have occurred, the poor performance of the electricity sector and the technical efficiency of appliances used in households.

The use of Autoregressive Distributed Lag (ARDL) has been prevalent in the modelling of energy in most developing countries including Nigeria. As a dynamic model, ARDL shows that the effect of the independent variable X on the dependent Y occurs over time rather than all at once.

In other words, the dependent variable (Yt) is explained in part by the lagged values of itself and the lagged values of the explanatory variable (Xt). This can be used where some variables are stationary and there is the possibility of co-integration between some of the variables. ARDL models are also generally used to test for long range (LR) relationship between economic time series and also allow for linearity in its estimation techniques. Another benefit of using ARDL is that the different variables used can be assigned different lag-lengths and therefore the model can be used with a mixture of different levels of integration. This type of model can accommodate very general lag structures and can easily be extended to incorporate panel data.

However, the presence of lagged variables as regressors may result in biased coefficient estimates, and the estimators obtained may be inefficient, biased and inconsistent if the disturbances are auto correlated. This means that models of this type are likely to have difficulties in successfully identifying the correct relationships between the variables in data which contain a unit root as issues of spurious correlation may happen. A simple ARDL equation can be written as below:

$$Yo=\beta o+\beta 1Yt\text{-}1+\ldots + \beta kYt\text{-}p+\alpha oXt+\alpha 1Xt\text{-}1+\alpha 2Xt\text{-}2+\alpha qXq\text{-}+\varepsilon t \quad \ldots\ldots\ldots\ldots(7.6)$$

The use of ARDL models is not without its difficulties. This includes the choice of the length of lags to include in a model and determining how many lagged dependent variables to include. Another pattern that is possible for some economic relationships is that permanent changes in x may lead to only temporary changes in y. Another difficulty of using ARDL is in identifying the correct relationships between the variables if any has a unit root. The presence of which will lead to issues of spurious correlation. In addition, in an instance where there is a random trend in the data, the use of ARDL will only approximate the trend rather than model the real dynamics.

Although, Ordinary Least Square (OLS) regression has been used so far in this research, which shows over 97 per cent of the variation in energy demand being explained (see Table 7.4), there are chances that the use of linear regression may be merely a symptom of the underlying linear positive trend in the variables used.

In addition, there are other variables that may contribute significantly to the demand for energy but which in this instance have not been captured by the data used.

Hymans (2008) however has suggested that all models contain variables that the model cannot predict because they are determined by forces “outside” the model hence no econometric model is ever truly complete.

GDP, for instance, plays an important role in the consumption of energy but GDP measurement may not be a true reflection of the economy in a developing country as the GDP is recorded for the formal sector of the economy. These models do not generally take into cognisance the state of the informal economy in Nigeria which activities are at a greater level than the formal sector and are found mostly in the rural areas as opposed to the urban areas; the latter being the major areas of concentration of most evaluators. It becomes imperative therefore to find out the impact of the informal economy, which is estimated to be about 50.2 per cent of Nigerian economic activities in 2010 (IFAD, 2010) including how it operates and how it can be accounted for both in the urban and rural sectors.

Other dominant problems with the issue of modelling energy for Nigeria has been that of availability and quality of data, as data on many of the factors or variables that may have aided the demand for electricity are unavailable. In addition, most of those available were not segregated into the different sectors and many of them are not disaggregated on a regular basis i.e. monthly or quarterly.

7.6 Summary of the Chapter

The issue of energy modelling with particular reference to the use of a regression approach has been discussed in this chapter. It can, however, be noted that the result produced to indicate the likelihood of the need for other variables or factors in analysing the demand for energy. It is important to also note that energy use in a developing country such as Nigeria will be diversified across households and most of the present day global energy models are too aggregated to account for this diversification.

There is the need to understand how the different sectors of the country use energy. Generally, rural consumption tends to rely strongly on fuel wood; charcoal and so on, though there is increasing pressure to adopt electricity because of appliances like phones. Conversely, urban areas, may use kerosene, fuel wood, electricity from the grid, gas and diesel generators. Therefore, in the context of a developing economy, the issue of urbanisation and transformation from rural to urban areas and the requirements of energy are worth considering. In other words, it is important to understand the economics of urbanisation and the demand for energy; otherwise, it may be difficult or impossible to generate policies that will aid the development of both sectors.

The issues of urbanisation and informal economy in relation to the use of energy in a developing country have therefore been dealt with in chapter 4.

Chapter 8 Primary Data Analysis

8.1 Overview of the Chapter

The importance of collating precise data on energy supply and demand across the various sectors cannot be overemphasised as this is a prerequisite for viable energy policies for development, the satisfaction of social needs and environmental sustainability. The energy for cooking, heating and cooling in the residential sectors mainly within households have consistently accounted for over half of the energy consumption in Nigeria.

In this chapter, the results of the energy consumption study conducted as part of the integrated assessment of energy consumption are presented. This study forms the main part in ascertaining the factors that may influence the demand or consumption of energy in a region within sub Saharan Africa. The questionnaire used sought information from householders on the type of housing, housing demographics, energy sources, energy appliances and the ownership of household appliances. Consequently, the results are presented and discussed within this chapter. This provides a general summation of the findings of the many sub-sets of the research.

This study provides empirical data and attempts to link this with energy ladder hypothesis as discussed earlier within this thesis.

This study aims to investigate the relationship between different factors affecting the energy demand by households in Nigeria and to develop a conceptual framework to analyse and estimate energy consumption by household types.

The objectives will therefore include the following:

1. To evaluate the relationship between energy consumption and economic development.
2. To identify factors affecting energy consumption in the economy in general and in the household sector in specific.
3. To critically evaluate theories of economic development and urbanisation and assess their underlying assumptions in explaining energy consumption in the residential sector.

4. To assess the validity of identified factors in explaining energy consumption behaviour using secondary data.
5. To develop a conceptual framework to estimate the behaviour of households using socio-economic factors.

8.2 Introduction

As seen in chapter 4, energy ladder is one of the key theories that have been noted mainly for its ability to explain the income dependency of fuel choices. The concept of energy ladder being that the differences in the pattern of energy use in households vary with their economic status. In this research, this concept is being investigated in the process of analysing the factors that contribute to the consumption of energy in households. As such the hypotheses that were generated from this energy ladder model were tested.

The aim of this chapter is to provide empirical evidence as a means of further assessing and testing the hypotheses outlined in section 8.2.1. It involves energy consumption details for a sub-sample from 501 households. Following an initial explanation, further studies examine factors contributing to the consumption of energy among the selected area.

8.2.1 Methodology

An interview/survey was conducted to investigate the choice of energy for households and the way of consumption, what factors affect people's behaviour and also the survey was used to try to capture other details that secondary data may not have captured. A survey interview was carried out within Ibadan metropolis using questionnaires. Details of how the survey was conducted are set out in the methodology chapter (Chapter 6).

A pilot study was initially carried out using a sample size of 30 to test the reliability and validate the effectiveness of the instrument (the questionnaire) and to ensure that the values of the questions were sufficient to obtain the required information. Some time was spent after this to make slight amendments to the questionnaires.

This was to ensure that the questions were easily understood so that the relevant information can be provided by the interviewees.

Ethical Issues: It was important that information obtained from the survey was interpreted correctly and therefore, there was a meeting/briefing with all the interviewers prior to the survey/ questionnaire being distributed. This provided the forum to review the questions and ensure everyone had an understanding of what was required from those being surveyed. The briefing session also gave us the opportunity discuss about the research ethics as well as how to minimise researcher's bias.

It was advised that in Ibadan and in Nigeria generally, it is culturally appropriate to talk to people considered "strangers" outside of the house and so interviewers may not be invited into the house but may be on the premises. Also for the issue of safety, interviewers were advised to where possible to go in pairs but must not in any circumstance conduct the survey when it is dark/night time.

Prior to the survey, respondents were informed about the objective of the research, the possibility of publicising the data and the possibility of withdrawing from participating at any time. They were also given consent forms to complete. The interviewers were instructed not to force participation, nor to invade the privacy of households when they seem unwilling to participate.

It was also advised that some people may not be comfortable being with the interviewer on their own as the interviewer may be considered a "stranger" in their homes. It was advised that interviewers should always try to establish who the head of the household is and direct questions to them.

8.2.2 Problems encountered in obtaining information

There were few problems encountered in the process of collating information using the questionnaire. This section details those issues and how they were dealt with so that it was still possible to obtain the relevant information and data needed for the research.

Concerns about disclosing personal information: Confidentiality was assured to make the respondents more comfortable in responding to the questions as appropriate. Participants were given the option to be anonymous in order to increase the response rate by not taken personal identification details (names) of the respondents instead, a code number or identifier was ascribed to each household.

Length of questionnaire: Some individuals were equally concerned about the time taken to complete the questionnaire. In all cases, prior noticewas given to the participants informing them of the study. The head of households were given the qustionnaires to complete and return. Though not to the extent of causing any form of bias, incentives were provided for some participants to take away- the pen needed to complete the questionnaire was given to them.

Identification of administrator: There were also instances were respondents were apprehensive of the identity of the administrator, but the provision of an identification card and a cover letter or an introduction letter addressed to the respondent helped to resolve the problem.

Returning of questionnaires: Some questionnaires were not returned. This problem was minimized in two ways. One, reminder to the respondent was adopted to increase the response rates and secondly another copy was given in instances where participants had lost or mislaid the previous questionnaire.

Level of understanding: There were cases where some of the wordings or language used in the questionnaire was not properly understood because of the literacy level of some participants. This problem was reduced largely by helping the participants put down their responses and providing clarity on questions as necessary. This helped to reduce low quality of answers.

Incomplete information: By design, the questionnaires, were structured for the participants to give range in cases where they could not remember the exact figure required to some question, and in few instances, these were not completed and as such it was not possible to obtain data for such questions.

The questions generated are summarised in Table 8.1 (with the detailed questionnaire in Appendix 9) and are directly related to the consumption of energy within households, so as to be able to obtain information that could then be analysed and the results used to accept or reject the hypothesis created by the energy ladder model. The hypotheses includes:

- Energy consumption is determined only by economic factors;
- Movement to different forms of energy is unidirectional and linear in progression;
- Movement on the energy ladder depends on the income of the household;
- Energy consumption depends on the preferences for particular fuel type.

Table 8.1 Summary of questionnaire used in study

Question Group	Sub- questions
Section A You and other people in the household	Person in charge of the household Age Marital status Education Employment Relation with other people in the household Income
Section B Your home and your appliances	Type of property lived in Ownership status of property Size of property Quantity of functioning appliances
Section C Your household energy consumption /usage	Type of fuel used in household Factors considered in choosing fuel Monthly usage of fuel
Section D Household's electricity consumption and energy efficiency	Type of electricity meter in property Type of appliances owned Length of usage of appliances

Source: Author's compilation

8.3 Results from Survey

8.3.1 Sample size and characteristics

A survey of the demand for energy by households was carried out in the Ibadan metropolis in Nigeria. Questionnaires were issued at different locations within Ibadan to gather information on the energy consumption within households. The studies were conducted in a total of 561 residential buildings within five of the local government areas in Ibadan between November and December 2014. There were, however, only a total of 501 respondents.

Table 8.2 Summary statistics of variables used (N=501)

Stratum	Sub-Stratum	Household	Cumulative per cent
Gender	Male	272	54.6
	Female	226	45.4
Age	18-25	102	20.5
	26-35	165	33.2
	36-45	117	23.5
	46-55	73	14.6
	56-65	38	7.6
	>66	2	0.4
Education level	PhD	56	11.9
	MSc	88	18.7
	BSc	177	37.7
	Secondary	84	17.9
	Primary	9	1.8
	No Formal education	13	2.8
	Other	43	9.1
Income level (per annum)	Low (0-29999)	141	36.6
	Medium (30000-99999)	160	41.5
	High (100000 and above)	84	21.8
Number of people living as a family	Average	4	_
	Minimum	1	_
	Maximum	14	_
	Number of children	2	_
Type of house	Bungalow	102	22.4
	Duplex	77	16.9
	Flat	277	55.3
Electricity connection	Yes	287	78
	No	81	22

Source: Author’s compilation

A summary of the data collected of those who participated in the survey is presented in Table 8.2. Two hundred and seventy-two (272) of the overall samples were male while two hundred and twenty-six (226) were female with three respondents (0.6per cent) who failed to indicate their gender on their questionnaires. This meant cumulatively, 54.6per cent of the respondents were male while 45.4 per cent were female.

From the data collected, it was established that about 87 per cent of the respondents had moved within the last 4 years with 223 of the respondents having moved into bigger properties. Based on this information, it is reasonable to assume that most respondents are already accustomed to their way of living and have an established pattern of energy consumption.

The education stratum which was six previously was later reclassified into four, namely: non formal, primary, secondary and tertiary education. This was to allow for ease of analysing the data obtained. Housing, which is represented by the types of houses can be considered as a common variable for households and provides the context for the observation of other factors that determine energy consumption.

The largest proportion of properties lived in as shown in Table 8.2 are flats which make up 55 per cent of the types of property in the sample areas. These flats are mostly occupied by civil servants who also own in total over 51per cent (98) the properties in these areas. This is followed by those that are self-employed as they own about 44 per cent of the total number of properties inhabited by those that are self-employed. Figure 8.1a showing the distribution of the different housing types in the sample area with Figure 8.1b shows a cross section of the various types of houses in the Ibadan area.

Figure 8.1a Housing type distribution in study area (N=501)

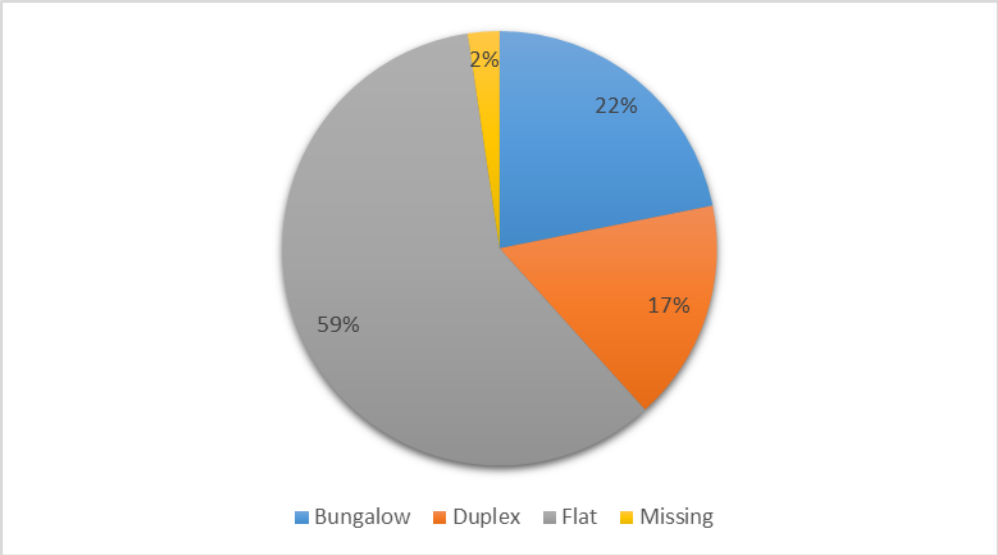
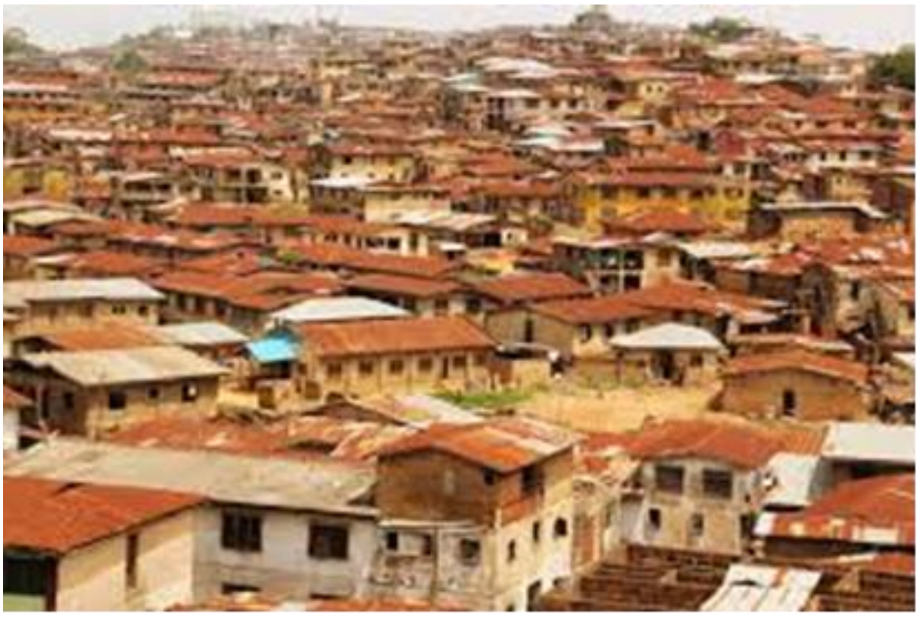


Figure 8.1b Housing Topography in Ibadan



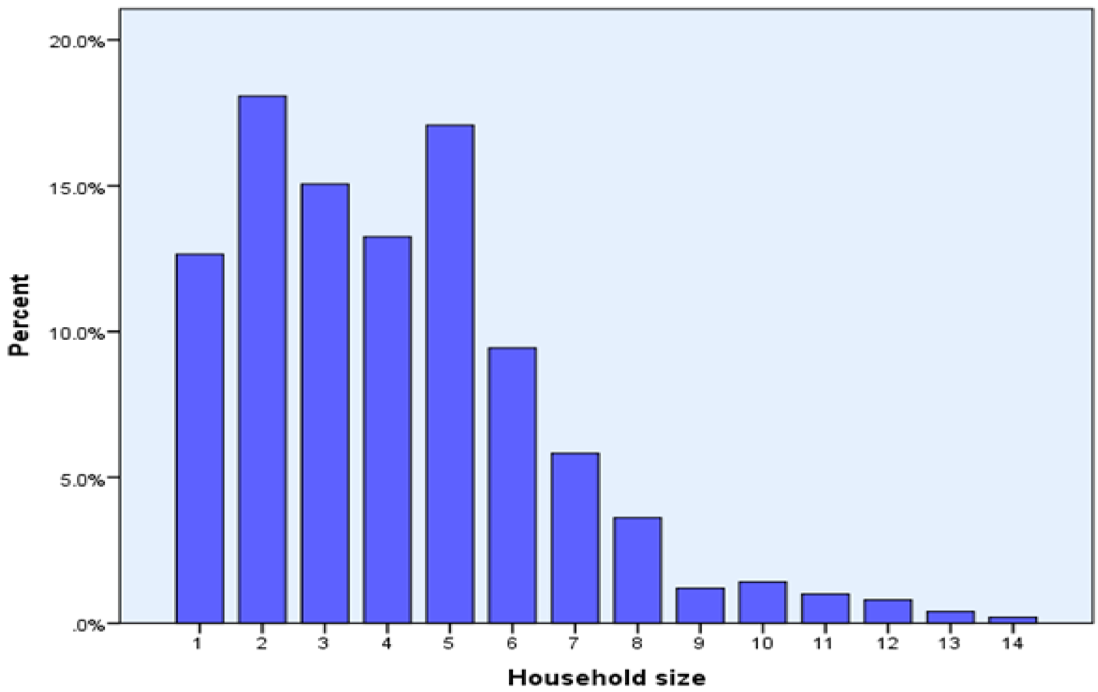
The houses are heterogeneous in pattern. Some of the houses are owned and built by individuals but the type of tenure is largely dominated by family houses, which belong either collectively to the family or to the head of the family. Some of the respondents have bought their land and built their own houses. Some of the houses are built to rent out and there are instances where a few others, generally young, are tenants who rent a room in a house or a room and a parlour or a flat. The houses built in cement, makeshift houses of wood, and there are some derelict mud houses plastered with cement. In the same neighbourhood, while the facilities for electricity supply are sometimes available, lack of potable water is one of the main problems of these areas.

8.4 Households Characteristics

The results of the household characteristics is discussed fully in this section which includes household size, age distribution, level of occupancy, income and expenditure patterns. The survey shows an average of four people in the households in the sample area. This figure includes an average of two children per household.

The household size ranges from one to fourteen representing 12.7 per cent and 0.2 per cent respectively of the sample size. However, most frequently occurring households had two people who represent 18.1 per cent while over 2.4 per cent had more than 10 people in their households. Only about 1.3 per cent of the sample population had no children in the household whilst 38.7per cent had one child and 34.7 per cent had two children. Figure 8.2 clearly shows this.

Figure 8.2 Distribution of the household size within the sample area



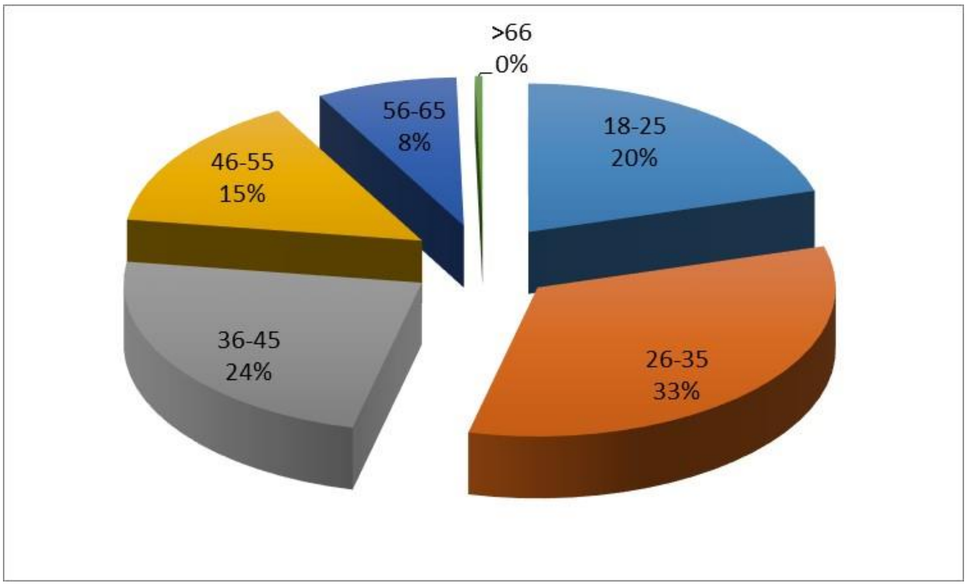
Source: Author’s compilation

Although, the majority of the respondents live in flats, a closer examination of the data reveals that 80 per cent of the household of nine people live in flats. In addition, the analysis shows that the numbers of people renting their properties are slightly higher (46.5 per cent) than those who owned their properties (42.9 per cent) with about 8 per cent not declaring whether they are owners of the property they live in or not.

Figure 8.3 shows about 23 per cent of all household members in the sample group are above the age of 45. A breakdown shows that 20 per cent are aged between 18 and 25 years, 33per cent between 26 and 35 years and 23.5 per cent between 36 and 45 years. Household members aged between 46 and 55 constitute about 15 per cent and those between 56 and 65 years are about 8 per cent while only less than 1per cent of household members is above 65 years old.

Further analysis of the households also indicates that most of the respondents are married (about 46.7 per cent) of the sample population. The sample area has people whose form of employment is majorly in the Civil Service sector (214) with another 107 people being self-employed. Of the Civil Servants, almost 38 per cent of them had first degrees whilst 17.3 per cent have PhDs (see Table 8.3a). This should have an impact on the income level (Table 8.3b) and, subsequently according to the energy ladder hypothesis, (Chapter 5) an increase in energy consumption.

Figure 8.3 Age distribution within the sample area



Source: Author's compilation

The highest number of those who mostly use electricity was recorded among the civil servants who were middle income earners. This was followed closely by civil servants who were in the high income category.

Table 8.3a Employment status within the sample area

		Frequency	Per cent	Valid Per cent	Cumulative Per cent
Valid	Civil Servant	214	42.7	44.7	44.7
	Formally employed	89	17.8	18.6	63.3
	Informally employed	44	8.8	9.2	72.4
	Self employed	107	21.4	22.3	94.8
	Other	25	5	5.2	100
	Total	479	95.6	100	
Missing	99	22	4.4		
Total		501	100		

Source: Survey results

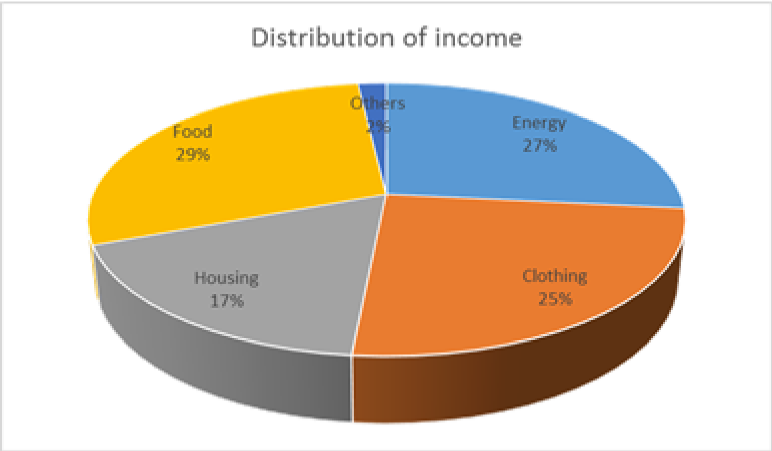
Table 8.3b Income vs forms of employment

		Employment				Total
		Civil servant	formally employed	informally employed	self employed	
Income cat	Low income	45	28	16	50	139
	Middle income	99	31	10	40	180
	High income	43	13	5	27	88
Total		187	72	31	117	407

8.5 Household Income and Expenditure

Household income and expenditure are very important as many studies done have attributed energy demand to the income of the household. The energy ladder theory is one of such that implies that people will only move up the energy ladder when there is an increase in income. Obtaining data on such is therefore imperative. However, it is important to note that issues centred on household finances are usually viewed with suspicion in Nigeria and worth noting that some of the income declared by householders may be inaccurate. The chances are that the figures are more likely to be underestimated than overestimated, possibly for fear of tax implications.

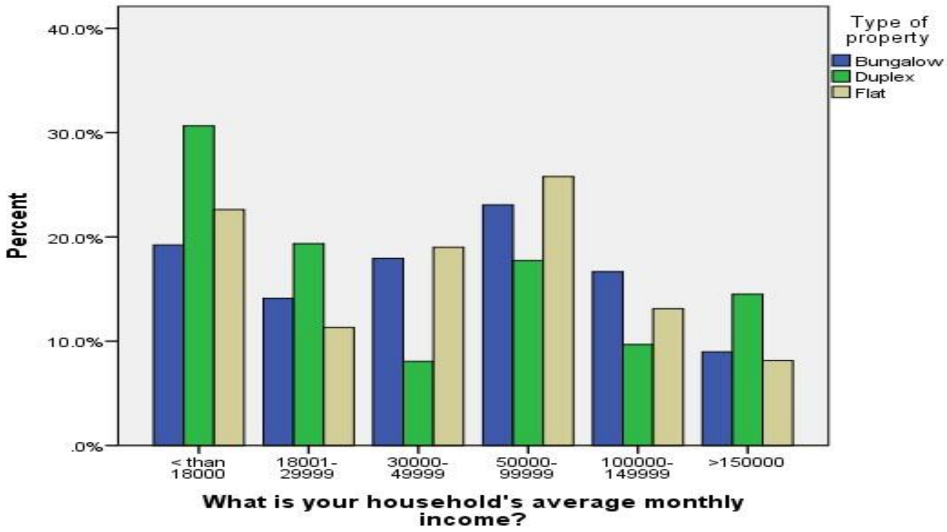
Figure 8.4 Distribution of income



Source: Survey results

Figure 8.4 shows that the highest proportion of the households' income is spent on food (29 per cent). This is followed by energy (27 per cent) and clothing (25 per cent). Figure 8.7 also shows that, over 30 per cent of those who are classified as low income earners (N0-29,999) and the majority of those who earn over N150, 000 live in duplex houses. It is interesting to note that less than 20 per cent of the sampled size lives in flats. A correlation analysis of these two factors (household income and type of property) showed that there was no correlation between the two while the median household income level across the types of property is N50, 000-99,000 (see Figure 8.5).

Figure 8.5 Income and type of property



Source: Survey results

This may help to explain why those on low income are able to occupy duplex properties which are usually considered more expensive than flats or bungalows. It may be that those on low income live with other people who are either owners of such property or responsible for the payment of the rent on such.

8.6 Household Appliances

Households engage in various activities daily that requires the use of energy. These include cooking, lighting, cooling, and heating. Analysis of the type of fuel mostly used in the households within the sample area indicates that electricity was the preferred choice (see Table 8.4). This had the highest ranking of 48.5 per cent. This was followed closely by the use of gas (46.2 per cent) and kerosene (45.6per cent). The least used fuel was firewood (19.5 per cent).

Table 8.4 Type of fuel mostly used in households for daily activities (N=501)

Fuel	Per cent (mostly used)
Electricity	48.5
Gas	46.2
Kerosene	45.6
Fuelwood	51.0
Diesel	31.4
Coal	21.6

Source: Survey results

This indicates that most households will not use just one form of energy but rather a combination of different types of energy for different purposes. For instance, a household may use electricity for lighting and cooling but use kerosene or gas mainly for cooking. The survey also reveals that the issue of availability was the most important factor to be considered when it comes to deciding whether to change from one energy type to another. This factor ranked highest with about 72 per cent followed by the issue of convenience (69 per cent). Other factors considered in making such decision includes: efficiency (58 per cent), cost (52 per cent and marketing 29 per cent) in order for the respondents to switch from one energy type to another.

Table 8.5 Household expenditure pattern between different income categories

Expenditure category	Household's average monthly income					
	< than N18000	N18001-N29999	N30000-N49999	N50000-N99999	N100000-N149999	>N150000
Clothing	27%	21%	22%	16%	13%	14%
Energy	17%	21%	18%	17%	15%	15%
House rent	20%	22%	20%	24%	25%	21%
Food	36%	38%	32%	33%	30%	30%
Others	.	35%	35%	19%	17%	20%

Source: Output from SPSS

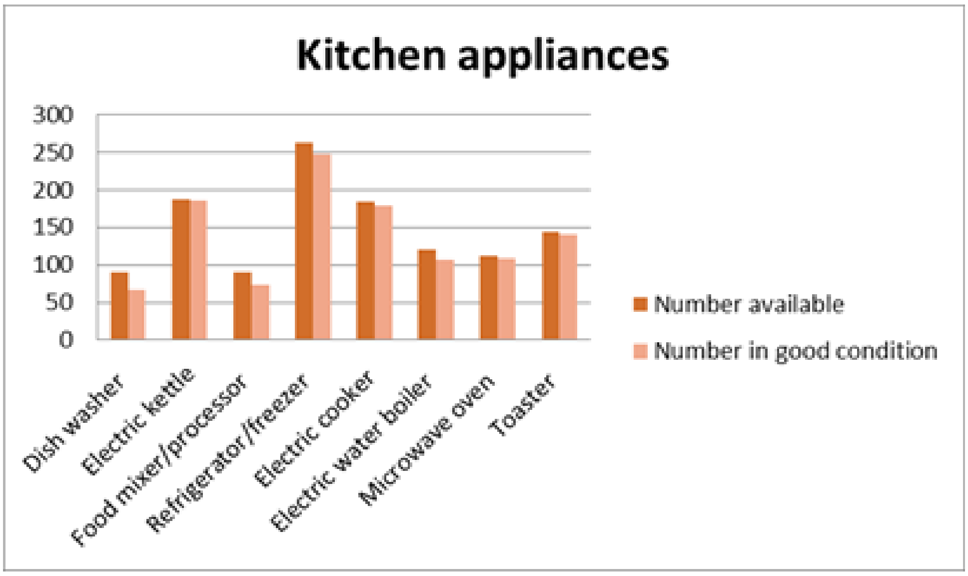
8.6.1 Kitchen appliances used in the sample area

There were questions in the survey (section C) about the ownership of appliances in the households. These include kitchen appliances used mainly for cooking and other electrical appliances categorised as comfort and leisure appliances of the respondents. The questionnaire was used to capture the number and type of kitchen appliances used by the different households in the area. Figure 8.6 shows that households nearly, in all instances, have more kitchen appliances available than those in good working conditions.

Generally, respondents in this study were found to tend to keep and use appliances that are in good working condition. This being one way of ensuring that they use energy efficiently as appliances that are faulty or not in good condition tends to use up more energy. The rate of kitchen appliances in working condition ranges from 73.6 per cent for dishwashers to 98.4 per cent for electric kettle and for other appliances from 53.1 per cent for televisions to 100 per cent for washing machines.

In some households, some appliances that are not in very good conditions were kept as 'back ups' in emergencies.

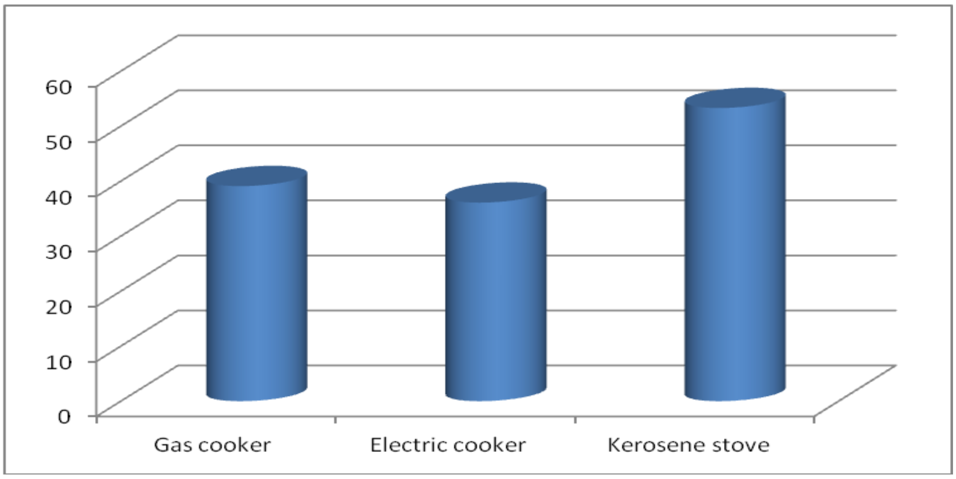
Figure 8.6 Kitchen appliances used in survey area



Aside from the above appliances, the survey showed that over half of the sample population uses kerosene stove (53.3 per cent) with almost 40 per cent using gas cooker and 36 per cent electric cooker as seen in Figure 8.7. However, it is difficult to conclude that these appliances are solely used in the different households. It is more likely for a household to have two or more different cooking appliances in order to be able to overcome the unavailability of one fuel or form of energy or the other, in view of the epileptic supply of electricity or the non- availability of the different types of energy.

Conversely, only 9 per cent of those surveyed pay the highest average of more than N5000 for gas, 15 per cent for petrol and only 8 per cent pay such amount for electricity. This may be attributed to the irregularity in the supply of electricity in the nation, leading to people spending more money on the petrol/diesel needed for the generators instead.

Figure 8.7 Levels of the use of cooking appliances



In terms of deciding on a choice of fuel, respondents indicated that the following factors will be considered. They include mainly the availability of the fuel, the efficiency, convenience and the cost. The same factors according to Table 8.6 were highlighted as what will motivate them to switch between fuel types.

Table 8.6 Factors considered in the choice of fuel

Important factors in choosing fuel type	Proportion of respondents (per cent)	Motivating factors to change fuels	Proportion of respondents (per cent)
Availability	66.6	Availability	71.7
Efficiency	48.8	Efficiency	58.7
Convenience	60.8	Convenience	68.7
Marketing	-	Marketing	29.9
Cost	49.6	Cost	52.3

Source: Author's compilation

However, in terms of changing from one fuel to another, the issue of efficiency rated higher than costs whereas in the initial onset of deciding on the type of fuel to use, consideration for cost was more relevant to the respondents than efficiency.

8.7 Summary of the Chapter

This chapter has concentrated on analysing the energy consumption in households using mainly the results obtained from the survey carried out. It analysed the impact of the various socio economic factors on energy consumption and concludes that factors such as availability of energy, efficiency and convenience rank higher than costs in considering the choice of fuel type or changing from one to another.

Chapter 9 Discussion of the Results

9.1 Overview of the Chapter

In this chapter, the results of the energy consumption study conducted as part of the estimation of energy demand are presented. This study forms an important contribution to understanding the factors that may influence the demand or consumption of energy in Nigeria, a country within sub Saharan Africa. The questionnaire used sought information from householders on the type of housing, housing demographics, energy sources, energy appliances and the ownership of household appliances. Consequently, the results are presented and discussed within this chapter. Sections 9.2-9.6 deal with the effects of the different social demographic factors on energy consumption while section 9.7 discussed the model estimation using the ordinal regression method. The results obtained from the regression analysis are discussed in 9.8.

9.2 Introduction

The importance of energy planning cannot be over emphasised and so is the importance of collating precise data on energy supply and demand especially in a developing country such as Nigeria where it is important that the available resources are harnessed properly. This will also aid development, satisfaction of social needs and environmental sustainability. This section will concentrate on ascertaining the impact of the various factors on the demand of energy.

The household sector in the country is regarded as the highest consumer of energy (electricity) and, therefore, the household energy analysis offers perceptions into the trends which does not necessarily comply with the economic-oriented assumptions of the energy ladder model and the energy transition theories. Arnold et al. (2006), argued that in most studies the effect of income on energy consumption may be negligible, irrespective of how income is measured. There are also previous studies by various people (Campbell et al. 2003, Heltberg et al. 2000, Oudraogo, 2006) on classic energy transition theory who identified factors such as income, education, size of household, access to electricity and so on as contributors to the demand of energy and reason for switching fuels.

This chapter provides a general summation of the findings of the many sub-sets of the research. These and other factors were therefore evaluated in this thesis in order to substantiate or refute the notion of energy ladder theory. This study provides empirical data and attempts to link this with energy ladder hypothesis discussed earlier (chapter 3) in this thesis.

This study therefore aims to investigate the relationship between different factors affecting the energy demand by households in Nigeria and to develop a conceptual framework to analyse and estimate energy consumption by household types. This will be by achieving the following objectives:

- Evaluating the relationship between energy consumption and economic development.
- Identifying factors affecting energy consumption in the economy in general and in the household sector in specific.
- Evaluating theories of economic development and urbanisation and assess their underlying assumptions in explaining energy consumption in the residential sector.
- Assessing the validity of identified factors in explaining energy consumption behaviour using secondary data.
- Developing and testing a conceptual framework to estimate the behaviour of households using socio-economic factors.

The decision by households to allocate their total expenditures to energy, and subsequently to the different fuels that they consume depends on the type of fuels that they have access to and the cost of having such. This supports the reasoning for splitting the consumption of electricity, kerosene and gas into three different levels-low, medium and high levels. This section presents the empirical results of estimation carried out in this research.

9.3 Energy Consumption in Relation to Income

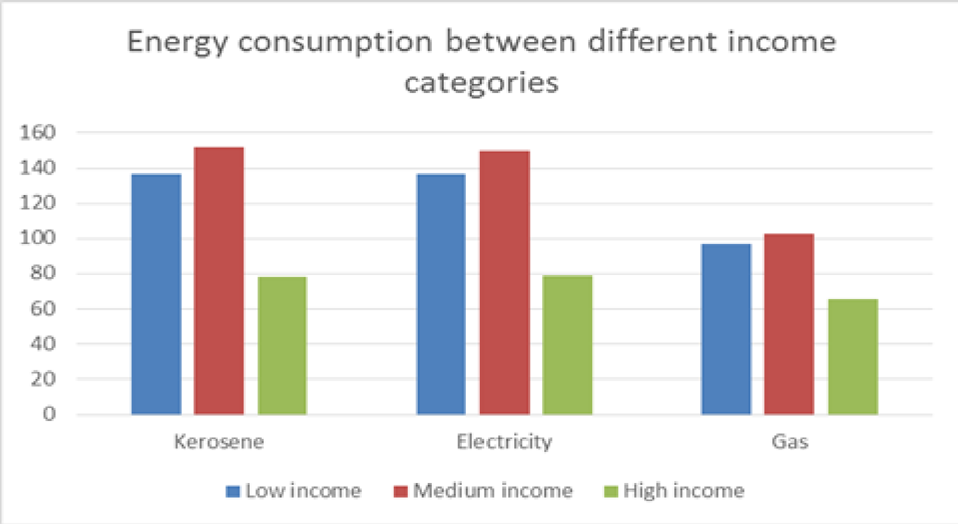
When asked about the factors that consumers consider important in choosing a fuel type or what would motivate them in switching fuels, only 10 per cent of the high income earners considered cost as important in choosing a fuel but the biggest motivating factor for them to change is the efficiency of the fuel type. Interestingly, too, the issue of cost was not paramount as a factor for those on low or medium income when choosing a fuel type; rather it is the availability, efficiency and convenience of the fuel that motivates them.

The analysis of the data collected does not show any statistical difference between the consumption of any of the energy fuels among the high income earners and certainly there is not an abandonment of one form of energy in preference to another due to income. In our instance, only 25.4 per cent of the high income earners used a high level of electricity whilst 24.8 per cent of that category consumed a high level of kerosene while only 15.4 per cent used a high level of gas.

Although there was an increase in the number of consumers for different types of energy when people moved from low to medium income earnings, the same does not hold for changes in earnings from medium to high income.The medium income earners (N30000 to N99999) also accounted for the highest number of consumption of the different forms of energy at the medium level (Figure 9.1). In all instances of energy consumption, those in the urban area were the highest consumers of electricity, kerosene and gas at the medium level. Only in the case of kerosene consumption was the number of consumers at the medium level slightly higher than those at the low level.

The research results show that income is not the sole determining factor for household energy choice and so does not support the energy ladder theory which suggests that energy demand depends entirely on income as people move to more sophisticated form of energy as their income increases.

Figure 9.1 Energy consumption vs different income groups



Source: Survey's results

9.4 Energy Consumption in Relation to Locality

Table 9.1 shows that only 27 of the 123 that live in urban area consumed kerosene at a high level. The figure which amounts to 5.7 per cent is low when compared to 6.7 per cent and 8.2 per cent of the urban population (as reflected in Table 9.1) that consumed a large quantity of gas and electricity respectively. This can be used to substantiate the notion that urbanisation, when accompanied by economic development and increasing incomes, tends to lead to a change in consumer needs, which results in increasing energy consumption.

Table 9.1 Average monthly consumption of fuels in different areas

	Average monthly consumption								
Location	Low Consumption			Medium consumption			High consumption		
	Kerosene	Electricity	Gas	Kerosene	Electricity	Gas	Kerosene	Electricity	Gas
Rural	102 21.5%	93 19.7%	62 19.8%	104 21.9%	129 27.3%	101 32.3%	96 20.2%	78 16.5%	29 9.3%
Urban	76 16.0%	75 15.9%	40 12.8%	70 14.7%	59 12.9%	60 19.2%	27 5.7%	39 8.2%	21 6.7%

Contrarily, in the rural area, there was a decrease in the number of those who consumed high level of fuel from 20.2 per cent for kerosene to 9.3 per cent to 16.5 per cent for electricity and 9.3 per cent for gas and for low consumption level, it appears that the rate reduced as the fuel became more sophisticated. In this instance consumption at the low level for kerosene was 21.5 per cent and reduced to 19.7 per cent for electricity.

In terms of the location of properties, those in the urban areas tend to consume a greater proportion of electricity at the medium level (27 per cent) when compared to those in the rural area where the highest proportion of those who consume electricity is at a low level of 15.9 per cent.

9.5 Energy Consumption in Relation to Education and Ownership Status

Of the population surveyed, about nine per cent had no formal education, only 1.4 per cent stopped education at the primary school level whilst over 70 per cent had post-secondary school education (Table 9.2). These set of people with tertiary education consumed more gas than either electricity or kerosene with 73 per cent of those consuming a high level of electricity compared to 74 per cent in kerosene. It can be said therefore that higher levels of education can be associated with a greater probability of the household using modern fuels.

Table 9.2 Consumption of energy in relation to education

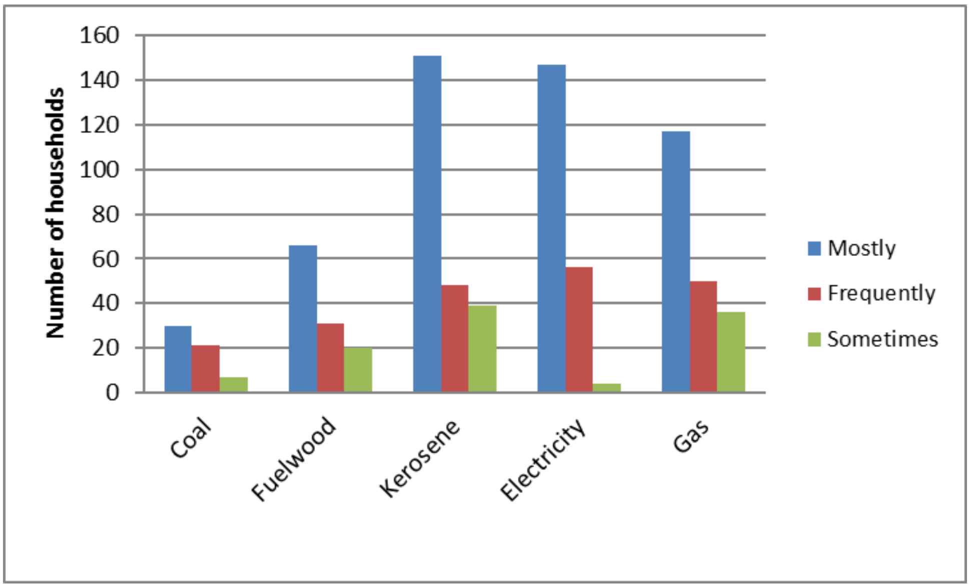
		Frequency	Per cent	Valid Per cent	Cumulative per cent
Education	Tertiary level	364	72.7	72.7	72.7
	Secondary level	85	17.0	17.1	89.6
	Primary level	7	1.4	1.4	91.0
	Non formal	45	9.0	9.0	100.0
	Total	501	100.0	100.0	100.0

Source: Survey results: Output from SPSS

This research has found that education plays a significant part in the demand for energy and thus helps to promote fuel switching and this in line with findings by Heltberg (2004) and Khattak el al., (2010). Generally, a highly educated nation tend to have higher GDP, the inclusion of all factors will unfortunately not be able to show the real impact of each factor on consumption of energy. However, the use of Ordinal regression provides the opportunity for the impact of each of the variable in the consumption of energy to be seen at the different levels.

About 90 per cent of those surveyed informed that they have electricity meter connection, with more than half of them confirming to using electricity and kerosene for different activities as reflected in the graph in Figure 9.2.
Also about 31 per cent of those who own their property were in the low energy consumer category compared to 60 per cent of those renting. Contrarily, 28 per cent of owners were high consumers of electricity compared to only about 20 per cent of those renting. This thus typifies that the ownership status of a property can determine how much or type of fuel being used.

Figure 9.2 Combination of fuels within households



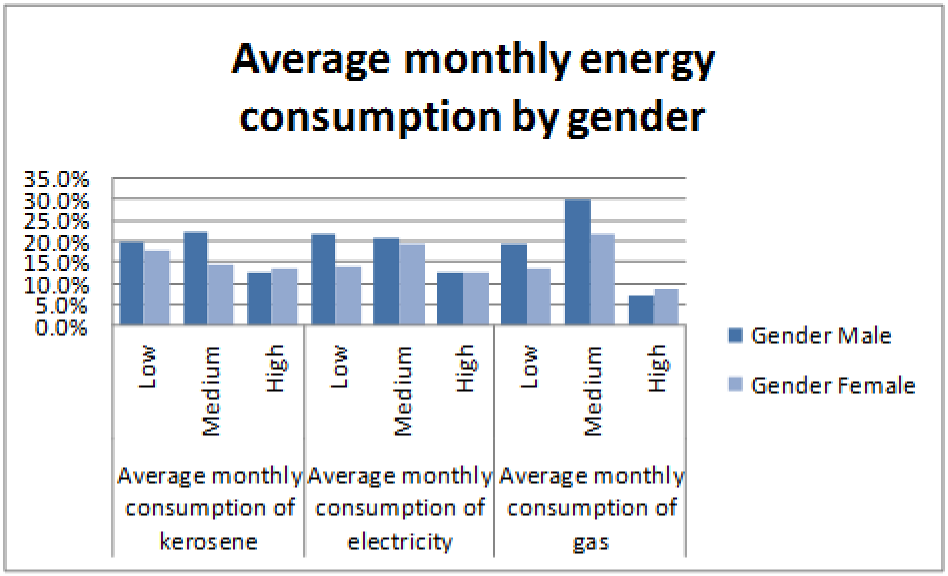
Source: Survey results

9.6 Energy Consumption in Relation to Age and Gender

The largest group of energy users were the 26-35- year old constituting over 30 per cent of the total sample population. They formed the bulk of those on middle incomes and as mentioned earlier form the largest share of energy users.

In nearly all instances, the male head of households seems to consume more energy both at the low level and medium level of consumption. It is only at the high level of kerosene and gas consumption was there more female recorded. The females made up 13.3 per cent and 8.6 per cent respectively whilst the males accounted for only 12.6 per cent and 7.3 per cent. Women, of course tend to be the higher user of some form of energy that is used mainly for cooking. For electricity, the number of males was 12.5 per cent which was slightly higher than the number of females recorded (12.3 per cent). It must be noted though that the number of males indicated made up over 50 per cent of the sample population and this may be the reason for the high number of males at the different level of energy consumption.

Figure 9.3 Average energy consumption by gender



Source: Output from SPSS

In addition, although generally, the population were mostly medium income earners (41.6 per cent), a greater proportion of that consists of the age 26-35 (making up about 26 per cent of the males in the sample population. This, again may be a reason for the increase in numbers of males consuming energy.

9.7 Model Estimation

This section presents the empirical results of estimation carried out using ordinal regression. The decision by households is to allocate part of their total expenditures to energy, and subsequently to the different fuels that they consume depends on the type of fuels that they have access to and the cost of having such.

Table 9.3 Summary of variables used in estimating models

Variable	Label	Measure
lnAge	Natural logarithm of age	Number
Educ1	Education level of household head	Qualification received
Employ	Employment status of head of household	1= Employed, 0=Unemployed
Exp_Elect	Expenditure spent in electricity	Nigerian Naira
Exp_Gas	Expenditure spent on Gas	Nigerian Naira
Exp_kero	Expenditure spent on kerosene	Nigerian Naira
Func_Kero	Number of functioning kerosene stoves	Number
HH_size	Household size	Number of people in household
Income_cat	Income category	1= Low, 2 = Medium, 3= High (Nigerian Naira)
Owner	Ownership status	1= Rented, 0= Owned
Price_elect	Price of electricity	Nigerian currency (kobo)
Price_gas	Price of gas	Nigerian currency (kobo)
Price_kero	Price of kerosene	Nigerian currency (kobo)
Housing_Type	Type of property	1=Bungalow, 2= Duplex, 3= Flat
Location	Household location	1= Urban, 2= Rural
Tot_Appliances	Total number of appliances	Quantity

Source: Author's compilation

This supports the reasoning for splitting the consumption of electricity, kerosene and gases into three different levels- low, medium and high levels and as such the need to use ordinal regression. Above is a summary of all the variables used in the regression with their full names and measurement units (see Table 9.3).

Fuel subsidy is not included in the analysis of the primary data collected via the use of the survey questionnaire in this study as it was not possible to collect the information or data about the fuel subsidy directly from consumers.

Fuel subsidy was included previously (see chapter 7) in the earlier modelling carried out using secondary data in order to establish the factors that determine the consumption of electricity in the households. In Nigeria, subsidies were introduced in the energy sector around the mid-1980s with the values have risen from 1 billion US$ in the 1980s to an expected 6 billion US$ in 2011 (CPPA, 2012). The concept of the price-gap approach to estimating consumption subsidies was on the basis that subsidies to energy consumers decreases the end-user prices and thus lead to increase consumption. This should also provide the ability to give average Nigerians access to reduced price of gasoline to aid transportation and production costs (Adewunmi et al, 2014). Subsidies, however, according to Kosmo (1989) reduce incentives to use energy efficiently and dampen the government finances through fiscal deficit.

However, in this study, the inclusion of fuel subsidy was not significant in determining the level of energy consumption in Nigeria and therefore appears not to have a short term effect on the consumption of energy. This could have been because the impact of fuel subsidy in terms of price reduction is not instant. Therefore, the lagged value of fuel subsidy was included in the analysis instead (see 7.4.2) and this do have a positive long term effect on energy consumption.

Removal of subsidy if implemented correctly, the subsidy funds could lead to major development gains. Moreover, the removal of the fuel subsidy - if successfully implemented - creates the space for Nigeria to finally develop refinery capacity and consequently increase its potential revenue from the oil sector and create jobs. It was discovered that there is long run benefits of the subsidy removal, no such relationship existed in the short run.

9.7.1 Use of Ordinal logistic regression

As the major aim of this thesis is to develop an appropriate analysis of household energy demand, ordinal regression was used to predict an ordinal dependent variable given one or more independent variables.

The purpose of the analysis is to establish how well energy consumption can be predicted by the responses to questions, some of which are quantitative. That is an ordinal regression was also used to find the determinants of energy consumption within households. In doing so, this thesis estimates the probability that a case will be classified into each of the levels of the ordinal dependent variable. The use of ordinal regression enables the study of the effect of the independent variables on all levels of ordered categorical response. Other than correlation analysis for ordinal variables which focuses on the strength of the relationship between two or more variables, ordinal regression analysis assumes a dependence or causal relationship between one or more independent and one dependent variable. The goal of such a cumulative odds model is to simultaneously consider the effects of a set of explanatory variables across these possible consecutive cumulative splits in the outcome.

An ordinal regression model was evaluated to identify the determinants of energy choice; that is factors explaining the decision to consume a particular fuel. The ordinal regression was done as each of the fuel-kerosene, electricity and gas each had three different level of consumption. This provided insights in how the different sources of fuel are related to each other in terms of what constitutes the demand. The summary results are presented in Table 9.4.

As seen in Table 9.4, the age of the household head, the education level achieved, location of the property, the ownership status, number of appliances including functioning kerosene stoves were some of the explanatory variables used in explaining the level of energy consumption in households. Other variables considered included employment, income and price of the different fuels to see whether any has an impact on the consumption of energy.

Table 9.4 Summary of model estimates

Explanatory Variable	**Dependent variable (Fuel consumed)**		
	Kerosene	**Electricity**	**Gas**
Expenditure on kerosene	-6.52E-006 (4.22E-006)*		
Expenditure on electricity		.491(.164)*[j]	
Expenditure on gas			1.202(.456)**[k]
Household size	.035 (.058)		-.065(.066)
Income			-0.52(.427)
Age of household head[l]	-1.426 (.622)	17.74(.451)**	
Employment type			
Education of household head [m]	-.805(.598)	1.061(.407)*	-1.070(.644)*
Total appliances in household		.018(.015)	
Location of property (0=urban, 1=rural)	.-.563(.183)*	.477(.220)*	
Ownership status (0=owned, 1=rented)	.289 (.289)	-3.00(1.08)	2.410(1.369)**
Type of house[n]			-.702(.425)**
Functioning kerosene stove	-.827 (.355)*		
Model Fitting Information	**314.170 (.002)**	**639.808(.000)**	**273.011(.001)**
Goodness of Fit	**124.871 (.054)**	**581.221(.213)**	**.263.028(.759)**
Pseudo R-Square	**.054**	**.139**	**.201**
Test of Parallel Lines	**306.484(.361)**	**622.067(.168)**	**263.126(.626)**

[j] indicate statistically significant at 5per cent

[k] indicate statistically significant at 1per cent

[l] Age of head of household was captured on 1-6 scale;1=18-25, 2=26-35,3=36-45,4=46-55,5=56-65, 6=>66

[m] Education of head (highest grade completed) was captured on a 1-4 scale; 1 = Tertiary, 2 = Secondary, 3 = Primary, 4=non formal

[n] Type of property captured on 1-3 scale; 1=Bungalow, 2= Duplex , 3= Flat

9.7.2 Assumptions of Ordinal logistic regression

In using ordinal logistic regression, it is assumed among other issues that each independent variable has an identical effect on each cumulative split of the ordinal dependent variable i.e. there are proportional odds. Other assumptions that were met includes the fact that there is only one dependent variable (electricity consumption) which is being measured an ordinal scale and also that the independent variables included continuous and categorical variables. One other assumption that needed to be fulfilled in order to be able to use ordinal logistic regression was the assumption of not having multicollinearity among the independent categorical variables. The independent categorical variables included location of property, ownership status, marital status, gender, age and education. Other variables included were the expenditure on electricity of the household and the total number of electrical appliances in the household.

Multicollinearity usually occurs when there are two or more independent variables that are highly correlated with each other. That is where one of the independent variable can be linearly predicted from the others with a substantial degree of accuracy. This usually leads to problems with understanding which variable contributes to the explanation of the dependent variable and technical issues in calculating an ordinal logistic regression.

Table 9.5 Collinearity between variables coefficients

Model	Collinearity Statistics	
	Tolerance	VIF
Ownership1	.968	1.033
Location	.966	1.035
Age	.805	1.243
Education	.948	1.054
Gender of Head of household	.940	1.064
Marital status	.808	1.238
Expenditure on electricity	.962	1.040
Total electricity appliances	.975	1.026

Dependent Variable: Average monthly consumption of Electricity
Source: SPSS generated output

A test for multicollinearity was carried out by checking the “Tolerance" and "VIF" values in the Coefficients table that was produced, as shown in Table 9.5.

The table shows that there is no collinearity problem as the Tolerance value for each variable is more than 0.1. It is mainly assumed though that in ordinal regression, the effects of any explanatory variables are consistent across the different thresholds and in this instance, SPSS has been used to model the probability of achieving each level below and so the last category is automatically used as reference category. A one-sample t-test was also run to determine whether the average monthly energy consumption (dependent variable) was different to normal. The values were found to be normally distributed. As $p<.05$ in all cases, ($p=.001$ for kerosene, .002 for electricity and .000 for gas).

It can be concluded that the population mean is statistically significantly different. The few outliers observed when data was assessed by inspection of the boxplot were replaced by data from similar observations. The mean score for kerosene consumption ($M=1.88$, $SD=0.79$) was lower than the normal mean of 2.0, a statistically significant mean difference of 0.12, 95 per cent CI [0.04, 0.19], $t(474)=3.201$, $d=0.14$. In the case of electricity consumption, mean score was $M=1.89$, $SD=0.77$ and gas was $MD=1.83$ and $SD=0.69$. They were both lower than the normal mean of 2. The statistical differences being 0.11 and 0.17 for electricity and gas respectively and at 95 percent CI, electricity – CI[0.04,0.11], $t(472)=-3.047$, $p=0.002$, $d=0.14$and gas CI[0.09,0.16], $t(312)=-4.336$, $p=.000$, $d=0.09$.

A cumulative odds ordinal logistic regression with proportional odds was run to determine the effect of ownership of a property, the location of the property, education level, age of the head of the household and amount spent on energy on the consumption level of electricity in the household. In carrying out the analysis, certain control variables including the sex of the head of the household, age and education were used (see Table 9.4). The above equation may be different as this may not have been the case in the earlier studies by Ebohon (1996), Iwayemi (2000) and many other studies that was done prior to the spread of solar energy.

In ordinal regression, the probability of the event and all others above it in the ordinal ranking is usually being considered instead of modelling the probability of an individual event. This thus simplifies the assumption that the effects of the explanatory variables are the same across the different thresholds. Various criteria were considered in order to determine if the ordinal regression was suitable for identifying the effects of the different factors on household energy demand as part of the objectives of this thesis. They include:

- Model Fitting Information
- Goodness of Fit
- Proportional odds assumption
- Parameter estimates

9.8 Results of Ordinal Logistic Regression

The data set was collected, analysed and comparisons made in terms of estimates, log likelihood, a test of parallel lines. These were carried out and discussed in this chapter. The result of the different estimates of the different models of ordered regression is shown in Appendix 11 but the details of the estimates of the preferred model are outlined in Table 9.6.

Table 9.6 Estimates of Ordinal regression model

Model fitting information	Model	-2Log Likelihood	Chi-Square	df	Sig.
	Intercept	412.047			
	Final	376.648	35.399	11	.000
Goodness-of –fit	Pearson		222.72	201	.140
	Deviance		242.799	201	.023

Source: Computation from SPSS

The value of the chi square was used to compare the final model against the baseline in order to check if the model produced will significantly improve the fit to the data. In this instance, the chi square statistics of the model (35.399) is significant as it is less than p value of 0.05. This indicates that the model will give significant improvement

over the baseline-intercept only model. Essentially, this implies that the model will give better predictions than if the predictions had been made using the marginal probabilities based on the outcome categories.
In effect, the model is improved by including the explanatory variables. The likelihood of the model is used to test whether all predictors' regression coefficients in the model are simultaneously zero and in tests of nested models.

The final model statistically significantly predicted the dependent variable (electricity consumption) over and above the intercept-only model, $\chi2$ (11) = 35.399, p < .001. It can therefore be concluded that at least one independent variable is statistically significant. The Goodness-of Fit contains statistics that tests whether the observed data are consistent with the fitted model or not. The null hypothesis is accepted if the fit is good and therefore one can conclude that the data and model predictions are similar and the model is a good one. If p <0.05, then the model does not fit well and the null hypothesis is rejected. Of course, it must be noted that this measure is affected by the number of missing data. Both the deviance goodness-of-fit test and Pearson indicates that the model was a good fit to the observed data, $\chi2$ (201) = 222.772, p = .140.

The measures in the Pseudo- R^2 do not have the direct interpretation that they do in ordinary linear regression but it is still an attempt to explain the variance in a model. In considering the Psedo-R^2, (Table9.7) using Nagelkerke reading, the model can be used to explain only 11per cent of the variance.

Table 9.7 Pseudo R-square

Cox and Snell	.098
Nagelkerke	.110
McFadden	.048

Link function: Logit

A low R^2 will normally indicate that a model containing those variables is likely to be a poor predictor of energy consumption but as they do not necessarily have the same reading as these measures do, they are often, referred to as "pseudo" R^2. As such, this R^2 measure is not considered to be of much value in choosing a model. The threshold coefficients are not usually interpreted individually. They just represent the intercepts, specifically the point (in terms of a logit). For other variables, positive coefficients implies that higher values of the explanatory variable are associated with higher outcomes, while negative coefficients indicate that higher values of the explanatory variable are associated with lower outcomes.

One of the assumptions of ordered logistic regression is that of the proportional odds assumption or the parallel regression assumption. That is it is assumed that the coefficients that describe the relationship between, the different categories of the response variable are the same. The null hypothesis for the Test of parallel lines states that the location parameters (slope coefficients) are the same across response categories. In other words, the null hypothesis of the chi-square test is there is no difference in the coefficients between models.

Table 9.8 Test of Parallel Lines

Model	**-2Likelihood**	**Chi-Square**	**df**	**Sig.**
Null Hypothesis	376.648			
General	366.760	9.888	11	.540

This test compares the ordinal model which has one set of coefficients for all thresholds (null hypothesis), to a model with a separate set of coefficients for each threshold (general). If the general model does not give a significantly better fit to the data than the ordinal (proportional odds) model (i.e. if *p<.05*) then the assumption of proportional odds will be rejected. A test of Parallel Line (TPL) is used to check that the odds of the explanatory variables are consistent across the different thresholds of energy consumption in this instance. If the result is significant, then it suggests that the odds are different between the different thresholds.

Therefore, as p>0.05, it means that the differences in log-odds at different thresholds have not occurred by chance and the assumption of proportional odds has not been violated. For our model, the proportional odds assumption appears to have held because our significance of our Chi-Square statistic is .540 > .05 as in Table 9.8 above.

It must be noted though that TPL test is a very conservative measure as it takes into account any missing data.

Table 9.9 Parameter estimates

Parameter		B	Std Error	95per cent Wald C.I		Hypothesis test			Exp(B)		
				Lower	Upper	Wald Chi square	df	Sig		Lower	Upper
Threshold	Cons Elect=1	22.36	34815.5	-68214.17	68259.49	0	1	0.999	5.16E+09	0	a
	Cons Elect=2	24.16	34815.5	-68212.97	68261.29	0	1	0.999	3.12E+10	0	a
Location1=0		-0.43	0.22	-0.86	-0.01	3.958	1	0.047	0.648	0.423	0.994
Location1=1		0b	.	.	.	.	.	.	1	.	.
Ownership=0		-0.41	0.21	-0.83	0.01	3.706	1	0.054	0.662	0.662	1.008
Ownership=1		0b	.	.	.	.	1	.		.	.
Educ_1=1		0.95	0.39	0.18	1.71	5.917	1	0.015	2.583	1.202	5.55
Educ_1=2		-0.09	1.17	-2.38	2.21	0.006	1	0.94	0.916	0.092	9.096
Educ_1=3		0.54	0.45	-0.34	1.42	1.447	1	0.229	1.716	0.712	4.138
Educ_1=4		0b	.	.	.	.		.	1		.
Age_Grp=1		21.6	34815.5	-68215.53	68258.73	0	1	1	2.40E+09	0	a
Age_Grp=2		21.57	34815.5	-68215.56	68258.70	0	1	1	2.34E+09	0	a
Age_Grp=3		21.68	34815.5	-68215.45	68258.81	0	1	1	2.60E+09	0	a
Age_Grp=4		21.66	34815.5	-68215.47	68258.79	0	1	1	2.55E+09	0	a
Age_Grp=5		22.23	34815.5	-68214.9	68259.36	0	1	0.999	4.50E+09	0	a
Age_Grp=6		0b	.	.	.	.	.	.	1		.
Exp_Electricity		0.5	0.16	0.18	0.82	9.311	1	0.002	1.648	1.196	2.272
(Scale)		1c									

Dependent Variable: Average monthly consumption of Electricity

Model: (Threshold), Ownership, Location1, Educ_1, Age_Grp, Exp_Electricity

a. Set to system missing due to overflow

b. Set to zero because this parameter is redundant.

c. Fixed at the displayed value.

The Parameter Estimates with the coefficients, the standard errors, Wald test and associated p-values (sig.), and the 95 per cent confidence interval of the coefficients are shown in Table 9.9. The following variables- expenditure on electricity, ownership of property, location of the property and level of education are statistically significant.

The first row, [$Cons\_eiec_1$ = .00], is the threshold for the equation representing the first cumulative logit of electricity consumption (i.e., low and all higher categories). The next threshold row ($Cons\_elec_2$) represents the thresholds for the next cumulative logit, (i.e. consumption of electricity at medium level respectively. The ordinal logistic model for a single independent variable is then $\ln(\partial\ ) = \alpha_j - \beta X$ where j goes from 1 to the number of categories minus 1. The cumulative logit equation can be written as follows on the basis of the B values reflected in Table 9.9

$\ln(Cons\_Elect_1)$= 22.36 +0.433*$Urban_{(yes)}$ - 0.412*$Owner_{(yes)}$ + 0.949*$Educ_{(tertiary)}$ + 21.74*Age+ 0.500*Exp_electricity ……………………………………………..(9.1)

$\ln(Cons\_Elect_2)$ = 24.163 +0.433*$Urban_{(yes)}$) - 0.412*$Owner_{(yes)}$ + 0.949*$Educ_{(tertiary)}$ + 21.74*Age+ 0.500*Exp_electricity ……………………………………………..(9.2)

Where $Cons\_Elect_1$ is the amount of electricity consumed at medium level.
$Cons\_Elect_2$ – amount of electricity consumed at high level
Urban – whether property is in urban or rural area
Owner – ownership status i.e. is property owned or rented
Educ – level of education of the head of household i.e. primary, secondary or tertiary.
Age – age of the head of household
Exp_electricity – amount spent on electricity.

The following coding has been used in this instance: 0 for those who live in urban areas and 1 for those in rural areas. Likewise, 0 used for those who own their property and 1 for those renting. Therefore, by default, the procedure makes the last category the reference category; hence the reference category for owned property is rented.

As the model did not violate the proportional odds assumption, the slope coefficients are the same for all cumulative logits with only the thresholds differing.

This parameter estimate (slope coefficient) represents the change in the log odds of living in an urban area as opposed to living in a rural area (the reference category). As positive coefficients mean higher scores on the dependent variable compared to the reference category. Thus, there is a decrease in the log odds of 0.433 of consuming low level of electricity for those who live in urban areas compared to those who live in rural areas.

The exponential of the log odds of the slope coefficient; that is, the exponential of 0.433, (which is $e^{0.433}$) is 0.648. This means that, for rural dwellers, the odds of using a low amount of electricity is about one and a half times more than for those who live in urban areas. In other words, those who live in urban areas have odds of 0.648 to consuming a low amount of electricity. The probability of consuming low level of electricity with an increase in the number of households in the urban area is lower than at original number of urban residents.

In effect, the chances of using low level of electricity for those who live in urban areas is low (0.433) compared to those in rural areas. Conversely, those in rural areas have a higher tendency to consume low amount of electricity either because they are not connected to the grid or maybe because they do not have as much electrical appliances in their homes. In terms of urbanisation, this will imply that a more consumers of electricity will be at the medium or high level.

In other words, for an additional number of household in urban area, the odds of consuming a low level of electricity is lower as the odds ratio is 0.648 for any additional household in urban area.

This can be expressed as follows:

The odds ratio of being in a low category of the dependent variable for urban dwellers versus rural dwellers is

0.648(95 per cent CI, 0.423 to 0.994), a statistically significant effect, $\chi^2(1) = 3.958$, $p = .047$ and for those who own their property, this will be

0.662 (95 per cent CI, 0.436 to 1.008) with a statistically significant effect, $\chi^2(1)$ of 3.704, p= 0.54.

From the table above,(Table 9.9), it can also be seen that an increase in education is also associated with an odds ratio of 2.583; that is, for every one increase in the number of those achieving tertiary level of education, the odds of considering consuming low amount of electricity increases by 0.949 times. Consumers who achieve tertiary level of education are more likely to consider consuming electricity at the higher level as chances are that such people would be earning more and be in a position to acquire electrical or modernised equipment that will use electricity.

Table 9.10 Average monthly consumption of electricity * Predicted response category cross tabulation

			Predicted response category			Total
			Low	Medium	High	
Average monthly consumption of electricity	Low	Count	89	43	1	133
		percent within average monthly cons of electricity	66.90%	32.30%	0.80%	100.00%
	Medium	Count	50	77	5	132
		percent within average monthly cons of electricity	37.90%	58.30%	3.80%	100.00%
	High	Count	33	37	10	80
		percent within average monthly cons of electricity	41.30%	46.30%	12.50%	100.00%
Total		Count	172	157	16	345
			49.90%	45.50%	4.60%	100.00%

Source: Author's compilation from SPSS output

This is still statistically significant at 95 per cent CI, 1.202 to 5.550) with, χ^2 (1) of 5.917, p = 0.15

There were proportional odds, as assessed by a full likelihood ratio test comparing the fitted model to a model with varying location parameters, $\chi^2 = 35.399$, $p = .000$. (Table 9.6) The Pearson goodness-of-fit test indicated that the model was a good fit to the observed data, χ^2 (222.772), $p = 0.140$, but some cells were sparse with zero frequencies in 45.5per cent of cells.

However, the final model statistically significantly predicted the dependent variable over and above the intercept-only model, as seen in Table 9.10 showing the predicted response category with χ^2 (4)=37.807, p=.000. The fact that the afore-mentioned variables were found to be significant is to expectation.

Table 9.11 below shows the predicted and observed monthly electricity consumption with the lowest percentage error (-11.8per cent) being recorded against urban rented accommodation of low electricity consumers.

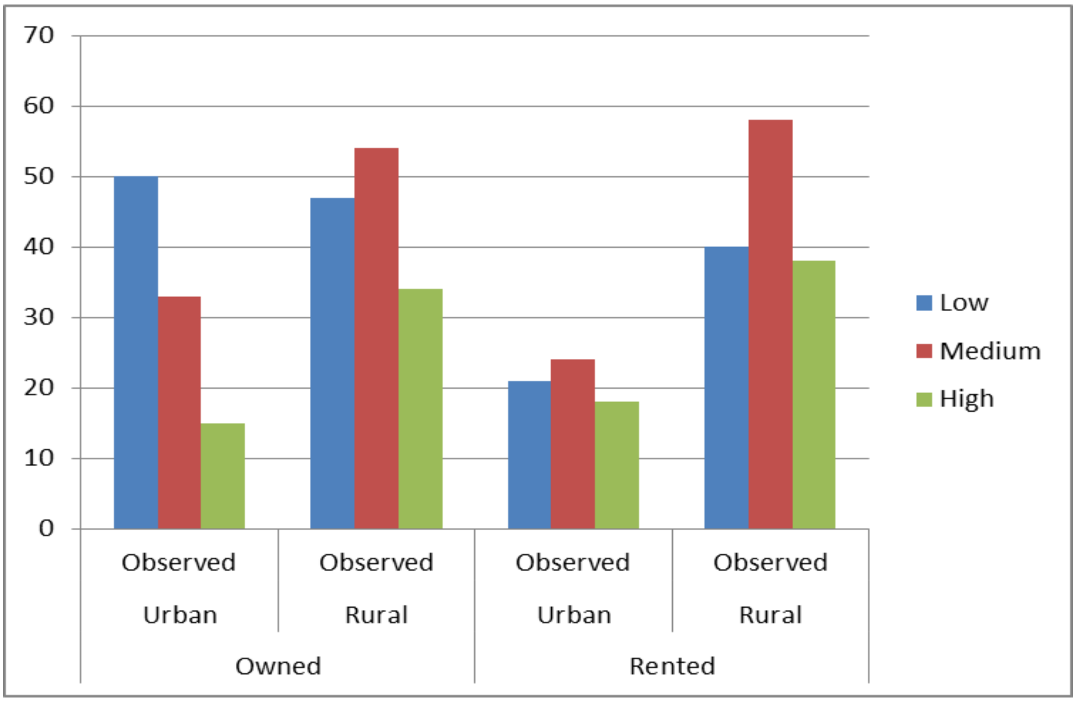
Table 9.11 Income spent by consumers on each fuel

	Kerosene	Electricity	Gas	Total
Per cent of income spent				
5 per cent	32 (30.48%)	44 (42.00%)	29 (27.61%)	105
10 per cent	3 (3.80%)	47 (59.50%)	29 (36.70%)	79
15 per cent	16 (34.04%)	17 (36.17%)	14 (29.78%)	47
20 per cent	42 (32.81%)	51 (38.00%)	35 (29.76%)	128
25 per cent	27 (32.14%)	32 (38.10%)	25 (29.76%)	84

Source: Author's compilation

The highest error was recorded for high consumption of electricity within the rented urban accommodation as in Figure 9.4.

Figure 9.4 Average monthly electricity consumption



Source: Survey results

9.9 Energy Ladder Test

As already discussed in section 3.7, the energy ladder speculates that households move from one energy fuel to another on the ladder as the income increases. Some of the assumptions of the energy ladder theory as discussed earlier includes the following: that there is the positive relationship between socio-economic level and modern fuel uptake, that inherently ranked fuel preferences ordered by physical characteristics as well as fuel costs and that there is an assumption of complete substitution of one fuel for another as there is a linear transition from one fuel to another. The model is reassessed again on the basis that income is not the sole determinant of fuel choice and also that households rarely abandon the use of one fuel completely whilst taking up a new one.

The overall validity of the regression models using the model fitting criteria were significant as reflected in Table 9.9. The increase in the proportion of income spent on any form of energy did not result in an increase in the number of consumers.

For example, only 32.81 per cent of consumers spent about 20 per cent of their income on kerosene and 32.14 per cent spent 25 per cent on the same fuel. In the case of electricity, there was a slight increase in the number of consumers (from 38.00 per cent to 38.10 per cent) whilst there was no increase in the case of gas consumption as reflected in Table 9.11 above.

A cross tabulation of average household income and the number of electrical appliances in the household did not necessarily show an increase in the quantity of electrical appliances owned as income increased. The highest number of appliances in any household was observed at an income range level of N50, 000 to N99, 999. Any increase in income after this did not result in a corresponding increase in the number of electrical appliances acquired. Furthermore, it can be noticed from Table 9.11 that although there is an increase in the proportion of income spent on energy, this did not necessitate a corresponding increase in the number of people using the different fuels. All these show that the consumption of energy does not follow the hypothesis of the energy ladder discussed in chapter 3 but rather in an instance of a developing country, the consumers tend to support the energy mix theory as they have and use a mixture of their fuels.

Moreover, the data from the households in Ibadan area used in this study do not indicate the use of one form of fuel type to satisfy their energy needs. This is because some fuels are better suited for some functions within the household and at other times, it is the availability of the fuel that determines whether it will be used. In reality, the linear switch assumption made under the energy ladder theory (see 3.8) for the use of fuel cannot be proven in this instance as households tend to adopt a multiple fuel use approach.

For instance, it was found that some households will only use gas for cooking quick meals like pasta but will switch to the use of kerosene stove in cooking local stew. This is because, the making of the latter takes longer and it is cheaper and easier to buy kerosene than to get gas. In this multiple fuel use approach, lower level fuels are kept and used simultaneously or as supplement. Furthermore, income was found not be statistically significant as a determinant of energy consumption.

This study therefore also confirms the suggestion by Arnold et al. (2006) that the effect of income on fuelwood consumption turns out to be small, irrespective of how income is measured.

9.10 Summary of the Chapter

The results obtained from the survey has been analysed using the ordinal regression. This was to enable the opportunity to estimate the consumption of electricity at different levels and identify the effects of the various factors that affects energy demand in households.

It was discovered that the notion of the energy ladder did not hold in this instance as the increase in income which may have resulted in spending more on electrical appliances leading to increase in energy did not result in any significant corresponding effect. This is contrary to the perception that increase in income may result into increase in the demand for a particular form of energy or abandoning one fuel for another.

The analysis of the data collected did not show any statistical difference between the consumption of any of the energy fuels among the high income earners. The results in this study indicate that, more people tend to consume more electricity than gas or kerosene in urban areas. More males consumed a higher level of electricity than female but within the sample population, there were more males that were heads of their households. The analysis also show that education plays a major role in energy consumption and this thesis suggests that higher levels of education can be associated with a greater probability of the household using modern fuels. More of those that had post-secondary education used more gas than electricity or kerosene.

Although the increase in the proportion of income spent on any form of energy did not result in an increase in the number of consumers, the final model generated met the assumptions of the ordinal regression and statistically predicted the dependent variable over and above the intercept-only model. The result though did not indicate the use of one form of fuel type to satisfy their energy needs.

Chapter 10 Conclusion and Recommendations

10.1 Introduction

The aim of this study was to develop an appropriate analysis of the factors that contribute to the consumption of energy in households in Nigeria. Previous researches have sought to establish the relationship between national income and energy consumption but many of such have yielded mixed reports. Likewise many studies done in investigating the demand for energy have included income as a major determinant of energy without necessarily incorporating or taking into account the distinctive features of such countries like the rate of urbanisation and the existence of informal markets.

The scope of this thesis explores the energy situation in Nigeria, where even though the country is rich in resources, a large proportion of the country does not have access to them. This thesis was to investigate the factors that contribute to the consumption of energy in households in Nigeria and in so doing, broaden the understanding of the concept of modelling energy consumption in general. The review of a causality relationship between energy consumption and economic growth was the first step in doing so and this was the focus in chapter 2. There was the review of various modelling techniques and the different theories associated with the techniques. This was the central focus in chapter 3.

In addition, the need for energy modelling and forecasting was also considered in the chapter. To advance the current thinking and to make further contribution to knowledge, various literature connected to energy demand as in appendix 1 were reviewed in chapter 3. The various modelling approaches and factors that could contribute to the demand of energy were also identified. Furthermore, our conceptual framework identified two main theories that are in line with the demand for energy in chapter 3. These are the energy ladder and energy mix concepts with their different assumptions.

A review of the literature on the energy modelling showed that econometric approach may not be able to provide satisfactory explanation of the factors that affect the demand or consumption of energy in households in Nigeria as some other important factors are not usually considered with the econometric approach. I also set out to explore the components of the conceptual framework in more detail starting with the evaluation of the energy ladder theory. The characteristics of the energy ladder model and the energy mix model provided the basis upon which a framework for household energy consumption in Nigeria was set. Households usually utilise the concepts of separability and multi- stage budgeting in maximising their utility. As disposable income is a constraint for most households in developing countries, many are inclined to firstly determine how much of their income will be spent on energy and then determine the amount to be spent on the different types of the fuels and the quantity of such fuels.

Chapter 4 explored the role of urbanisation and informal economy on the concept of energy consumption. There was the examination of the research methodology for this thesis in chapter 5 including the use of a mixed approach in ascertaining the factors that contribute to the consumption of energy in households. The forms and use of energy in the Nigerian context and an overview of energy was examined in chapter 6 prior to the analysis of energy consumption in households using secondary data (chapter7). The discussion in chapter 8 was centred on the analysis of primary data for factors which contribute to energy consumption of households whilst using the ordinal logistic regression method for analysing the primary data obtained from the survey.

Although, it had always been possible to forecast the use of energy using an econometric approach (chapter 7), the use of ordinal regression (chapter 8) was beneficial as it was possible to analyse the data whilst taking into account that people consume energy at different levels.

One of the main difficulties in a research of this nature is the availability and quality of data. Some of the data that was used for analysis 1 (chapter 7) can be accessed online and in the printed format. However, errors in the data, non-availability in some cases or delay in making it public and its discontinuity meant that the use of secondary data used was limited.

From the evaluation of the energy ladder (chapter 3), the following hypothesis were generated

Hypothesis 1: Energy consumption is determined only by economic factors.

Hypothesis 2: Movement to different forms of energy is unidirectional and linear in progression.

Hypothesis 3: Movement on the energy ladder depends on the income of the household.

Hypothesis 4: Energy consumption depends on the preferences for particular fuel type.

These hypotheses aimed to test the impact of income on the increase in the consumption of modern energy. To test these hypotheses, we explored the relationship between a range of socioeconomic factors including age, education status, gender, marital status, location of the property, expenditure on the different fuels, fuel prices, ownership status, employment status and income of the head of the household (chapter 9). Each of the hypotheses was based on the concept of energy ladder model which implies that improvement in energy use correlates with an increase in the household income. This is because it is assumed that as income increases, the energy types used by households would be cleaner and more efficient, but more expensive as moving from traditional biomasses to electricity.

This relationship was explored through a case study analysis of 501 households in Ibadan metropolis using ordinal logistic regression (section 8.1). The impact of the factors on household energy consumption using data obtained from 501 households was analysed. The models 1 and 2 outlined in Chapter 8 confirmed a positive and significant association between the locality of the property, ownership status, age, education status, the expenditure on electricity and consumption of energy. The strengths of the ordinal regression model lies in its ability to be able to identify significant independent variables that influence the ordinal response analysis for all levels of the ordinal outcome and subsequently evaluate and predict validity of the regression model.

10.1.1 Aim and objectives revisited

This aim of this thesis was to investigate the factors that contribute to the consumption of energy in households in Nigeria and in so doing, broaden the understanding of the concept of modelling energy consumption in general. The various associated objectives are addressed in different chapters of the thesis.

The review of a causality relationship between energy consumption and economic growth was the first step in doing so and this was the focus in chapter 2. This chapter ties in with the objective (1) set in evaluating the relationship between energy consumption and economic development.

In chapter 3, the central focus was the review of various modelling approaches and the different theories associated with the techniques. This assisted in achieving the objective (2) of identifying factors that affect energy consumption generally and specifically in households. In addition, the need for energy modelling and forecasting was also considered in the chapter. To advance the current thinking and to make further contribution to knowledge, various literature connected to energy demand as in appendix 1 were reviewed in chapter 3. The various modelling approaches and factors that could contribute to the demand of energy were also identified. Furthermore, our conceptual framework identified two main theories that are in line with the demand for energy in chapter 3. These are the energy ladder and energy mix concepts with their different assumptions.

Chapter 4 explored the role of urbanisation and informal economy on the concept of energy consumption and with the section on economic development and exploring the various theories in chapter 2, this thesis was able to meet the objective (3) set in evaluating the theories and the underlying assumptions in explaining energy consumption in residential sector.

The focus of chapter 7 (in achieving objective 4) was in assessing the validity of identified factors in explaining energy consumption using secondary data, modelling the various factors identified from literature and using secondary data.

A conceptual framework was developed (objective 5) on the basis of empirical evidence provided in chapter 8.

By carrying out a survey, it was possible to obtain primary data that was analysed to investigate the choice of energy and consumption pattern of households.

10.2 Contribution of the Research

The research proceeded to analyse the demand for electricity in households using secondary data of some identified factors from literature (7.4). The results obtained were inconclusive as some other relevant factors were not included due to the lack of appropriate relevant secondary data. In some instances, there were uncertainties in interpreting some of the diagnostic analysis of results obtained. This resulted in the use of primary data in this thesis (9.7). Information/data were collected using survey questionnaires from over 500 households.

This research has adopted the use of the mixed method research - combining both qualitative and quantitative in analysing the factors that contribute to the consumption for energy and in this way contributes to the expanding field of energy analysis in developing countries. The novelty of the study is in its use of ordinal regression model (chapter 8) to analyse the factors that contribute to the consumption of different alternative forms of energy used in households. This represents the first time that the ordinal regression model has been applied in this context to Nigerian household data. This is very useful as the model takes into account the fact that that energy in households is usually consumed at different levels although the range between the levels may not be the same. Therefore, the impact of a factor of consumption on households may differ depending on the associated level of energy consumption i.e. whether a household is a low, medium or high energy consumer.

This research highlights the importance of the various socio-cultural factors that affects the consumption of energy within the household, and in the same vein, it was able to show that contrary to the hypotheses suggested in the energy ladder model, economic contribution is not the sole determinant in the choice of fuel energy, that movement to different forms of energy is not necessarily unidirectional and linear in progression and that movement on the energy ladder does not depend solely on the income of the household. However, only one of the hypotheses (hypothesis 4) generated was supported by this thesis in the sense that energy consumption depends

on the preferences for particular fuel type. Whilst it is important to note that it may not be possible to move up the energy ladder with the highest educational knowledge about energy characteristics or the individual factors identified, without income, this study shows that it is a combination of those factors that brings about the changes in the level of electricity consumption in households and not solely economic factors.
The study of the case in five areas in Ibadan metropolis area of Nigeria presented its results based on the use of ordinal regression analysis.

Different models were analysed having different combinations of factors that influence energy (electricity) consumption such as locality, ownership status of the property, education status, expenditure spent on energy, income etc. The ordinal regression analysis was used and the most appropriate model was chosen to prevent over or under estimation of the level of electricity consumption in the households. The model chosen incorporated all possible driving factors and also met the relevant criteria of the model fitting, the goodness of fit and the assumption of proportional odds.
The major findings of this research study are as follows:

- Data analysis

There may be issues about results obtained from modelling with secondary data due to the availability and quality of data, as the data on many of the factors or variables that may have aided the demand for electricity are unavailable in a developing country setting.
Findings from this research from a survey of five different areas within a metropolis has shown that based on the trend of the primary data used in this research and the predictive results obtained, whilst energy is important in developing countries, income and the price of energy do not have a statistically significant effect in determining the amount, type or level of fuel used in households.
In addition, the use of GDP although plays an important role in the consumption of energy may not be a true reflection of the economy in a developing country. This is because GDP is recorded for the formal sector of the economy and does not take into account the informal economy that is a characteristic of a developing country.

- Consumers’ behaviour

The assumption of consumers’ rationality to an extent in this instance was seen to be of relevance as it was discovered that although, there may be financial constraints for consumers, the decision to use a particular type of fuel was determined by factors other than income such as the locality of the property, ownership status and education.

Furthermore, consumers also had preferences of the types of fuel they will use. The ranking of preferences was based more on the availability and efficiency of the fuel as opposed to the financial status of such consumers.
The impact of a factor of consumption on households may differ depending on the associated level of energy consumption i.e. whether a household is a low, medium or high energy consumer.

- Energy ladder

It was discovered that the notion of the energy ladder did not hold in this instance/ study as the increase in income which may have resulted in spending more on electrical appliances leading to an increase in energy did not result in any significant corresponding effect. The increase in the proportion of income spent on any form of energy did not result in an increase in the number of consumers estimated or the quantity demanded, rather a final model generated met the assumptions of the ordinal regression and statistically predicted the dependent variable over and above the intercept-only model. The result though did not indicate the use of one form of fuel type to satisfy their energy needs. In other words, households use energy mix in satisfying their energy need.

This disparate pattern of development across neighbourhoods and the findings that different house types consume significantly different quantities of energy supports the notion that energy demand assessments need to be conducted at micro rather than macro levels in order to reveal actual demand patterns.

Overall, the evidence from the study suggests that the divergence in the energy need of households and the different determinants of the various fuels used has led to not being able to adopt the energy ladder concept. This meant therefore that the concept of energy ladder cannot (based on this study) be confirmed. The findings of this study also supports the work carried out by Heltberg (2003) and confirms that income alone may not be sufficient to determine the consumption of energy by a household. Other factors such as the location of the property, the ownership status of the property and the expenditure spent on energy seemed to be more relevant in determining the consumption level of energy in the households and households tend to use mixtures of fuels as opposed to using one and abandoning others.

Table 10.1 Summary of factors affecting consumption of energy at high level

	Type of fuel (High level)		
Factors	**Electricity**	**Gas**	**Kerosene**
Expenditure	X	X	X
Income			
Medium level	X	X	X
High level			
Location			
Rural			X
Urban	X		
Age (26-35)	X	X	X
Education			
Primary			
Secondary			
Tertiary		X	X
Ownership			
Renting			
Owned	X		
Gender			
Male	X		
Female		X	X

This research highlights the importance of the various socio-cultural factors that affects the consumption of energy within the household, but in the same vein, it has been able to show that economic contribution is not the sole determinant in the choice of fuel energy. Summary of the various factors that determine the consumption of the different fuels at high level is shown in Table 10.1.

10.3 Conclusions

The energy sector in Nigeria is underdeveloped and characterised by shortage and supply constraints with about 76.4 per cent of the population without electricity. The low level of energy consumption is evident in the low level of electricity consumption per capita of 148.93kWh in 2011 (World Bank) which is an indicator of energy and income poverty. For a developing country like Nigeria, there is the need to maintain a right balance between the competing demands of growth and sustainable development. The general increase in population coupled with the rate of urbanisation in Nigeria has led to an increase in the demand for resources and, therefore, the need for planning for energy for the country. As the rate of urbanisation is not homogenous within the country, it means that the energy requirement varies among different areas in the country.

The residential sector in Nigeria consumes about 70 percent of total electricity consumption, and is characterised with inefficient use of energy due to several factors, including a very low energy price and lack of awareness.

The use of a questionnaire survey as developed in this study and the application of ordinal regression to the survey data analysis has provided a valuable tool for analysing and estimating energy consumption in households.

The core focus of this thesis was on factors that contribute to the consumption of electricity (as a form of energy) in the household sector. This means investigating the dynamics of demand for energy over time in Nigeria, identifying and evaluating the effects of different factors on household energy demand analysing and estimating the ultimate impact of such factors on energy consumption. In the absence of standardised data categorisations and in order to complete data gaps due to the absence of other relevant data gathering relating to households therefore, a questionnaire survey was used.

To deal with these objectives, both theoretical and practical frameworks were developed. The theoretical framework was based on the literature review of work undertaken in the area of energy and energy modelling (generally the use of economic theories) whilst the practical framework included carrying out a survey for five different local government areas giving energy use for various appliances and in relation to residential properties and exploring the relationship between ranges of socioeconomic factors.

10.4 Recommendations for Further Research

As the energy database becomes more developed in Nigeria, there will be a need for more comprehensive analyses. The availability of longer and more quality data on energy consumption and relevant factors or variables would enable more accurate and usable models. Significant time could have been saved if there is a good energy database that is important to energy modelling. Ways and means of developing quality energy databases must be embarked on by relevant institutions and organisations in order to aid energy planners in analysing the energy system of the country. Although significant works have been done in this thesis in areas related to use of econometric techniques on energy consumption, more detailed research on energy supply side in Nigeria could be pursued separately by other researchers.

The focus of the study was on Ibadan, so the results obtained may be peculiar to the area or region (Western Nigeria). It is therefore recommended that similar studies be carried out in cities in other regions of Nigeria as Ibadan the study area is different from other major cities in Nigeria. So there is value in testing the survey questionnaire in other areas and regions of the country to ascertain its appropriateness across the country.

It will also be beneficial if a study is done for urban areas separately from peri-urban and rural regions and the results from the different areas compared. Future studies are also required to fully understand the main determinants of energy across the urban and rural regions as this will contribute to assisting the formation of relevant energy policies.

Future research to compare the results of modelling the household energy consumption using different statistical packages and methods, in order to be able to establish whether the choice of modelling technique has an impact on results generated from analysis of primary data would also be interesting.

References

- Abila, N. (2015) Econometric estimation of the petroleum products consumption in Nigeria: Assessing the premise for biofuels adoption. Renewable Energy 74, 884892.
- Abumere, S.I., Arimah, B.C. and Jerome, T.A. (1998) The informal sector in Nigeria's development process. Development Policy Centre (DPC), Research Report no. 1. Ibadan, Nigeria: DPC
- Adegbulugbe, A.O. and Akinbami, J. F. K. (1995), Urban household energy use patterns in Nigeria. Natural Resources Forum, 19: 125–132. doi: 10.1111/j.14778947.1995.tb00600x [accessed 20 January 2013].
- Adenikinju, A. (2005) Analysis of the cost of infrastructure failures in a developing economy the case of electricity sector in Nigeria. African Economic Research Consortium AERC Research Paper 148, February 2005.
- Adelaja, A and Ojolo, S. (2013) Forecasting Local Consumption of Dual Purpose Kerosene (DPK) in Nigeria. Int. J. of Energy Technology and Policy, 9(3), 224-237.
- Adom, P, Bekoe, W and Akoena, S. (2012) Modelling aggregate domestic electricity demand in Ghana: An autoregressive distributed lag bounds cointegration approach. Energy Policy 42, 530-537.
- Annual Report 2013 African Development Bank Annual Report www.afdb.org/fileadmin/uploads/afdb/.../Annual_Report_2013.pdf [accessed 15 April 2015].
- Ahuja, D and Marika, T. (2009) Sustainable energy for developing countries. Vol 2 (1) [Online]. Available www.sapiens.revues .org/823 [accessed 15 September [2014].
- Agnolucci, P.(2011) Stochastic Trends and Technical Change: The Case of Energy Consumption in the British Industrial and Domestic Sectors. The Energy Journal 31(4) 111-135.
- Akinbami, J, Ilori, M, Oyebisi, T, Akinwunmi, I and Adeoti, O. (2001) Biogas energy use in Nigeria: current status, future prospects and policy implications. Renewable and Sustainable energy Reviews 5, 97-112.

- Akinyemi, O, Ogundipe , A.A and Alege, P.O.(2014) Energy Supply and Climate Change in Nigeria. Journal of Environment and Earth Science 4 (14).
- Akinlo, A.E. (2008) Energy consumption and economic growth: Evidence from 11 Sub-Sahara African countries. Energy Economics 30, 2391–2400.
- Akinlo, A.E. (2009) Electricity consumption and economic growth in Nigeria: Evidence from cointegration and co-feature analysis. Journal of Policy Modelling, 31(5), 681-693.
- Akinlo, A. How Important is Oil in Nigeria's Economic Growth? Journal of Sustainable Development 5(4) · March 2012
- Akintoye, I.R. (2006) Enhancing the performance of the Informal Sector for the Economic Development of Nigeria: A Case Study of Lagos State. International Journal of Social Sciences, 5(1), 100-112.
- Al-Salam, M. (2007) Household energy demand in Kuwait. J. King Saudi University, Admin. Science 2(19),51-60 available http://repository.ksu.edu.sa/jspui/bitstream/123456789/228/1/Householdper cent20demandper cent20forper cent20energyper cent20inper cent20Kuwait.pdf [accessed 12 January 2013]
- Altinay, G.and Karagol, E. (2005) Electricity consumption and economic growth: evidence from Turkey. Energy Economics 27, 849-856.
- Amarawickrama and Hunt, L. C. (2007) Electricity Demand for Sri Lanka: A Time Series Analysis .SEEDS Discussion paper.
- Amusa, H, Amusa, K and Mabugu, R. (2009) Aggregate demand for electricity in South Africa: An analysis using the bounds testing approach to Cointegration. Energy Policy 37, 4167-4175.
- Apergis, N. and Tang, C. (2013) Is the energy-led growth hypothesis valid? New evidence from a sample of 85 countries. Energy Economics 38, 24-31.
- Arimah,B.C. and Ebohon, O.J (2000) Energy transition and its implications for environmentally sustainable development in Africa. International Journal of Sustainable Development and World Ecology, 7(3), 201-216.
- Arnold, J, Köhlin, G and Persson, R. (2006) Woodfuels, Livelihoods, and Policy Interventions: Changing Perspectives. World Development 34(3), 596-611.

- Asafu-Adjaye, J. (2000) The relationship between energy consumption, energy prices and economic growth: Time series evidence from Asian developing countries. Energy Economics, 22 (6), 615-625.
- Azam, A. Khan, A. Zaman, K. and Ahmad, M. (2015) Factors determining energy consumption: Evidence from Indonesia, Malaysia and Thailand. Renewable and Sustainable Energy Reviews, 42, 1123-1131
- Babatunde, A. and Shauaibi, I. (2009) The demand for Residential electricity in Nigeria: A Bound Testing approach [online], available: www.africametrics.org/documents/conference09 [accessed 11/03/2010].
- Barnes, D. and Floor, W.M. (1996) Rural energy in developing countries: A Challenge for Economic Development. Annual Review of energy and environment 21, 497-530.
- Beenstock, M.and Goldin, E. (1999) The demand for electricity in Israel, Energy Economics 21, 168-183.
- Bentzen, J. and Engsted, T. (2001) A revival of Autoregressive model in estimating energy demand relationship. Energy 26(1), 45-55.
- Bhattacharyya, SC (1996). Applied general equilibrium models for energy studies: a survey, Energy Economics, 18 (3), 145-164.
- Bhattacharyya, S.C. and Timilsina G.R. (2009) Energy demand models for policy formulation: a comparative study of energy demand models. The World Bank Development Research Group Environment and Energy Team, Policy Research Working Paper No: 4866. Policy Research Working paper 4866.
- Bhattacharyya, SC. and Timilsina G.R. (2010) Modelling energy demand of developing countries: Are the specific features adequately captured? Energy Policy 38(4), 1979-1990.
- Bhattacharyya, S.C. (2011) Energy Economics: Concepts, Issues, Markets and Governance Springer, London.
- Bildirici, M. E. (2013), Economic growth and electricity consumption: MS-VAR and MS-Granger causality analysis. OPEC Energy Review, 37: 447–476.
- Black, I. ((2006) The presentation of interpretivist research, Qualitative Market Research: An International Journal, Vol. 9(4) ,319 - 324

- Buongiorno, J. (1996), Forest sector modelling: a synthesis of econometrics, mathematical programming and system dynamics methods. International Journal of Forecasting, 12(3) 329-43.
- Broadstock D.C. and Hunt L.C. (2010). Quantifying the Impact of Exogenous Non- Economic Factors on UK Transport Oil Demand. Energy Policy; 38, 1559- 1565.
- Carson, D., Gilmore, A., Perry, C. and Gronhaug, K., (2001), Qualitative Marketing Research, Sage Publications, London
- Campbell, B.M., Vermeulen, S.J, Mangono, J.J. and Mabugu, R.(2003).The energy transition in action: urban domestic fuel choices in a changing Zimbabwe. Energy Policy 31(6), 553-562.
- Central Intelligence Agency (2011) [online], available www.cia.gov/library/publications/download/download-2011/index.html [accessed 15 October 2014].
- Central Bank of Nigeria Annual Statistical Bulletins (2003-2009).
- Chan, H. and Lee, S. (1997) Modelling and forecasting the demand of coal in China. Energy Economics 19(3), 271-287.
- Chambwera, M., (2004) Economic analysis of urban fuel wood demand: the case of Harare in Zimbabwe. Ph.D. Thesis, Wageningen University, The Netherlands.
- Chitnis, M. and Hunt, L.C. (2011). Modelling UK household expenditure: economic versus noneconomic drivers. Applied Economics Letters; 18(8), 753-767.
- Couture, S, Garciab, S and Reynaud, A. (2012) Household energy choices and fuel wood consumption: An econometric approach using French data. Energy Economics 34(6), 1972-1981.
- Creswell, J. and Plano Clark, V.L. (2011) Designing and conducting mixed methods research. 2nd ed., London. Sage Publications Inc.
- Dang, G. and Sui Pheng, L. (2015) Infrastructure Investments in Developing Economies: The Case of Vietnam. Springer, Science and Business media, Singapore.
- Davidson, O. and Sokona, Y. (2002). A New Sustainable Energy Path for African Development: Think Bigger Act Faster, available:

http://webdav.uct.ac.za/depts/erc/Research/publications-pre2004/02DavidsonSokona_Think_bigger.pdf [accessed 24 June 2012].

- De vita, G., Endresen, K and Hunt, L.C. (2006) An empirical analysis of energy demand in Namibia. Energy Policy 34(18), 3447-3463.
- Dewhurst, F. (2006) Quantitative Methods for Business and Management 2nd ed., McGraw-Hill Education.
- Dilaver, Z. (2012) Structural Times Series Modelling of Energy Demand. PhD Thesis, University of Surrey, Guildford.
- Dimitropoulos J, Hunt L.C. and Judge G. (2005). Estimating Underlying Energy Demand Trends using UK Annual Data. Applied Economics Letters; 12 (4); 239244.
- Dziobinski O.and Chipman R. (1999): Trends in Consumption and Production: Household Energy Consumption. Economic & Social Affairs. DESA Discussion Paper No 6.United Nations, available: http://www.un.org/en/development/desa/publications/index.html [accessed 20 March 2009].
- Ebohon, O.J. (1992) Empirical analysis of energy consumption behaviour: an input to an effective energy plan in Nigeria. Energy Policy, 20(8), 781-796.
- Ebohon, O.J. (1996) Energy, economic growth and causality in developing countries: A case study of Tanzania and Nigeria. Energy Policy, 24(5), 447-453.
- Ebohon, O.J., Field, B. and Pugh, C. (2000) Satisfying current and future energy demand in sub-Saharan African cities: The implications for urban environmental sustainability. Proceedings: Strategies for a Sustainable Built Environment, Pretoria, 23-25 August 2000, available www.researchgate.net/.../242518748 [accessed 21 December 2014].
- Economic Commission for Africa (ECA) 2004[online], available: http://www.uneca.org/publications/economic-report-africa-2004 [accessed 09 September 2010].
- Egelioglu, F., Mohamad A.A. and Guven, H. (2001) Economic variables and electricity consumption in Northern Cyprus. Energy 26 (4), 355–362.
- Ekpo, U.N., Chuku, C A. and Effiong, E. (2011) The Dynamics of Electricity Demand and Consumption in Nigeria: Application of the Bounds Testing

Approach. Current Research Journal of Economic Theory 3(2): 43-52, available: maxwellsci.com/print/crjet/v3-43-52.pdf [accessed 16 December 2012].

- Erdogdu, E. (2007) Electricity demand analysis using cointegration and ARIMA modelling: A case study of Turkey. Energy Policy, 35(2), 1129-1146.
- Food Agricultural Organisation (1992) www.fao.org/docrep/017/z9550e/z9550e.pdf [accessed 13 June 2014].
- Foster, V., Tre, J. and Wodon, Q. (2000) Energy Prices, Energy efficiency and Fuel Poverty. World Bank Mimeo.
- Fagbenle, R (2001) National renewable energy policy objectives and programmes in Bo Residential electricity demand dynamics in Turkey tswana, Renewable Energy, 24(3-4), 419-437.
- Farschi, M. (2009) Evolutionary Patterns of Corporate Diversification: The Case of International Contracting. PhD Thesis. University of Reading, United Kingdom.
- Farsi, M., Filipini, M. and Pachauri, S. (2007), Fuel choices in urban Indian households. Environment and Development Economics, 12(6), 757-774
- Fatai, K., Oxley, L. and Scrimgeour, F.G. (2003) Modelling and Forecasting the demand for electricity in New Zealand: a comparison of Alternative Approaches. The Energy Journal, 24(1), 75-102.
- Fatai, K, Oxley, L. and Scrimgeour FG, (2004) Modelling the causal relationship between energy consumption and GDP in New Zealand, Australia, India, Indonesia, The Philippines and Thailand, Mathematics and Simulation, 64(3-4), 431-445.
- Filippini, M., Pachauri, S. (2004) Elasticities of Electricity Demand in Urban Indian Households. Energy Policy, 32(3), 429- 436.
- Folawewo, A. O. (2006) Determinants of Informal Sector Labour Demand: An Application of Alternative Methodological Approaches to South Western States of Nigeria’, Applied Econometrics and International Development, Vol. 6(2) 147-162.
- Friends of the Earth, 2005 Annual report (online), available: http://www.foe.org/publications/annual-report [accessed 05 March 2010].

- Fung, Y.H. and Tummala, V.M.R. (1993) Forecasting of electricity consumption: a comparative analysis of regression and artificial neural network models. IEE 2nd International Conference on Advances in Power System Control, Operation and Management, 7-10 December 1993. Hong Kong: 782-787.
- Galea, S. and Vlahov, D. (2005) Urban health: evidence, challenges, and directions. Annual Rev Public Health. 26:341-365.
- Glasure, Y. and Lee, A. (1998) Co integration, Error correction and the relationship between GDP and energy: The case of South Korea and Singapore. Resource and Energy Economics, 20(1), 17-30.
- Glaeser, E.L (2013) A World of Cities: The Causes and Consequences of Urbanization in Poorer Countries,NBER Working Paper No. 19745, Issued in December 2013.
- Godwin, N., Harris, J.M., Nelson, J.A., Roach, B. and Torras, M. (2013), Macroeconomics in context. 2nd ed. Oxon. Routledge.
- Gray, D. (2014) Doing research in the real world. 3rd ed. Sage publication.
- Haghighi, M (2009) Combination of Econometric Methods and System Dynamics Approach to Improve the Iranian Agricultural Policies http://www.systemdynamics.org/conferences/2009/proceed/papers/P1033.pdf [accessed 21 February 2011].
- Halicioglu, F (2007). Residential electricity demand dynamics in Turkey. Energy Economics 29 (2), 199-210.
- Halvorsen, B., and Larsen, B. M. (2001). Norwegian residential electricity demand: A microeconomic assessment of the growth from 1976 to 1993. Energy Policy 29 (3), 227-236.
- Hanneson, R. (2002) Energy Use and GDP growth, 1950-97’. OPEC Review, 26 (3), 215-233.
- Harris, J L. and Liu L. (1993) Dynamic structural analysis and forecasting of residential electricity consumption. International Journal of Forecasting 9(4), 437- 455.
- Hawdon, D. (1992) The economic analysis of energy demand. Energy Demand: Evidence and Expectations. London: Surrey University Press.

- Heltberg, R. (2004) Fuel switching: evidence from eight developing countries. Energy Economics 26(5), 869-887.
- Hiemstra-van der Horst, G. and Hovorka, A. (2008) Reassessing the ‘‘energy ladder’’: Household energy use in Maun, Botswana. Energy Policy 36(9), 3333- 3344.
- Holtedahl, P. and Joutz, F.L. (2004) Residential electricity demand in Taiwan. Energy Economics 26(2), 201-224.
- Hondroyiannis, G. (2004) Estimating Residential Demand for Electricity in Greece. Energy Economics, 26(3), 319- 334.
- Hosier, R. and Dowd, J. (1987) Household fuel choice in Zimbabwe: An empirical test of the energy ladder hypothesis. Resources and Energy 9(4), 347-361.
- Hosier, R.H and Kipyonda, W. (1993) Urban household energy use in Tanzania: prices, substitutes and poverty. Energy Policy 21 (5), 454-473.
- Hunt, L.C. and Ninomiya, Y. (2003) Unravelling Trends and Seasonality: A Structural Time Series Analysis of Transport Oil Demand in the UK and Japan. The Energy Journal Vol 24(3), 63-96.
- Hymas, S.H. Forecasting and Econometric Models. The Concise Encyclopaedia of Economics. 1993. Library of Economics and Liberty. http://www.econlib.org/library/Enc1/ForecastingandEconometricModels.html [accessed 28 December 2014].
- International Energy Agency (IEA), 2002. World Energy Outlook: Energy and Poverty.
- Ibitoye, F. and Adenikinju, A. (2007) Future Demand for Electricity in Nigeria. Applied Energy 84(5), 492-504.
- Ighodaro, C.A.U. (2010) Co-integration and causality relationship between energy consumption and economic growth: further empirical evidence for Nigeria. Journal of Business Econ Management, 1/2010, 97-111.
- Ikeme, J. and Ebohon, O.J. (2005) Nigeria’s Electric power sector reform: What should form the key objectives? Energy Policy 33(9), 1213-1221.
- Inglesi, R. (2010), Aggregate Electricity Demand in South Africa: Conditional Forecasts to 2030. Applied Energy 87(1), 197- 204.

- Iwayemi, A. (2008) Nigeria's Dual Energy Problems: Policy Issues and Challenges www.iaee.org/en/publications/newsletterdl.aspx?id=53 [accessed 21 July 2010].
- Iwayemi, A., Adenikinju, A. and Babatunde, M.A. (2010) Estimating petroleum products demand elasticities in Nigeria: A multivariate cointegration approach. Energy Economics 32(1), 73-85.
- Jebaraj, S and Iniyan, S, (2006) A review of energy models. Renewable and Sustainable Energy Reviews 10(4), 281-311.
- Jumbe, C.B.L. (2004). Cointegration and Causality between Electricity Consumption and GDP: Empirical Evidence from Malawi. Energy Economics, 26(1), 61-68.
- Kankal, M., Akpinar, A. Komurcu, M.A. and Ozsahin, T. S. (2011) Modelling and forecasting of Turkey's energy consumption using socio-economic and demographic variables. Applied Energy 88(5), 1927-1939.
- Kalogirou, S and Bojic, M. (2000) Artificial neural networks for the prediction of the energy consumption of a passive solar building. Energy 25(5), 471-491.
- Karekezi, S and Kimani, J. (2002) Status of power reform in Africa: impact on the poor. Energy Policy 30(11-12), 923-945.
- Khattak, N., Tariq, M .and Khan, J. (2010) Determinants of Households' Demand for Electricity in district Peshawan. European Journal of Social sciences 14(1), 7-13.
- Karekezi, S. and Majoro, L. (2002) Improving modern energy services for Africa's urban poor. Energy Policy 30(11-12), 1015-1028.
- Karekezi, S., Kimani, J. and Onguru, O. (2008) Energy access among the urban poor in Kenya. Energy for Sustainable Development, 12 (4) 38–48.
- Kebede,B., Bekele, A. and Kedir, E.(2002) Can the urban poor afford modern energy? The case of Ethiopia. Energy Policy, 30 1029–1045.
- Khanna, M. and Rao, N.D. (2009). Supply and Demand of Electricity in the Developing World. Annual Review of Resource Economics 1(1) 567-596.
- Kialashaki, A and Reisel, J.R. (2013) Modeling of the energy demand of the residential sector in the United States using regression models and artificial neural networks. Applied Energy 108, 271-280.

- Khanna, M. and Rao, N.D. (2009). Supply and Demand of Electricity in the Developing World. Annual Review of Resource Economics. Vol. 1: 567-596.
- Kosmo M (1989) Commercial energy subsidies in developing countries: opportunity for reform, Energy Policy 17(3):244-53
- Kulshreshtha, M. and Parikh, J.K. (2000) Modeling demand for coal in India: Vector Autoregressive models with cointegrated variables. Energy, 25(2), 149-168.
- Kung, H (2012) Comparing Top-down with Bottom-up Approaches: Teaching Data Modeling 2012 Proceedings of the Information Systems Educators Conference.
- Lancaster, K.J.(1966) A New Approach to Consumer Theory. The Journal of Political economy, Vol. 74, No. 2 , Apr. 1966, 132-157
- Leach, G. (1992), The Energy Transition. Energy Policy, 20(2), 116-123.
- Leung, W (2001) How to design a questionnaire. student.bmj.com/student/view-article.html? Id=sbmj010618 (accessed 08 September 2014).
- Levin, J. and Milgom, P.(2004) Introduction to Choice Theory http://web.stanford.edu/~jdlevin/Econ%20202/Choice%20Theory.pdf. (accessed 25 May 2016)
- Liu, X.Q., Ang, B.W. and Goh, T.N. (1991) Forecasting of electricity consumption: a comparison between an econometric model and a neural network model. Neural Networks, 1991 IEEE International Joint Conference vol.2, 18-21 Nov 1991, 1254- 1259.
- Liu, Y. (2009) Exploring the relationship between urbanisation and energy consumption in China using ARDL (autoregressive distributed lag) and FDM (factor decomposition model). Energy, Volume 34(11), 1846-1854.
- Louw, K., Conradie, B., Howells, M. and Dekenah, M. (2008) Determinants of electricity demand for newly electrified low-income African households. Energy Policy 36(8), 2812-2816.
- McAvinchy, I. (2002). Modeling and Forecasting in an energy demand system with high and low frequency information. Energy modeling 20(1), 207-226.
- McPhail, K. (2000) How Oil and Mining Projects Can Contribute to Development. IMF/World Bank Finance and Development. Vol. 37(4), 46-49.

- Madlener R, and Sunak, Y. (2011). Impacts of Urbanisation on Urban Structures and Energy Demand: What Can We Learn for Urban Energy Planning and Urbanisation Management? Sustainable Cities and Society, 1(1),45-53.
- Makridakis, S., Wheelwright SC. Forecasting methods for management, 5th ed. New York: Wiley; 1989
- Makridakis, S., Wheelwright, S.C, and Hyndman, R J. Forecasting methods and Applications, 3rd ed.Wiley, New York (1998).
- Maliki, O. S., Agbo, A.O., Maliki, A.O., Ibeh, L.M.and Agwu, C.O. (2011), Comparison of Regression Model and Artificial Neural Network Model for the prediction of Electrical Power generated in Nigeria. Advances in Applied Science Research, 2011, 2 (5):329-339. http://pelagiaresearchlibrary.com/advances-inapplied-science/vol2-iss5/AASR-2011-2-5-329-339.pdf. [accessed 22 September 2013].
- Martino, A and Fiorello, D. (2006) A paper presented at European Transport conference on Strategic Modelling of Transport and Energy Scenarios. 18 -20 September 2006 Palais de la Musique et des Congrès, Strasbourg, France.
- Masih, A.M. and Masih, R. (1996). Energy consumption, real income and temporal causality: results from a multi-country study based on cointegration and errorcorrection modelling techniques. Energy Economics, 18(3)165-183.
- Masih R. and Masih A.M. (1997) On the temporal causal relationship between energy consumption, real income and prices: some evidence from Asian energy dependent NICs based on a multivariate co integration / error correction approach. Journal of Policy Modelling (19), 17 – 44.
- Masera, O., Saatkamp, B.D. and Kammen, D.M. (2000) From Fuel Switching to Multiple Cooking Strategies: A Critique and Alternative to the Energy Ladder Model. World Development Vol 28, No.12 Pp. 2083-2103.
- Medlock K.B. (2009) Energy Demand Theory in International Handbook on the Economics of Energy, Evans J and Hunt LC (Eds), Edward Elgar Publishing, UK.
- Mielnik, O. and Goldemberg, J. (2000) Converging to a common pattern of energy use in developing and industrialized Countries. Energy Policy 28(8), 503-508.

- Meier, G.M. and Stiglitz, J.E. (2000) Frontiers of Development Economics: The Future in Perspective. Oxford University Press.
- Mekonnen, A. and Köhlin, G. (2008) Determinants of Household Fuel Choice in Major Cities in Ethiopia ,Environment for Development Discussion Paper Series August 2008
- Mohamed, Z. and Bodger, P.S. (2005) Forecasting electricity consumption in New Zealand using economic and demographic variables. Energy 30(10), 1833-1843.
- Montgomery, M. (2008) The urban transformation of the developing world. Science 319,761-764.
- Munasinghe, M. and Meier, P. (1993), Energy Policy Analysis and Modelling, Cambridge: Cambridge University Press.
- Musango, J.K., Amigun,B and Brent AC(2010) Understanding the implication of investing in biodiesel production in South Africa: a system dynamics approach http://www.systemdynamics.org/conferences/2010/proceed/papers/P1198.pdf
- Narayan, P.K., Smyth, R (2005). The residential demand for electricity in Australia:
- an application of the bounds testing approach to co integration. Energy Policy 33(4), 467-474.
- Ncube, M.(2007) Financial Services and Economic Development in Africa. Journal of African economies Vol 16 (1)13-57.
- Neuman, L. R. (2000), Social Research Methods - Qualitative and Quantitative Approaches. Boston: Allyn and Bacon.
- Ngo,C. and Natowitz, J.B. (2009) Our Energy Future, Resources, Alternatives and the Environment. John Wiley Publications.
- Nwachukwu, M.U., Mba, H. C., Jiburum, U. and Okosun, A. E.(2013), Empirical analysis of fuel price and subsidy reform in Nigeria. OPEC Energy Review, 37(3), 314-326.
- Nwachukwu, M.U., and Chike, H. (2011) Fuel subsidy in Nigeria: Fact or fallacy. Energy, 36(5), 2796-2801.

- Nwaka, G.I. (2005) The urban informal sector in Nigeria: towards economic development, environmental health, and social harmony. Global Urban Development Vol 1(1), 1-11 [accessed 11 June 2014].
- Ogbonna, A.C. (2008). An Integrated Assessment of Domestic Energy Demand and Use for Energy Planning In Sub-Saharan Africa: The Case of Jos, Nigeria. PhD Thesis, Heriot-Watt University, Edinburgh.
- Odihi, J. (2003) Deforestation in afforestation priority zone in Sudano-Sahelian Nigeria. Applied Geography, 23(4) 227–259.
- Odularu, G.O. and Okonkwo, C. (2009) Does Energy consumption contribute to Economic Performance? Empirical evidence from Nigeria. Journal of Economics and International Finance, 1(2), 44-58.
- Okoro, O.I. and Chikuni, E. (2007) Power sector reforms in Nigeria: opportunities and challenges. www.erc.uct.ac.za/jesa/volume18/18-3jesa-okoro.pdf [accessed 01 November 2010].
- Onahaebi, S. (2009). Power Outages in the Nigeria Transmission Grid. Research Journal of Applied Sciences, 4(1), 1-9.
- Ogunleye, E.O. and Ayeni, R.K. (2012) Energy demand in Nigeria: a disaggregated analysis. International Research Journal of Finance and Economics, Issue 86, 52-62.
- Ogwumike, F. O., Ozughalu, U.M. and Abiona, G.A. (2014) Household Energy Use and Determinants: Evidence from Nigeria, International Journal of Energy Economics and Policy, 4(2) 248-262.
- Oh, W. and Lee, K. (2004) Energy consumption and economic growth in Korea: testing the causality relation. Journal of Policy Modeling, 26(8-9), 973-981).
- Omri, A and Kahouli, B. (2014) Causal relationships between energy consumption, foreign direct investment and economic growth: Fresh evidence from dynamic simultaneous-equations models. Energy Policy 67, 913-922.
- Onwe, O.J. (2013) Role of the Informal Sector in Development of the Nigerian Economy: Output and Employment Approach. Journal of Economics and Development Studies, 1(1), 60-74.

- O’Neill, B.C., Ren, X., Jiang, L. and Dalton, M. (2012) The effect of urbanisation on energy use in India and China in the iPETS model. Energy Economics 34 supplement 3. S339-S345.
- Onyebueke, V. and Geyer, M. (2011) The Informal Sector in Urban Nigeria: Reflections from Almost Four Decades. http://www.ajol.info/index.php/trp/article/download/77222/67671 [accessed 18 February 2015].
- Osorio, F.A. (2009) A System Dynamics Model for the World Coffee Market. http://www.systemdynamics.org/conferences/2009/proceed/papers/P1312.pdf. [accessed on 25 February 2012].
- Otegbulu, A.C. (2011) Energy Efficient Practice: A Focus on Residential Households Journal of Sustainable Development, 4(2) 240-248.
- Otto, P. (2008) A system dynamics model as a decision aid in evaluating and communicating complex market entry strategies. Journal of Business Research, 61(1), 1173-1181.
- Ouedraogo, B. (2006), Household Energy Preference for Cooking in Urban Ouagadougou, Burkina Faso. Energy Policy, 34(18), 3787-3795.
- Ouedraogo N. S., (2013). Energy consumption and economic growth: Evidence from the economic community of West African States (ECOWAS). Energy Economics, 36, 637–647
- Oyedepo, S.O.(2012) Energy and sustainable development in Nigeria: the way forward. Energy, Sustainability and Society, 2(15) (Springer Open journal). http://www.energsustainsoc.com/content/2/1/15 [accessed 14 November 2013].
- Ozturk, I., Aslan, A. and Kalyoncu, H. (2010) Energy consumption and economic growth relationship: Evidence from panel data for low and middle income countries. Energy Policy 38, 4422-4428.
- Pachauri, S. (2012) Demography, Urbanisation and Energy Demand. Energy for Development Environment and Policy, 54 (2) 81-94.
- Pachauri, S and Jiang, L (2008). The household energy transition in India and China. Energy Policy, 36(11), 4022-4035.
- Paul, S and Bhattacharyya, R.N. (2004) Causality between energy consumption and economic growth in India: a note on conflicting results. Energy Economics, 26(6), 977-983.

- Pesaran, M.H. and Pesaran B. (1997) Working with Microfit 4.0: Interactive Econometric Analysis, Oxford University Press, and Oxford.
- Pillai, N.V. (2001) Electricity demand analysis and forecasting- the tradition is questioned. Working paper, no.312 Centre for Development Studies.
- Pindyck, R.S. and Rubinfield, D.L. (1997) Econometric Models and Economic Forecasts. 4th ed. Irwin McGraw-Hill.
- Pindyck, R.S., Rubinfield, D.L. and Mehta, P.L (2009) Microeconomics, 7th ed. Pearson International edition Publisher.
- Popp, J., Lakner, Z., Harangi-Rákos, M., & Fári, M. (2014). The effect of bioenergy expansion: food, energy, and environment. Renewable and Sustainable Energy Reviews, 32, 559-578.
- Qudrat-Ullah, H. and Davidsen P.I. (2001) Understanding the dynamics of electricity supply, resources and pollution: Pakistan's case. Energy, 26(6), 595-606.
- Rajan, M. and Jain, V.K. (1999) Modelling of electrical energy consumption in Delhi, Energy 24(4), 351–361.
- Rijal, K., Basal,N.K. and Grover, P.D.(1990) Rural household energy demand modelling: A case study of Nepal. Energy Economics 12 (4) 279-288
- Rady, H (1992) Renewable Energy in rural areas of developing countries. Energy Policy, 20(4), 581-588.
- Reddy, A.K. (2000) Energy and social issues, in J. Goldemberg(ed), World energy assessment, energy and the challenge of sustainability. UNDP, New York
- Reddy, B.S. and Nathan, H. S. (2013) Energy in the development strategy of Indian households—the missing half. Renewable and Sustainable Energy Reviews Volume 18, February 2013, Pages 203–210
- Richardson G.P and Pugh A.L (1981) Introduction to System Dynamics with DYNAMO Cambridge, Productivity Press, MA.
- Ryan D. and Plourde A. (2009) Empirical Modelling of Energy Demand in International Handbook on the Economics of Energy, Evans J and Hunt LC (eds), Edward Elgar Publishing, UK.
- Sa'ad, S. (2009) Electricity Demand for South Korean Residential Sector. Energy Policy, 37, 5469–5474.

- Sa’ad, S (2011) Underlying energy demands trends in South Korean and Indonesian aggregate whole economy and residential sectors. Energy Policy 39(1), 40-46.
- Sambo, A.S (2008) Matching Electricity Supply with Demand in Nigeria. https://www.iaee.org/documents/newsletterarticles/408sambo.pdf [accessed 01April 2011].
- Sambo, A.S (2008) Electricity demand from customers INGA hydropower projects: The case of Nigeria. Paper presented at the WEC Workshop on Financing INGA Hydropower Projects, 21 – 22 April, 2008, London, U.K.
- Sambo, A.S (2009) Energy Issues and Challenges in Nigeria: Sustainable Energy Future for Nigeria: The Role of Engineers. Paper presented to the Nigerian Society of Engineers Forum, Abuja Chapter, 2nd April 2009.
- Sambo, A.S., Garba, B., Zarma, I.H. and Gaji, M. (2010) Electricity Generation and the Present Challenges in the Nigerian Power Sector. www.worldenergy.org/documents/congresspapers/70pdf [accessed 30 June 2012].
- Sari, R. and Soytas, U. (2007) The Growth of Income and Energy Consumption in Six Developing Countries. Energy Policy 35 (2), 889-898.
- Sengupta (2013). Rural Household Preferences for Cooking Fuels in Developing Countries: A Microeconomic Analysis Paripex - Indian Journal of Research, Vol: 2(2) (assessed 16 June2015)
- Shukla PR (1995) Greenhouse gas models and abatement costs for developing nations: A Critical Assessment. Energy Policy 23 (8) 677–687.
- Siddayao, C.M. (1986) Energy Demand and Economic Growth: measuring and conceptual issues in policy analysis. Westview Press, Bouderi, CO
- Soytas, U. and Sari, R.(2003) Energy consumption and GDP: causality relationship in G-7 countries and emerging markets. Energy Economics, 25(1), 33-37.
- Sparks, D.L. and Barnett, S.T. (2010) The Informal Sector In Sub-Saharan Africa: Out Of The Shadows To Foster Sustainable Employment And Equity? International Business & Economics Research Journal, 9(5), 1-7.
- Stern, D. I. (2000) Multivariate cointegration analysis of the role of energy in the U.S. macroeconomy. Energy Economics, 22(2), 267- 283.

- Stern, D.I. (2004) Economic growth and Energy. In Encyclopaedia of Energy, Volume 2. Elsevier. Academy Press
- Stern, P C.,(1984) ‘Improving Energy Demand Analysis’ Washington D.C National Academy Press,
- Sterman, J.D. 2000. Business Dynamics. Systems Thinking and Modelling for Complex World. Irwin McGraw-Hill.
- Strang V (1997) Contextualising values and behaviour. Conference proceedings of European Council for an Energy Efficient Economy (ECEEE) summer study June 914, 1997. Sustainable energy opportunities for a greater Europe. Spindleruv Ml´yn, Czech Republic http://www.eceee.org/conference_proceedings/eceee/1997/Panel_4/p4_3/paper [accessed 16 January 2011].
- Subair, K and Oke, D.M. (2008). Privatisation and Trends of Aggregate Consumption of Electricity in Nigeria: An Empirical Analysis. African Journal of Accounting, Economics, Finance and Banking Research.3 (3), 18-26.
- Swan, L.G. and Ismet Ugursal,V. (2009) Modeling of end-use energy consumption in the residential sector: A review of modeling techniques. Renewable and Sustainable Energy Reviews 13 (8), 1819–1835.
- Todaro, M.P. and Smith, S.C. (2011) Economic development: 8th ed. Harlow: Addison Wesley.
- Toman T. and Jemelkova, B. (2003) Energy and economic development: An assessment of the state of knowledge. The Energy Journal 24(4), 93–112.
- Tso, G K.F and Yau, K.W. (2007) Predicting electricity energy consumption: a comparison of regression analysis, decision tree and neural networks Energy, 32 (9), 1762-1768.
- Turkson, J. and Wohlgemuth, N. (2001) Power sector reform and distributed generation in sub-Saharan Africa. Energy Policy 29(2), 135-145.
- Ubani, O. (2013), Determinants of the dynamics of electricity consumption in Nigeria. OPEC Energy Review, 37(2), 149-161.
- Ubogu, R. (1985), Demand for Electricity in Nigeria: Some Empirical Findings. Socio-Economic Planning Science, 19(5), 331-337.
- Urban F., Benders, R.M.J. and Moll, H.C. (2007) Modelling energy systems for developing countries. Energy Policy 35(6), 3473-3482.

- van der Kroon B., Brouwer, R and van Beukering P.J.H. (2013) The energy ladder: Theoretical myth or empirical truth? Results from a meta-analysis. Renewable and Sustainable Energy Reviews; (20), 504-513.
- Vincenzo, B., Oronzio, M. and Sergio, N (2009). Electricity consumption forecasting in Italy using regression models. Energy 34(9), 1413-1421.
- Wainwright, J. and Mulliga, M. (2013) Environmental Modelling: Finding Simplicity in Complexity, 2nd ed. Willey & Sons Ltd
- Wolde-Rufael, Y. (2005) Energy demand and economic growth: The African experience. Journal of Policy Modeling 27(8), 891-903.
- Wolde-Rufael, Y. (2006). Electricity consumption and economic growth; a time series for 17 African countries, Energy Policy 34(10), 1106 – 1114.
- Wooldridge, J.M. (2008) Introductory Econometrics, A modern Approach 4th Ed. South-Western Cengage Learning, USA.
- Wolstenholme, E.F. (1998). Qualitative v. Quantitative Modelling: The Evolving Balance. International System dynamics Conference. www.systemdynamics.org/conferences/1998/PROCEED/00071.PDF [accessed 25 January 2011].
- Wolstenholme, E F. (2003). Towards the definition and use of a core set of archetypal structures in system dynamics, System Dynamics Review 19(1), 726.
- World Bank (2003). Africa development indicators. www.data.worldbank.org/datacatalog/africa-development-indicators [accessed 16 June 2014].
- World Bank (2011). World Development Indicators (Edition: April 2011). ESDS International, University of Manchester. DOI: http://dx.doi.org/10.5257/wb/wdi/2011-04 [accessed 13 August 2014].
- World Bank (2013) World Development Indicators [online].http://databank.worldbank.org/data/download/WDI2013-ebook.pdf[[accessed 23 April 2014].
- World economic Forum - Energy for Economic Growth , Energy Vision Update 2012 energy for Economic Growth - Reports - World Economic Forum [accessed 11October 2014].

- World Energy Outlook 2011. www.iea.org/publications/freepublications/publication/world-energy-outlook2011.html [accessed 20 November 2013].
- Yan, Y.Y. (1998) Climate and residential electricity consumption in Hong Kong. Energy, 23(1), 17-20.
- Yoo, S.H., Lee, J.S., and Kwak, S.J. (2007) Estimation of residential electricity demand function in Seoul by correction for sample selection bias. Energy Policy 35(11), 5702 – 5707.
- Yu-Ting Lee, L. (2013) Household energy mix in Uganda. Energy Economics Vol 39, 252–261.
- Yuan, J., Zhaoa, C., Yu, S. and Hub, Z. (2007) Electricity consumption and economic growth in China: Cointegration and co-feature analysis. Energy Economics 29 (6), 1179-1191.
- Yusuff, O.S. (2011) Theoretical Analysis of the Concept of Informal Economy and Informality in Developing Countries. European Journal of Social Sciences, 20(4), 624-634.
- Zachariadis, T. and Pashourtidou, N. (2007) An Empirical analysis of electricity consumption in Cyprus. Energy Economics 29(2), 183-198.
- Ziramba, E. (2008). The demand for residential electricity in South Africa. Energy Policy 36 (2008) 3460 –3466.
- http://www.systemdynamics.org/conferences/2009/proceed/papers/P1106.pdf [accessed 04 November 2009].
- www.systemdynamics.org/conferences/1990/proceed/.../bronk155.pdf [accessed 04 December 2009].
- http://researchspace.csir.co.za/dspace/handle/10204/3565 [accessed 13 December 2009].
- www.og.decc.gov.uk [accessed 30 October 2011].
- http://www.energybc.ca/ [accessed 19 November 2011].
- http://www.theinformationdaily.com/ [accessed 20 August 2012].
- http://www.eia.gov/countries/cab.cfm?fips=NI [accessed 21/October 2012].
- http://www.worldenergy.org/documents/congresspapers/70.pdf [accessed 28 October 2012].

- http://www.power-nigeria.com/en/IndustryNews/ [accessed 30 October 2013].
- http://www.geni.org/globalenergy/library/national_energy_grid/nigeria/nigeria nnatio nalelectricitygrid.shtml [accessed 19 November 2013].
- www.indexmundi.com/Nigeria [accessed 03 March 2014].

Appendices

Appendix 1 – Summary of some of the studies carried out in relation to energy demand.

Author(s) & date of study	Region/ Country of study (developed (D) / developing)(DL)	Data used	Dependent variable used/ Type of energy	Independent variables	Issues investigated	Modelling Technique	Conclusion
1.Haris & Liu 1993	*South East of United States(D)*	*Monthly data 1969-1990*	*Electricity consumption*	*weather, price of electricity &income*	*To find the dynamic relationship between energy consumption and relevant variables*	*Linear Transfer function*	*Conservation of electricity consumption was best explained by consumer theory and that Price plays a major role in explaining conservation behaviour by consumers.*
2.Liu et al, 1991	*Singapore*	*Annual data 1960-1990*	*Annual electricity consumption (kWh)*	*GDP, real price of electricity , previous consumption and population*	*Investigation in the use of econometric model and Neural Network in forecasting*	*Regression & neural network*	*Neural network may be good for fitting past date but econometric model better at forecasting the future due to the structure of NN*
3.Yan 1998	*Hong Kong (D)*	*Monthly data*	*Residential electricity consumption*	*climatic variables*	*Effect of climate on use of energy*	*Stepwise multiple regression*	*Found relationship satisfactory but the use of weekly data may produce more precise models*

4.Beenstock et al 1999	*Israel (D)*	*Quarterly data 1973-1994*	*Household electricity demand*	*Price, consumer spending and weather*	*Comparing three different econometric methodologies*	*Dynamic Regression model, OLS and Maximum Likelihood*	*Results obtained differ and therefore suggested not to rely on one approach*
5.Rajan & Jain, 1999	*India(DL)*	*Monthly 1984-1993*	*Electrical energy*	*Weather & Population*	*Investigated the variation in the electrical energy consumption as a function of population and weather sensitive parameters*	*Linear multiple regression*	*Use of linear multiple regression accounts for most of the variation in the consumption of electrical energy*
6.Kulshreshtha & Parikh, 2000	*India*	*Annual data 1970-1995*	*Demand for coal*	*Price , GDP and industrial index for production*	*Modelling the demand for coal*	*Multivariate cointegrating VAR*	*High response to GDP but not to changes in price*
7.Bentzen and Engsted 2001	*Demark(D)*	*Annual data 1960-1996*	*Residential energy consumption*	*Income and price*	*Comparing the use of different approaches in estimating electricity consumption*	*Auto regressive distributed lag (ARDL) and Error correction mechanism (ECM)*	*Similar results produced, therefore ARDL to be used as a supplement rather than a substitute*

8.Engelioglu et al 2001	*Northern Cyprus(D)*	*Annual data 1988-1997*	*Electrical energy consumption (GWh)*	*number of tourists, customers and price of electricity*	*To find the determinants of energy consumption*	*Multiple regression*	*Different methods of evaluation resulted in different information, better to use stepwise regression in cases of large data and that electrical consumption model is not sufficient for effective and efficient utility planning for Cyprus.*

9.Halvorsen &Larsen, 2001	*Norway*	*Annual data 1976-1993*	*Household electricity demand*	*Number of households, price of electricity, income, stock of appliances, number of rooms and consumption of electricity*	*Investigating the growth of household electricity consumption*	*2SLS*	*Lower estimates of variables obtained compared to studies that use aggregate data*
10.Fatai et al, 2003	*New Zealand*	*Annual data 1960-1999*	*Electricity demand*	*Price of electricity, temperature, GDP and index of price substitute*	*Comparing different approaches in electricity demand*	*Engle-Granger ECM, Fully Modified Lease Squares and ARDL*	*ARDL –better a forecasting than other approaches*
11. Hunt & Nimoniya, 2003	*UK and Japan*	*Quarterly data 1971-1997*	*Energy demand*	*GDP, Price and UEDT*	*Estimating transport oil demand*	*STSM*	*STSM is superior to other conventional techniques*

12. Heltberg, 2004	*Brazil ,Nicaragua , South Africa, Vietnam, Guatemala, Ghana, Nepal, India*	*Survey*		*HH size, per capita income, electrification, education*	*What contributes to fuel use and fuel switching*	*Multinomial logistic regression*	*There is an association between electrification and fuel use and that economic development process such as urbanisation, electrification and education will help to promote fuel switching*
13.Holtedahl and Joutz 2004	*Taiwan(D)*	*Annual data 1955-1996*	*Residential electricity consumption*	*Disposable income, rate of urbanisation, population growth, price of oil and price of electricity*	*Examining the residential demand of electricity*	*Error correction model*	*Findings used to determine the value of electric market in utilization program. Chosen variables are significant in estimating residential electricity in both short run and long run. Price was negative and inelastic whereas income was unit elastic. Also found that the effect of urbanisation was stable.*
14.Hondrayiann is 2004	*Greece(DL)*	*Monthly 1986-1999*	*Residential electricity demand*	*Income, price level and temperature*	*Analysing the residential energy demand*	*Vector error correction model*	*Electricity demand is sensitive to the variables used*

15.De Vita el al 2006	*Namibia(DL)*	*Quarterly data 1980-2002*	*Energy demand*	*GDP, price of electricity and temperature*	*Estimating the elasticity of the different energy forms*	*ARDL*	*Positive relationship between energy consumption and GDP but negative to prices. Price elasticity was lowest for electricity when compared to other energy forms.*
16. Dimitropoulos et al 2005	*United Kingdom*	*Annual data 1967-2002*	*Energy demand*	*GDP, Price and UEDT*		*STSM*	*The use of STSM is better than the traditional regression methods*
17.Mohammed & Bodger 2005	*New Zealand(D)*	*Annual data 1965-1999*	*Annual electricity consumption*	*GDP, price of electricity and population*	*Influence of economic and demographic variables on consumption of energy*	*Linear Regression*	*Relationship between variables was good and forecasts produced by model was comparable to national forecasts*

18.Narayan & Smyth, 2005	*Australia(D)*	*Annual data 1969-2000*	*Residential demand of electricity*	*Income, temperature, price of electricity and price of gas*	*Analysing electricity demand*	*Bounds testing to cointegration ARDL*	*Real income and price of electricity were found to be very significant in determining the demand for electricity whereas gas prices was insignificant .Level of consumption in response to environmental policies was also found to be slow.*
19.Tien Pao, 2006	*Taiwan ( )*	*Monthly data 1990-2002*	*Electricity consumption*	*National Income, GDP population, CPI and temperature*	*Investigating the influence of economic variables on electricity consumption and forecasting electricity consumption*	*Regression & Neural network*	*Linear model is weaker at forecasting peaks and troughs*
20.Erdogdu, 2007	*Turkey*	*Quarterly data 1984-2004*	*Electricity demand*	*Real electricity prices, real GDP per capita and net electricity consumption per capita*	*Analysing the demand for electricity consumption*	*Cointegration-ARIMA*	*Changes in price and income receives limited response from customers*
21.Halicoglu, 2007	*Turkey*	*Annual data 1968-2005*	*Residential electricity*	*Income, energy price and urbanisation*	*Residential demand function*	*Bounds testing approach*	*Urbanisation is a significant factor in both long and short terms. Short run income and price elasticities lower than long run elasticities.*

22.Tso & Yau 2007	*Hong Kong(D)*	*Survey, monthly 1999-2000*	*Residential electricity energy consumption*	*Size of flat, household number and ownership of air conditioner*	*Comparing the accuracy in predicting electricity energy consumption between 3 different modelling methods*	*Multiple regression, Neural Networks(NN) and Decision Tree(DT)*	*Decision tree model and NN viable alternatives to stepwise regression and DT more accurate than the other two based on the square root of the average square error. The three methods are comparable in general*
23. Amarawickrama and Hunt, 2008	*Sri Lanka*	*Annual data 1970-20036*	*Electricity demand*	*GDP, Price and UEDT*	*Comparing the use of STSM and cointegration approach*	*STSM*	*STSM performed equally well when compared to cointegration approaches*
24.Louw et al 2008	*South Africa(DL)*	*Monthly data 2001-2002*	*Energy demand in low income houses*	*Income, price of paraffin, length of grid connection, appliances, size of household and availability to credit facilities*	*Finding the determinants of residential electricity*	*OLS Regression*	*Income was found to be inelastic and therefore concludes that electricity is a basic need./However, income was found to be significant indicating that the use of electricity was cost -based*
25.Ziramba 2008	*South Africa(DL)*	*Annual 1978-2005*	*Residential electricity demand*	*Income and Price of electricity*	*Electricity demand*	*ARDL Cointegration*	*Electricity consumption is a normal good as it increases with increase in income.*

26.Amusa et al, 2009	*South Africa*	*Annual 1960 -2007*	*Aggregate electricity consumption (GwH)*	*GDP and average price of electricity*	*Investigating the contributors to the aggregate demand of electricity*	*ARDL- Bounds testing*	*Income is the main determinant of electricity whilst changes in price have no effect on aggregate demand.*
27.Babatunde & Shaibu 2009	*Nigeria(DL)*	*Annual data 1970-2006*	*Residential electricity consumption*	*Income, Price of electricity, population ,Price of substitute*	*Examining the residential electricity demand*	*Bounds testing ARDL Cointegration*	*Long run residential electricity demand using income, price of electricity and population was stable over estimation period; therefore allowing for forecasting. Increase in price does not lead to a significant increase in demand.*
28. Vincenzo et al 2009	*Italy(DL)*	*Annual data, 1970-2007*	*Electricity consumption*	*GDP, Price of electricity, GDP per capita and population*	*Estimating the elasticities of GDP, Price and GDP per capita*	*Multiple regression*	*Pricing policy cannot be used to promote efficient use of electricity as price was insignificant in determining the consumption of electricity*
29.Dilaver and Hunt 2009	*Turkey(DL)*	*Annual data 1960-2008*	*Residential electricity demand*	*Household total final expenditure, energy prices and energy demand trend*	*Examining the relationship between electricity and different variables*	*Structural times series*	*All variables included in modelling are important for implementation and evaluation. Also the use of STSM and UEDT tends to provide a better estimation for electricity demand*

30. Odularu and Okonkwo, 2009	*Nigeria(DL)*	*Annual data 1975-2005*	*Electricity consumption*	*Gross fixed capital formation, labour force, crude Oil consumption, electricity consumption and coal consumption.*	*Investigating the relationship between energy consumption and the economy*	*Cointegration*	*Increased energy consumption is a strong determinant of economic growth*
31. Agnolucci 2010	*UK(D)*	*Quarterly data 1973-2005*	*Domestic and Industrial energy demand*		*Estimating the domestic and industrial demand of energy*	*STSM*	*STSM is an effective approach for estimating energy demand*
31.Iwayemi et al. 2010	*Nigeria(DL)*	*Annual data 1977-2006*	*Aggregate petroleum products consumption*	*Income, weighted average price, GDP*	*Estimating the demand functions for petroleum products*	*Multivariate cointegration*	*Generally, energy consumption responds positively to changes in GDP and negatively to changes in energy price depending on the product type. It was suggested that taxation will help to regulate the level and structure of energy consumption.in the country.*
32.Sa'ad, 2009	*Korea & Indonesia*	*Annual data 1973-2008*	*Energy demand*	*Per capita energy consumption, per capita real GDP, average of real energy price and UEDT.*	*Estimating energy demand functions for aggregated whole economy and residential sectors*	*Structural Times Series Model*	*Various factors affect energy demand but energy demand is more responsive to income than price*

33.Khattak et al 2010	*Peshawar district (India)(DL)*	*Monthly data 2009*	*Electricity consumption*	*Income, price of electricity, number of rooms, education and weather*	*Evaluating the determinants of HH electricity consumption*	*Multinomial Logistic model*	*All chosen factors have significant effect on demand*
34.Adom et al 2011	*Ghana(DL)*	*Annual data 1975-2005*	*Domestic electricity generated*	*Real GDP, industry efficiency, structural changes and degree of urbanisation*	*Investigating the determinants of aggregate domestic electricity demand*	*ARDL Cointegration*	*Industrial efficiency is the only factor that influences the domestic demand of electricity*
35.Ekpo et al, 2011	*Nigeria(DL)*	*Annual data, 1970 -2008*	*Electricity consumption*	*GDP per cap, price of electricity population and individual output*	*Finding the determinants of electricity consumption*	*Auto regressive Distributed lag(Bounds testing approach)*	*Consumption is influenced by income, population and industrial output while price is insignificant*
36. Kankal et al, 2011	*Turkey(DL)*	*Annual data 1980-2007*	*Energy consumption*	*GDP, population, import, export and employment*	*Use of alternative method in forecasting energy consumption*	*Fuzzy regression, genetic algorithm and ANN*	*Artificial Neural Network better at forecasting*
37.Maliki et al 2011	*Nigeria(DL)*	*Annual data 1973-2007*	*Electric power generated*	*Annual average Load Demand and Instantaneous annual peak demand*	*Examining the Electric power generated*	*Regression and Artificial Neural Networks*	*NN when trained is better at predicting the electric*

38.Adom & Bekoe, 2012	*Ghana*	*Annual data 1975-2008*	*Aggregate demand of electricity*	*Real per capita income, urbanisation, industrial efficiency and industrial output*	*Identifying factors that affect electricity demand*	*Partial Adjustment model & ARDL*	*ARDL better at forecasting*
39.Dilaver 2012	*Turkey*	*Annual data 1960-2008*	*Aggregate electricity demand*	*Income, price and UEDT*	*The effect of including UEDT in analysing the demand of energy*	*Structural Times Series modelling*	*Use of STSM was able to distinguish the structural changes of demand behaviour. Impact of price and income are limited in the short-run.*
40.Ogunleye 2012	*Nigeria*	*Annual data 1970 -2007*	*Energy Demand*	*Real income, price, CPI, consumption level*	*Analysing energy demand at a disaggregate level*	*VAR*	*Shocks to electricity consumption and petroleum are due to disturbance in production and not because of price change.*

41. Ubani, 2013	*Nigeria*	*Annual data 1985-2005*	*Electricity consumption rate*	*Per capita income, price per unit of electricity, degree of urbanisation, population density, land area, number of residential units in state per capita, number of banks per capita, number of manufacturing industry per state, households with electricity per capita, employment rate per capita, number of markets per state and distance to the closest functional electricity power generating station.*	*Determining the various factors that affect the electricity consumption rate in Nigeria*	*Multiple linear regression*	*Only six of the socio economic variables- degree of urbanisation, population density, number of manufacturing industry, number of households with electricity, employment rate and distance to nearest power generating station were found to be significant in determining the electricity consumption at the aggregate level.* ,
42.Kialashak and Reisel, 2013	*United States*	*Annual data 1980-2010*	*Energy demand*	*Resident population, gross domestic product, household size, median household income, cost of residential electricity, cost of residential natural gas, and cost of residential heating oil*	*Development of energy model for forecasting residential energy demand*	*Artificial Neural Network and Multiple linear regression*	*Models from both were robust but different results in forecasting. There is the need to further research in order to be able to establish which of the two is better. ANN models were sensitive to the recent fluctuations caused by the economic recession*

43.Abila, 2015	*Nigeria*	*Annual data*	*Aggregate petroleum product consumption*	*GDP, population, electricity generation, electricity generation capacity, and the consumption of individual petroleum products*	*Estimation of the petroleum products consumption*	*Multiple linear regression*	*All petroleum products significantly contribute to aggregate consumption of petroleum products in Nigeria.*
44.Alam et al,2015	*Indonesia, Malaysia &Thailand*	*Annual data 1980-2012*	*Energy consumption*	*FDI inflows, economic growth, trade openness and human development and urbanisation*	*Finding the impact of various factors on energy consumption*	*Linear regression*	*Urbanisation and foreign direct investment positively influences energy consumption in all 3 countries*

Appendix 2 –OLS regression estimates

Ordinary Least Squares Estimation Model 1			
Dependent variable is LREC			
39 observations used for estimation from 1971 to 2009			
Regressor	Coefficient	Standard Error	T-Ratio[Prob]
CONST	-27.8928	4.1694	-6.6899[.000]
LGDP	.63681	.18014	3.5351[.001]
LEDU	.56947	.14370	3.9628[.000]
LPE	2.36950	.55838	4.2436[.000]
LFS1	-.07369	.03460	-2.1295[.041]
LCON	-.77783	.64668	-1.2028[.238]
R-Squared	.97228	R-Bar-Squared	.96808
S.E. of Regression	.14522	-Stat. F(4,34)	285.2849[.000]
Mean of Dependent Variable	5.9879	S.D. of Dependent Variable	.80755
Residual Sum of Squares	.71699	Equation Log-likelihood	22.5885
Akaike Info. Criterion	17.5885	Schwarz Bayesian Criterion	13.4295
DW-statistic	1.2854		

Diagnostic Tests		
* Test Statistics	LM Version	F Version
* A:Serial Correlation	CHSQ(1) = 4.1497[.042]	F(1,32) = 3.8103[.060]
* B:Functional Form	CHSQ(1) = .25586[.613]	F(1,32) = .21132[.649]
* C:Normality	CHSQ(2) = .51316[.774]	Not applicable
* D:Heteroscedasticity	CHSQ(1) = 1.3464[.246]	F(1,37) = 1.3231[.257]
* E:Predictive Failure	CHSQ(2) = .18887[.910]	F(2,33) = .094436[.910]

A:Lagrange multiplier test of residual serial correlation

B:Ramsey's RESET test using the square of the fitted values

C:Based on a test of skewness and kurtosis of residuals

D:Based on the regression of squared residuals on squared fitted values

E:A test of adequacy of predictions (Chow's second test)

Estimated Correlation Matrix of Variables

41 observations used for estimation from 1971 to 2011

	LREC	LGDP	LPE	LEDU	LFS1	LCON
LREC	1.0000	.77775	.96563	.93467	.81412	.94260
LGDP	.77775	1.0000	.78268	.57758	.76501	.86984
LPE	.96563	.78268	1.0000	.89873	.91227	.95817
LEDU	.93467	.57758	.89873	1.0000	.70509	.86376

LFS1	.81412	.76501	.91227	.70509	1.0000	.87849
LCON	.94260	.86984	.95817	.86376	.87849	1.0000

Ordinary Least Squares Estimation Model 2			
Dependent variable is LREC			
39 observations used for estimation from 1971 to 2009			
Regressor	Coefficient	Standard Error	T-Ratio[Prob]
CONST	-24.9962	3.4259	7.296**[.000]
LGDP	.48363	.12824	3.7714[.001]
LEDU	.48163	.12457	3.8663[.000]
LPE	2.18160	.53957	4.0432[.000]
LFS1	-.08336	.03388	-2.4607[.019]
***			
R-Squared .97107	R-Bar-Squared .96766		
S.E. of Regression .14522	F-Stat. F(4,34) 285.2849[.000]		
Mean of Dependent Variable 5.9879	S.D. of Dependent Variable .80755		
Residual Sum of Squares .71699	Equation Log-likelihood 22.5885		
Akaike Info. Criterion 17.5885	Schwarz Bayesian Criterion 13.4295		
DW-statistic 1.2725			
***			
***			
* Test Statistics *	LM Version *	F Version *	
***			
* * * *			
* A:Serial Correlation*CHSQ(1) = 4.5542[.033]*F(1,33) = 4.3631[.045]*			
* * * *			
* B:Functional Form *CHSQ(1) = .71911[.396]*F(1,33) = .61991[.437]*			
* * * *			
* C:Normality *CHSQ(2) = .14764[.929]* Not applicable *			
* * * *			
* D:Heteroscedasticity*CHSQ(1) = 1.5577[.212]*F(1,37) = 1.5393[.223]*			
* * * *			
* E:Predictive Failure*CHSQ(2) = .49033[.783]*F(2,34) = .24516[.784]*			
***			
Ordinary Least Squares Estimation Model 3			
***			
Dependent variable is LREC			
39 observations used for estimation from 1971 to 2009			
***			

Regressor	Coefficient	Standard Error	T-Ratio[Prob]
CONST	-14.7590	3.8206	-3.8631[.000]
LREC1	.51106	.12716	4.0191[.000]
LGDP	.53949	.15926	3.3875[.002]
LEDU	.41264	.13007	3.1725[.003]
LPE	.82932	.38449	2.1569[.038]
LCON	-1.0376	.54984	-1.8872[.068]

R-Squared .97883 R-Bar-Squared .97563
S.E. of Regression .12607 F-Stat. F(5,33) 305.2225[.000]
Mean of Dependent Variable 5.9879 S.D. of Dependent Variable .80755
Residual Sum of Squares .52452 Equation Log-likelihood 28.6838
Akaike Info. Criterion 22.6838 Schwarz Bayesian Criterion 17.6931
DW-statistic 2.2569

Ordinary Least Squares Estimation Model 4
Dependent variable is LREC
39 observations used for estimation from 1971 to 2009

Regressor	Coefficient	Standard Error	T-Ratio[Prob]
CONST	-12.1273	3.8917	-3.1162[.004]
LREC1	.65501	.10787	6.0721[.000]
LGDP	.17866	.10327	1.7300[.093]
LPE	1.2552	.49795	2.5207[.017]
LFSK	-.057387	.028407	-2.0202[.051]

R-Squared .97501 R-Bar-Squared .97207
S.E. of Regression .13497 F-Stat. F(4,34) 331.5985[.000]
Mean of Dependent Variable 5.9879 S.D. of Dependent Variable .80755
Residual Sum of Squares .61935 Equation Log-likelihood 25.4430
Akaike Info. Criterion 20.4430 Schwarz Bayesian Criterion 16.2841
DW-statistic 2.3465
****
Diagnostic Tests
****
* Test Statistics * LM Version * F Version *
****
* A:Serial Correlation*CHSQ(1) = 2.3041[.129]*F(1,33) = 2.0720[.159]*
* B:Functional Form *CHSQ(1) = .74047[.390]*F(1,33) = .63868[.430]*
* C:Normality *CHSQ(2) = 2.7294[.255]* Not applicable *
* D:Heteroscedasticity*CHSQ(1) = 1.1368[.286]*F(1,37) = 1.1109[.299]*

* E:Predictive Failure*CHSQ(2) = .15597[.925]*F(2,34) = .077983[.925]*
Ordinary Least Squares Estimation Model 5

Dependent variable is LREC			
41 observations used for estimation from 1970 to 2010			
Regressor	Coefficient	Standard Error	T-Ratio[Prob]
CONST	-49.5685	5.4282	-9.1316[.000]
LGDP	-.81185	.13752	-5.9037[.000]
LPK	.13737	.02261	6.0768[.000]
LEE	20.6864	1.9287	10.7255[.000]
LCON	-1.1977	.57242	-2.0923[.044]
R-Squared	.97515	R-Bar-Squared	.97239
S.E. of Regression	.14569	F-Stat. F(4,36)	353.2135[.000]
Mean of Dependent Variable	5.9734	S.D. of Dependent Variable	.87679
Residual Sum of Squares	.76407	Equation Log-likelihood	23.4682
Akaike Info. Criterion	18.4682	Schwarz Bayesian Criterion	14.1843
DW-statistic	1.2154		
Diagnostic Tests			
* Test Statistics *	LM Version *	F Version *	
* A:Serial Correlation*CHSQ(1) = 6.3839[.012]*F(1,35) = 6.4547[.016]*			
* B:Functional Form *CHSQ(1) = .37375[.541]*F(1,35) = .32199[.574]*			
* C:Normality *CHSQ(2) = 18.6470[.000]* Not applicable *			
* D:Heteroscedasticity*CHSQ(1) = .0070523[.933]*F(1,39) = .0067095[.935]*			
* E:Predictive Failure*CHSQ(1) = .27458[.600]*F(1,36) = .27458[.603]*			
Ordinary Least Squares Estimation Model 6			
Dependent variable is LREC			
39 observations used for estimation from 1971 to 2009			
Regressor	Coefficient	Standard Error	T-Ratio[Prob]
CONST	-24.6124	3.3023	-7.4531[.000]
LGDP	.48363	.12824	3.7714[.001]

LEDU .48163 .12457 .8663[.000]
LPE 2.1816 .53957 4.0432[.000]
LFSK1 -.083360 .033877 -2.4607[.019]
R-Squared .97107 R-Bar-Squared .96766
S.E. of Regression .14522 F-Stat. F(4,34) 285.2849[.000]
Mean of Dependent Variable 5.9879 S.D. of Dependent Variable .80755
Residual Sum of Squares .71699 Equation Log-likelihood 22.5885
Akaike Info. Criterion 17.5885 Schwarz Bayesian Criterion 13.4295
DW-statistic 1.2725
Diagnostic Tests
* Test Statistics * LM Version * F Version *
* A:Serial Correlation*CHSQ(1) = 4.5542[.033]*F(1,33) = 4.3631[.045]*
* C:Normality *CHSQ(2) = .14764[.929]* Not applicable *
* D:Heteroscedasticity*CHSQ(1) = 1.5577[.212]*F(1,37) = 1.5393[.223]*
* E:Predictive Failure*CHSQ(2) = .49033[.783]*F(2,34) = .24516[.784]*

Appendix 3- Data used for OLS regression

	Consumer price index (2005 = 100)	Electric power consumption (kWh per capita)	Electric power transmission and distribution losses (per cent of output)	Electricity production (kWh)	Energy use (kg of oil equivalent per capita)	GDP (constant 2005 US$)	GDP growth (annual per cent)	GDP per capita (constant 2005 US$)	Life expectancy at birth, total (years)	Population (Total)	Population growth (annual per cent)
1970	0.1616	..	..	..	..	38983564554	25.0072	694.5000	41.1810	56131845	2.2933
1971	0.1874	28.4925	13.2485	1887000000	627.822	44533861861	14.2375	775.1256	41.6022	57453735	2.3277
1972	0.1939	32.6368	14.1708	2237000000	634.08787	46032097666	3.3643	782.4686	42.0385	58829321	2.3660
1973	0.2044	35.1992	19.1619	2625000000	645.48903	48514498439	5.3928	804.7463	42.4862	60285455	2.4450
1974	0.2303	32.7529	11.4123	2287000000	648.01429	53929043719	11.1607	871.8338	42.9399	61857025	2.5735
1975	0.3085	45.6379	16.2529	3464000000	656.60152	51109769452	-5.2277	804.0476	43.3976	63565601	2.7247
1976	0.3834	51.4161	18.0711	4106000000	669.69944	55731294575	9.0424	851.8091	43.8593	65426979	2.8862
1977	0.4413	58.9837	14.6828	4713000000	683.11171	59088613437	6.0241	876.3549	44.3169	67425439	3.0088
1978	0.5371	60.4786	7.2068	4579000000	693.28983	55682652166	-5.7642	801.0482	44.7601	69512236	3.0480

	Consumer price index (2005 = 100)	Electric power consumption (kWh per capita)	Electric power transmission and distribution losses (per cent of output)	Electricity production (kWh)	Energy use (kg of oil equivalent per capita)	GDP (constant 2005 US$)	GDP growth (annual per cent)	GDP per capita (constant 2005 US$)	Life expectancy at birth, total (years)	Population (Total)	Population growth (annual per cent)
1981	0.7972	50.7067	49.2670	7776000000	724.44527	53813895881	-13.1279	710.6061	45.8524	75729574	2.7192
1982	0.8585	81.5775	24.2850	8532000000	740.1818	53247135431	-1.0532	685.0285	46.0835	77729805	2.6070
1983	1.0578	81.4130	24.0331	8713000000	742.64858	50557914889	-5.0505	634.1195	46.2396	79729313	2.5399
1984	1.2463	61.8158	42.2306	8984000000	727.35741	49535867646	-2.0215	605.7565	46.3242	81775217	2.5337
1985	1.3390	80.1296	32.8539	10221000000	732.14373	53658653550	8.3228	639.5429	46.3453	83901572	2.5670
1986	1.4155	90.5153	27.5961	10766000000	721.63092	48961280054	-8.7542	568.5368	46.3183	86118046	2.6075

	Consumer price index (2005 = 100)	Electric power consumption (kWh per capita)	Electric power transmission and distribution losses (per cent of output)	Electricity production (kWh)	Energy use (kg of oil equivalent per capita)	GDP (constant 2005 US$)	GDP growth (annual per cent)	GDP per capita (constant 2005 US$)	Life expectancy at birth, total (years)	Population (Total)	Population growth (annual per cent)
1987	1.5753	88.9350	30.1997	11265000000	727.73324	43697110037	-10.7517	494.2390	46.2637	88412920	2.6299
1988	2.4341	86.7763	32.4095	11654000000	729.46239	46992974187	7.5425	517.6942	46.2030	90773617	2.6351
1989	3.6625	96.6626	29.7042	12813000000	734.81257	50032099652	6.4672	536.9417	46.1498	93179760	2.6162
1990	3.9322	86.7102	38.4164	13463000000	738.17444	56419202083	12.7660	590.0519	46.1103	95617350	2.5824
1991	4.4436	89.2182	37.5803	14167000000	752.81002	56070615711	-0.6179	571.6511	46.0870	98085373	2.5484
1992	6.4250	89.6689	38.5735	14834000000	762.3156	56313808189	0.4337	559.8226	46.0750	100592242	2.5237
1993	10.0979	100.4511	27.8525	14505000000	755.68361	57490979534	2.0904	557.3815	46.0728	103144749	2.5058
1994	15.8569	95.1464	34.3249	15531000000	720.58361	58014011386	0.9098	548.5813	46.0856	105752796	2.4971
1995	27.4063	91.0861	37.7184	15857000000	715.14821	57835636304	-0.3075	533.4169	46.1141	108424827	2.4953

	Consumer price index (2005 = 100)	Electric power consumption (kWh per capita)	Electric power transmission and distribution losses (per cent of output)	Electricity production (kWh)	Energy use (kg of oil equivalent per capita)	GDP (constant 2005 US$)	GDP growth (annual per cent)	GDP per capita (constant 2005 US$)	Life expectancy at birth, total (years)	Population (Total)	Population growth (annual per cent)
1995	27.4063	91.0861	37.7184	15857000000	715.14821	57835636304	-0.3075	533.4169	46.1141	108424827	2.4953
1996	35.4276	85.5206	41.4702	16243000000	726.64354	60723777676	4.9937	546.2431	46.1598	111166210	2.4969
1997	38.4496	81.6287	42.2721	16117000000	739.71179	62425413646	2.8023	547.6899	46.2245	113979481	2.4992
1998	42.2931	76.6082	40.7478	15110000000	722.59586	64120663260	2.7156	548.6618	46.3157	116867371	2.5021
1999	45.0923	75.4056	43.8374	16089000000	729.95683	64424747539	0.4742	537.6261	46.4427	119831888	2.5050
2000	48.2186	74.1312	38.1476	14727000000	737.28775	67850915773	5.3181	552.1869	46.6240	122876727	2.5092
2001	57.3193	75.2034	38.7182	15463000000	751.02586	70843863904	4.4111	562.2306	46.8812	126004992	2.5140
2002	64.7000	104.1520	37.5278	21544000000	753.64	73525054912	3.7846	568.9709	47.2197	129224641	2.5231
2003	73.7786	101.4258	33.3895	20183000000	746.94281	81137974799	10.3542	612.1304	47.6377	132550146	2.5409

	Consumer price index (2005 = 100)	Electric power consumption (kWh per capita)	Electric power transmission and distribution losses (per cent of output)	Electricity production (kWh)	Energy use (kg of oil equivalent per capita)	GDP (constant 2005 US$)	GDP growth (annual per cent)	GDP per capita (constant 2005 US$)	Life expectancy at birth, total (years)	Population (Total)	Population growth (annual per cent)
2005	100.0000	128.6591	23.7053	23539000000	763.03885	1.12248E+11	3.4447	804.1524	48.6645	139585891	2.6031
2006	108.2395	111.1468	31.0731	23110000000	746.64097	1.21465E+11	8.2110	847.5391	49.2286	143314909	2.6364
2007	114.0652	138.1097	11.5328	22978000000	731.60567	1.29759E+11	6.8284	881.5914	49.7916	147187353	2.6662
2008	127.2717	126.4549	9.4221	21110000000	735.57569	1.37895E+11	6.2703	911.9575	50.3294	151208080	2.6951
2009	141.9559	119.8151	5.8654	19777000000	703.14377	1.47458E+11	6.9344	949.0064	50.8305	155381020	2.7223
2010	161.4325	135.3973	17.2160	26121000000	720.9278	1.59018E+11	7.8397	995.6802	51.2894	159707780	2.7465
2011	178.9331	148.9285	9.5472	27034000000	720.64365	1.66418E+11	4.6533	1013.5486	51.7102	164192925	2.7696

	Urban population (per cent of total)	Urban population growth (annual per cent)	Per centage connectivity	Total Electricity consumption(MW)	Residential electricity consumption (MW)	Fuel subsidy (N)	Premium Motor Spirit Consumption	Dual Purpose Kerosene Consumption	Automotive Gas Oil Consumption	Energy Demand(Gwh)	Price of electricity (Kobo)
1970	22.71	4.61	22	145.3	53.90	0.24	1375745	367123	234587	2533478	1130
1971	23.27	4.79	22	181.1	66.20	0.24	1396570	397564	255864	2856720	1760
1972	23.84	4.77	22	211.1	72.90	0.24	1473256	478222	347895	3012587	1980
1973	24.40	4.79	22	232.7	86.60	0.24	1500643	500923	253250	3298561	2065
1974	24.97	4.86	25	266.2	103.00	0.24	1589475	544781	268756	3456782	2270
1975	25.53	4.96	25	318.7	118.30	0.24	1697895	653585	300756	4997853	2326
1976	26.14	5.25	25	369.8	155.20	0.24	1861618	735949	335975	5166942	2382
1977	26.75	5.31	25	435.7	182.70	0.24	2291514	943645	382422	6544645	2438
1978	27.36	5.30	25	504.4	253.20	0.24	2515789	1020224	450891	6898505	2494
1979	27.97	5.19	30	460.1	221.90	0.24	5284570	1823958	475642	11775663	2550
1980	28.58	5.02	30	536.9	243.10	0.36	6573007	2161368	499729	14412252	2612
1981	29.23	4.97	30	335.9	193.60	0.36	4300647	1551484	535156	10773902	2674
1982	29.88	4.81	30	685.6	344.50	0.36	4244798	1811914	497265	11208600	2736
1983	30.54	4.69	30	696.7	358.00	0.36	4012041	1724021	501568	9726539	2798
1984	31.19	4.64	30	625.5	326.60	0.36	3787895	1520777	555816	9328113	2860
1985	31.84	4.63	30	717.4	372.00	0.36	3597356	1928190	626271	9562837	2924

	Urban population (per cent of total)	Urban population growth (annual per cent)	Per centage connectivity	Total Electricity consumption(MW)	Residential electricity consumption (MW)	Fuel subsidy (N)	Premium Motor Spirit Consumption	Dual Purpose Kerosene Consumption	Automotive Gas Oil Consumption	Energy Demand(Gwh)	Price of electricity (Kobo)
1987	33.22	4.73	30	852.9	468.60	0.95	3103079	1554391	867235	8058195	3052
1988	33.90	4.69	30	853.5	443.80	0.95	3256442	1583488	798608	7700969	3116
1989	34.59	4.63	30	976.8	523.60	0.96	3302808	1546848	808725	7693273	3180
1990	35.28	4.55	33	898.5	450.80	1.20	3380049	1311893	773803	8652200	3250
1991	35.99	4.55	33	946.6	459.30	1.45	3969275.9	1612074.5	750786.6	10791498	3320
1992	36.71	4.48	33	993	481.60	1.48	3336215	1427784	688072	8633123	3390
1993	37.42	4.43	33	1141.4	592.40	7.50	3015634	1131057	670846	8020047	3460
1994	38.13	4.38	33	1115	575.00	27.00	2735700	686719	472754.4	6175507.8	3530
1995	38.84	4.35	35	1050.9	552.60	27.00	3454327.5	916206	715386.8	8353260.2	3602
1996	39.54	4.29	35	1033.3	518.00	27.00	4461348	1453194	2145392	8831160	3674
1997	40.25	4.26	35	1009.6	508.30	27.00	2792112	1104061	1150462	5758233	3746
1998	40.95	4.23	35	972.8	500.00	27.00	4475565	1459464	1700089	8337602	3818
1999	41.65	4.20	35	883.7	455.10	22.00	4752568	1508065	2093866	8976870	3890
2000	42.35	4.18	38	1017.3	518.80	22.00	5397577.4	1744430.1	2179226.4	10096319	3962
2001	43.03	4.11	38	1104.7	564.50	22.00	6556675.5	1567863.1	2275129.8	11235323	4034
2002	43.71	4.09	38	1271.6	752.80	22.00	6585614	1123935	2042744	10235770	4106

	Urban population (per cent of total)	Urban population growth (annual per cent)	Per centage connectivity	Total Electricity consumption(MW)	Residential electricity consumption (MW)	Fuel subsidy (N)	Premium Motor Spirit Consumption	Dual Purpose Kerosene Consumption	Automotive Gas Oil Consumption	Energy Demand(Gwh)	Price of electricity (Kobo)
2004	45.07	4.09	40	1825.8	938.50	22.00	7308100.23	907705.7	1760313.5	10434146	4250
2005	45.75	4.10	40	1873.1	1194.30	22.00	5925738.22	674032.0	1361296	8342354.9	4324
2006	46.40	4.05	40	1924.3	1258.60	22.00	6200555.35	753200	1589754	8563251	4398
2007	47.05	4.06	45	2000.8	1300.00	22.00	7355100.00	786550	1625000	8879699.5	4472
2008	47.70	4.07	45	2070.77	1367.80	79.70	7892354.90	823670	1687560	9582515	4546
2009	48.35	4.08	50	2430.8	1575.30	79.70	8215055.20	853000	1780325	10078425	4620
2010	49.00	4.08	55	2650.8	1625.00	79.70				11345782	

2011	49.62	4.02	55							13004576	

Year	School enrolment, secondary (per cent gross)	Premium Motor Spirit (kobo)	Dual Purpose Kerosene (kobo)	Automated Gas Oil (kobo)	Year	School enrolment, secondary (per cent gross)	Premium Motor Spirit (kobo)	Dual Purpose Kerosene (kobo)	Automated Gas Oil (kobo)
1970	4.4069	4.20	3.9	5.2	1986	27.0830	42.00	11	35
1971	4.7582	4.80	4.3	6	1987	27.0726	42.00	11	35
1972	5.2967	5.70	5	6.5	1988	..	60.00	11	35
1973	5.9139	6.70	5.7	7.2	1989	24.1320	60.00	11	35
1974	..	7.80	6	7.9	1990	24.5958	70.00	50	55
1975	..	8.30	7.6	8.5	1991	..	70.00	50	55
1976	..	9.10	8.1	8.8	1992	..	325.00	275	300
1977	7.6088	11.00	8.1	9.3	1993	..	1100.00	600	900
1978	8.9787	16.80	10.5	11	1994	..	1100.00	600	900
1979	10.9061	16.80	10.5	11	1995	..	1100.00	600	900
1980	13.6018	16.80	10.5	11	1996	..	2000.00	1700	1900
1981	17.0086	20.00	10.5	11	1997	..	2000.00	1700	1900
1982	20.9100	20.00	10.5	11	1998	..	2000.00	1700	1900
1983	25.0405	20.00	10.5	11	1999	23.4154	2200.00	1700	2100
1984	28.6849	20.00	10.5	11	2000	24.4599	2200.00	1700	2100
1985	29.1736	39.50	10.5	35	2001	26.8612	2600.00	1700	2100

Year	School enrolment, secondary (per cent gross)	Premium Motor Spirit (kobo)	Dual Purpose Kerosene (kobo)	Automated Gas Oil (kobo)
2002	29.4223	3400.00	3200	3200
2003	..	4900.00	4900	5300
2004	34.7517	6500.00	6950	7800
2005	34.6985	6500.00	6950	7800
2006	34.1881	6500.00	7900	8400
2007	31.6107	7200.00	7900	8400
2008	35.0941	7200.00	8700	9000
2009	38.9010	8000.00	9200	9000
2010	43.8291			

Appendix 4: Residuals and fitted values of regression models

Model 1

****

*********** Based on OLS regression of LREC on:

CONST LGDP LEDU LPE LFS1

LCON

39 observations used for estimation from 1971 to 2009

Observation	Actual	Fitted	Residual
1971	4.1927	4.0183	.17437
1972	4.2891	4.3795	-.090440
1973	4.4613	4.5754	-.11405
1974	4.6347	4.7949	-.16015
1975	4.7732	4.8790	-.10574
1976	5.0447	5.0088	.035929
1977	5.2078	5.1384	.069402
1978	5.5342	5.2487	.28546
1979	5.4022	5.3119	.090309
1980	5.4935	5.5209	-.027385
1981	5.2658	5.5842	-.31844
1982	5.8421	5.7494	.092686
1983	5.8805	5.8722	.0083740
1984	5.7887	5.9885	-.19973
1985	5.9189	6.1014	-.18254
1986	6.1667	6.0521	.11462
1987	6.1497	6.0296	.12013
1988	6.0954	6.0163	.079108
1989	6.2607	6.0762	.18453
1990	6.1110	6.1402	-.029213
1991	6.1297	6.1711	-.041378
1992	6.1771	6.2129	-.035836
1993	6.3842	6.2688	.11537
1994	6.3544	6.1998	.15459

1995	6.3146	6.1022	.21248
1996	6.2500	6.1775	.072442
1997	6.2311	6.2382	-.0071178
1998	6.2146	6.2968	-.082158
1999	6.1205	6.3310	-.21051
2000	6.2515	6.3835	-.13193
2001	6.3359	6.5069	-.17100
2002	6.6238	6.6244	-.5813E-3
2003	6.8086	6.7687	.039927
2004	6.8443	7.0088	-.16454
2005	7.0853	7.0704	.014896
2006	7.1378	7.1524	-.014686
2007	7.1701	7.0978	.072329
2008	7.2210	7.2349	-.013979
2009	7.3622	7.1977	.16446

Single Equation Static Forecasts

Based on OLS regression of LREC on:

CONST LGDP LEDU LPE LFS1 LCON

39 observations used for estimation from 1971 to 2009

****

Observation	Actual	Prediction	Error	S.D. of Error
2010	7.3933	7.3449	.048341	.18206
2011	7.4533	7.4940	-.040659	.17625

****

Residuals and Fitted Values of Regression Model 2

****

*********** Based on OLS regression of LREC on:

CONST LGDP LEDU LPE LFS1

39 observations used for estimation from 1971 to 2009

****

****

Observation	Actual	Fitted	Residual
1971	4.1927	4.0353	.15736
1972	4.2891	4.3599	-.070833
1973	4.4613	4.5301	-.068813
1974	4.6347	4.8109	-.17614
1975	4.7732	4.8893	-.11603
1976	5.0447	4.9985	.046197
1977	5.2078	5.1091	.098760
1978	5.5342	5.2096	.32453
1979	5.4022	5.3834	.018844
1980	5.4935	5.5621	-.068621
1981	5.2658	5.6191	-.35327
1982	5.8421	5.7634	.078688
1983	5.8805	5.8740	.0064852
1984	5.7887	5.9774	-.18869
1985	5.9189	6.0725	-.15361
1986	6.1667	6.0396	.12705
1987	6.1497	6.0307	.11909
1988	6.0954	5.9986	.096735
1989	6.2607	6.0495	.21123
1990	6.1110	6.1634	-.052373
1991	6.1297	6.1889	-.059209
1992	6.1771	6.2238	-.046693
1993	6.3842	6.2731	.11106
1994	6.3544	6.1836	.17073
1995	6.3146	6.1166	.19804
1996	6.2500	6.1812	.068798
1997	6.2311	6.2344	-.0033323
1998	6.2146	6.2859	-.071245

1999	6.1205	6.3179	-.19736
2000	6.2515	6.4210	-.16952
2001	6.3359	6.5263	-.19037
2002	6.6238	6.6267	-.0029311
2003	6.8086	6.7802	.028419
2004	6.8443	6.9703	-.12606
2005	7.0853	7.0236	.061671
2006	7.1378	7.0917	.046065
2007	7.1701	7.1223	.047833
2008	7.2210	7.2379	-.016891
2009	7.3622	7.2478	.11440

Residuals and fitted values of regression model 3

Residuals and Fitted Values of Regression

****

Based on OLS regression of LREC on:

CONST LREC1 LGDP LEDU LPE LCON

39 observations used for estimation from 1971 to 2009

****

Observation	Actual	Fitted	Residual
1971	4.1927	4.1405	.052151
1972	4.2891	4.4054	-.11626
1973	4.4613	4.5633	-.10200
1974	4.6347	4.6740	-.039304
1975	4.7732	4.7978	-.024547
1976	5.0447	4.9483	.096458
1977	5.2078	5.1649	.042951
1978	5.5342	5.3034	.23080
1979	5.4022	5.4149	-.012689
1980	5.4935	5.4808	.012705
1981	5.2658	5.5632	-.29737
1982	5.8421	5.5453	.29678
1983	5.8805	5.9048	-.024314
1984	5.7887	5.9877	-.19898
1985	5.9189	6.0093	-.090364
1986	6.1667	6.0136	.15305
1987	6.1497	6.0963	.053439
1988	6.0954	6.1170	-.021676
1989	6.2607	6.1195	.14119
1990	6.1110	6.1959	-.084848
1991	6.1297	6.1342	-.0045253
1992	6.1771	6.1660	.011080
1993	6.3842	6.2153	.16887
1994	6.3544	6.3407	.013683
1995	6.3146	6.2771	.037580

1996	6.2500	6.2976	-.047626
1997	6.2311	6.2934	-.062367
1998	6.2146	6.3114	-.096806
1999	6.1205	6.3116	-.19109
2000	6.2515	6.2394	.012159
2001	6.3359	6.3832	-.047234
2002	6.6238	6.4986	.12519
2003	6.8086	6.7182	.090375
2004	6.8443	6.9942	-.14992
2005	7.0853	7.0444	.040918
2006	7.1378	7.2181	-.080355
2007	7.1701	7.1398	.030296
2008	7.2210	7.2459	-.024961
2009	7.3622	7.2546	.10757

Single Equation Static Forecasts

****

Based on OLS regression of LREC on:

CONST LREC1 LGDP LEDU LPE

LCON

39 observations used for estimation from 1971 to 2009

****

Observation	Actual	Prediction	Error	S.D. of Error
2010	7.3933	7.3547	.038544	.15907
2011	7.4533	7.4532	.1001E-3	.15436

****

Summary statistics for single equation static forecasts

****

Based on 2 observations from 2010 to 2011

Mean Prediction Errors .019322 Mean Sum Abs Pred Errors .019322

Sum Squares Pred Errors .7428E-3 Root Mean Sumsq Pred Errors

.027255 Predictive failure test F(2,33) = .033281[.967]

Appendix 5: DW Statistics Table

Table A-1 Models with an intercept (from Savin and White) Durbin-Watson Statistic: 1 Per Cent Significance Points of dL and dU k'*=1 *k' is the number of regressors excluding the intercept k'=2 k'=3 k'=4 k'=5 k'=6 k'=7 k'=8 k'=9 k'=10
n dL dU dL dU dL dU dL dU dL dU dL dU dL dU dL dU
dL dU dL dU 6 0.390 1.142 ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- ---- ----- ----- 7 0.435 1.036 0.294 1.676 ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- -----
----- ----- ----- 8 0.497 1.003 0.345 1.489 0.229 2.102 ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- ---- ----- ----- ----- 9 0.554 0.998 0.408 1.389 0.279 1.875 0.183 2.433 ----- ----- ----- ----- ----- ----- ---- ----- ----- ----- ----- ----- 10 0.604 1.001 0.466 1.333 0.340 1.733 0.230 2.193 0.150 2.690 ----- ----- ---- ----- ----- ----- ----- ----- ----- ----- 11 0.653 1.010 0.519 1.297 0.396 1.640 0.286 2.030 0.193 2.453
0.124 2.892 ----- ----- ----- ----- ----- ----- ----- ----- 12 0.697 1.023 0.569 1.274 0.449 1.575 0.339
1.913 0.244 2.280 0.164 2.665 0.105 3.053 ----- ----- ----- ----- ----- ----- 13 0.738 1.038 0.616 1.261
0.499 1.526 0.391 1.826 0.294 2.150 0.211 2.490 0.140 2.838 0.090 3.182 ----- ----- ----- ----- 14
0.776 1.054 0.660 1.254 0.547 1.490 0.441 1.757 0.343 2.049 0.257 2.354 0.183 2.667 0.122 2.981
0.078 3.287 ----- ----- 15 0.811 1.070 0.700 1.252 0.591 1.465 0.487 1.705 0.390 1.967 0.303 2.244
0.226 2.530 0.161 2.817 0.107 3.101 0.068 3.374 16 0.844 1.086 0.738 1.253 0.633 1.447 0.532 1.664
0.437 1.901 0.349 2.153 0.269 2.416 0.200 2.681 0.142 2.944 0.094 3.201 17 0.873 1.102 0.773 1.255
0.672 1.432 0.574 1.631 0.481 1.847 0.393 2.078 0.313 2.319 0.241 2.566 0.179 2.811 0.127 3.053 18
0.902 1.118 0.805 1.259 0.708 1.422 0.614 1.604 0.522 1.803 0.435 2.015 0.355 2.238 0.282 2.467
0.216 2.697 0.160 2.925 19 0.928 1.133 0.835 1.264 0.742 1.416 0.650 1.583 0.561 1.767 0.476 1.963

0.396 2.169 0.322 2.381 0.255 2.597 0.196 2.813 20 0.952 1.147 0.862 1.270 0.774 1.410 0.684 1.567

0.598 1.736 0.515 1.918 0.436 2.110 0.362 2.308 0.294 2.510 0.232 2.174 21 0.975 1.161 0.889 1.276

0.803 1.408 0.718 1.554 0.634 1.712 0.552 1.881 0.474 2.059 0.400 2.244 0.331 2.434 0.268 2.625 22

0.997 1.174 0.915 1.284 0.832 1.407 0.748 1.543 0.666 1.691 0.587 1.849 0.510 2.015 0.437 2.188

0.368 2.367 0.304 2.548 23 1.017 1.186 0.938 1.290 0.858 1.407 0.777 1.535 0.699 1.674 0.620 1.821

0.545 1.977 0.473 2.140 0.404 2.308 0.340 2.479 24 1.037 1.199 0.959 1.298 0.881 1.407 0.805 1.527

0.728 1.659 0.652 1.797 0.578 1.944 0.507 2.097 0.439 2.255 0.375 2.417 25 1.055 1.210 0.981 1.305

0.906 1.408 0.832 1.521 0.756 1.645 0.682 1.776 0.610 1.915 0.540 2.059 0.473 2.209 0.409 2.362 26

1.072 1.222 1.000 1.311 0.928 1.410 0.855 1.517 0.782 1.635 0.711 1.759 0.640 1.889 0.572 2.026

0.505 2.168 0.441 2.313 27 1.088 1.232 1.019 1.318 0.948 1.413 0.878 1.514 0.808 1.625 0.738 1.743

0.669 1.867 0.602 1.997 0.536 2.131 0.473 2.269 28 1.104 1.244 1.036 1.325 0.969 1.414 0.901 1.512

0.832 1.618 0.764 1.729 0.696 1.847 0.630 1.970 0.566 2.098 0.504 2.229 29 1.119 1.254 1.053 1.332

0.988 1.418 0.921 1.511 0.855 1.611 0.788 1.718 0.723 1.830 0.658 1.947 0.595 2.068 0.533 2.193 30

1.134 1.264 1.070 1.339 1.006 1.421 0.941 1.510 0.877 1.606 0.812 1.707 0.748 1.814 0.684 1.925

0.622 2.041 0.562 2.160 31 1.147 1.274 1.085 1.345 1.022 1.425 0.960 1.509 0.897 1.601 0.834 1.698

0.772 1.800 0.710 1.906 0.649 2.017 0.589 2.131 32 1.160 1.283 1.100 1.351 1.039 1.428 0.978 1.509

0.917 1.597 0.856 1.690 0.794 1.788 0.734 1.889 0.674 1.995 0.615 2.104 33 1.171 1.291 1.114 1.358

1.055 1.432 0.995 1.510 0.935 1.594 0.876 1.683 0.816 1.776 0.757 1.874 0.698 1.975 0.641 2.080 34

1.184 1.298 1.128 1.364 1.070 1.436 1.012 1.511 0.954 1.591 0.896 1.677 0.837 1.766 0.779 1.860

0.722 1.957 0.665 2.057 35 1.195 1.307 1.141 1.370 1.085 1.439 1.028 1.512 0.971 1.589 0.914 1.671

0.857 1.757 0.800 1.847 0.744 1.940 0.689 2.037 36 1.205 1.315 1.153 1.376 1.098 1.442 1.043 1.513

0.987 1.587 0.932 1.666 0.877 1.749 0.821 1.836 0.766 1.925 0.711 2.018 37 1.217 1.322 1.164 1.383

1.112 1.446 1.058 1.514 1.004 1.585 0.950 1.662 0.895 1.742 0.841 1.825 0.787 1.911 0.733 2.001 38

1.227 1.330 1.176 1.388 1.124 1.449 1.072 1.515 1.019 1.584 0.966 1.658 0.913 1.735 0.860 1.816

0.807 1.899 0.754 1.985 39 1.237 1.337 1.187 1.392 1.137 1.452 1.085 1.517 1.033 1.583 0.982 1.655

0.930 1.729 0.878 1.807 0.826 1.887 0.774 1.970 40 1.246 1.344 1.197 1.398 1.149 1.456 1.098 1.518

1.047 1.583 0.997 1.652 0.946 1.724 0.895 1.799 0.844 1.876 0.749 1.956 45 1.288 1.376 1.245 1.424

1.201 1.474 1.156 1.528 1.111 1.583 1.065 1.643 1.019 1.704 0.974 1.768 0.927 1.834 0.881 1.902 50

1.324 1.403 1.285 1.445 1.245 1.491 1.206 1.537 1.164 1.587 1.123 1.639 1.081 1.692 1.039 1.748

0.997 1.805 0.955 1.864 55 1.356 1.428 1.320 1.466 1.284 1.505 1.246 1.548 1.209 1.592 1.172 1.638

1.134 1.685 1.095 1.734 1.057 1.785 1.018 1.837 60 1.382 1.449 1.351 1.484 1.317 1.520 1.283 1.559

1.248 1.598 1.214 1.639 1.179 1.682 1.144 1.726 1.108 1.771 1.072 1.817 65 1.407 1.467 1.377 1.500

1.346 1.534 1.314 1.568 1.283 1.604 1.251 1.642 1.218 1.680 1.186 1.720 1.153 1.761 1.120 1.802 70

1.429 1.485 1.400 1.514 1.372 1.546 1.343 1.577 1.313 1.611 1.283 1.645 1.253 1.680 1.223 1.716

1.192 1.754 1.162 1.792 75 1.448 1.501 1.422 1.529 1.395 1.557 1.368 1.586 1.340 1.617 1.313 1.649

1.284 1.682 1.256 1.714 1.227 1.748 1.199 1.783 80 1.465 1.514 1.440 1.541 1.416 1.568 1.390 1.595

1.364 1.624 1.338 1.653 1.312 1.683 1.285 1.714 1.259 1.745 1.232 1.777 85 1.481 1.529 1.458 1.553

1.434 1.577 1.411 1.603 1.386 1.630 1.362 1.657 1.337 1.685 1.312 1.714 1.287 1.743 1.262 1.773 90

1.496 1.541 1.474 1.563 1.452 1.587 1.429 1.611 1.406 1.636 1.383 1.661 1.360 1.687 1.336 1.714

1.312 1.741 1.288 1.769 95 1.510 1.552 1.489 1.573 1.468 1.596 1.446 1.618 1.425 1.641 1.403 1.666

1.381 1.690 1.358 1.715 1.336 1.741 1.313 1.767 100 1.522 1.562 1.502 1.582 1.482 1.604 1.461

1.625 1.441 1.647 1.421 1.670 1.400 1.693 1.378 1.717 1.357 1.741 1.335 1.765 150 1.611 1.637

1.598 1.651 1.584 1.665 1.571 1.679 1.557 1.693 1.543 1.708 1.530 1.722 1.515 1.737 1.501 1.752

1.486 1.767 200 1.664 1.684 1.653 1.693 1.643 1.704 1.633 1.715 1.623 1.725 1.613 1.735 1.603

1.746 1.592 1.757 1.582 1.768 1.571 1.779 5 Durbin-Watson Significance Tables k'* =11 *k' is the number of regressors excluding the intercept k'=12 k'=13 k'=14 k'=15 k'=16 k'=17 k'=18 k'=19 k'=20 n dL dU dL dU dL dU dL dU dL dU dL dU dL dU dL dU dL dU dL dU 16 0.060 3.446 ----- ---

-- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- 17 0.084 3.286 0.053

3.506 ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- 18 0.113 3.146

0.075 3.358 0.047 3.557 ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- -- --- ----- 19 0.145 3.023 0.102 3.227 0.067 3.420 0.043 3.601 ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- 20 0.178 2.914 0.131 3.109 0.092 3.297 0.061 3.474 0.038 3.639 ----- ----- ----- ----- ----- ----- ----- ----

- ----- ----- 21 0.212 2.817 0.162 3.004 0.119 3.185 0.084 3.358 0.055 3.521 0.035 3.671 ----- ----- ---- ----- ----- ----- ----- ----- 22 0.246 2.729 0.194 2.909 0.148 3.084 0.109 3.252 0.077 3.412 0.050

3.562 0.032 3.700 ----- ----- ----- ----- ----- ----- 23 0.281 2.651 0.227 2.822 0.178 2.991 0.136 3.155

0.100 3.311 0.070 3.459 0.046 3.597 0.029 3.725 ----- ----- ----- ----- 24 0.315 2.580 0.260 2.744

0.209 2.906 0.165 3.065 0.125 3.218 0.092 3.363 0.065 3.501 0.043 3.629 0.027 3.747 ----- ----- 25

0.348 2.517 0.292 2.674 0.240 2.829 0.194 2.982 0.152 3.131 0.116 3.274 0.085 3.410 0.060 3.538

0.039 3.657 0.025 3.766 26 0.381 2.460 0.324 2.610 0.272 2.758 0.224 2.906 0.180 3.050 0.141 3.191

0.107 3.325 0.079 3.452 0.055 3.572 0.036 3.682 27 0.413 2.409 0.356 2.552 0.303 2.694 0.253 2.836

0.208 2.976 0.167 3.113 0.131 3.245 0.100 3.371 0.073 3.490 0.051 3.602 28 0.444 2.363 0.387 2.499

0.333 2.635 0.283 2.772 0.237 2.907 0.194 3.040 0.156 3.169 0.122 3.294 0.093 3.412 0.068 3.524 29

0.474 2.321 0.417 2.451 0.363 2.582 0.313 2.713 0.266 2.843 0.222 2.972 0.182 3.098 0.146 3.220

0.114 3.338 0.087 3.450 30 0.503 2.283 0.447 2.407 0.393 2.533 0.342 2.659 0.294 2.785 0.249 2.909

0.208 3.032 0.171 3.152 0.137 3.267 0.107 3.379 31 0.531 2.248 0.475 2.367 0.422 2.487 0.371 2.609

0.322 2.730 0.277 2.851 0.234 2.970 0.193 3.087 0.160 3.201 0.128 3.311 32 0.558 2.216 0.503 2.330

0.450 2.446 0.399 2.563 0.350 2.680 0.304 2.797 0.261 2.912 0.221 3.026 0.184 3.137 0.151 3.246 33

0.585 2.187 0.530 2.296 0.477 2.408 0.426 2.520 0.377 2.633 0.331 2.746 0.287 2.858 0.246 2.969

0.209 3.078 0.174 3.184 34 0.610 2.160 0.556 2.266 0.503 2.373 0.452 2.481 0.404 2.590 0.357 2.699

0.313 2.808 0.272 2.915 0.233 3.022 0.197 3.126 35 0.634 2.136 0.581 2.237 0.529 2.340 0.478 2.444

0.430 2.550 0.383 2.655 0.339 2.761 0.297 2.865 0.257 2.969 0.221 3.071 36 0.658 2.113 0.605 2.210

0.554 2.310 0.504 2.410 0.455 2.512 0.409 2.614 0.364 2.717 0.322 2.818 0.282 2.919 0.244 3.019 37

0.680 2.092 0.628 2.186 0.578 2.282 0.528 2.379 0.480 2.477 0.434 2.576 0.389 2.675 0.347 2.774

0.306 2.872 0.268 2.969 38 0.702 2.073 0.651 2.164 0.601 2.256 0.552 2.350 0.504 2.445 0.458 2.540

0.414 2.637 0.371 2.733 0.330 2.828 0.291 2.923 39 0.723 2.055 0.673 2.143 0.623 2.232 0.575 2.323

0.528 2.414 0.482 2.507 0.438 2.600 0.395 2.694 0.354 2.787 0.315 2.879 40 0.744 2.039 0.694 2.123

0.645 2.210 0.597 2.297 0.551 2.386 0.505 2.476 0.461 2.566 0.418 2.657 0.377 2.748 0.338 2.838 45

0.835 1.972 0.790 2.044 0.744 2.118 0.700 2.193 0.655 2.269 0.612 2.346 0.570 2.424 0.528 2.503

0.488 2.582 0.448 2.661 50 0.913 1.925 0.871 1.987 0.829 2.051 0.787 2.116 0.746 2.182 0.705 2.250

0.665 2.318 0.625 2.387 0.586 2.456 0.548 2.526 55 0.979 1.891 0.940 1.945 0.902 2.002 0.863 2.059

0.825 2.117 0.786 2.176 0.748 2.237 0.711 2.298 0.674 2.359 0.637 2.421 60 1.037 1.865 1.001 1.914

0.965 1.964 0.929 2.015 0.893 2.067 0.857 2.120 0.822 2.173 0.786 2.227 0.751 2.283 0.716 2.338 65

1.087 1.845 1.053 1.889 1.020 1.934 0.986 1.980 0.953 2.027 0.919 2.075 0.886 2.123 0.852 2.172

0.819 2.221 0.789 2.272 70 1.131 1.831 1.099 1.870 1.068 1.911 1.037 1.953 1.005 1.995 0.974 2.038

0.943 2.082 0.911 2.127 0.880 2.172 0.849 2.217 75 1.170 1.819 1.141 1.856 1.111 1.893 1.082 1.931

1.052 1.970 1.023 2.009 0.993 2.049 0.964 2.090 0.934 2.131 0.905 2.172 80 1.205 1.810 1.177 1.844

1.150 1.878 1.122 1.913 1.094 1.949 1.066 1.984 1.039 2.022 1.011 2.059 0.983 2.097 0.955 2.135 85

1.236 1.803 1.210 1.834 1.184 1.866 1.158 1.898 1.132 1.931 1.106 1.965 1.080 1.999 1.053 2.033

1.027 2.068 1.000 2.104 90 1.264 1.798 1.240 1.827 1.215 1.856 1.191 1.886 1.166 1.917 1.141 1.948

1.116 1.979 1.091 2.012 1.066 2.044 1.041 2.077 95 1.290 1.793 1.267 1.821 1.244 1.848 1.221 1.876

1.197 1.905 1.174 1.943 1.150 1.963 1.126 1.993 1.102 2.023 1.079 2.054 100 1.314 1.790 1.292

1.816 1.270 1.841 1.248 1.868 1.225 1.895 1.203 1.922 1.181 1.949 1.158 1.977 1.136 2.006 1.113

2.034 150 1.473 1.783 1.458 1.799 1.444 1.814 1.429 1.830 1.414 1.847 1.400 1.863 1.385 1.880

1.370 1.897 1.355 1.913 1.340 1.931 200 1.561 1.791 1.550 1.801 1.539 1.813 1.528 1.824 1.518 1.836 1.507 1.847 1.495 1.860 1.484 1.871 1.474 1.883 1.462 1.896

Appendix 6- Letter of Introduction

Letter of Introduction

Dear Resident,

I am currently a PhD student researching into the use and demand for energy in general and electricity in particular in Nigeria's residential sector. I will be knocking on your door with a request for you to complete a questionnaire survey. The feedback obtained will help me in analysing the demand for energy /electricity for the households.

This questions in the survey are to be answered by an adult (a person 18 years old or above). Your household has been randomly selected as part of this study. I will be grateful for providing me with the required information.

This survey should take approximately about 30 to 40 minutes of your time. The information provided shall be used solely for this research and your anonymity will be fully protected. All responses will be compiled and analysed as a group. The result will be available at a later date for you to view or sent to you if you wish.

Please leave this card outside your door if you are willing to take part in the survey.

I will be back on between ….am/pm and ….am/pm. If you have any questions or concerns, please contact Remi Kayode on 0702 314569 to discuss them.

Thank you.

Appendix 7: Written consent form

Title of Study: A critical analysis of household energy consumption in Ibadan metropolis of Nigeria

Name of Participant:

Please tick to consent.

- I have read the attached information sheet on the research in which I have been asked and agree to participate and have been given a copy to keep. I have had the opportunity to discuss the details and ask questions about this information ☐
- The Researcher has explained the nature and purpose of the research and I believe that I understand what is being proposed ☐
- I understand that my personal involvement and my particular data from this study will remain strictly confidential. Only researchers involved in the study will have access ☐
- I have been informed about what the data collected will be used for, to whom it may be disclosed, and how long it will be retained ☐
- I have received satisfactory answers to all of my questions ☐
- I hereby fully and freely consent to participate in the study which has been fully explained to me ☐
- I understand that I am free to withdraw from the study at any time, without giving a reason ☐
- I consent to have the have the interview audio recorded using a digital recorder and transcribed ☐

- I consent to having anonymised direct quotations from the interviews used in publications

☐

Participant's Name:(Block Capitals) ………………………..

Participant's Name: Signature ………………………..

Participant's Witness' Name: ………………………..

Witness' Signature: ………………………..

As the Researcher responsible for this study I confirm that I have explained to the participant named above the nature and purpose of the research to be undertaken.

Researcher's Name: Oluremi Kayode

Researcher's Signature

IF YOU ARE AT ALL CONCERNED ABOUT THIS RESEARCH STUDY YOU ARE RECEIVING PLEASE CONTACT:
Dr Mahtab Farshchi

Tel. No 0207 815 7597 or email m.farshchi@lsbu.ac.uk

If you wish to speak to someone not directly related to the research, please contact the Chair, London South Bank University Research Ethics Committee (ethics@lsbu.ac.uk).

Appendix 8: Participant information sheet

Topic: A critical analysis of household energy consumption in Ibadan metropolis of Nigeria

You are being invited to take part in a study which is being completed as part of a PhD at London South Bank University by Oluremi Kayode. The survey process has been reviewed and ethically approved by the London South Bank University's Research Ethics Committee. The aim of this study is to investigate the relationship between different factors affecting the energy demand by households in Nigeria and to develop a conceptual framework to analyse and estimate energy consumption by household types.

You have been chosen to be invited to participate in this study as you live in an urban area. In total, up to 600 people will be included in the study. It is up to you to decide whether or not to take part. If you do, you will be given this information sheet to keep and be asked to sign a consent form. You are still free to withdraw anytime up to the submission of the dissertation and without giving a reason. A decision to withdraw, or a decision not to take part, will not affect the programme of study. You are free to withdraw from the study any time up to the time of completion of the dissertation and I will not include your information in my database. However, after that time, it would be impossible for the researcher to comply.

Before you decide to participate in this survey it is important for you to understand why the research is being carried out and what it will involve. Please take time to read the following information carefully. Talk to others about the study if you wish. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

If you are willing to participate, the researcher / interviewer will come to your house with a friend or colleague (both will have at least a form of ID). You will be invited for an interview lasting approximately 40 minutes at a mutually agreeable time during the day. During the interview, you will be asked questions and for the ease of analysis, record the conversation with your permission as well as take notes. If you do not wish to be recorded but are still willing to participate, the researcher will take notes only.

It is not anticipated that you will be at any disadvantage or suffer any risk form this study.

It is also unlikely that you will gain any personal benefit from participating in this research. However, the information you share with the researcher may help the government in putting appropriate policies in place and that will be of benefit to you and your community.

I will not collect any personal information about you and all information received from you will be handled in a strictly confidential manner and stored in a locked filing cabinet and on a password protected computer in an environment locked when not occupied. Only the researcher and supervisor will have direct access to the information. If there are any references by which you can be identified those will be coded. This information (i.e. any personal information) will be held until July 2015 and any data will be deleted by July 2020.
If you have a concern about any aspect of this study, you should ask to speak with the researcher Ms. Oluremi Kayode on Mobile number 0804401518 who will do her best to answer your questions. If you wish any further information regarding this study or have any complaints about the way you have been dealt with during the study or other concerns you can contact: Dr Mahtab Farshchi the Academic Supervisor for this study on (+44) 207 8157597.
Finally, if you remain unhappy and wish to complain formally, you can contact the Chair of the University Research Ethics Committee. Details can be obtained from the university website: https://my.lsbu.ac.uk/page/research-degrees-ethics. Thank you for your time and look forward to meeting you should you accept to go ahead with this survey.

Ms. Oluremi Kayode

PhD candidate

London South Bank University

Appendix 9- Questionnaire

For Office use only:

RK_HED-001IBNB01

A STUDY OF HOUSEHOLD ENERGY DEMAND IN NIGERIA

This questionnaire has four sections. Section A consists of questions relating to the composition of your household. Section B includes questions about your status and ownership of appliances. This is followed by questions in Section C which aim to identify the types of energy that you currently use in your household and also aims to identify the activities that these are used for. Section D aims to explore your consumption of electricity and the efficiency of your appliances.

YOU AND OTHER PEOPLE IN THE HOUSEHOLD

☐ M ☐ F | **Head of household** ☐ Yes ☐ No

Are you in charge of making decisions on the use of energy? ☐ Yes ☐ No

Marital status

☐ Single ☐ Partnered ☐ Married ☐ Separated ☐ Divorced ☐ Widowed ☐ Don't want to disclose

Age : ☐ 18-25 ☐ 26-35 ☐ 36-45 ☐ 46-55 ☐ 56-65 ☐ >66

Education	☐ PhD	☐ MSc	☐ Secondary education
	☐ BSc	☐ Primary education	☐ No Formal education
		☐ Other *(please specify)*	

For question below, please tick as many as are applicable to you

Employment	☐ Civil Servant	☐ Formally employed	☐ Informally employed
	☐ Self employed	☐ Other *(please specify)*	

Do you live with other people? ☐ Yes ☐ No

How many people live in this household? Male ___ Female ___ (Adults) Children (up to 18 years) ___

How are th related to you	☐ Spouse	☐ Parent	☐ Friend
	☐ Brother	☐ Sister	☐ Co-tenant
	☐ Other *(please specify)*		☐ Don't want to disclose

How many people in your household (including you) are *(Tick those relevant and include numbers)*

☐ Civil Servant ___	☐ Formally employed ___	☐ Informally employ

		___
☐ Self employed ___	☐ Unemployed ___	☐ Other *(please specify)* ___
What is your household's average monthly income (in Naira)? *(Tick one relevant box)*		
☐ < 18,000	☐ 18,001- 29,999	☐30,000- 49,999
☐ 50,000- 99,999	☐ 100,000- 149,999	☐ > 150,000

What is your household's average monthly expenditure (in Naira)? *(Tick one relevant box)*			
☐ < 15,000	☐ 15,001 - 29,999	☐ 30,000 - 44,999	☐ > 45,000

Referring you to last month, what proportion of your household income (per cent) was spent on		
☐ Clothing ___	☐ Housing / Rent ___	☐ Food ___
☐ Energy ___		☐ Other *(please specify)* ___
What proportion (per cent) of energy was spent on		
☐ Coal ___	☐ Diesel for generator ___	☐ Electricity ___
☐ Firewood ___	☐ Fuelwood ___	☐ Gas ___
☐ Kerosene ___	☐ Other *(please specify)* ___	

What is the average monthly amount (in Naira) that you spend on			
Electricity	☐ < 2000	☐ 2000 - 5000	☐ > 5000
Kerosene	☐ < 2000	☐ 2000 - 5000	☐ > 5000
Gas	☐ < 2000	☐ 2000 - 5000	☐ > 5000

YOUR PROPERTY

Do you live in a	☐ Bungalow	☐ Duplex	☐ Flat

Which of the following sentences explain the way you live		
☐ I own my property	☐ I rent my property	☐ Other *(please explain)*

How many bedrooms are in your property					
☐ One	☐ Two	☐ Three	☐ Four	☐ Five	☐ Six and more

When you moved to this property, did you move to a bigger or smaller property?	
☐ Yes, I moved to a bigger property	☐ No, I moved to a smaller property
When did you move?	

☐ In the last 6 months	☐ 12 months	☐ 18 months	☐ 24 months
☐ 36 months	☐ 48 months	☐ > 48 months	☐ None of the above
Reason for move	☐ New job		☐ Promotion

(Tick as many as relevant)	☐ Proximity to work	☐ Proximity to town/city
	☐ Increase in number of family members	☐ Decrease in number of family members
	☐ Loss of job	☐ Other *(please specify)*

Are you likely to move home in the next

☐ 6 months	☐ 12 months	☐ 18 months	☐ 24 months
☐ 36 months	☐ 48 months	☐ Not likely to move in this period	

If you are likely to move, please give your reasons. *(Please tick as many as are relevant)*

☐ New job	☐ Promotion	☐ Proximity to work
☐ Proximity to town/city	☐ Completion of personal property	☐ Loss of job
☐ Increase in number of family members	☐ Decrease in number of family members	☐ Other *(please specify)*

How many of the following do you have in your household that is still functioning. (*Please indicate numbers)*

Item	*Number functioning*	*Item*	*Number functioning*	*Item*	*Number functioning*
☐ Car	___	☐ Motorcycle	___	☐ Kerosene stove	___
☐ Gas cooker	___	☐ Electric cooker	___	☐ Generating set	___
				☐ Other *(please specify)*	___

YOUR HOUSEHOLD ENERGY CONSUMPTION /USAGE

Which of the fuel types do you mostly use in your daily activities in your residence?

(*Please circle when:1=Most used and 5 = Least used)*

Fuel type	*Level of importance*	*Fuel type*	*Level of importance*	*Fuel type*	*Level of importance*
Coal	1 2 3 4 5	Diesel	1 2 3 4 5	Electricity	1 2 3 4 5
Firewood	1 2 3 4 5	Fuelwood	1 2 3 4 5	Gas	1 2 3 4 5

Kerosene	1 2 3 4 5	Other *(please specify)*	1 2 3 4 5

Which of these factors do you consider important in choosing a type of fuel?
(*Please circle when 1= Very important and 5 = Least important)*

Factor	*Level of importance*	*Factor*	*Level of importance*	*Factor*	*Level of importance*
Availability	1 2 3 4 5	Convenience	1 2 3 4 5	Cost	1 2 3 4 5
Efficiency	1 2 3 4 5	Other *(please specify)*			1 2 3 4 5

What is your average monthly usage/consumption of the following

Electricity (in Watts)	☐ 0 - 200	☐ 200 – 500	☐ more than 500
Gas cylinder(in cubic meter)	☐ 0 - 5	☐ 5 – 12	☐ more than 12
Kerosene (in litres)	☐ 0 - 4	☐ 4 – 8	☐ more than 8
Diesel (in litres)	☐ 0 - 4	☐ 4 – 8	☐ more than 8

What factors would motivate you to switch between your choices of energy types?
(*Please rank when 1=Highest motivation and 5 =Lowest motivation*

Availability ___	Convenience ___	Cost ___
Efficiency ___	Marketing ___	Other *(please specify) and give the degree of importance* ___

YOUR HOUSEHOLD’S ELECTRICITY CONSUMPTION AND ENERGY EFFICIENCY

Do you have any electricity meter in your household? ☐ Yes ☐ No. If yes, is it

☐ Prepaid	☐ Analogue	☐ Other *(please specify)*

What other alternative source of electricity do you use?

☐ Generator	☐ Inverter	☐ Other *(please specify)*

Which of the following appliances do you own and how many?

Kitchen Appliances

Appliance/ Item	**Quantity**	**Good condition**	**Appliance/ Item**	**Quantity**	**Go od condition**

☐ Dish washer	___	Y / N	☐ Electric cooker	___	Y / N
☐ Electric kettle	___	Y / N	☐ Electric water boiler	___	Y / N
☐ F mixer/processor	___	Y / N	☐ Microwave oven	___	Y / N
☐ Refrigerator/ freezer	___	Y / N	☐ Toaster	___	Y / N

			☐ Other *(please specify)*	___ / N	Y
Comfort and Leisure					
☐ Air-conditioner	___	Y / N	☐ CD player	___	Y / N
☐ Clothes dryer	___	Y / N	☐ Computer/ Laptop	___	Y / N
☐ Electric pressing iron	___	Y / N	☐ Fan	___	Y / N
☐ Halogen lamps			☐ Mobile phone charges		
☐ Radio	___	Y / N	☐ Rechargeable lamps	___	Y / N
☐ Television	___		☐ Water heater		
☐ Water pumping machine	___	Y / N	☐ Washing machine	___	Y / N
			☐ Other *(please specify)*	___	Y / N

Other Gadgets					
☐ Electric shaver	___	Y / N	☐ Electric shower	___	Y / N
☐ Hand hair dryer	___	Y / N	☐ Hair straighteners	___	Y / N
			☐ Other *(please specify)*	___	Y / N

How many of these bulbs do you use in your home?

☐ 100 watts bulbs) ___ ☐ 60watts bulbs ___ ☐ Low energy bulbs ___

For the appliances that is still in working condition, please state how many times you use each in the week and how long for

Appliance/ Item	**Frequency of use in a week**	**Average length of use each time**

	1-3 times	4-6 times	More 6 than times	Less than 30 minutes	31-60 minutes	1-2 hours	3-4 hours	More than 4 hours
Kitchen Appliances								
Dish washer								
Electric cooker								
Electric kettle								
Electric water boiler								
Food mixer/processor								
Microwave oven								
Refrigerator/ freezer								

Toaster								
Other *(please specify)*								
Comfort & Leisure								
Air-conditioner								
CD player								
Clothes dryer								
Computer/Laptop								
Electric pressing iron								
Fan								
Halogen lamps								
Radio								
Rechargeable lamps								
Television								
Water heater								
Washing machine								
Other *(please specify)*								
Other gadgets								
Electric shaver								
Hand dryer								

Electric shower								
Hair straighteners								
Other *(please specify)*								

Are you likely to buy any of the listed appliances/items in the next									
	6-12 months	*1-2 years*	*2-3 years*	*3-4 years*		*6-12 months*	*1-2 years*	*2-3 years*	*3-4 years*
Kitchen Appliances									
☐ Dish washer					☐ Electric cooker				
☐ Electric kettle					☐ Electric water boiler				
☐ Food mixer / processor					☐ Microwave oven				
☐ Refrigerator/ freezer					☐ Toaster				
					☐ Other *(please specify)*				
Comfort and Leisure									
☐ Air-conditioner					☐ CD player				
☐ Clothes dryer					☐ Computer/ Laptop				
☐ Electric pressing iron					☐ Fan				
☐ Halogen lamps					☐ Radio				
☐ Rechargeable lamps					☐ Television				
☐ Washing heater					☐ Washing machine				
					☐ Other *(please specify)*				
Other Gadgets									
☐ Electric shaver					☐ Electric shower				
☐ Hand hair dryer					☐ Hair straighteners				
					☐ Other *(please specify)*				

If you were to buy a new appliance, would you consider its energy efficiency? ☐ Yes ☐ No				
How efficient are your cooking and lighting activities when using the following *(Please circle when 1= Highly and 5= Not efficient)*				
Activity	**Energy Type Efficiency**			
	Electricity	Gas	Kerosene	Other
Cooking	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Lighting	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Has your use of electricity increased or decreased over the last 5 years? ☐ Yes ☐ No				
Please give your reasons for this change.				

Thank you for completing this questionnaire. Please hand it to the interviewer or email it to
Oluthree@yahoo.co.uk

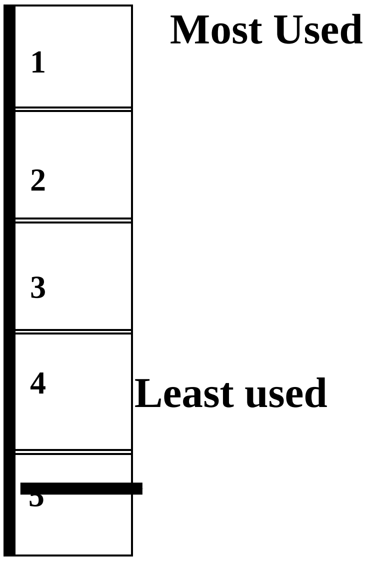
Appendix 10 – Checklist and Interviewer's guide

Checklist for carrying out the survey

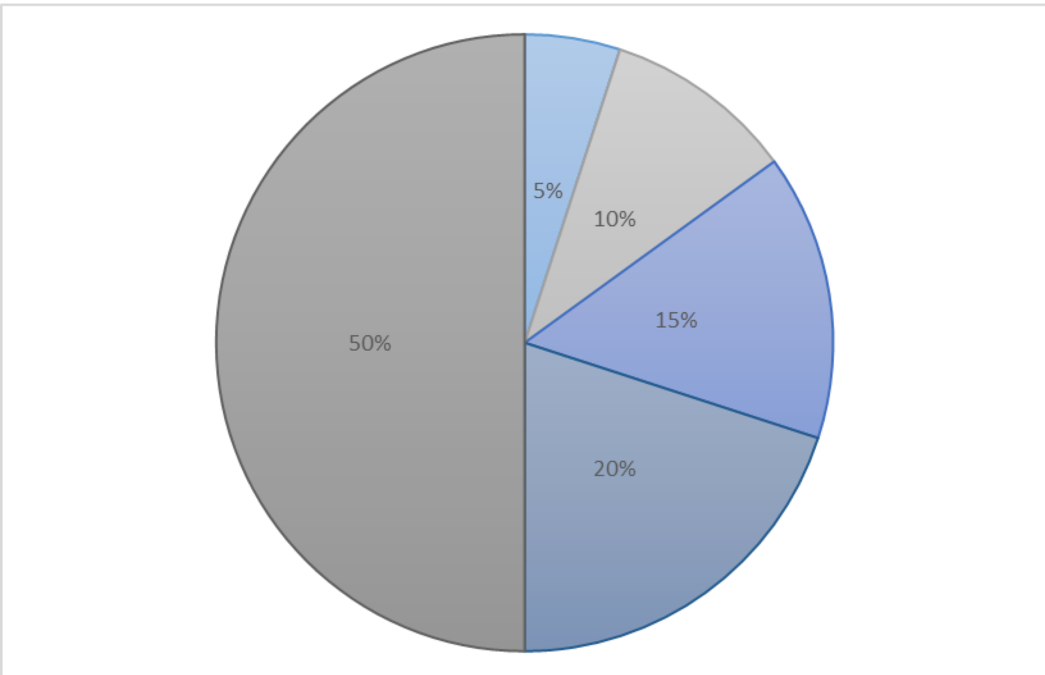
The interviewer must ensure that the following is done in carrying out the survey-

- Solicit the interviewee for information courteously.
- To take along form of identification
- Read the "Letter of Informed Consent" to each interviewee and only interview those that accept to be interviewed.
- Fill out the entire questionnaire.
- Complete the demographic and sample information required on the form.
- After the interview, the interviewer must check each questionnaire and ensure that all of the questions were asked and that all of the solicited data has been recorded
- Give sufficient time to complete the survey at the time chosen by the interviewees
- Complete the identification information of the questionnaire: local government, area – urban or rural, date of the interview, start time, etc.
- For questions relating to proportions or requiring a percentage (per cent), the interviewee can be shown an appropriate pie chart or line measure for Likert questions to help with identifying their answers.

Survey Response card



Pie Chart



- Paper questionnaires should always be filled out with clear, legible, and unabbreviated handwriting

- The interviewer should count each page of every form to ensure that none are missing.

- Answers given by participants must not be disclosed or shared with other people as all information provided by respondents is confidential.
- Documents are checked as soon as they are completed to ensure that all necessary questions are completed.

Appendix 11 Ordinal Regression models

Model 1				Model 2			Model 3		
Electricity									
		Estimate	Significance		Estimate	Significance			
Independent variables	Total appliances	0.019	0.210	Total number of applianc	0.018	0.234	Expenditure on electricity	0.500	0.002
	Ownership status	-0.503	0.018	Ownership status	-0.397	0.058	Ownership of property	-0.412	
	Expenditure of energy	-0.602	0.063	Location of property	-0.437	0.044	Location of property	-0.433	0.054
	Location of property	-0.398	0.018						
Control variables	Age	18.110	0.000	Age	0.082	0.352	Age	17.600	0.000
	Education	-0.858	0.033	Education	0.397	-0.808	Education	0.949	0.015
Model fitting information	Chi square	669.835 (32.939)	0.003	Chi Square	652.181(32.819)	0.000		376.648(35.399)	0.000
								222.772	0.140
Test of Parallel lines		652.157 (17.678)	0.222		644.144(8.037)	0.430		366.760(9.888)	0.540
GAS									
Independent variables	Total appliances						Location	0.245	0.433
	Ownership status			Ownership status	-0.164	0.666	Ownership status	-0.261	0.779
	Expenditure of gas	0.000007079	0.093	Expenditure ofgas	-1.898	0.003	Expenditure on gas	0.766	0.001
	Location of property	-0.577	0.002	Functioning gas applianc	0.070	0.860			
Control variables	Age	17.359	0.000	Age					
	Education	0.133	0.661	Education	0.613	0.444	Age	-1.141	-0.572
	Sex of head of household	0.121	0.507	Sex of head of household	0.322	0.407	Education	-0.635	0.271
Model fitting information		849.678(27.070)	0.012					206.893(20.195)	0.043
Goodness of fit(Pearson)		738.013	0.421					122.515	
Test of Parallel lines		821.426(28.252)	0.008					201.602(5.291)	0.916
Kerosene									
	Model 1								
Independent variables	Number of kerosene stove	0.556	0.005	Household size	0.035	-0.55	Household size	0.019	0.694
	Location of property	0.008	0.973	lnexp of kerosene	-0.827	0.02	Average expenditure	0.004	0.508
	Ownership status	0.674	0.458	lnFunKerostove	0.727	0.052	lnFunKerostove	0.877	0.006
				Location	0.230	-0.373	Marital status	-0.157	0.582
				Ownership status	0.258	-0.373	Ownership status	0.136	0.584
Control variables	Education	0.153	0.095	Age	-1.476	0.018	Age	17.29	0.000
	Age	17.414	0.000	Education	-0.805	0.179	Education	-0.631	0.165
Model fitting information		399.625(22.107)	0.077		358.120(19.56)	0.076		489.644(22.001)	0.055
Goodness of fit(Pearson)		295.371	0.138		328.578	0.249		449.478	0.282
Test of Parallel lines					340.365(17.55)	0.123		471.295(18.349)	0.145

Appendix 12 – Cross tabulation of various factors of electricity consumption

Average monthly electricity consumption vs Gender

			Gender		Total
			male	female	
Average monthly electricity consumption	Low	Count	94	66	160
		% of Total	29.7%	20.8%	50.5%
	Medium	Count	64	42	106
		% of Total	20.2%	13.2%	33.4%
	High	Count	29	22	51
		% of Total	9.1%	6.9%	16.1%
Total		Count	187	130	317
		% of Total	59.0%	41.0%	100.0%

Age vs Average amount spent on electricity

			Average monthly amount spent on electricity			Total
			Low	Medium	High	
Age	18-25	Count	48	36	18	102
		% of Total	9.6%	7.2%	3.6%	20.4%
	26-35	Count	79	70	21	170
		% of Total	15.8%	14.0%	4.2%	33.9%
	36-45	Count	50	45	20	115
		% of Total	10.0%	9.0%	4.0%	23.0%
	46-55	Count	31	34	10	75
		% of Total	6.2%	6.8%	2.0%	15.0%
	56-65	Count	20	15	4	39
		% of Total	4.0%	3.0%	.8%	7.8%
Total		Count	228	200	73	501
		% of Total	45.5%	39.9%	14.6%	100.0%

Age vs Income Category

			Income cat			Total
			Low income	Middle income	High income	
Age	18-25	Count	46	22	12	80
		% of Total	11.3%	5.4%	2.9%	19.7%
	26-35	Count	48	60	23	131
		% of Total	11.8%	14.7%	5.7%	32.2%
	36-45	Count	21	52	26	99
		% of Total	5.2%	12.8%	6.4%	24.3%
	46-55	Count	15	31	19	65
		% of Total	3.7%	7.6%	4.7%	16.0%
	56-65	Count	9	15	8	32
		% of Total	2.2%	3.7%	2.0%	7.9%
Total		Count	139	180	88	407
		% of Total	34.2%	44.2%	21.6%	100.0%

Education level vs Income category

			Income cat			Total
			Low income	Middle income	High income	
Education level	Tertiary level	Count	100	135	63	298
		% of Total	24.6%	33.2%	15.5%	73.2%
	Secondary level	Count	24	26	15	65
		% of Total	5.9%	6.4%	3.7%	16.0%
	Primary level	Count	0	4	2	6
		% of Total	0.0%	1.0%	.5%	1.5%
	Non formal	Count	15	15	8	38
		% of Total	3.7%	3.7%	2.0%	9.3%
Total		Count	139	180	88	407
		% of Total	34.2%	44.2%	21.6%	100.0%

Average monthly electricity consumption vs Age

			Age					Total
			18-25	26-35	36-45	46-55	56-65	
Average monthly electricity consumption	Low	Count	30	52	41	25	12	160
		% of Total	9.5%	16.4%	12.9%	7.9%	3.8%	50.5%
	Medium	Count	23	45	17	11	10	106
		% of Total	7.3%	14.2%	5.4%	3.5%	3.2%	33.4%
	High	Count	9	13	15	11	3	51
		% of Total	2.8%	4.1%	4.7%	3.5%	.9%	16.1%
Total		Count	62	110	73	47	25	317
		% of Total	19.6%	34.7%	23.0%	14.8%	7.9%	100.0%

Ownership status of property vs Average monthly electricity consumption

			Average monthly electricity consumption			Total
			Low	Medium	High	
Ownership status of property	I own my property	Count	59	57	36	152
		% of Total	18.6%	18.0%	11.4%	47.9%
	I rent my property	Count	101	49	15	165
		% of Total	31.9%	15.5%	4.7%	52.1%
Total		Count	160	106	51	317
		% of Total	50.5%	33.4%	16.1%	100.0%

Income vs Gender category

			Sex		Total
			Male	Female	
Income_category	Low income	Count	82	59	141
		% of Total	21.3%	15.3%	36.6%
	Medium income	Count	86	74	160
		% of Total	22.3%	19.2%	41.6%
	High income	Count	44	40	84
		% of Total	11.4%	10.4%	21.8%
Total		Count	212	173	385
		% of Total	55.1%	44.9%	100.0%

Local Government Area vs type of property

			Type of property			Total
			Bungalow	Duplex	Flat	
Local Government Area	Ibadan North West	Count	22	20	60	102
		% within Type of property	21.4%	26.3%	21.7%	22.4%
	Akinyele	Count	14	14	46	74
		% within Type of property	13.6%	18.4%	16.6%	16.2%
	Ido	Count	26	15	47	88
		% within Type of property	25.2%	19.7%	17.0%	19.3%
	Ibadan North	Count	17	15	65	97
		% within Type of property	16.5%	19.7%	23.5%	21.3%
	Ibadan South East	Count	24	12	59	95
		% within Type of property	23.3%	15.8%	21.3%	20.8%
Total		Count	103	76	277	456
		% within Type of property	100.0%	100.0%	100.0%	100.0%

Percentage of income spent on each fuel

% of Income spent	Kerosene	Electricity	Gas	Total
5%	32	44	29	115
10%	3	47	29	79
15%	16	17	14	47
20%	42	51	35	128
25%	27	32	25	84

Household's average income vs Average monthly amount spent on electricity

			What is the average monthly amount that you spend on electricity			Total
			<2000	2000-5000	>5000	
What is your household's average monthly income?	< than 18000	Count	53	15	3	71
		% of Total	16.6%	4.7%	.9%	22.2%
	18001-29999	Count	24	15	6	45
		% of Total	7.5%	4.7%	1.9%	14.1%
	30000-49999	Count	28	22	4	54
		% of Total	8.8%	6.9%	1.3%	16.9%
	50000-99999	Count	30	38	9	77
		% of Total	9.4%	11.9%	2.8%	24.1%
	100000-149999	Count	12	26	4	42
		% of Total	3.8%	8.1%	1.3%	13.1%
	>150000	Count	9	16	6	31
		% of Total	2.8%	5.0%	1.9%	9.7%
Total		Count	156	132	32	320
		% of Total	48.8%	41.3%	10.0%	100.0%