AN ANALYSIS OF HOUSEHOLD ENERGY CHOICE AND CONSUMPTION IN BAUCHI STATE, NIGERIA

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BY

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ABSTRACT

The main choice of energy sources remains one of the most important aspects of households' living. This study was conducted with the main aim of assessing the factors that influence household energy choice and consumption in Bauchi State, Nigeria. To achieve these objectives, samples were selected using cluster area sampling technique, whereby a total number of 539 respondents were utilised. The multinomial logit model (MNLM) result has shown that higher incomes, higher education levels, location in the urban areas and living in self – owned homes; have positive impacts on the probability of adopting cleaner sources of cooking fuel. Additionally, the estimated MNLM for the lighting fuel choice indicates that the age of the household head, the income level, location in the urban areas, the number of rooms and the availability of electricity; have positive impacts on the probability of using electricity. Furthermore, the estimated Ordinary Least Square (OLS) model indicates that gender and the number of rooms have positive impacts on firewood consumption, while the level of education and the firewood price have negative impacts on the quantity of firewood consumption. Moreover, the Tobit estimate indicates that age, income and firewood price; have positive impacts on the use of kerosene. Contrarily, kerosene price has a negative impact on the intensity of kerosene use. In addition, the OLS estimate for electricity expenditure indicates that location in the urban areas and the number of electricity devices at home; have positive impacts on the expenditure on electricity. Finally, the estimated Verme models for testing the relative income hypothesis indicate that the theory is relevant in explaining households' energy choice and consumption. Therefore, a sound policy that will introduce some households with modern source of energy will have strong and wide impact on more households that will move towards the use of modern energy sources through the relative influence. Additionally, raising incomes and campaign awareness will help to improve the situation. Lastly, a study that will analyse household energy choice and consumption over time is recommended.

Keywords: household, energy, choice, cooking fuel, lighting fuel

ABSTRAK

Pilihan sumber tenaga telah menjadi salah satu aspek yang paling penting dalam kehidupan isi rumah. Kajian ini dijalankan untuk menilai faktor-faktor yang mempengaruhi pilihan sumber tenaga oleh isi rumah dan penggunaannya di Bauchi, Nigeria. Untuk mencapai objektif ini, satu sampel telah dipilih dengan menggunakan teknik persampelan berkelompok iaitu seramai 539 responden. Hasil model logit multinomial (MNLM) telah menunjukkan bahawa pendapatan yang lebih tinggi, tahap pendidikan yang lebih tinggi, lokasi bandar, dan tinggal di rumah milik sendiri; mempunyai kesan positif ke atas kebarangkalian menggunakan sumber bahan api untuk memasak yang lebih bersih. Selain itu, pilihan bahan api untuk lampu menunjukkan bahawa usia ketua isi rumah, tahap pendapatan, lokasi di bandar, bilangan bilik dan ketersediaan elektrik; mempunyai kesan positif ke atas kebarangkalian penggunaan elektrik. Tambahan pula, anggaran model Kaedah Kuasa Dua Terkecil (OLS) menunjukkan bahawa jantina dan bilangan bilik mempunyai kesan positif terhadap penggunaan kayu api, manakala tahap pendidikan dan harga kayu api didapati mempunyai kesan negatif keatas kuantiti penggunaan kayu api. Selain itu, anggaran model Tobit menunjukkan bahawa umur, pendapatan dan harga kayu api; mempunyai kesan positif ke atas penggunaan minyak tanah. Sebaliknya, harga minyak tanah mempunyai kesan negatif kepada penggunaan minyak tanah. Di samping itu, anggaran OLS bagi perbelanjaan elektrik menunjukkan bahawa lokasi bandar dan bilangan peranti elektrik di rumah mempunyai kesan positif ke atas perbelanjaan elektrik. Akhir sekali, anggaran model Verme yang menguji hipotesis pendapatan relatif menunjukkan bahawa teori ini relevan dalam menjelaskan pilihan tenaga dan penggunaan isi rumah. Kajian ini mencadangkan agar pengenalan penggunaan sumber tenaga moden kepada isi rumah yang terpilih. Keadaan ini seterusnya akan nempengaruhi isi rumah lain untuk menggunakan sumber tenaga moden ini. Tambahan lagi, peningkatan pendapatan serta kempen kesedaran akan memperbaiki keadaan yang sedia ada. Akhir sekali, kajian ini ingin mencadangkan analisis pilihan sumber tenaga isi rumah dan penggunaanya mengikut peredaran masa.

Kata kunci: isirumah; tenaga; pilihan; bahan api memasak; bahan api lampu

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LIST OF ABBREVIATIONS

Abbreviation	Full Meaning
BASEEDS	Bauchi State Economic Empowerment and Development strategy
CIA	Central Intelligence Agency
ECN	Energy Commission of Nigeria
EEC	Energy Efficiency Centre
EIA	Energy Information Administration
GDP	Gross Domestic Product
HDI	Human Development Index
IEA	International Energy Agency
IIA	Independence of Irrelevant Alternatives
LGAs	Local Government Areas
LPG	Liquefied Petroleum Gas
MDGs	Millennium Development Goals
MNLM	Multinomial Logit Model
NBS	National Bureau of Statistics
OECD	Organisation for Economic Cooperation and Development
OLS	Ordinary Least Squares
RIH	Relative Income Hypothesis
SORS	Statistical Office of the Republic of Slovenia
UNDP	United Nations Development Programme
UNFPA	United Nations Population Fund
VIF	Variance Inflation Factor

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Energy is one of the most important aspects of human life. It is a commodity that is vital for the existence of modern life. In fact, the nature and extent of energy demand and utilization in a national economy are, to a large extent, indicators of its level of economic development (Energy Commission of Nigeria (ECN), 2003). This is because in every economy, all sectors ranging from residential, manufacturing, agriculture, transport as well as services sectors depend to a large extent on various energy sources to function.

However, despite that the importance of different end uses for energy varies significantly from country to country because of differences in climatic conditions, policies, level of economic development and other factors, it is generally agreed that the household sector is one of the most important energy consumption sector (Wang, Zhang, Yin, & Zhang, 2011). It has the highest rate of energy consumption in most countries (Oyedepo, 2013). For instance, energy consumption of the residential sector accounts for about approximately 30% of the total world energy consumption (Swan & Ugursal, 2008). Table 1.1 indicates the share of household energy consumption (in relation to other sectors) nationally for some selected countries in the world.

Table1.1
Proportion of Residential Energy Consumption for Some Selected Countries

Country	**Percentage of Energy Consumption by Residential Sector (%)**
Saudi Arabia	50
Malaysia	19
Japan	22
Jordan	29
Turkey	37
Italy	17
Norway	21
Sweden	19
Europe	26
Brasil	26
Mexico	23
USA	25
Canada	24
Nigeria	65
World	31

Source: Oyedepo (2013) and Palazzo (2014)

Table 1.1 shows that in Nigeria, residential sector energy consumption far outweighs other sectors by taking about 65% of the country's total energy consumption. In Saudi Arabia, the residential energy consumption is 50% of the total fuel use in the country. Moreover, Italy has the minimum proportion of the residential energy consumption, the household energy consumption accounted about only 17% of the total energy consumption in the country. In fact, the total residential energy accounted 31% of the total world's energy consumption. This indicates that household sector plays a vital role in terms of energy utilisation in many countries of the world.

Similarly, as obtainable in most countries, also specifically in Nigeria, the household sector is the major role player in terms of domestic energy consumption. When Nigerian economy is disaggregated into industry, transport, commercial, household and agricultural sectors, the household sector has the highest rate of energy consumption followed by transportation sector, industry, services and then agriculture as shown in Figure 1.1

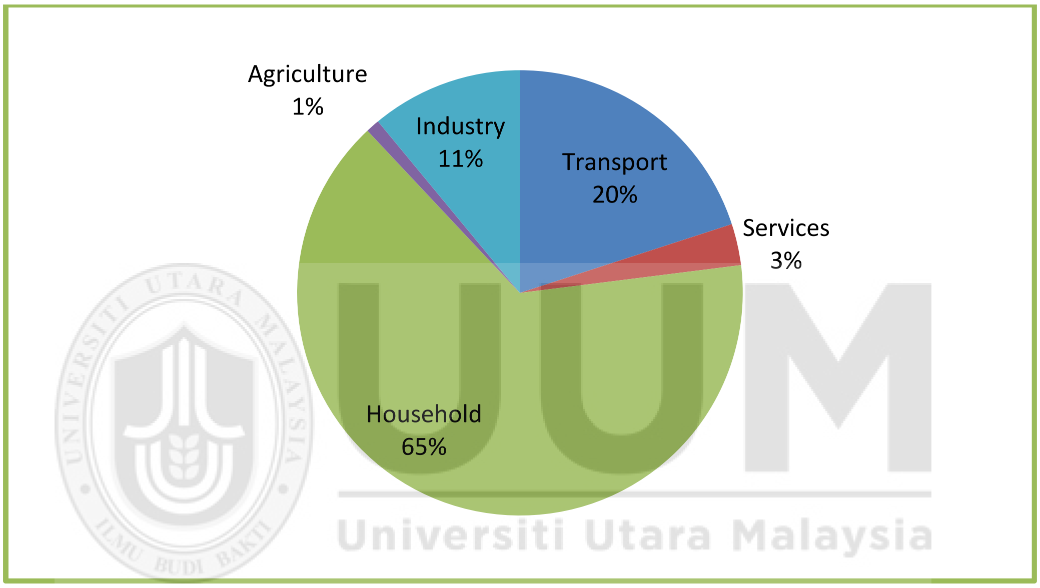

Figure 1.1
Nigerian Sectoral Categorisation of Energy Use
Source: Oyedepo (2013).

This implies that energy sources remain one of the most important aspects of today's households' living. However, households mostly demand energy not for direct consumption, but for the purpose of consuming other goods and services. Such as the consumption of the goods and services that constitute the total welfare of a household, like; food items, hot or cool soft drinks. Additionally, for the use of home facilities like; air conditioner, fan, electric lamp, television, water pump, satellites and room warmer.

However, despite the above situation, the understanding of household energy use patterns is very limited especially in the context of some regions of the developing world (Kowasari & Zerriffi, 2011). Therefore, there is a need for empirical analyses of households' energy use and consumption so as to come up with up to date information on households' energy use. This will contribute to the improvement in the household energy consumption and will raise the living standard of the households. As Reddy (2004) argued that a direct improvement in energy services would allow the poor to enjoy advances in living standard.

1.2 Household Energy Use in Bauchi State

It is argued that about more than two and a half billion people world over depend majorly on the traditional biomass fuel as their source of energy for cooking, heating and lighting; mainly in developing countries (Kowasari & Zerriffi, 2011). For instance, Onoja (2012) argued that evidences from China have shown that there are considerable number of households (in some regions, majority e.g. Wolong region) that are stick to traditional biomass fuel use despite their access to electricity. Likewise in Africa, solid biofuels is reported to account for about 50% of Africa's energy needs (International Energy Agency (IEA), 2011).

Additionally, in the case of Nigeria, despite that the country is blessed with abundant primary energy resources, majority of household energy source in Nigeria comes from fuel-wood especially for cooking purposes. Such wider use of traditional solid fuels affects the environment negatively causing higher rate of deforestation, soil erosion air pollution among others. For instance the trend of deforestation in Nigeria is reported to be about 300,000 hectares per year (Darlin, Hoyt, Murao & Ross, 2008). This is equivalent to about 3.5% of the current area of forests and woodlands, whereby the reforestation is only about 10% of the deforestation rate. According to ECN (2003) the Nigerian 15 million hectares of forest and woodland reserves could be depleted within the next 50 years. This implies the need for government intervention to tackle the situation.

The household energy consumption pattern in Bauchi State can be categorised into three major dimensions; cooking, lighting and cooling purposes. For satisfying the needs of cooking, the various sources available include; fuel-wood, kerosene, gas and electricity, plus elements of plant residues and animal dung which are used in some parts of the rural areas of the state. However, fuel wood source is the dominant source of energy in this category. For lighting purpose, the various choices mainly include; electricity, petroleum/diesel (used for fuelling generators), kerosene, candles and traditional lamps as well as firewood, mostly based on socio-economic status of a household. Figure 1.2 indicates the proportional categorisation of households in Bauchi State based on their main lighting source of energy

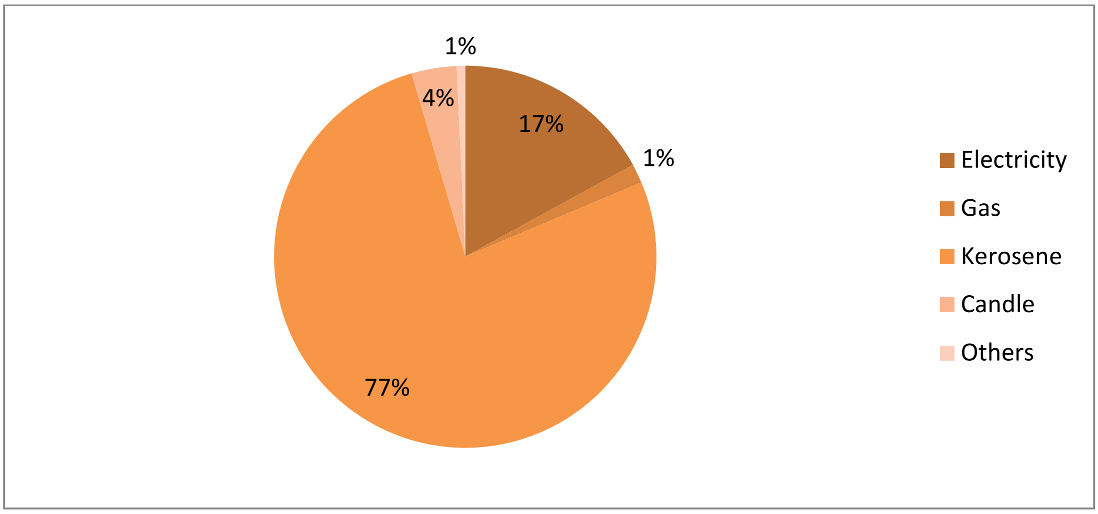

Figure 1.2
Categories of Households by Main Lighting Fuel Source in Bauchi State

Figure 1.2 indicates that only 1% of households in Bauchi State rely majorly on other sources of lighting energy such as; solar energy, rechargeable lanterns, battery lanterns and torch lights respectively. Furthermore, another 1% of the households in the State use electric generator (i.e. gas fuel) as the main source of lighting their homes. On the other hand, the main source of lighting for the majority of households in Bauchi State is kerosene whereby nearly 77% of the households use traditional lamp in order to light their homes mostly due to poor electricity supply.

However, the use of such traditional lamp as the main source of light is a treat to the health and the life of the users, this is because such traditional lamp produces high rate of carbon monoxide that is harmful to human health, that is why in most of the rooms whereby such lamps are being used, there exist black dust in ceilings and the walls closer to the lamp. Furthermore, for the purpose of drinks and space cooling, the various energy sources available consist of mainly electricity and petroleum or diesel (gas) power generator.

Of all the above categories of fuel sources; electricity, liquefied petroleum gas (LPG) and kerosene are regarded to be either cleaned (i.e. in the case of electricity and gas) and/or transitional (i.e. in the case of kerosene) energy sources (Yamamoto, Sie, & Sauerborn, 2009), while the traditional biomass fuel which include fuel-wood, animal dung and plant residues are not cleaned energy, that can lead to numerous economic, social, health and environmental problems (Jan, Khan & Hayat, 2012).

The underlying rational here is to encourage households to shift from the use of non-cleaned energy sources to the adoption cleaned energy sources (Ritche, Mcdougal & Claxto, 1981). This is because there are so many benefits in using a cleaned energy source. It has been widely argued, moving towards the use of cleaned fuels is an important option to improve standard of living for households that rely heavily on biomass (Lee, 2013). It is the key factor to improve the mode of living for rural population (Ganchimeg & Havrland, 2011).

Moreover, encouraging households to switch to cleaned energy would lead to the consumption of less fuel per meal and less time spent gathering fuel, which could be used in other activities such as attending school and other income generating activities (Yamamoto *et al*., 2009). Cleaned energy provides easy access to education, health care and household resources. Children who do not have to collect bio fuels can attend school (Wilkinson, Smith, Joffe, & Haines, 2007; Smith, Rogers, & Cowlin, 2005). Switching to cleaned fuels could also free up time for women to engage in income-generating pursuits (Wilkinson *et al*., 2007).

To attain these benefits, a very important and effective policy which provides access to cleaned energy is required (Farsi *et al*., 2007 in Nlom & Karimove, 2014). However such effective policy also depends on a good research conducted to investigate and explore households' energy consumption pattern in relevant area (Nlom & Karimove, 2014).

However, despite the above benefits of using cleaned fuel source and also despite the fact that Nigeria is blessed with abundant primary energy resources which include reserves of crude oil and natural gas, coal, tar sands and renewable energy resources such as hydro, fuel-wood, solar, wind and biomass. Furthermore, despite that the country is the sixth largest exporter of crude oil in the world and was once the fourth largest exporter of LPG, with an estimated reserve of 35 billion barrels and 185 trillion cubic feet of both crude oil and natural gas, in addition to other various energy sources in commercial quantity (Iwayemi, 2008), over the years, there has been wider use of firewood as the main source of fuel for many households in Bauchi State, especially for cooking purposes. Bauchi State is one of the most populous States with higher rate of firewood use in Nigeria (Nigerian Bureau of Statistics (NBS), 2012). Available data have shown that the average rate of cleaned fuel use in Bauchi State is far lower than the national average. The rate of household fuel wood use (for cooking purpose) in Bauchi State, Nigeria is about more than 95% which is far higher than the urban national average of about 36% and the whole national average of about 70% (NBS, 2012). Table 1.2 shows the categories of fuel sources for some selected States in Nigeria.

Table 1.2
Percentage Categorisation of Households' Cooking Fuel Source

States	**Rate of fuel-wood use**	**Other sources (%)**	**Population estimates (2015)**
Bauchi	95.7	4.3	6,319,159
Bayelsa	42.5	57.5	2,212,637
Delta	49.8	50.2	5,484,632
Edo	68.9	31.1	4,123,280
Ekiti	51.1	48.9	3,171,137
Enugu	76.1	23.9	4,266,568
Kwara	66.2	33.8	3,099,075
Kogi	64.3	35.7	4,342,045
Lagos	8.0	92.0	12,154,514
Ogun	24.3	75.7	5,049,308
Osun	38.0	62.0	4,557,086
Oyo	41.1	58.9	7,579,207
Rivers	45.4	54.6	7,060,184
FCT	62.4	37.6	3,248,060
National	72.2	27.8	
National Urban	36.0	64.0	

Source: NBS (2012)

Furthermore, Figure 1.3 shows the categories of some selected households and their main source of cooking fuel in Bauchi State.

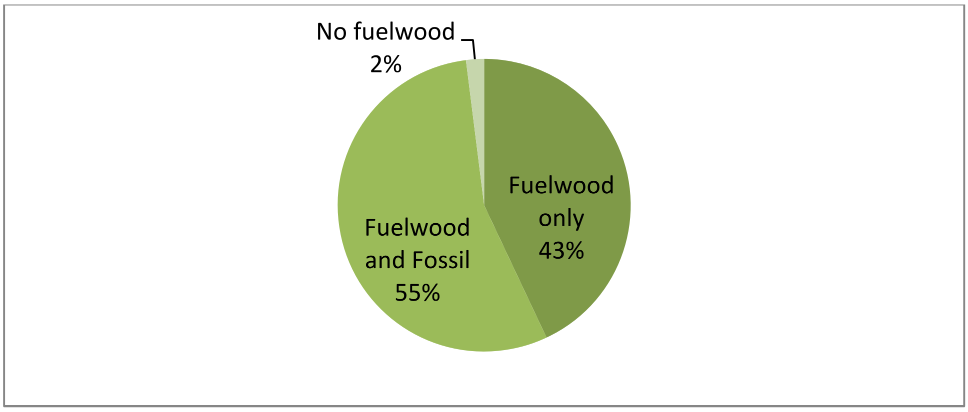

Figure 1.3
Categories of Households by Fuel Sources in Bauchi State
Source: Akpan *et al*. (2010)

Figure 1.3 shows the categories of households based on their cooking fuel sources in Bauchi State. About 43% of households use fuelwood solely as their source of cooking fuel while the majority of the households combine both the fuelwood and fossil fuels to source energy for cooking purposes. This shows that more than 95% of households in Bauchi State use fuelwood as their source of cooking fuel (NBS, 2012). On average, the consumption of firewood per a household in Bauchi State is about more than 600kg/month which are mainly sourced from forest reserve, friends' farmlands and or buy from the market (Akpan *et al*., 2010). As for those supplied in the market, it is argued that the monthly quantity supply of firewood per person in Bauchi State is about 750kg (Ay *et al*., 2011). Most of these fuel woods are sourced from the chosen preferred trees (among the available trees in the state) such as; Madobiya, Kirya, Baushe and Marke mainly due to availability, efficiency affordability and cultural reasons (Wakili et al., 2012; Akpan *et al*., 2010).

However, the use of fuel-wood for cooking purpose is totally not environmentally friendly. It has negative impacts on the atmosphere and peoples' lives (Nlom & Karimove, 2014). Apart from deforestation, desertification and soil erosion, the use of fuel wood has a very low thermal efficiency and the smoke is also hazardous to human health, especially to women and children who mostly do the cooking in homes (ECN, 2003). Furthermore, approximately 1.5 million deaths world over every year from respiratory infections can be attributed to the environment, including the effects of indoor and outdoor air pollution (Ustun & Corvalan, 2007). Acute respiratory infections (ARI) in children are among the leading causes of infant and child morbidity and mortality (Emmelin & Wall, 2007; Schirnding, Bruce, Smith, Ballard, Ezzati, & Lvovsky, 2002). Studies have found positive associations between biomass fuel use and lung cancer. A 30 year old woman cooking with straw or wood has an 80% increased chance of having lung cancer later in life (Hong, 1991; WHO, 1991).

In fact, indoor air pollution from solid fuels is ranked as the world's eighth largest health risk, causing 2.7% of global losses of healthy life (WHO, 2002 in Heltberg, 2005). Due to these adverse effects of traditional biomass fuel use, the Millennium Development Goals (MDGs) emphasized the reduction of the biomass consumption in order to improve the welfare of billion poor worldwide (Suliman, 2010). Also, the United Nations Millennium Project recommends halving the number of households that rely on traditional solid biofuels for cooking by 2015, which consists of about 1.3 billion people switching to other fuels (Mekonnen & Kohling, 2008; Suliman, 2010).

That is why the Bauchi State Economic Empowerment and Development Strategies Document (2004) vividly stated the fuelwood policy as: (i) the state shall promote the use of alternative energy sources to fuel-wood and (ii) planting of one million trees every year within the period of next four years. The document continued to state that the strategies to achieve the above objectives of fuel wood policy are: (i) enforcement of stiffer penalties for illegal felling of trees and bush burning (ii) massive campaign on tree planting in all public places (iii) schools at all levels should be encouraged to form 'Tree Planting Clubs' across the state (iv) planting of one million gum Arabic trees yearly and 250000 of other species in each local government of the state yearly (Bauchi State Economic Empowerment and Development Strategies (BASEEDS), 2004).

However, such energy plan needs various comprehensive and up to date studies that analyses the factors influencing households to adopt a particular source of energy in order to facilitate the achievement of the stated energy policy target; to contribute to the reduction of using fuel-wood as the main source of energy and to encourage the adoption of other cleaner energy sources. According to ECN (2003), "*energy issues are multidimensional in nature and there are strong interactions among factors that influence energy demand, supply and consumption, which must be recognised in order to have an effective energy plan*."

1.3 Problem Statement

The rampant use of firewood as a cooking fuel source for the majority of the households has posed negative impacts to the inhabitants of Bauchi State. The first negative impact of wider use of firewood as the main source of fuel in Bauchi State is the systematic destruction of the state's forest reserves and wood lands (Ay et al., 2011). The rapid environmental problems in the state such as; soil erosion and the persistent desertification are some of the consequences of such rapid felling of trees. In fact Bauchi State government argued that the state loses on average not less than one kilometre of land area because of desertification mainly caused by high rate of felling trees for cooking fuel and some other relevant uses (Tide, 2010). Furthermore, the use of firewood has a very low thermal efficiency and the smoke is also hazardous to human health, especially to women and children who mostly do the cooking in homes (ECN, 2003). It causes infant child morbidity and mortality as well as high rate of premature loss of lives (Emmelin & Wall, 2007; Schirnding *et al*., 2002).

Additionally, in modern times, electricity source of lighting is regarded as one of the most efficient and most widely source of lighting especially in high income countries. However, in Bauchi State where mostly electricity supply is unavailable and unreliable, and also its cost is sometimes unaffordable, the alternative sources of lighting in some cases are from semi-electric sources like battery torch lights and rechargeable lanterns. The most widely source of lighting, especially in the rural areas of Bauchi State consists of traditional sources of lighting which appear in the form of fuel-based lighting sources like oil lamps, candles, firewood and kerosene lamps. Such wider use of traditional lighting sources also aggravates the problem of indoor air pollution which increases the risk of respiratory diseases. Similarly, the use of candles and kerosene lamps inside homes increases the danger of fire accidents. Moreover, such traditional lighting devices do not give sufficient lighting situations for reading and studying which limit the capacity of literacy and school performance. For instance, a typical traditional kerosene lamp delivers only a useful light of in between 1 – 6 lumens per meter square (lux), compared to the required standard of 300 lux for tasks such as reading (Mills, 2003). The wider use of both the firewood (for cooking purposes) and the traditional sources of lighting are caused by many socio-economic characteristics of households in Bauchi State. Factors like low income, low price of firewood and traditional lighting sources which made them easily affordable, low level of awareness on the dangers of the use of such type of energy, non availability and high price of the cleaner sources of household energy as well as the culture of massive use of firewood in the environment encourage the adoption and use of firewood and the traditional sources of lighting.

In order to eliminate or remove the above problems, households' energy consumption pattern needs to be geared away from the use of firewood and other traditional source of fuel to the use of clean source of fuel. The strategy of reducing massive use of firewood and the traditional sources of lighting depends on a very important and effective policy that ensures access to cheap cleaned fuels, which in turn must be based on a good research conducted to investigate and explore households' energy consumption pattern and the factors the make households to adopt cleaned or otherwise source of fuel the in Bauchi State.

Though many studies on household energy choice were carried out in different countries, such types of studies are limited within the Nigerian context (Ogwuimike et al., 2014; Naibbi & Healey, 2013). Most of these studies conducted in Nigeria are specific in approach concentrating in a province, local government area or a state as case studies (For instance Onoja & Emodi, 2012; in Kogi State, Oyekale *et al*., 2012;

a local government in Ekiti State, Nnaji *et al*., 2012; Enugu State & Julius, 2013; Abuja) in which the findings of one study from a particular specific area cannot be generalised to another area due to environmental cultural and socio-economic differences. None of these studies conducted took Bauchi State as the case of analysis. Moreover, all these studies (except Ogwuimike *et al*., 2014) concentrated only on cooking aspect of household energy consumption (mostly firewood use alone) thereby neglecting other aspects of household energy use. Additionally, most of them used only descriptive percentage as the tools of their analysis and therefore they lack wider application of econometric tools in their analysis.

Furthermore, according to the theory of Relative Income Hypothesis (RIH), consumption of individuals and households is relatively determined, that is, it is influenced by the consumption behaviour of their immediate neighbour. Likewise energy consumption behaviour of households in Bauchi State can be influenced by that of their immediate neighbours. However, previous studies on household energy use did not incorporate the idea of RIH (in relation to household energy consumption) in their analyses. This study will test such hypothesis in relation to household energy use and may come up with a conclusion that may be useful for policy making.

1.4 Research Questions

Because of the above issues raised, the followings are some of the questions answered by the study.

i. What are the socio-demographic characteristics of households and the pattern of their energy consumption in Bauchi State?

ii. What are the determinants of household cooking fuel choice in Bauchi State?

iii. What are the socio-economic factors influencing households' lighting source of energy in Bauchi State?

iv. What are the factors affecting the household demand for firewood, kerosene and electricity in Bauchi State?

v. What is the relevance of the RIH in explaining household energy consumption?

1.5 Objectives of the Study

The main objective of the study is to analyse and assess determinants of household energy choice and consumption in Bauchi State, Nigeria. The specific objectives are:

i. to explore socio-demographic characteristics of households and the pattern of their energy consumption in Bauchi State;

ii. to identify the determinants of household cooking fuel choice;

iii. to assess the socio-economic factors that influence households' choice for lighting source of energy;

iv. to identify the factors that affect the household demand for firewood, kerosene and electricity in Bauchi State.

v. to test the relevance of the RIH in explaining household energy consumption.

1.6 Justification of the Study

Energy is one of the major aspects of a household's welfare, availability of energy supply at a cheaper price means raising standard of living for household members. Therefore, it is very important to carry out an empirical study in order to provide up to date and relevant information on the households' energy consumption pattern, in order to improve their energy consumption. Micro level analysis of household sector energy demand provides detailed information and understanding of household energy consumption behaviour that are useful for formulating specific energy policies that will encourage households to switch away from the used of biomass fuels that is harmful to human health and environment, to the use and adoption of cleaned fuel sources which improves the households' general welfare.

It is generally agreed that energy strategies have impacts on major issues related to poverty, women, population, urbanisation and lifestyles, those strategies are essential for economic, social development and improved quality of life. Analysis of household energy demand can provide information relevant for implementing such strategies. Similarly, the technological characteristics of different household energy appliances vary widely from one use to another across sectors. Macro demand analysis cannot treat these issues properly. This justifies disaggregated energy demand analysis independently of or in addition to a macro level demand analysis.

Furthermore, assessing determinants of household energy demand helps to reveal the most important determinants of household energy choice and why a household chooses a particular source of energy instead of another. In other words, it gives information regarding who is the most important decision maker of what kind of energy to use. Knowing this can aid in making relevant energy policy so as to influence the energy use determinants to improve household choice of energy to a cleaner source.

Moreover, the manner of different final uses and consumption for energy varies significantly from one country to another due to different levels of economic development, climatic conditions, policies and other factors, even within a country similar variations can be found among different climatic zones and economic regions, the results and findings of studies and analysis of household energy demand pattern at a regional levels can serve as a basis for comparative regarding energy utilisation choice, consumption and expenditure, from one area to another.

Additionally, study on household energy demand provides detailed information which is desirable for better prediction of consumer demand response to changes in energy price and income. Furthermore, estimating various elasticities of energy demand provides information not only on what factors influence the demand but also the degree of responsiveness of the change in the quantity of energy demand as a result of some factors, knowing this can help policy makers to know by how much a particular factor can be changed (increase or decrease) to achieve a particular desired level of energy use.

Furthermore, analysis of household energy consumption pattern can explore the energy consumption behaviour of the household as regard to how the households perceive efficiency in energy use and whether they try to attain maximum possible cleaned use of energy. This also can help when making policies regarding cleaned use of energy by households. Lastly, micro level study of household energy consumption at local level can create or increase the households' energy use awareness especially the selected households under the research.

Specifically, this study contributed to the existing literature in the following ways; firstly, this study is the first study that used household micro data in Bauchi State, Nigeria not only to analyse households' energy choice and demand, but also with wider application of econometric models, which made the study to have a unique pattern relative to the few existing relevant studies in the whole country (Nigeria). Secondly, the study further exceeded the scope of most of the previous researches by covering multiple aspects of household energy consumption (such as the aspects of cooking fuel and lighting fuel choices, the consumption of firewood, kerosene and electricity) taking Bauchi State as the area of the study. Thirdly, the study estimated comprehensive variables that have not been jointly studied together. This includes testing for relative income hypothesis in relation to household energy use.

Furthermore, an interaction variable was created to ascertain the impact of neighbourhood energy choice via the household environment. Lastly, the analysis of the lighting source of energy was considered from three dimensions (i.e electric, semi-electric and traditional sources of lighting) which most of the previous studies overlooked (with the exception of study by Ogwumike *et al*. (2014) in which they considered only two dimensions).

Therefore, different stakeholders may benefit from this research. For instance, the research may benefits the individual households as the main focus of the study. Governments at the local, state and national levels may find the study relevant especially when designing policies relevant to household energy use. Energy Commission of Nigeria and other energy related organisations (both governmental and Non Governmental Organisations) may find the study useful for their activities.

The researcher will also benefit from the study. Finally, future researchers in relevant field of study may use the study as one of their material of reference.

1.7 Scope of the Study

The area under the study is Bauchi State, Nigeria which consists of three different geopolitical zones. These zones are categorised as; Bauchi South consisting of seven different local government areas namely; Bauchi, Alkaleri, Dass, Bogoro, Tafawa-Balewa, Toro and Kirfi. While, the second geopolitical zone known as Bauchi Central (Ningi zone) consists of six different local government areas such as; Ningi, Warji, Ganjuwa, Darazo, Misau and Dambam. The last category is Bauchi North (i.e. Katagum zone) consisting seven local government areas namely; Giade, Shira, Jama'are, Katagum, Itas-Gadau, Zaki and Gamawa. As of 2014, there were about 769,960 estimated households (UNFPA, 2014) who are spread in the entire three geopolitical zones of the state in both the rural and urban areas of the state are the elements of the study out of which samples were selected for the purpose of conducting the study.

1.8 Organisation of the Study

The study consists of six chapters. Chapter One, which is the introduction, consists of background to the study, scenario analysis of household energy use in Bauchi, statement of the problem, research questions and objectives of the study, significance of the study, scope of the study as well as organisation of the study. Chapter Two consists of background of the study area. Chapter Three consists of reviews of the related literature. Chapter Four which is on the methodology, explains; theoretical framework of the study the population of the study, the tools and methods to be used in data collection, sample size and sampling technique, tools of data analysis as well as justification of the variables of the study. Chapter Five consists of the results and findings of the study, while, chapter Six consists of summary, conclusions and recommendations of the study.

1.9 Conclusion

This chapter discussed the issues of household energy choice and consumption in Bauchi State. It was shown that energy is indispensable in households' living. However, majority of households in Bauchi State adopt non cleaned sources of energy which exact negative impacts in both the wellbeing of the people and the environment. That is why the issue of how to encourage people to switch to cleaner energy sources is one of the most important issues in Bauchi State in the current period. Furthermore, this chapter vividly explained the targeted objectives of the study, the importance and benefits of conducting this study as well as the expected stake holders that may benefit from the study.

CHAPTER TWO

OVERVIEW OF THE STUDY AREA

2.1 Introduction

This chapter gives brief description on the background of Nigeria as a whole, such as the geographical and historical background of the country, the Nigerian economy at a glance and some insight information on some of the natural resources in abundance quantity in the country. Additionally, background information was provided specifically on the area of the study (Bauchi State), such as the information on geographical and historical background of the State, the various main economic activities in the State as well as the social settings of the State.

2.2 A Brief Insight of Nigeria

Since the area of study is a State in Nigeria, this section provides a brief highlight on geographical and historical background of Nigeria as a whole as well as on the Nigerian economy.

2.2.1 Geographical and Historical Background of Nigeria

The boundary area of Nigeria today came into existence in 1914 when the Northern area and Southern area of the country were amalgamated to form a colony of Nigeria. Such a colony (Nigeria) gained an independence from the colonial rule on 1^{st} October, 1960, which made it to become an independent country. Furthermore, by the year 1963, the country became a full republic when the Queen of England seized to be the ceremonial queen of the country.

The federal republic of Nigeria has a total landmass area of about 923769 km^2 divided into 909890 km^2 of land area and 13879 km^2 of water area. The country is located between longitude 3^0 and 14^0 East and latitude 4^0 and 14^0 South. The longest distance from North to South is 1605 km and 767 km from West to East. Nigeria is surrounded by Chad and Niger Republics on the North, by the Cameroon Republic on the East, also by the Benin and Niger Republics on the West and by the gulf of Guinea on the South. The shoreline of Nigeria is a sash of mangrove swamps navigated by a system of springs and rivers. The average climate of the country is tropical equatorial and semi-equatorial that is characterised by high humidity and generous precipitation. On average, there exists two seasons namely wet and dry seasons. The wet season takes place from April to October, whereas the dry season keeps going from November through March. Figure 2.1 is a diagram constitutes a typical map of Nigeria showing the 36 states of the federation and the federal capital territory Abuja as well.

Figure 2.1
A Typical Map of Nigeria

Figure 2.1 is a map of Nigeria exhibiting the various 36 states of the country and its federal capital territory, Abuja. The whole of the federation is headed by a president, whereas each of the 36 States is ruled by a governor. Additionally, each of these States are further divided into various local government areas on the basis of population, landmass and economic activity, the overall number of local government areas in the country is 776 each of which is headed by a local government chairman. In a nutshell, there are three tiers of government in Nigeria namely, federal government, headed by a president, various State governments, headed by a governor and local governments, headed by local government chairmen.

2.2.2 An Insight of the Nigerian Economy

The economy of Nigeria is among the middle income class mixed economy characterised by growing market and expanding technology, communications, financial, services and entertainment sectors. In terms of gross domestic product (GDP) the economy is ranked 26th in the world and the largest in Africa. The economy is one of the two economies from Africa that are among the 11 global growth generators economies. In fact, it is argued that the Nigerian economy has been changing gradually, shifting away from agricultural oriented economy to other sectors, such as services, energy information and communication sectors. Recently, the Nigerian economy is regarded as the largest economy in Africa having an estimated GDP of $522 billion as at 2013, with the rate of growth of real GDP of seven percent over the same period. While the rate of growth for the year 2014 was 6.3%, and the GDP per capita estimate over the same period was $2800. The national savings were estimated to be 15.5%, 15.9% and 15.4% of GDP for the periods of 2013, 2012 and 2011, respectively. However, due to the fall in the crude oil price in the world, the country recorded only about 3% GDP growth rate in the year 2015 (CIA, 2016; World Bank, 2016).

Immediately after independence, agriculture contributed to about 60% to the GDP and employed about 70% of the labour force. These immense contributions by agricultural sector however, have later fall down drastically in favour of other sectors of the economy. For instance, by 2012, though Nigeria is ranked as the sixth worldwide and first in Africa in terms of agricultural production, its contribution to the GDP was estimated to be about 40% over the same period. Apart from agriculture, the estimation of the contributions of other sectors to the GDP are; services 30%, manufacturing 15%, oil 14% and others 1% (CIA, 2014).

Though the manufacturing performance is affected by inadequate power supply and other basic infrastructures for the smooth running of daily production, in terms of services sector performance, Nigerian economy is ranked 63rd globally and occupies the fifth position in Africa (CIA, 2014). The performance of this sector is seriously constraint by low power generation in the country.

In terms of labour force, their number is estimated to stand at 51.53 million as at 2011, whereby agricultural sector employs about 30%, services sector 32%, manufacturing sector 11%, while 24% are unemployed. In terms of Human Development Index (HDI), the Nigerian economy is ranked 153 out of 187 countries. The latest value of HDI stands as 0.471, which is little bit lower when compared to an average value of Sub-Saharan Africa (0.475) and also very lower compared to that of USA (0.910) and the world average 0.694 signifying that Nigeria has low level of human development (UNDP, 2013).

In April 2006, Nigeria was able to settle its external debt by a cash payment of about $12 billion and a debt write off of about $18 billion. However, by 2012 the country's external debts stood at about $5.9 billion, most of the debts were incurred to finance capital expenditure, though corruption and mismanagement prevent the proper use of the incurred debts. By the year 2015, the total recorded exports stood to the value of $34.50 billion and $14.23 billion stood as the total import value for the last quarter of the year 2015, apart from the illegal transactions for both exports and imports that have been carried out and are not part of the recorded transaction value.

Most of the exported products are basically primary products mainly petroleum and related products plus very few agricultural products like cocoa and rubber that serve as raw materials for manufacturing industries. On the other hand, most of the imported goods are finished and capital goods. To summarise, the clear picture of Nigeria's economy is that despite it is a very large and expanded economy, the economy is monocultural in nature depending majorly on crude oil as the major source of foreign exchange. In addition, the economy is characterised by high rate of importation of finished consumer goods and capital goods to meet the growing demand of these commodities.

2.2.3 Natural Resources (Energy Sector)

As the Nigeria's economy is concerned, energy sector is the back bone of the economy on which all the other subsectors of the economy depend. Furthermore, Nigeria is blessed with so many resources which if utilised properly will be among the leading economies of the world. Such energy resources available in the country in abundance quantity constitute both renewable and non-renewable energy resources such as; crude oil, natural gas, tar sands, coal, electricity fuel-wood and solar energy. The crude oil was discovered at Oloibiri in 1956 in commercial quantity, the quantity of the oil reserve is estimated to be about 36.5 billion barrels making the country to be the 10^{th} largest in the world and the second largest in Africa.

In terms of natural gas, Nigeria is blessed with abundant natural gas resources much larger than the oil reserve quantity. Based on official record, the natural gas reserve stood at 187 trillion cubic feet (TCF) which place the country the ninth largest gas owner in the world and the African largest gas owner. Furthermore, recent geological survey by USA (in Nigeria) indicates that the country has an estimated reserve of about 600 trillion cubic feet (TCF) of natural gas, a statement if true will place the country as the fourth largest owner of natural gas in the world (EIA, 2013).

Furthermore, coal is one of the resources in abundance quantity in Nigeria. It is believed that it exists and spread over 13 states of the country occurring in about 22 coal fields. The deposit is estimated to be about 639 million tonnes. In addition, the secondary reserve is estimated to be about 2.75 billion tonnes. Coal production in Nigeria reached its peak in 1958/1959 whereby a total tonnes of 905,000 coal output were produced. However, following the oil discovery in 1956 and its first exploitation in 1958, by the early 1960's coal production drastically reduced and by early 2000's, a total output of 14,390 tonnes was produced. Now a day, coal production reached its loWest level whereby the resource contributes about less than 0.01% of the country's commercial energy consumption (ECN, 2003).

Nigeria has an abundant deposit of tar sands which is estimated to be about 30 billion barrels of oil equivalent. Bitumen which is also obtained from tar sands is used for construction of roads. Similarly, it is used in petro-chemical, chemical, electrical and other related industries. If properly utilised, this resource (i.e. tar sands) can contribute greatly to the Nigeria's resource base.

In Nigeria, the story of electricity originated since the year 1896, when electricity was first generated in Lagos just about a decade after its inception in Britain. However, despite it is more than 100 years of existence in the country, the development of electricity is very low or stagnant. Despite that the national grid of electricity composed six thermal generating stations and three hydro power stations, the combination that have almost 6000mw capacity, however, only 2000mw-3000mw is being generated due to poor maintenance, mismanagement and corruption.

Moreover, fuel – wood is one of the most important sources of energy in Nigeria. Over 60% of Nigerians use fuel – wood as their major source of energy especially for cooking purposes. Nigeria is endowed with wood and timber resources. The Nigerian areas of timber land and forest is estimated to be about 15 million hectares of land (ECN, 2003).

In the case of solar energy, Nigeria exists in a high sunlight belt and within the country; sunlight base radiation is evenly distributed. On average, the yearly sunlight based energy varies from 12.6mj|m^2 daily along the coastal latitudes to about almost 25.2mj|m^2 in the North. The availability of solar energy to the surface of Nigeria shows its practical viability. It is argued that Nigeria receives about 5.08×1012kwh of energy daily from sunlight. Furthermore, when sunlight based energy equipments with only 5% efficiency are used to wrap only 1% of Nigeria's region, then 2.54×106mwh of electricity may be acquired from sunlight based radiation. Such quantity of electrical energy is almost equal to 4.66 million barrels of oil for every day. Table 2.1 contains the figures for total energy production and consumption in Nigeria (1971 – 2011).

Table 2.1
Energy Production and Consumption in Nigeria

Years	Energy production (kt of oil equivalent)	Energy use (kt of oil equivalent)	CO_2 emissions (kt)	Fossil fuel energy consumption (% of total)
1971	111494.89	36070.72	32280.60	5.49
1972	127156.17	37302.96	41426.10	6.39
1972	139929.43	38913.60	49577.84	7.93
1974	150870.71	40084.24	62291.33	8.31
1975	128220.06	41737.27	47395.98	9.56
1976	144012.29	43816.41	55247.02	11.51
1977	146288.17	46059.11	50567.93	13.59
1978	137264.90	48192.13	48294.39	15.27
1979	159206.59	50139.67	70289.06	16.12
1980	148478.75	52459.88	68154.86	17.65
1981	118938.39	54861.93	65958.33	19.07
1982	112898.57	57534.19	65602.63	20.57
1983	111937.07	59210.86	59929.78	20.64
1984	121157.16	59479.81	69625.33	18.62
1985	128446.85	61428.01	69893.02	18.93
1986	127937.11	62145.45	73505.02	17.57
1987	123342.38	64341.02	59343.06	18.28
1988	131835.16	66215.94	70747.43	18.39
1989	147155.80	68469.66	42441.86	18.97
1990	150452.36	70582.28	45375.46	19.31
1991	156709.54	73839.65	45247.11	20.67
1992	161988.95	76683.04	64883.90	21.55

Table 2.1 (continued)

Years	Energy production (kt of oil equivalent)	Energy use (kt of oil equivalent)	CO_2 emissions (kt)	Fossil fuel energy consumption (% of total)
1993	164875.91	77944.80	60061.79	20.79
1994	166163.23	76203.73	466658.90	16.78
1995	169186.04	77539.82	34917.17	15.93
1996	181955.38	80778.21	40421.34	16.82
1997	193860.18	84311.97	40190.32	17.84
1998	188582.82	84447.88	40182.99	15.78
1999	187676.01	87472.11	44788.74	16.74
2000	201602.98	90595.51	79181.53	17.74
2011	211055.86	94633.01	83350.91	19.32
2002	195974.18	97388.86	98125.25	19.47
2003	216318.83	99007.38	93138.13	18.90
2004	229819.19	101751.11	97047.16	19.07
2005	233791.65	106509.46	104696.50	20.79
2006	235809.72	107004.78	98513.96	19.31
2007	232537.45	107683.10	95209.99	17.81
2008	230206.53	111224.99	92621.09	18.47
2009	228077.63	109255.20	71719.19	15.00
2010	254779.14	115137.78	78910.17	17.16
2011	256927.24	118324.59	75314.68	17.40

Source: World Development Indicators (2014)

Table 2.1 exhibits the time series pattern of total energy production and consumption and their impacts (i.e. carbon emission) in Nigeria for the period of more than 40 years. The energy production constitutes all types of basic energy – petroleum (such as liquid of natural gas, crude oil and non conventional oil sources). It also includes natural gas and other solid fuels (like lignite and coal) as well as primary electricity, waste and consumable renewable that are all converted to oil equivalents. The energy use means the consumption of primary energy before alteration to other end fuel products. The carbon emission refers to those emissions originating from flaming of fossil fuels and the production of cement.

From Table 2.1, energy production in Nigeria shows oscillatory pattern whereby at some years, it rises and sometimes decreases. However, over the same period (i.e. 1971 - 2011), the minimum amount of energy production was in the year 1971 when it was about 111495kt of oil equivalent. On the other hand, the maximum production level is at year 2011 in which about 256927kt of oil equivalent was produced. Meanwhile, regarding energy use, there was an upward trend whereby the quantity used increases until the year 1994 in which there was a slight dropdown on the quantity of energy use form 77944kt of oil equivalent in 1993 to 76203kt (just about 2% decrease). Then, it rises again till year 2009 whereby a total of 109255kt was used which is slightly lower than that of 2008 (i.e. 111224kt). It then continued to rise and the quantity of energy use was at its maximum level in year 2011 when about 118325kt of oil equivalent of energy was used.

2.3 Bauchi State at a Glance

This section provides little information on the area under the study (i.e. Bauchi State) by highlighting on the historical background of the State, the major economic activities as well as the manner of social settings in the State.

2.3.1 Geographical and Historical Background of Bauchi State

The area known as Bauchi State today came into existence in 1976 when the former North Eastern State was divided. It is, therefore, among the current six North Eastern States of Nigeria. Bauchi State lies between latitude 9.3^0 and 12.3^0 North of the equator, while longitudinally, it lies between 8.5^0 and 11^0 East. The State has an area of about 49119sqkm which is about 5.3% of total land area of Nigeria. The State is surrounded by Kano and Jigawa States from the North, while the North East part of the State is bordered with Yobe and Gombe States. Furthermore, from the South it is surrounded by Plateau and Taraba States, and then Kaduna State to the West. Figure

2.2 exhibits a map of Nigeria containing a clear picture map of Bauchi State and its neighbouring states.

Figure 2.2
Map of Nigeria

On the other hand, Figure 2.3 exhibits map of Bauchi State showing its various local government areas.

Figure 2.3
Map of Bauchi State

Figure 2.2 is a map of Nigeria exhibiting Bauchi State and its surrounded neighbouring states as just explained above. On the other hand, Figure 2.3 is a typical map of Bauchi State showing the various 20 local government areas of the State. The entire State is divided into three geopolitical zones namely; Bauchi South which consists of seven different LGAs such as; Alkaleri, Bauchi, Bogoro, Dass, Kirfi, Tafawa-Balewa and Toro; Bauchi Central which consists of six LGAs like; Dambam, Darazo, Ganjuwa, Misau, Ningi and Warji; lastly Bauchi North which consists of seven LGAs such as; Gamawa, Giade, Itas-Gadau, Jama'are, Katagum, Shira and Zaki.

In terms of weather, Bauchi State has both wet and dry seasons with the highest amount of rainfall of around 700mm yearly in the Northern part of the State and around maximum of 1300mm also yearly in the South. The wet raining season lasts from May to September/October. On the other hand, the dry season lasts from October to March/April. Temperatures are, as would be expected, generally high in the State. Mean daily maximum temperatures range from about 29°C in July and August to about 37°C in March and April. The mean daily minimum ranges from about 11°C in December and January to about 24°C in April and May. The vegetation zones of the region comprise of Sudan Savannah and Northern Guinea Savannah.

2.3.2 Economic Background of Bauchi State

The main economic activity in Bauchi State is agricultural production. This is because the significant portion of the population lives in rural areas and engages in agricultural activity as their primary occupation. It is argued that 80% of rural dwellers engage in farming, the enormous intensity nature of the fertility of the soil encourages agricultural production. Both cash crops and food crops are produced though mainly at subsistence level of production. These include; beans, maize, groundnut, millet, cotton, Guinea corn, sesame cassava rice and others. Also, the existence of some rivers and dams like Gongola, Jama'are and Dindima rivers, Balanga and Gubi dams supports and encourages some activities of irrigational farming in the rural areas of the State.

In addition, there exists some elements of manufacturing production in the State which appear in the form of activities of some industries like; Alind cable ware industry, Kuda Nails factory, Bauchi State fertiliser company, Yankari natural water production, Bauchi meat products, Bauchi furniture company and lots more manufacturing activities that take place in both small scale and medium sizes capacity. In terms of mineral resources, the State has abundant deposits of resources like limestone, gold, zinc, columbite, iron-ore, gypsum, coal, sulphur and petroleum related resources. However, unfortunately, few of these resources available in the State are utilised mostly in small scale operation. For instance, some amounts of tin ore are mined in some areas of Maijuju and Gumau. Also, clay and silica sands for ceramic are being mined in Misau. Similar deposit of clay is also obtainable in Udubo and some other areas of the State.

Interms of income distribution and poverty status, about 50% of inhabitants of Bauchi state belongs to the poor income group. Figure 2.4 shows the income distribution and poverty status of people of Bauchi State.

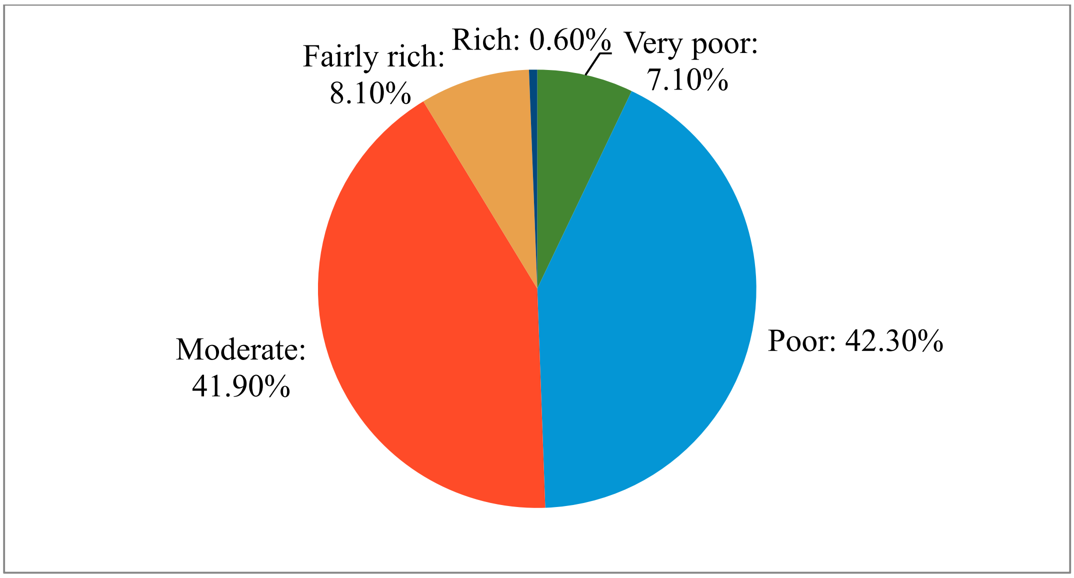

Figure 2.4
Percentage Distribution of Households Based on Income, Bauchi State
(Souce: NBS, 2012)

Figure 2.4 exhibits the income distribution of households in Bauchi State. Figure 2.4 indicates that about 50% of households belong to the poor income group out of which about 7% live in extreme poverty. Furthermore, only less than 10% of households comprise of rich income group. Additionally, Figure 2.5 indicates the average price of Kerosene per litter monthly for the last one year from July 2015 to July 2016.

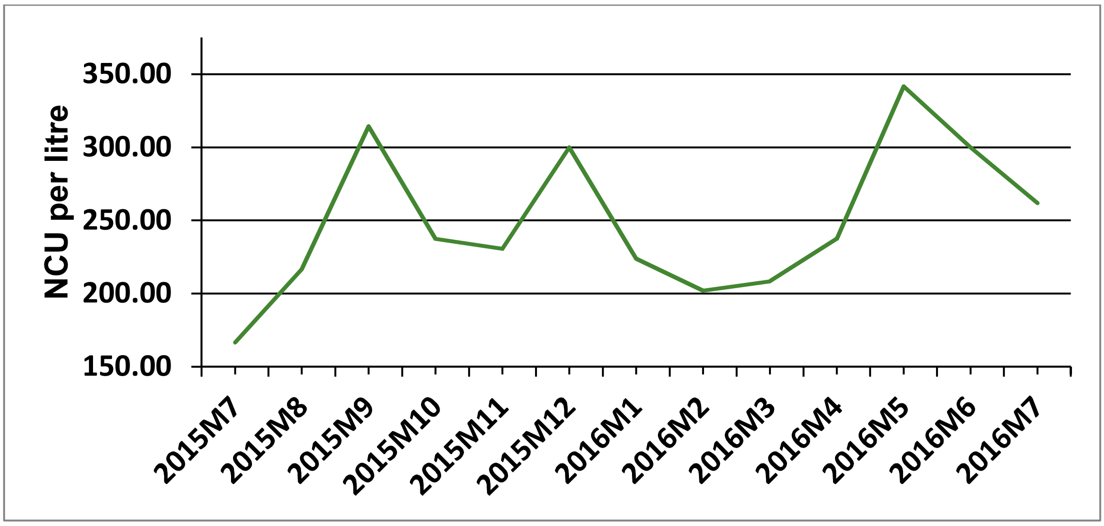

Figure 2.5
Household Kerosene Price in Bauchi
Source: NBS (2012)

Figure 2.5 indicates the average monthly price of kerosene per litter as purchased by household in Bauchi State over the last one year. The figure indicates how fluctuated the kerosene price is due to mostly variations in the quantity supply available in the market. The minimum average price of kerosene for the period under consideration was in July 2015, when it was about ₦170 per litter, while the price riched its peak by May 2016, when it was ₦340 there after began to fall down.

2.3.3 Social Settings

Bauchi State is a multi ethnic State in Nigeria. It has a total number of 60 different tribal and ethnic groups. The major tribes in the State are Hausa, Fulani, Terawa, Sayawa, Waja, Jarawa, Tangale, Kare-Kare, among others. However, it should be noted that almost everybody in the State can speak Hausa language as he can speak his mother's tongue language. In terms of population, the estimated population in the State is about 5.7 million people making the State to be ranked number 7^{th} among the various states in Nigeria in terms of population. The state enjoys about 30% youth unemployment rate.

In terms of tourism, the state is endowed with many tourist attraction areas. For instance, there are areas, like Yankari national park (the biggest game reserve in West Africa), Lame-Burra game reserve, Wikki warm spring, Sumu wildlife parks, Babban Gwani architectural designs, Geji Rock painting monuments, premier Game reserve, Tafawa Balewa Tomb monuments among others.

2.4 Conclusion

This chapter provides a brief highlights on the background of the Nigeria and its economy in general and that of Bauchi State in particular. It was shown that the Nigeria's economy is the largest economy in Africa and also one of the 11 global growth generators in the world. Lastly, the chapter gives a highlight on some of the various energy resources available in abundance quantity in Nigeria.

CHAPTER THREE

LITERATURE REVIEW

3.1 Introduction

This chapter consists of meaning of energy, energy demand, the energy choice and demand determinants and the reviews of the empirical literature on the various aspects of household energy choice and consumption.

3.2 Definition of Energy

According to IEA (2004), energy refers to the capability to perform action or to create heat. Bhattacharyya (2011) held the view that energy manifests in forms like; chemical transformation, motive force, light and heat which can be harnessed and captured from different sources that can be found in various physical States, and also with varying degrees of difficulty or ease of capturing their potential energies. Therefore energy means any substance or stimulus that makes a system to function effectively.

3.3 The Concept of Energy Demand

Energy demand means any type of energy that is consumed to satisfy individual or household energy needs. Such consumption can appears inform of cooking, transportation, heating and cooling. In whichever case, energy commodities are used as a fuel and hence create demand for energy consumption (Bhattacharyya, 2011). Ozcan et al. (2013) categorised household energy demand in to direct and indirect. The direct household energy demand is the household consumption of energy for space heating and cooling, transportation, use of appliance, lighting, water heating among others. On the other hand, the indirect household energy consumption constitutes the household energy use in the transportation and the creation of other goods.

3.4 Review of Empirical Studies

This section consists of the review of empirical studies on the factors that influence the level of household energy choice and consumption. Each of these factors is expected to relate with the quantity of energy consumption of households either positively or negatively. Also, they are the factors that play a good role in shaping the consumption behaviour of a household to adopt either traditional energy source or cleaner source of energy as the situation warrants. Normally, the extent and the dimension of how these factors exact influence on household energy adoption and consumption varies from area to area and also from one type of energy to another. Below is the explanation of how different categories of factors influencing household energy choice and consumption.

3.4.1 Economic Factors

This constitutes factors that serve as measure of economic status of the household which can influence the households' fuel consumption decision. This includes; households' income, home ownership, number of energy use appliances at home, fuel cost and the prices of other energy.

Income: Studies have established that there is a positive relationship between income and adoption of cleaned energy (Danlami *et al*., 2016; Mensah & Adu, 2013; Ozcan *et al*., 2013; Couture *et al*., 2012). Poorer households especially in developing countries tend to adopt firewood, plant residues, animal dung and other un-cleaned energy sources, where as wealthier households tend to adopt energy from cleaner sources like; electricity and gas.

For instance, a two stage least square analylisis by Onoja (2012) indicated that household income have negative impacts on the consumption of firewood in Kogi state. Contrarily, a probit analysis by Oyekale *et al*. (2012) indicated that income of the household has a positive relationship with the use of firewood by the households. On the other hand, Heltberg (2003) concluded that increase in the household's per capita expenditure encourages households to adopt more non solid fuels. Using OLS regression, Petersen (1982) conducted a study to investigate the determinants of variation in households' electricity usage. Family income was among the variables that have significant positive impact on household electricity usage. Using the same OLS model, Abrahamse and Steg (2009) concluded that total households' energy use increase with increase in households' income. Similarly, Louw *et al*. (2008) found that increase in income significantly increases the households' electricity use.

Furthermore, some studies such as Pourazam and Cooray (2013), Svoboda and Br (2013), Cebula (2012) and Ziramba and Kavezeri (2012) were conducted with the major aim of assessing the various elasticities of household energy consumption using time series data. The conclusions were that income elasticities of the demand for most of the household energy is normal good for both short run and long run periods. However, the use of time series data to analyse household energy behaviour is a macro based analysis which does not reflect the disaggregated heterogeneity nature and behaviours of different households.

In addition, some studies (Braun, 2009; Laureti & Secondi, 2012; Couture *et al*., 2012; Ozcan *et al*., 2013; Nnaji *et al*., 2012; Maryam, 2011) used multinomial logit model to analyse the impact of income on household fuel choice. For instance, Braun (2009) indicated that higher income increases the adoption of gas while reduces the households' use of solid energy. Similarly, Laureti and Secondi (2012) concluded that the higher the level of income, the more households adopt gas and reduce the use of coal-wood as a source of energy. Couture *et al*. (2012) shows that increase in the level of households' income discourages the use of wood and encourage households' adoption of electricity, gas and fuel oil as major sources of energy for the households. Ozcan *et al*. (2013) concluded that a higher income for households means increase in the households' adoption of coal, natural gas, and liquid fuel at the expense of firewood.

Furthermore, Nnaji *et al*. (2012) analysed determinants of household energy choice in rural areas of Enugu state using multinomial logit model. The study shows that increase in household income encourages households to adopt more charcoal or kerosene instead of firewood. This is in line with the findings and conclusions of Maryam (2011).

Nlom and Karimove (2014) and Mensah and Adu (2013) used ordered probit model to analyse the determinants of household energy switching from non cleaned source to the highest possible cleaned source. Both studies find that households' income encourages households switching to cleaner energy. Meanwhile, Link *et al*. (2011) indicated that household income increases the probability of households to adopt firewood source of energy than otherwise. On the contrary, Jiangchao and Kotani

(2011) estimated five different Tobit models in their studies to analyse the determinants of households' energy use from different sources (coal, electricity, LPG, fuel wood and crop residue). The results indicated that higher per household member income increases households' energy consumption from coal, electricity and LPG. Moreover, Abebaw (2007) conducted a study to examine the determinants of household fuel-wood using in Jimma town, Ethiopia. Per capita income was found to encourage the consumption of fuel-wood. This is in line with the findings of Song et al. (2012). Additionally, Lee (2013) analysed the consumption of kerosene, charcoal and firewood by households, the results showed that more per capita expenditure are associated with higher use of all the three energy sources.

Home Ownership: Home ownership which is one of the indicators of the economic status of households also affects their decision on the type of energy sources to adopt. Those who live in their owned house tend to adopt cleaner energy source as established by previous studies (Couture *et al*., 2012). Similarly, Sardianou (2007) estimated the determinants of household energy conservation patterns of Greece Households. The OLS result indicates that home ownership is among the variables that have positive impact on households' energy conservation behaviour. Meanwhile, a Multinomial logit analysis by Laureti and Secondi (2012) indicated that home ownership increases the probability of adopting energy source from gas. Meanwhile, Pundo and Fraser (2006) concluded that households that live in their self-owned home have higher odd of adopting charcoal compared to firewood.

Home Appliances: Also number of energy consuming appliances, tends to increase the quantity of energy consumption by households. For instance, using OLS regression, Petersen (1982) conducted a study to investigate the determinants of variation in households' electricity usage. The variables that have significant positive impact on household electricity usage include; electric water heater, electric clothes dryer and dish washer. Similarly, a study to analyse the determinants of households' electricity use by Louw *et al*. (2008) found that ownership of iron has a significant positive impact in increasing the households' electricity use. However, Wang *et al*. (2011) used logit model to estimate the determinants of household electricity saving behaviour of households. The study concluded that subsidy for energy conservation appliance use encourages household energy conservation behaviour. Moreover, Couture *et al*. (2012) concluded that households that possesses wood burner and and room heater higher probability of adopting firewood or electricity as their main source of energy. Danlami *et al*. (2016) found that there is a negative relationship between home appliances and the adoption of cleaned source of fuel.

Price of Energy: Price of energy has a negative relationship with energy consumption. When the price of a particular energy source is high, households switch to other alternative fuel available. This is in line with law of demand and also has been established by so many previous studies (Nlom & Karimove, 2014; Lee, 2013; Ganchimeg & Havrland, 2011; Jingchao & Kotani, 2011; Osiolo, 2010). For instance, Abdurrazak *et al*. (2012) found that over the years, households keep on increasing their consumption of biomass fuel because of availability and cheapness. Similarly, it has been argued that as the price of firewood rises, households switch to an alternate source of fuels (Oyekale *et al*., 2012). On the same vein, a time series analysis by Dodgson *et al*. (2001) and Koshal *et al*. (1999) indicated that the various price elasticities of household energy consumption are negative and inelastic. A 1%

increase in the price attracts a less than 1% decrease in the use of electricity (Yanagisawa, 2011; Metcalf, 2008).

Lee (2013) estimated three different Tobit models to analyse the consumption of kerosene, charcoal and firewood by households. One of the findings of this study that commensurate with the theory is that the price of kerosene is shown to be negatively related to the kerosene consumption. Furthermore, the study found that the price of firewood has a negative relationship with the consumption of firewood respectively.

Furthermore, some studies (Mensah & Adu, 2013; Couture *et al*., 2012; Maryam, 2011; Osiolo, 2010) used multinomial logit model to analyse the influence of price of energy on household fuel swithching. Mensah and Adu (2013) found that price of firewood has positive influence on household fuel switching to cleaner energy. Meaning that the higher the price of firewood, the more households shifts their energy consumption to cleaner sources. In the same vein, Couture *et al*. (2012) established that a rise in the price of wood discourages the use of wood as a source of fuel in favour of non wood sources. Similarly, Maryam (2011) established that price of stove or cooker gas encourages the adoption of less kerosene or gas in favour of the adoption of fire wood respectively. On the contrary, Osiolo (2010) concluded that prices of LPG and electricity have positive relationship with their adoption by households, which is contrary to the existing theory of demand. Laslty, OLS analysis by Couture *et al*. (2012) on firewood consumption in France, indicated that as price of firewood increases, the quantity of firewood consumption decreases.

Price of Other Fuel: Various energy sources for household use are nearly close substitutes to one another, implying that the price of a particular household energy source influence the demand of another sources. A rise in the price of a particular energy source makes households to switch to the use of other fuels as established by presvious studies (Lee, 2013; Mensah & Adu, 2013; Onoja, 2012). Onoja (2012) used two stages least square method to analyse factors influencing fuel-wood demand in Kogi state, Nigeria. Price of kerosene has a positive relationship with the consumption of firewood respectively. Song *et al*. (2012) conducted a study to identify factors affecting wood energy consumption by US households. Moreover, the study concludes that all other factors estimated in the model have significant influence on wood consumption such as; price of non wood fuel sources.

Lee (2013) estimated three different Tobit models to analyse the consumption of kerosene, charcoal and firewood by households. One of the findings of this study is that as firewood and kerosene serve as substitutes (in most cases) the price of kerosene is shown to be positively related to the consumption of firewood. Furthermore, the study finds that the price of firewood is positively related to the consumption of kerosene respectively. In the same study, it was discovered that further rise in the price of firewood encourages households in both the urban and the rural areas to adopt non solid fuels. Similar argument was put forward by Mensah and Adu (2013) whereby the price of firewood was found to have positive influence on household fuel switching to cleaner energy. Meaning that the higher the price of firewood, the more households shifts their energy consumption to cleaner sources.

3.4.2 Socio-Demographic Factors of Households

The type and composition of socio – demographic factors of households influence their fuel switching and consumption behaviour. These factors include; marital status, level of education and age of the household's head, gender of the household head and gender composition in the household (female/male ratio), and size of the household. As the ratio of female to male members of household increases, the household adopts less cleaned energy. This statement was found to be real by previous studies (Suliman, 2010; Heltberg, 2005).

Marital Status: Laureti and Secondi (2012) indicates that households which comprise of couples with children tend to adopt more of coal-wood and less of oil and electricity when compared with a household of a single person. Similarly, a multinomial logit analysis by Nnaji *et al*. (2012) indicated that househoklds tend to adopt less kerosene in relation to firewood when the household head is married. On the contrary, a logit analysis by Danlami *et al*. (2016) found that there is a positive relationship between household head being male and the adoption of cleaned fuels. The household that is headed by a married individual has higher odd of adopting cleaned fuel than otherwise.

Gender of the Household Head: Previous studies such as; Nlom and Karimove (2014), Jumbe and Angelsen (2010) and Osiolo (2010) proved no significant relationship between the gender of the household head and its energy consumption behaviour. However, Abebaw (2007) conducted a study to examine the determinants of household fuel-wood using in Jimma town, Ethiopia. The study found that the household head being male encourages the consumption of fuel-wood. Furthermore, Mekonnen and Kohlin (2008) concluded that households with male head tend to adopt more non solid fuels than either solid or mixed solid and non solid. Moreover, using ordered probit model to analyse the determinants of household energy switching from non cleaned source to the highest possible cleaned source, mainly based on the assumption that the various energy choices available to households are in ordered manner, Mensah and Adu (2013) found that household head being male descourages the household's adoption of cleaned energy. Similarly, Suliman (2010) found that the household head being male increases the probability of adopting biogas, straws and animal dung as the main source of cooking fuel. Similarly, a logit analysis by Danlami *et al*. (2016) indicated that there is negative relationship between a household head being male and the household adoption of cleaned fuel source. A household that is headed by a female has higher odds of adopting cleaned fuel by about 3% compared to the male headed household.

Age of the Household Head: Age of the household head was found to have a negative relationship with the adoption of cleaned energy (Nlom & Karimove, 2014; Mensah & Audu, 2013; Suliman, 2010). Households adopt less cleaned energy source when the head is older. Nnaji *et al*. (2012) established that higher age of household head encourages the household to adopt more charcoal at the expense of firewood use. Eakins (2013) conducted a study to assess the determinants of household energy expenditure using OLS model. The results of the analysis indicated that households with head having age of 55 years and above tend to spent more on electricity and oil than otherwise. Using the same OLS regression, Petersen (1982) conducted a study to investigate the determinants of variation in households' electricity usage. Age of the respondents was found to be among the variables that have significant positive impact on household electricity usage.

Similarly, OLS regression by Osiolo (2010) for household fuel wood expenditure in Kenya indicated that older household head with 40 years and above tend to consume more firewood than otherwise. Risseeuw (2012) also used OLS to estimate the determinants of household's expenditure on charcoal in Mozambique. The study concludes that only age of the respondents was found to be statistically significant which has a negative impact on household expenditure on charcoal. Suliman (2010) concluded that age level of the household's head was found to have negative relationship with the adoption of cleaner cooking fuels by the households. The older the household's head the lesser the adoption of cleaned energy respectively. In the same vein, Mensah and Adu (2013) found that age of the household head, impact negatively on the adoption of more cleaned energy. The higher the age of the household head, the lower the probability of adopting cleaner energy, which is in line with the findings and conclusions of Nlom and Karimove (2014). On the contrary, Ozcan *et al*. (2013) concluded that age of the household's head has a positive relationship with the adoption of natural gas and liquid fuel instead of firewood; and it is negatively related to the adoption of dung and plant residue for firewood respectively.

Level of Education: Level of education of the household head has a positive relationship with the adoption of cleaned energy. The higher educated is the household head, the more he realises the negative impact of un-cleaned energy and therefore the less it will be adopted. This assertion was found to be true by previous studies (Nlom & Karimove, 2014; Eakins, 2013; Mensah & Audu, 2013; Ozcan *et al*., 2013; Laureti & Secondi, 2012). A study by Oyekale *et al*. (2012) in Oluyole local government area, Oyo state, using probit model indicated that the higher the households' heads' levels of education, the lower the probability of adopting firewood by the households. Furthermore, Nnaji *et al*. (2012) analysed determinants of household energy choice in rural areas of Enugu state using multinomial logit model. The study shows that the level of education of the household head encourages the household to adopt more charcoal at the expense of firewood use. Similarly, Maryam (2011) employs the use of multinomial logit model to analyse the factors influencing households' energy choice in Gombe state Nigeria. The study asserted that the housewife education level and higher level of education of the household head are associated with the adoption of kerosene instead of firewood.

Moreover, Eakins (2013) conducted a study to assess the determinants of household energy expenditure in Irish. Six different OLS models were estimated to capture the households' expenditure from various sources. The results of the analysis indicated that higher level of education leads to decrease in household energy expenditure from coal and turf. Lee (2013) concluded that level of education has a negative impact on the electricity consumption of households and that the higher the level of education of the household head, the higher the odd of adopting electricity source of energy instead of kerosene. Furthermore, the three different Tobit models to analyse the consumption of kerosene, charcoal and firewood by households shows that higher level of education is associated with higher use of all the three energy sources.

Osiolo (2010) used OLS regression to estimate the determinants of household fuel wood expenditure in Kenya. The study found that a household that has a head with only primary education tend to consume more firewood than otherwise.

Pundo and Fraser (2006) found that education level of both the husband and wife encourages households to adopt more energy source from charcoal instead of firewood. Meanwhile, Heltberg (2003) found that higher level of education encourages households to adopt more non solid fuels. Abebaw (2007) conducted a study to examine the determinants of household fuel-wood using in Jimma town, Ethiopia. The study found that level of education of the household's head exact negative impact on fuel wood consumption. Moreover, Heltberg (2005) found that level of education of households' head encourage households to adopt LPG alone than the combination of wood and LPG in both urban and rural areas.

Furthermore, Mekonnen and Kohlin (2008) in line with Heltberg (2005) concluded that level of education of the households' head encourages household to adopt less of solid and mixed of solid and non solid fuels, and encourages them to adopt non solid fuels. Additionally, a multinomial logit analysis by Braun (2009) indicated that higher education of the household's head is associated with the adoption of more gas and less solid fuel and electricity. Suliman (2010) conducted a study on the factors affecting the choice of households' primary cooking fuel in Sudan. This study concluded that education levels at both primary and post primary levels encourage households to adopt cleaner energy (LPG, biogas, kerosene and charcoal). In the same vein, Laureti and Secondi (2012) in conformity with Braun (2009), concluded that the household that have a head who studied up to a degree level adopts more electricity and less LPG or coal-wood when compared with household where the head has diploma as the highest school level attended. Nlom and Karimove (2014), Mensah and Adu (2013) used ordered probit model to analyse the determinants of household energy switching from non cleaned source to the highest possible cleaned source, mainly based on the assumption that the various energy choices available to households are in ordered manner. Both studies find that the level of education of the household head encourages households switching to cleaner energy.

Household Size: The number of a household's members (i.e household size) affects the household's energy consumption decision, the larger the size of a household, the lesser the cleaned energy to be adopted. This assertion is supported by previous studies (Ozcan *et al*., 2013; Mensah & Audu, 2013; Suliman, 2010; Heltberg, 2005). Onoja (2012) used two stages least square method to analyse factors influencing fuel-wood demand in Kogi state, Nigeria. The findings indicated that household size is positively related to the consumption of firewood. Furthermore, Nnaji *et al*. (2012) shows that household size discourages the adoption of charcoal or kerosene in favour of firewood use. The higher the size of the household, the higher the odd of adopting firewood

Similarly, Maryam (2011) employed the use of multinomial logit model to analyse the factors influencing households' energy choice in Gombe State Nigeria. The study asserted that the size of the household encourages the adoption of less kerosene or gas in favour of the adoption of fire wood respectively.

Lee (2013) used OLS to conduct a study on the relationship between households' characteristics and the consumption of electricity. Household size was found to have positive significant impact on households' electricity consumption. Using the same OLS regression, Petersen (1982) conducted a study to investigate the determinants of variation in households' electricity usage. The study concluded that family size, have significant positive impact on household electricity usage. Sardianou (2007) estimated the determinants of household energy conservation patterns of Greece Households. The OLS result indicated that households' size have positive impact on households' energy conservation behaviour. Furthermore, Abrahamse and Steg (2009) conducted a study with the major aim of estimating the determinants of households' total energy use. The result indicated that total households' energy use increase with increase in households' size.

Eakins (2013) used logit model to estimate households' fuel adoption between gas and electricity in Irish. The study established that number of adults in the home encourages households to adopt gas instead of electricity. Similarly, Link et al. (2011) used the same logit model to analyse the determinants of households' adoption of firewood. Number of adults in the household increases the probability of households to adopt firewood source of energy than otherwise. Heltberg (2003) found that household size encourages households to adopt more non solid fuels.

Similarly, some studies (Abebaw, 2007; Jiangchao & Kotani, 2011; Song *et al.*, 2012; Eakins, 2013) used Tobit model to analyse the impacts of households' sizes on their energy consumption. For instance, Abebaw (2007) found that as household size increases, the intensity of fuel wood consumption decreases. On the contrary side similar analysis by Song *et al*. (2012) indicated that the size of household have positive significant influence on household wood consumption. Moreover, Jiangchao and Kotani (2011) analysed the determinants of households' energy use from different sources (coal, electricity, LPG, fuel wood and crop residue). The results indicated that the size of household exacts negative impact on households' energy consumption from all the five sources of energy use. Eakins (2013) found that number of children below 18 years in the household increases the households' consumption of gas.

Other studies (Hosier & Dowd, 1987; Heltberg, 2005; Mekonnen & Kohlin, 2008; Braun, 2009; Suliman, 2010; Couture *et al*., 2012; Ozcan *et al*., 2013) used multinomial logit model to analyse the impact of household size on their fuel switching. Hosier and Dowd (1987) conducted an empirical test of energy ladder hypothesis in Zimbabwe. The results indicated that increase in the number of households' size leads to increase in consumption of kerosene in relation to wood energy. Moreover, Heltberg (2005) found that households' sizes have negative impact on the adoption of only LPG in both rural and urban areas. As the sizes of households increase, households tend to adopt less of only LPG and more of joint wood and LPG.

However, Mekonnen and Kohlin (2008) contrary to Hosier and Dowd (1987), this study found that as the households' size increases, households adopt more of solid fuels than non solid fuels, or more of mixed solid and non solid than the pure non solid fuel respectively. Similarly, Braun (2009) indicated that as the number of households' members increases, the households increase the use of solid fuels and reduce the use of gas and electricity. Furthermore, higher education of the household's head is associated with the adoption of more gas and less solid fuel and electricity. Suliman (2010) conducted a study on the factors affecting the choice of households' primary cooking fuel in Sudan. This study concluded that household's size was found to have negative relationship with the adoption of cleaner cooking fuels by the households. The higher the size of the households the lesser the odd of adopting cleaned energy.

Similarly, Couture *et al*. (2012) asserted that household's size have a positive relationship with the adoption of wood. The larger the number of household sizes, the more likely the household adopts wood as the major source of energy. In the same vein, Ozcan *et al*. (2013) concluded that the larger the size of the household, the less the household adopt modern energy for firewood and the more it adopts the use of dung and plant residue. Mensah and Adu (2013) used ordered probit model to analyse the determinants of household energy switching from non cleaned source to the highest possible cleaned source, mainly based on the assumption that the various energy choices available to households are in ordered manner. The study found that household's size, impact negatively on the adoption of cleaner energy.

3.4.3 House Characteristics

The characteristics of the building in which the households live can affect their energy choice behaviour. Factors such as; location of the house, the size of the residence, number of rooms in the house and share of dwellings (i.e. more than one households living in the same building), have significant influence on households energy consumption.

Location: The location of the home in which the households live have serious impact on their energy consumption decision. The households that are located in urban areas tend to adopt cleaner energy than their rural counterparts. This was proved to be true by some previous studies such as Eakins (2013), Ozcan et al. (2013) and Mensah and Audu (2013). Eakins (2013) conducted a study to assess the determinants of household energy expenditure in Irish. Six different OLS models were estimated to capture the households' expenditure from various sources. One of the findings of the analysis indicated that location factor has positive significant influence on household expenditure on gas, oil and LPG. Other categories of studies (Hosier and Dowd, 1987; Osiolo, 2010; Suliman, 2010; Ozcan *et al*., 2013) analysed the impact of location factor on household fuel switching using multinomial logit model.

For instance, Hosier and Dowd (1987) conducted an empirical test of energy ladder hypothesis in Zimbabwe. The results indicated that households living in urban area tend to use more kerosene or electricity in relation to wood and/or chose electricity other than kerosene. Similarly, Osiolo (2010) found that households living in rural areas tend to adopt less of kerosene and LPG and more of firewood. Suliman (2010) conducted a study on the factors affecting the choice of households' primary cooking fuel in Sudan. The study concluded that the location area in which household live, exacts significant influence on their choice for cooking fuels. Households living in urban areas adopt cleaner fuels than their rural counterpart. This is in line with the findings of Ozcan *et al*. (2013) whereby they concluded that households living in urban areas tend to adopt the modern energy sources instead of firewood.

Home Size: The size of the residence in which households live influences their energy consumption behaviour. Previous studies such as Couture *et al*. (2012) found that the larger the size of the building, the higher the adoption of fuel wood. A Tobit analysis by Song *et al*. (2012) indicated that size of the house in which the household lives have significant influence on wood consumption by US households. Similarly, Laureti and Secondi (2012) concluded that the larger the sizes of the home, the more households adopt oil and coal-wood and the less they adopt LPG and electricity. On the contrary, Tchereni (2013) found that there is a positive relationship between the home size and the adoption of electricity and charcoal sources of energy. The higher the size of the home in which the household lives, the higher the probability of adopting electricity and charcoal. Additionally, Danlami *et al*. (2016) found that adoption of cleaned source of fuel is positively related to the size of home in which the household lives. The higher the size of the home, the higher the odd of adopting cleaned source of fuel.

Number of Rooms: The number of rooms in the house is one of the building characteristics which influence households' energy consumption choice. Eakins (2013) conducted a study to assess the determinants of household energy expenditure in Irish. The study indicated that number of rooms in the house is positively related to household expenditure on energy from gas, electricity and oil respectively. Furthermore, a logit analysis by Eakins (2013) to estimate households' fuel adoption between gas and electricity in Irish established that number of rooms in the home encourages households to adopt gas instead of electricity. Louw *et al*. (2008) conluded that number of rooms has significant impact in increasing the households' electricity use. Moreover, Heltberg (2005) found that high number of rooms in the home tends to encourage the adoption of only LPG than the joint wood and LPG in urban areas. Meanwhile, Couture *et al*. (2012) established that where the dwelling has more than five rooms, the households tend to adopt more wood and less of gas as the major source of energy. Meanwhile, Danlami *et al*. (2016) asserted that the higher the number of rooms, the higher the odd of adopting cleaned source of fuel.

Share of Dwellings: Share of dwellings (i.e. more than one household living in the same building) is one of the factors which also shape the energy consumption behaviour of households. Couture *et al*. (2012) found that this factor has a positive relationship with the adoption of cleaned energy. Similarly, Mensah and Audu (2013) concluded that households that share dwelling with other households tend to adopt cleaner energy.

3.4.4 Exogenous (Supply) Factor

Another important category of factor that influences fuel choice is the exogenous factor. ThIs factor lies outside the domain of households but has significant impact on the household fuel choice. For instance, availability of a particular energy source can affect household behaviour of energy consumption.

Availability of Energy Source (Supply): Households often choose energy source that is available, cheaper and nearer for consumption purposes. Empirically, Mensah and Adu (2013) found a positive relationship between household energy consumption and the availability of the concerned energy. Reliable supply of LPG increases the probability of adopting cleaner energy while, access to firewood decreases the probability of moving towards the use of cleaner energy. That is why

Heltberg (2005) argued that as households have access to cheap electricity, the consumption of traditional biomass as the major fuel choice decreases.

In the same vein, Abdurrazak *et al*. (2012) found that over the years, households keep on increasing their consumption of biomass fuel because of availability and cheapness. Onoja (2012) used two stages least square method to analyse factors influencing fuel-wood demand in Kogi state, Nigeria. The findings indicated that whe the source of firewood is far away from the households, the household consumption of firewood tend to decrease. Similarly, a logit model analysis by Link *et al*. (2011) indicated that the availability and nearness to the source of firewood increases the probability of households to adopt firewood source of energy than otherwise. Furthermore, Heltberg (2003) found that households that have electricity tend to use more non solid fuel than otherwise. Moreover, a probit analysis by Osiolo (2010) showed that a short distance to wood-fuel sources have positive impact on wood fuel consumption in rural areas due to absence of alternatives to wood-fuel energy. Moreover, households that are connected to electricity have lower odd of adopting traditional fuel sources.

3.4.5 Empirical Review of Studies on Relative Income Hypothesis (RIH)

In the year 1949, Duesenberry came up with the theory of relative income hypothesis which was an alternative to the Keynes's absolute income hypothesis. According to the theory of relative income hypothesis, consumption behaviour of households does not depend solely on their absolute income but also relatively on other peoples' income and consumption behaviour. Households try to maintain their consumption pattern in such away to meet the average consumption standard of their community.

That is they try to keep up with Jonneses. According to Kosicki (1987) despite that the policy implication of the theory of relative income hypothesis appears to be apparent, it has been seldom analyse empirically.

However, many studies try to conduct an empirical test of the theory of relative income hypothesis in different aspect of consumption behaviour of individuals and households. Such as in household saving behaviour (Kosicki, 1987), individual health and mortality (Mangyo & Park, 2011; Lindley & Lorgelly, 2005; Gerdtham & Johannesson, 2004), household commodity consumption (Khan, 2014), individual performance on the work place and job satisfaction (Card *et al*., 2012; Torgler *et al*., 2006), depression (Hounkpatin, *et al*., 2014; Cuadrado & Long, 2011), life satisfaction and wellbeing (Brown *et al*., 2015; Senik, 2008; Carbonell, 2005; Senik, 2003; Mcbride, 2001; Clark & Oswald, 1996).

Brown *et al*. (2015) confirmed that the argument of relative income hypothesis is relevant in explaining life satisfaction and that the life satisfaction decreases as the relative income increases. In the same vein, Clark and Oswald (1996) concluded that the satisfaction of workers has an inverse relationship with their comparison wage rates. However, contrary to these assertions, Senik (2003) finds that the income of the reference group exerts a direct positive influence on individual satisfaction. Moreover, Carbonell (2005) conducted a study with the view to empirically analyse the significance of comparison income for individual happiness and wellbeing. The conclusion was that the reference group income is almost as important as the own income for happiness and wellbeing of individual. Furthermore, the empirical test of the relative income hypothesis by Senik (2003) indicated that the average income in an individual's occupational group influences negatively his subjective wellbeing in the old European countries, whereas in post transition economies, this correlation is positive.

Additionally, Kosicki (1987) conducted a study with the main aim of carrying out an empirical test of relative income hypothesis. The result strongly supports the hypothesis that rank has a significant impact of determining the rate of savings. Further analysis of the study indicated that the rank has a significant impact on savings rate even after allowing for the effect of differences in the level of permanent income. Gerdtham and Johannesson (2004) conducted an empirical test of relative income hypothesis in relation to mortality. They concluded that the relative income hypothesis is not relevant. Lindley and Lorgelly (2005) conducted an empirical test of relative income hypothesis in relation to self reported health of individual with a view to determine its validity over time. The conclusion was that there is absence of significant association between the self reported health and the measures of inequality and therefore the relative income hypothesis does not exist over time and does not exist within Britain.

Contrarily, study by Mangyo and Park (2011) indicated the validity of the relative income hypothesis in relation to the individual self deprivation and health. Furthermore, empirical test of consumption function under the argument of the relative income hypothesis by Khan (2014) in Northern Pakistan validated the argument of relative income hypothesis. The study concluded that farm households' consumption expenditure is not only influenced by their disposable income but also by the consumption pattern of other households. In addition, other studies such as

Card *et al*. (2012); Torgler *et al*. (2006) tested the applicability of relative income hypothesis to individual performance on the work place and job satisfaction. They found the validity of the concept of relative income hypothesis in relation to performance in the work place and job satisfaction.

However, though the studies that conducted the empirical test of relative income hypothesis used different aspect of individual and household life (as indicated earlier), they did not specifically test the relevance of this theory to household energy choice and consumption despite its policy relevant to household energy choice and consumption. Therefore, this study serves as an additional contribution to such literature by conducting an empirical test of the relative income hypothesis in relation to household energy choice and consumption which is one of the aspects of household living.
Figure 3.1 indicates the determinants of household energy choice and consumption behaviour.

Figure 3.1 shows how the interaction of some factors, influences households' energy choice and the implication of such energy choice decision by the households on the environment. The Figure indicates that there are five major categories of factors (i.e. economic, socio-demographic, home characteristics, attitudinal and environmental factors) that work together to influence fuel choice decisions by households. Under each of these factors, there are sub factors combined together to make a major factor. The household fuel choice decision can appear in the form of choosing either cleaned or non cleaned energy. Increase in the adoption of cleaned energy has a positive impact on the environment which in turn improves the average societal welfare.

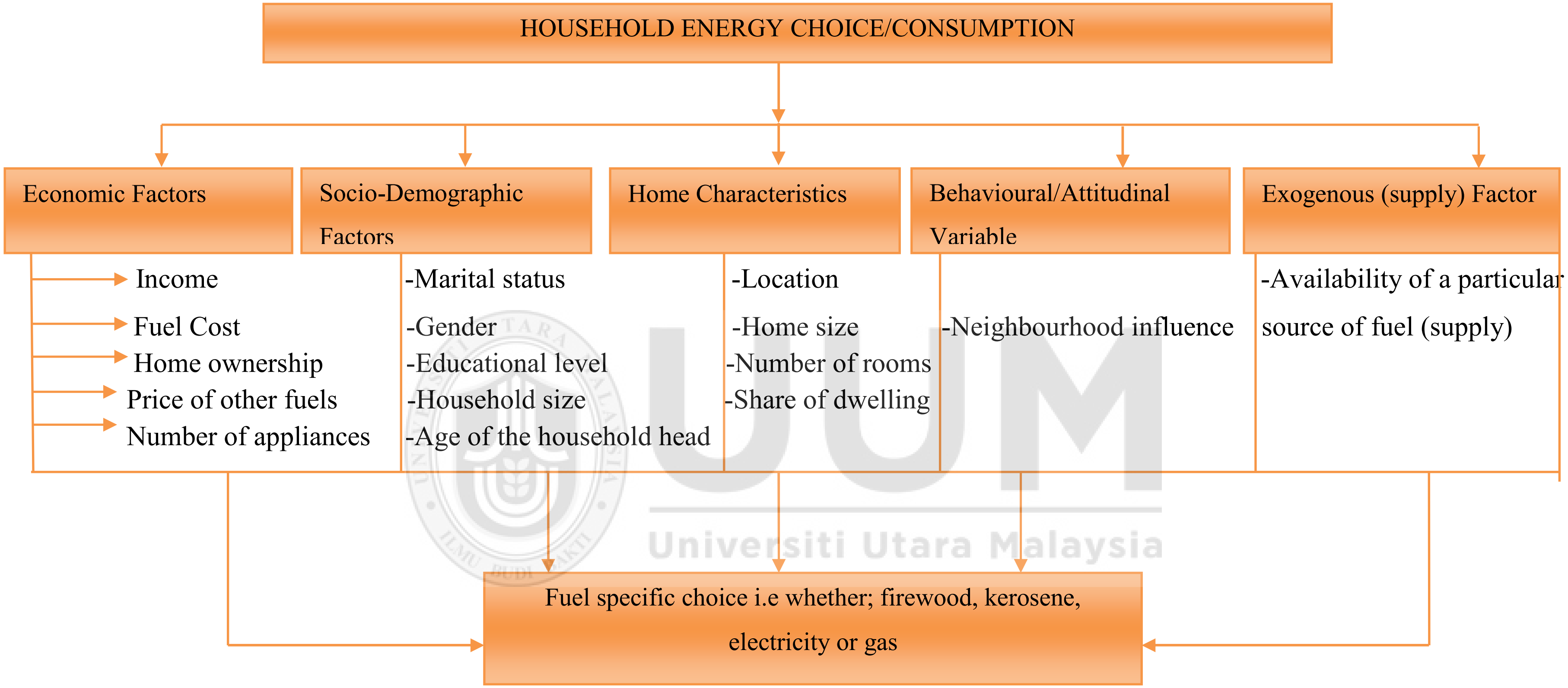

Figure 3.1
Theoretical Framework

On the other hand, adoption of non cleaned energy has a negative impact on the environment which in turn contributes to the decline in the average welfare of the people. Therefore, the main target of every energy policy is devising means of influencing such factors that determine households' energy choice decision in such a way as to push households towards the adoption of cleaner energy source for the whole societal welfare improvement.

3.5 Literature Gap

Though there are many empirical studies on household energy use and consumption conducted in different areas both in developed and developing countries, there are some identified gaps and limitations. For instance some studies on household energy consumption (e.g., Austin, 2011; Wang *et al*., 2011; Svoboda & Br, 2013; Pourazarm & Cooray, 2013; Inglesi-lotz & Blignaut, 2011; Reiss & White, 2014; Ziramba & Kavezeri, 2012) focused only on electricity aspect of household energy consumption, thereby neglecting other aspects; like consumption of fuel wood and other fuels, like households' consumption of kerosene, as well as LPG as a source of household energy consumption. In addition, some studies (Jumbe, & Angelsen, 2010; Naibbi & Healey, 2013; Onoja & Emodi, 2011; Amacher & Hyde, 1996; Arnold *et al*., 2005) focus only on fuel wood analysis as a source of house hold energy neglecting other aspects like; kerosene, electricity and gas.

Furthermore, some studies like that of Michael, Gallini *et al*. (2001), Verhallen and Raaij (1981), and Schmalensee and Stoker (1999) focused only their analyses on household consumption and use of LPG, neglecting other energy sources, like; fuel wood, kerosene and electricity. On the other hand, Laureti and Secondi (2012), Braun (2009) Hanemann *et al*. (2013) focused their study only on space heating, which is only one dimension of household energy consumption. These showed that most of the previous studies on household energy use, in both developed and developing countries are specific in scope, covering some aspects and dimensions of household energy demand while neglecting others as highlighted above.

Furthermore, there exist inconsistencies as per the findings and conclusions of previous studies on household energy use. For instance some studies (Oyekale *et al*., 2012; Lee, 2013; Nlom & Karimove, 2014) found that income has a positive significant relationship with household use of firewood. On the other hand, some studies such as; Mekonon and Kohlin (2008), Onoja (2012) and Song *et al*. (2012) found the relationship to be negative. While, Couture *et al*. (2011) and Jingchao and Kotani (2011) concluded that there is no any significant relationship between income and household firewood consumption. This indicates that the results and findings from one study from a particular area cannot be generalised to another area due to socio-economic, cultural and environmental differences. Therefore, studying household energy consumption in a new area is an additional contribution to the existing literature.

Additionally, variables like; age of the household head, level of education of the household head, household size, size of the dwellings among others; were concluded to be positively related to household fire wood consumption by studies like Nnaji et al. (2012), Ganchimeg and Havrland (2011) and Onoja (2012). While, Song *et al*.

(2012), Heltberg (2005) and Jingchao and Kotani (2011) found these relationships to be negative. Moreover, some studies such as Jumbe and Angelsen (2010) and Laureti and Secondi (2012) concluded that there is no significant relationship that exists between these variables and household fuel-wood consumption. So also applied to other sources of household energy such as kerosene, electricity and LPG, whereby some studies (Fan & Hyndman, 2010; Souza *et al*., 2009) concluded positive relationship, some studies like; Petersen (2002) Westly (1989) and Helden *et al*. (2001) found negative relationship and others such as; Ward (2001) and Terza (2001) found no relationship. This notifies that, results and findings of households' energy use studies carried out in one area, cannot be concluded and/or generalised to other different areas, due to heterogeneity in the pattern and styles of household energy consumption from one area to another. Hence, a study on household energy use taking new area under a consideration is an additional contribution to the existing literature.

Additionally, most of the previous studies did not consider the lighting source of household energy from different sources as obtainable in some developing countries (with the notable exception of study by Ogwumike *et al*. (2014) whereby they considered two dimensions; electricity and kerosene). Because in most of the developing countries, households lighting sources can be categorised into traditional (such as; firewood and traditional lamp i.e kerosene), semi electricity (i.e. like; hand torch lights, rechargeable lanterns, and batteries) and electricity however these dimensions was not considered by the previous studies of household energy consumption.

Furthermore, in economic theory of consumption, it is known that consumption of individuals is relatively determined, that is, it is influenced by the consumption behaviour of their immediate neighbour (Relative Income Hypothesis, (RIH)). According to RIH, households' consumption behaviour or function does not depend only on its current income but also relatively on the consumption behaviour of other neighbouring households. i.e. households are concerned about their community consumption standards and tend to make their consumption pattern on average based on the community's consumption behaviour. Therefore, for consumption behaviour, there is an interdependent between a household's consumption behaviour and that of its immediate neighbour. Likewise energy consumption behaviour of a particular household may be influenced by that of its immediate neighbour. However, despite that this conclusion may be very useful for policy making; previous studies on household energy use did not incorporate such hypothesis (in relation to household energy consumption) into their analysis.

Additionally, though there are some previous studies (Eakins, 2013; Lee, 2013; Couture *et al*., 2012; Osiolo, 2010; Mekonnen & Kohlin, 2009) that applied wider econometric techniques to analyse household energy choice outside the Nigerian context, none of the studies conducted within the context of Nigeria has wider econometric application. Most of the studies within the Nigerian context such as

Abdurrazak *et al*. (2012), Desalu *et al*. (2012), Nnaji *et al*. (2012), Onoja (2012) Oyekale *et al*. (2012) and Maryam (2011) are limited to descriptive analysis or estimated only one model to analyse household cooking fuel choice for some specific areas. Therefore, a study on household energy demand which employs various different econometric models is an additional contribution to the existing literature in the area.

In a nutshell, this study contributed to the existing literature in the following ways; firstly, this study is the first study that used household micro data in Bauchi State, Nigeria not only to analyse households' energy choice and demand, but also with wider application of econometric models, which made the study to have a unique pattern relative to the few existing relevant studies in the whole country (Nigeria). Secondly, the study further exceeded the scope of most of the previous researches by covering multiple aspects of household energy consumption (such as the aspects of cooking fuel and lighting fuel choices, the consumption of firewood, kerosene and electricity) taking Bauchi State, as the area of the study. Thirdly, the study estimated comprehensive variables that have not been jointly studied together. This includes testing for relative income hypothesis in relation to household energy use. Furthermore, an interaction variable was created to ascertain the impact of neighbourhood energy choice via the household environment. Lastly, the analysis of the lighting source of energy was considered from three dimensions (i.e electric, semi-electric and traditional sources of lighting) which most of the previous studies overlooked (with the exception of study by Ogwumike *et al*., 2014 in which they considered only two dimensions).

3.6 Review of Theories on Household Energy Choice and Consumption

This section reviews the various theories and models that explain household behaviour in terms of energy consumption, switching and decision. The various theories discussed are; Energy ladder hypothesis, Energy stacking model, theory of rational choice behaviour and household production theory. These theories and models provide a basis for understanding households' behaviour regarding their energy consumption and choice.

3.6.1 Energy Ladder Hypothesis

The Energy Ladder Hypothesis (ELH) was developed to explain how households switch to an alternative cleaner energy. According to ELH, as household income increases, the household tend to switch to cleaner energy automatically in response to the change of its economic status (i.e. income). This theory asserts that households are faced with three stages of fuel switching processes. In the first stage, there is a general use of traditional fuels such as plant residues, animal dung and firewood. In response to increase in income, the households tend to switch to the next ladder of energy sources known as transitional fuels such as charcoal, coal and kerosene. On the other hand, the last stage is characterised by the households' adoption of LPG and electricity. Therefore, the ELH is based on two major assumptions. Firstly, that the households' fuel switching is solely a function of income. Secondly, that the various energy sources alternatives are in an ordered ranked manner. Figure 3.2 illustrates the basic ideology of ELH.

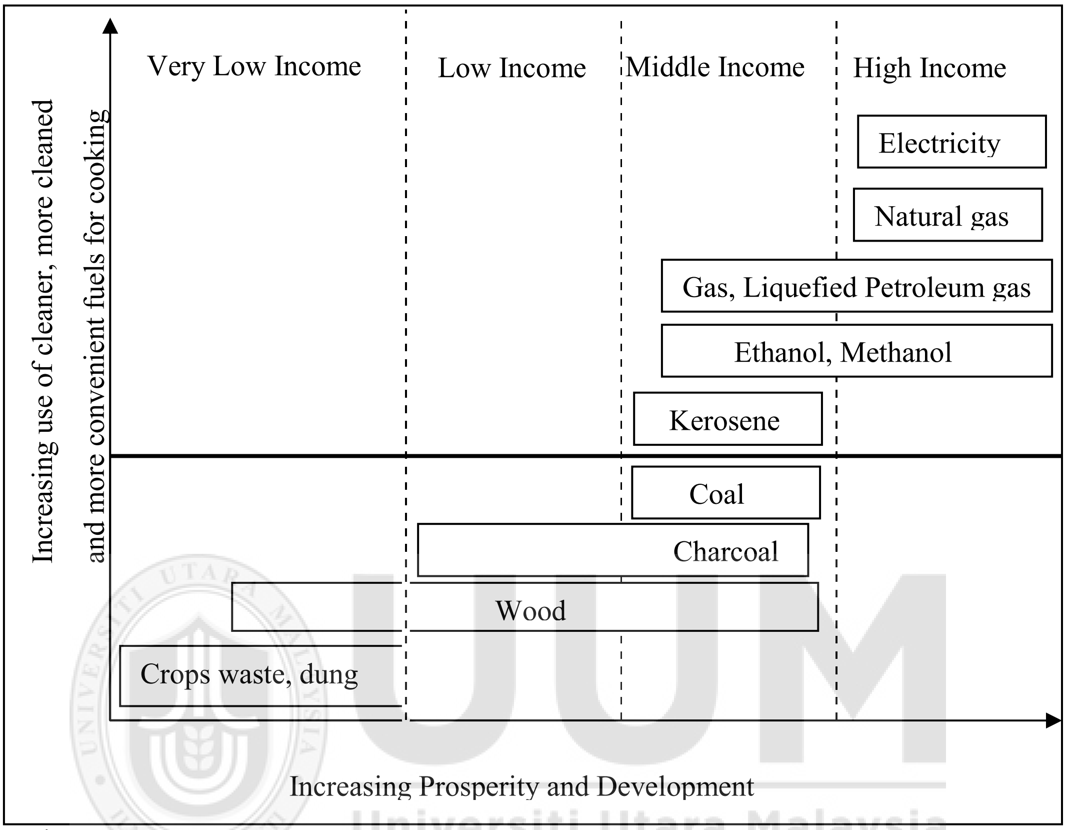

Figure 3.2
The Energy Ladder Model
Source: Maryam (2011)

Figure 3.2 shows the stages of household energy switching based on the household income categories. At a low income level, the energy is sourced from solid fuels like crop waste, dung and wood. After the income rises to the middle level, the household switch to transitional fuel source like charcoal and kerosene. Furthermore, at the high income level, the energy consumption switched to the more cleaned energy sources like LPG and electricity. The main achievement of ELH is its ability to relate household fuel switching to a very important determinant of household energy choice, which is income.

However, the ELH has been criticised on the following grounds. Firstly, the assumption of household fuel switching to depend solely on income is nullified. Some studies such as; Heltberg (2004) and Leiwen and O'Neill (2003) have shown that there are other socio-economic and residential factors that are equally important as income as per as household energy fuel switching is concerned. Secondly, the assumption that the various categories of household's energy sources are in a ranked order, is not realistic. Lastly, evidences have shown that households instead of completely switching to other source of energy prefer multiple sources of energy at a time than completed abandoning the previous energy source.

3.6.2 Energy Stacking Model

In response to the energy ladder's household's unidirectional fuel switching, some studies such as Heltberg (2004), Leiwen and O'Neill (2003) and Masera *et al*. (2000) have shown that household's fuel switching is not a complete adoption of new and/or abandoning of fuel sources but rather, a partial switching process. That is, households prefer to adopt a combination of multiple energy sources depending on their needs, preference and budget. This is because the various energy sources are not perfect substitutes to one another, but sometimes one is preferred over another due to a particular specific reason.

Therefore, though households may choose cleaner energy as its socio-economic status improves, that does not implies a complete abandonment of traditional fuels. Hence this model is based on the assumption of household fuel source accumulation. Various empirical studies conducted in different areas proof the assertion of energy stacking by households. For instance, studies conducted in; China; by Leiwen and O'Neil (2003), Mexico; by Masera *et al*. (2000), Ghana; and Nepal; by Heltberg (2004) have shown that the change of fuel sources by households can be characterised as 'accumulation of energy alternatives.' Figure 3.3 explains the basic idea of Energy Stacking Model (ESM)

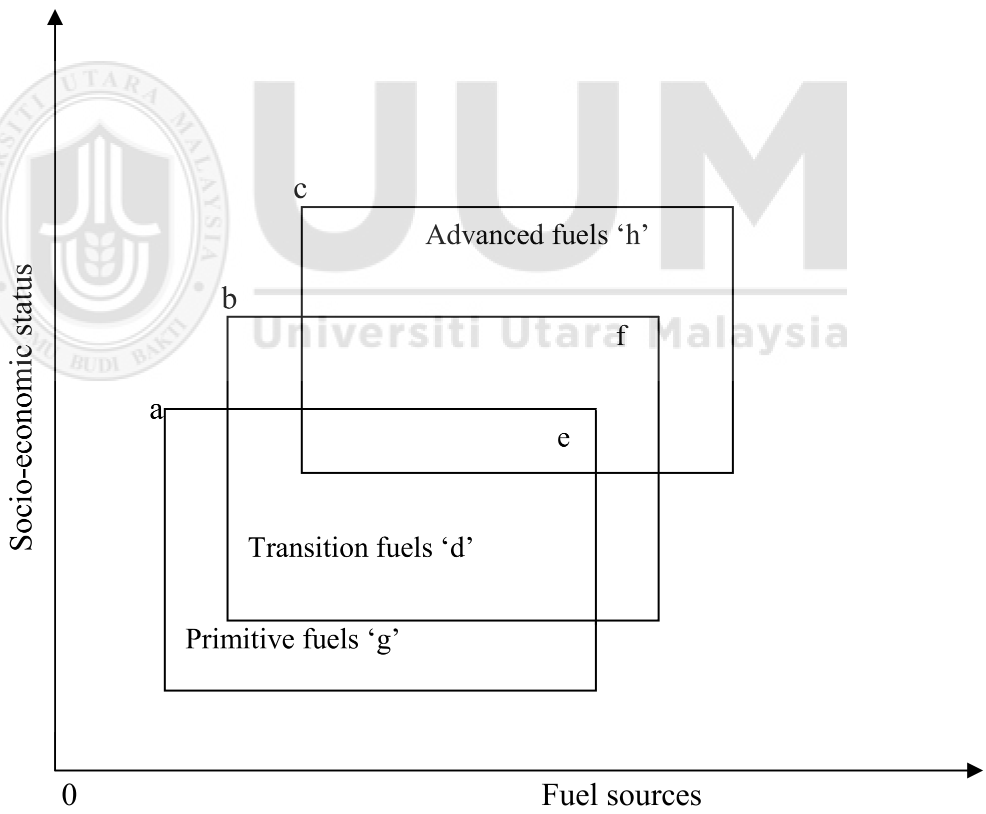

Figure 3.3
Energy Stacking Model
Source: Risseeuw (2012)

Figure 3.3 constitutes the basic ideology of ESM. It shows the relationship between the various energy sources and the socio-economic status of households. The three quadrants a, b and c represent the various fuel sources namely; primitive, transitional and advance fuels respectively. As can be seen from Figure 3.3 as households move to higher socio-economic status, they tend to adopt less traditional fuels and more of advanced fuels. But this does not implies complete abandonment of the former or the complete adoption of the later, rather an accumulation of fuel sources as in point d.

Furthermore, as indicated by points d, e and f, at point d, households adopt both traditional and transitional fuels respectively. Point 'e' indicates that households adopt energy fuels from all the three sources (i.e. primitive, transitional and advance fuel). At point 'f' the households are characterised by the adoption of both the advance and transitional fuel sources. This model is regarded as more superior to ELH because, it provides more comprehensive and realistic explanation of household energy choice than the ELH. However, the model is criticised because at the two extreme points (i.e. very low and very high economic status) the conclusion tends to be the same with that of ELH as indicated by points g and h, whereby the household energy use is characterised either by a sole use of primitive fuels (i.e. point 'g') or by a sole use of modern advance fuel (i.e. point 'h').

3.6.3 Household Production Theory

Household energy demand is a derived demand because energy is consumed by households not for direct satisfaction but for the purpose of producing other goods and services. Such as cooking food, home lighting, space heating, water boiling, soft drinks and cooling. According to household production theory, households buy commodities from the market which serve as raw input materials to produce other goods at home that appear as a component of the household's utility function. In other words, the households' utility function in addition to other factors constitutes of two components of commodities. The first component good is the purchased good which directly yields utility. The second component is other goods that serve as energy for producing home produced goods and services. Therefore, equation (3.1) constitutes a typical utility function of a household.

$$U = U(S(E, CS), X; D, G) \tag{3.1}$$

where: U = utility

S = the composite energy commodity

E = the relevant energy sources, like electricity and others.

CS = the stock of home appliances through which the purchased energy is consumed

X = a purchased commodity from the market that directly gives utility (i.e. directly consumed by the household).

D = the households' demographic characteristics

G = the geographic characteristics that have influence on household's preferences.

Given this framework, the households' decision involves a two-step process. At stage one, the household acts like a firm and the targeted goal is to minimise costs of producing S. in the second step, the household tries to maximise Utility, U.

3.6.4 Theory of Rational Choice Behaviour

This theory was developed by neoclassical economists to explain the decision behaviour of individuals. According to Rational Choice Behaviour, individuals are always rational that before taking a particular consumption decision, they weigh, measure compare and contrast the expected benefits and the cost of taking a particular decision. The main aim is to maximise utility and or satisfaction, and such utility can be maximised only by choosing the option that maximises the difference between the expected benefits and costs of undertaking a particular behaviour.

The Rational Choice Behaviour Theory is based on the assumptions that individuals have perfect knowledge about the market conditions and also individuals are rational enough to choose a combination of actions that have a minimum possible costs and maximum attainable satisfaction. Therefore, based on the rational choice behaviour, households tend to choose a particular energy source available that can give its maximum attainable level of satisfaction with the minimum possible cost. Equation (3.2) expresses the basic idea of rational choice behaviour.

$$J = \{a_1, a_2, a_3, a_4, \dots \dots \dots a_j.\} \tag{3.2}$$

Where: J is a bundle of energy choice decision containing different individual sources or combination of sources of household energy. While, $a_1, a_2, a_3, a_4, \dots \dots \dots a_j$. are the various energy sources available such as animal dung, plant residue, firewood, coal charcoal, kerosene, electricity and gas.

Given perfect information and available resources, a household choose one or more of these energy sources available that is believed to provide highest maximum satisfaction. According to Martiskairen (2007), Rational Choice Behaviour theory was used widely in 1970's energy conservation research.

However, this theory is criticised in many ways including the fact that the theory limits determinants of individuals' decision to only economic factors neglecting other factors like moral behaviours, emotions, social norms and habits. Also, the theory cannot provide explanation in the absence of perfect information which is the case of real life situation.

3.7 Conclusion

This chapter reviews the empirical and theoretical literature on household energy use. It was shown that different factors were proved to play roles as per shaping the energy consumption choice of households. Moreover, the chapter gives the highlight on the gaps identified from the reviewed literature on household energy consumption. Lastly, this chapter presents the theoretical review of the study.

CHAPTER FOUR

RESEARCH METHODOLOGY

4.1 Introduction

This chapter examines theoretical framework of the study, population of the study, sample size and the sampling techniques, method used in data collection, the tools of data analysis used for achieving the stated objectives of the study, the justification of variables used in the various models as well as the analysis of the pilot study,.

4.2 Theoretical Framework of the Study

This section examines the various theories and models that explain household behaviour in terms of energy consumption, switching and decision. These are the theories that serve as the framework of this study. The various theories discussed here include; theory of random utility, traditional demand theory and the relative income hypothesis. These theories and models provide a basis for understanding households' behaviour regarding their energy consumption and choice.

4.2.1 The Random Utility Theory

The Random Utility Theory of Consumption has its roots from the thinking of the early 20th century economists like Alfred Marshal and Hicks (Albarran, 2010). Utility refers to the satisfaction, pleasure and or benefits derived from the consumption or use of a particular product or service. According to the utility theory, given a household's budget constraints, the household chooses the consumption of bundles of commodities that maximise its utility. Consumers are assumed to behave in a rational manner and have preferences that are consistent, invariants, known and ordered. The following function represents a typical utility function of a household.

$$U = u\left(S\left(E, CS\right), X, D, G\right) \qquad (4.1)$$

where:

S = the composite energy commodity

E = the relevant energy sources such as; fuel-wood, kerosene, electricity, gas, petroleum and diesel

CS = the capital stock energy use appliances

X = the purchased goods that directly yield satisfaction

D and G are demographical and geographical features of households that influence the households' preferences. Many previous studies on household energy choice such as Jumbe and Angelsen (2010), Suliman (2010), Louw *et al*. (2008), Wilson and Dowlatabadi (2007) based this theory as a framework of their analysis.

Given the household budget function:

$$Y = P_1 X_1 + P_2 X_2 + \ldots + P_n X_n \qquad (4.2)$$

where Y is the households' given income.

$P_1, P_2 \ldots \ldots \ldots \ldots\ P_n$, are the various prices of the relevant commodities.

X_1, X_2, …, X_n are the quantity of commodities to be consumed.

However, by concentrating on only household energy consumption and choice, the modified households' utility function and the corresponding budget constraints can be expressed as:

$$U = u\left(ES\left(E_1, E_2, \ldots\ldots\ldots E_n, CS\right), D, G\right) \tag{4.3}$$

$$s.t.\ Y \leq P_1E_1 + P_2E_2 \ldots\ldots\ldots + P_nE_n \tag{4.4}$$

where: U, D, CS and G are as known before.

ES= expressed composite energy consumption function

E_1= energy source for option 1

E_2= energy source for option 2

E_n= energy source for option n

In order to maximise household utility from energy consumption, the following Lagrangian multiplier function is assumed as follows:

$$L = U\left(ES\left(E_1, E_2, \ldots\ldots\ldots C_n, C_s\right) D; G\right) + \lambda\left(Y - P_1E_1 - P_2E_2 \ldots\ldots\ldots P_nE_n\right) \tag{4.5}$$

The first order condition for utility maximisation from the Lagrangian function could enable the Marshallian demand function to be derived with respect to various energy sources as:

$$\frac{\partial L}{\partial E_1} = U_1^{'} - \lambda P_1 = 0 \tag{4.6}$$

$$\frac{\partial L}{\partial E_2} = U_2^{'} - \lambda P_2 = 0 \tag{4.7}$$

$$\frac{\partial L}{\partial E_n} = U_n^{'} - \lambda P_n = 0 \tag{4.8}$$

Therefore, since there are more than two fuel choice categories, the following multinomial logit model (MNLM) can be used to analyse the determinants of the households' fuel choice.

$$Prob\left(Z_{ij}\right)=\frac{\exp\left(\beta_j X_i\right)}{1+\sum_{m=1}^{m}\exp\left(\beta_j X_i\right)} \quad (4.9)$$

Where: j = 1, 2,…, m i.e. the various energy source options.

X = the various independent variables

All things being equal, households tend to choose the various energy sources available that best maximises their utility.

4.2.2 The Theory of Demand

The law of demand States that the higher the price of any commodity, the smaller the quantity of such commodity that is purchased and the lower the price, the higher the quantity demanded (Tawiah, 2000). Moreover, the price of other commodity plays a role in determining the quantity demand of another commodity depending on the relationship between the commodities.

However, it is not only price that influence the quantity of demand for a commodity but also there are non-price determinants of demand such as; income of the consumer, taste and preferences, number of consumers, and availability of substitutes. In its implicit form, the relationship between the quantity demand of a commodity and factors affecting it, is expressed as:

$$Qx = f\left(P_X, Y, P_S, P_C, T, N\right) \quad (4.10)$$

where

Q_x= quantity demanded

P_X= price of good X

Y = income

P_S = price of substitute

P_C = price of complement

T = preferences

N = number of consumers

Applying demand theory to the analysis of household energy demand, previous studies (Lee, 2013; Couture *et al*., 2012; Song *et al*., 2012) established a relationship between some factors and the quantity of energy demand. For instance, the impacts of some factors like; disposable household income, age, gender composition in the household, gender of the household head, education, marital status, home ownership, household size, number of children and location on the quantity of household consumption can be analysed using multiple linear regression model as expressed below:

$$Y_i = \beta_0 + \sum_{i=1}^{n} \beta_i X_i + u_i \qquad (4.11)$$

$i = 1, 2, \ldots, n$

Y_i = Quantity of energy consumption

β_i= Coefficients

X_i= Various independent variables which can be in form of continuous or dummy

u_i = Unobserved error term

On *ceteris paribus* basis, other variables (determinants) can be held unchanged to observe the impact that a particular variable exact on demand.

4.2.3 The Relative Income Hypothesis

The Relative Income Hypothesis (RIH) is a consumption theory developed by James Duesenberry (1949). According to this hypothesis, households' consumption behaviour or function does not depend only on its current income but also relatively on the consumption behaviour of other neighbouring households. In other words, households are concerned about their community consumption standards and tend to make their consumption pattern on average based on the community's consumption behaviour. Therefore, for consumption behaviour, there is an interdependent between a household's consumption behaviour and that of its immediate neighbour. According to Duesenberry (1949) "everybody tries to keep up with joneses." Applying this assertion to households' energy consumption choice and behaviour, households tend to choose an energy option that is being used predominantly by their immediate neighbours.

4.3 Methods of Data Analysis

This section consists of the specifications of the various models used in this study based on the stated objectives of the study.

4.3.1 The Multinomial logit model

The Multinomial Logit Model (MNLM) is used when dependent variable is unordered and it comprises more than two categories (Özcan *et al*., 2013). An individual chooses one alternative from the group of these categories, and the labelling of these categories of choices is arbitrary. In MNLM, the number of alternatives that are estimated is equal to the total number of choice available minus one category that is selected as comparison category. For example, assuming there are three alternatives, then two equations would be estimated; for four alternatives, then there is a need for three equations. In general, if there are T possible alternative choices, then T − 1 equations will be estimated (Brooks, 2008). The outcome for which an equation is not estimated then becomes the reference choice. Based on Wooldridge (2002) the MNLM has response probabilities as:

$$P(Y = j \mid x) = \frac{exp(\beta_j x_i)}{\left[1+\sum_k^j \exp(\beta_k x_i)\right]} \text{ for } j = 1, \ldots k \tag{4.12}$$

$$P(Y = 0|x) = \frac{1}{\left[1+\sum_k^j \exp(\beta_k x_i)\right]} \tag{4.13}$$

where:

P(Y = j|x) = probability of choosing one of the alternatives available

j = number of alternatives available (excluding the reference category)

j = 0 is the reference category

x_i = a vector of the predictor explanatory variables

β_k = a vector of the parameters to be estimated.

4.3.1.1 Independence of Irrelevant Alternatives

In MNLM estimation however, the assumption of independence of irrelevant alternatives (IIA) should hold true. IIA means that all choice alternatives are equal. An individual's preference and desire for one alternative out of two should not be influenced by other existing preferences. In other words, IIA assumes that if a new option becomes available, the probabilities for the earlier choices must adjust in exactly the amount necessary to maintain the original odds (Cheng & Long, 2007).

In literature, there are various ways of testing the IIA assumption. These are; Hausman and McFadden (HM) test, the Small and Hsiao (SH) test and Seemingly Unrelated Estimation (SUEST). In this study, we adopted the third method (SUEST) for testing IIA assumption of our model. This is because the IIA test conducted based on the two former methods (i.e. HM and SH) did not give clear defined results for our data. Moreover, according to STATA manual (2009)

"*Hausman test (IIA) has several limitations. First, the test statistic may be undefined because the estimated VCE does not satisfy the required asymptotic properties of the test. Second, the classic Hausman test applies only to the test of the equality of two estimators. Third, the test requires access to a fully cleaned estimator; such an estimator may not be available, for example, if you are analyzing complex survey data. Using SUEST can overcome these three limitations*" (STATA Manual Release 11, 2009 Pp 1803).

Additionally, other limitations of both the Hausman – McFadden and the Small – Hsiao tests as provided by literature are; in the first place, these tests sometimes provide inconsistent results. This is especially more relevant to Small and Hsiao test because it is based on random division of the sample into two group of subsamples and therefore is possible to arrive at different results with successive repetition of the test. Secondly, in Hausman and McFadden test, it is possible to have a negative test statistic (which do not have an evaluated probability) if the asymptotic assumptions of the test is not meet up. Thirdly, Cheng and Long (2007) after conducting a series of Monte Carlo simulations to evaluate the various tests; concluded that these tests are not satisfactory for applied work. Because the Hausman and McFadden test exhibits an ample size distortion that is not influenced by sample size in the simulation conducted. While, the Small and Hsiao test possesses grounded size properties in some data sets but shows severe size distortion even in huge samples when there exists sparse cells in the table of the outcome variable with a binary independent variable (Cheng & Long, 2007). Hence in this study SUEST method of IIA test was used and the result is presented in the next chapter of this document.

A situation where the IIA assumption has been violated, a number of suggestions have been provided in the literature. The first alternative is to merge related options and conduct the MNL estimation with lesser categories. In the extreme situation, a binary logit should be conducted on two subcategories only. This produces consistent though less cleaned estimates of parameters of the corresponding multinomial model (Kennedy, 2008 in Eakins, 2013). The second alternative is to use multinomial probit model, though it involves greater computational burden.

The third alternative involves the estimation of the nested logit model whereby the various alternatives are divided into groups so that the assumption of IIA is valid across the groups but not within groups (Eakins, 2013). For example if the various household energy options consisting firewood, charcoal kerosene, electricity and gas, are categorised into un-cleaned and cleaned energy source options, the initial logit model is to run for the choice of energy source between cleaned and un-cleaned. Then, the second logit should be on the options within each group.

4.3.1.2 Specification of the empirical Multinomial Logit Model

In this study, two aspects of household energy use and consumption were estimated using the MNLM. These are cooking aspect of household energy use and the lighting aspect of household energy use.

4.3.1.2.1 The Cooking Aspect of Household Energy Use

The second objective of this study was to analyse the factors that influence households' choice of main cooking fuel source. Since households have more than two alternatives, MNLM was employed for this analysis. Theoretically, households are assumed to be rational when making fuel choice decisions. These fuel choices are selected from among a set of independents and differentiated cooking fuel sources. In the case of Bauchi State, the major cooking fuel alternatives available are; firewood, kerosene, electricity, and LPG. The assumption is that a household select a particular source of energy in such a way as to maximise its satisfaction. This fuel choice is influenced by socio-economic and other related factors.

Where a household makes a choice j at a time, then the assumption is that Y_{ij}^{*} is the maximum utilised option among the four fuel sources. The observed energy category is defined as a vector ($Y_i = [Y_{ij}]$) of four dummy categories which takes a value, 1 if the household choose a particular j^{th} alternative and takes a value, 0 if otherwise. The possibility that j falls in i's choice set is P(Y*>0). This fuel preference probability can be expressed as:

$$P(Y_i = j) = \frac{\exp(\alpha_{ij} w_i)}{\sum_{j=0}^{m} \exp(\alpha_{ij} w_i)}, \text{ with j = 0, 1, 2, 3,} \quad (4.14)$$

Explicitly, the empirical model can be expressed as:

$$\begin{aligned} Y_{ij} &= \alpha_0 + \beta_1 HHGEND_i + \beta_2 HHAGE_i + \beta_3 HHEDU_i \\ &+ \beta_4 HHSIZE_i + \beta_5 HHHI_i + \beta_6 LOCATION_i + \beta_7 DWELSIZE_i \\ &+ \beta_8 HMOWN_i + \beta_9 PRICEY_i + \beta_{10} NCFUEL_i + \varepsilon_{ij} \end{aligned} \quad (4.15)$$

where: j takes the values 0, 1, 2, 3. representing the various fuel source categories i.e firewood, kerosene, electricity and gas.

$\mathbf{Y_{ij}}$	=	The probability of choosing one of the fuel sources instead of the based category variable. The based (referenced) category is firewood
$HHGEND_i$	=	Gender of the head of household
$HHAGE_i$	=	Age of the head of household
$HHEDU_i$	=	Level of education of the head of household
$HHSIZE_i$	=	Size of the household
$HHHI_i$	=	Monthly income of the head of household
$LOCATION_i$	=	Home location of the household
$DWELSIZE_i$	=	Size of the dwelling of the household
$HMOWN_i$	=	Home ownership of household
$PRICEY_i$	=	Unit price of firewood per bundle
$NCFUEL_i$	=	Similarity with the neighbour's main cooking fuel source

The relationship between the above economic and socio-demographic factors can be seen from Figure 4.1

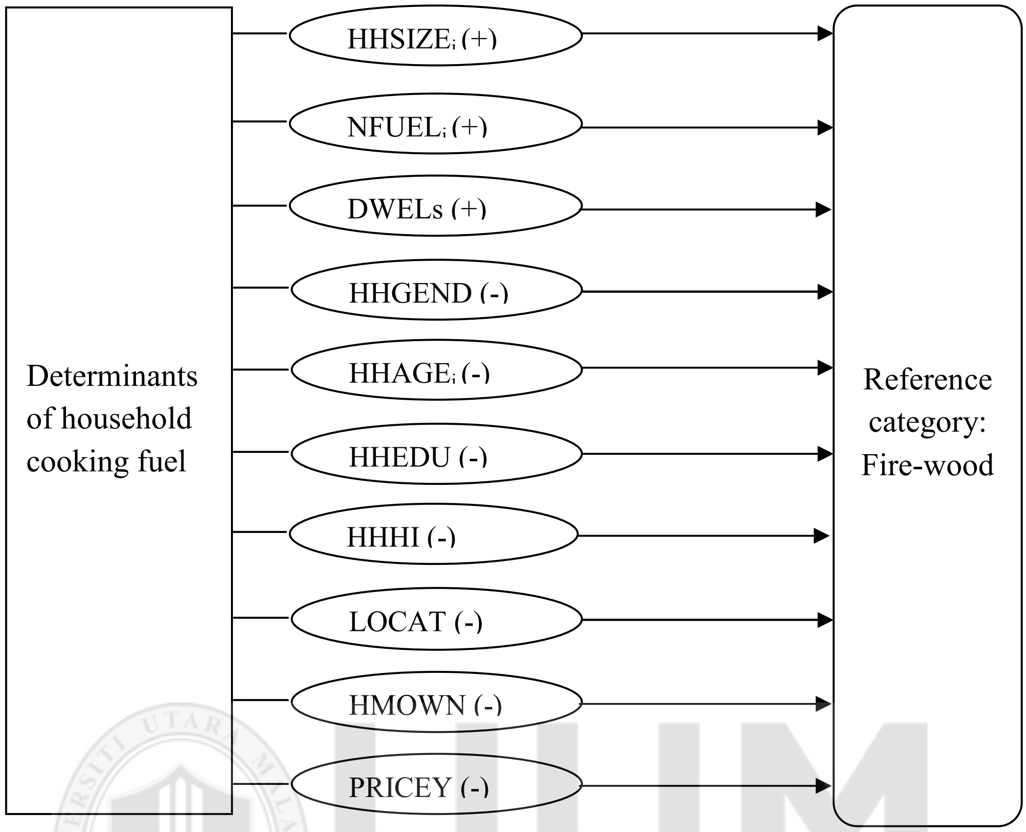

Figure 4.1
Determinants of households' Cooking Fuel Choice
Source: Modified from Danlami *et al*. (2015)

Note: The positive sing (+) indicates that the variable is hypothesised to have positive relationship with the adoption of firewood adoption, while the negative sing (-) indicates that the variable is hypothesised to have negative relationship with the adoption of firewood.

Figure 4.1, shows how the households' cooking fuel choice is affected by economic and socio-demographic factors. Economic factors may include market price of fuel, household income, size of the dwelling and home ownership. On the other hand, the socio-demographic factors may include a set of household characteristics such as household size, household's head gender, age and level of education, location of residence and the neighbourhood main cooking fuel source. The interplay of these factors determines the type of cooking fuel to be chosen by the households.

4.3.1.2.2 Choice for Lighting Source of Energy

The third objective of this study is to examine the determinants of households' choice for lighting source of energy. MNLM was also used to analyse the determinants of the households' choice for lighting fuel source. This is because the various household's lighting sources in Bauchi State can be categorised into three major sources namely; traditional source, semi-electricity and electricity. The traditional source includes the use of firewood and traditional lamp. The semi-electricity includes; rechargeable lanterns, battery lanterns and torch lights. The last category is electricity, which is use as a lighting source. The probability for a household to choose a particular source of lighting can be expressed as:

$$P\left(Y_i = j\right) = \frac{exp\left(\beta_i X_i\right)}{\sum_{j=0}^{j} exp\left(\beta_i X_i\right)} \qquad (4.16)$$

where:

$P(Y_i = j)$ = the probability of selecting either electricity, semi-electricity or traditional source of lighting, whereby the electricity source is the reference category.

X_i = the vector of the explanatory variables which are the socio-economic factors influencing the household lighting choice.

J = the number of categories of lighting source in this case, there are three categories in the choice set (0, 1 and 2). For j = 0, is the reference category in this case, electricity source of lighting.

β_i = the vector of the parameters to be estimated.

Explicitly, the empirical model is expressed as:

$$
\begin{aligned}
Y_{ij} = {} & \alpha_0 + \beta_1 HHGEND_i + \beta_2 HHAGE_i + \beta_3 MSTATUS_i + \beta_4 HHSIZE_i + \\
& \beta_5 HHHI_i + \beta_6 LOCATION_i + \beta_7 HRSOFELECSS + \beta_8 NROOMS_i + \\
& \beta_9 NLFUEL_i + \beta_{10} + NHAPP + \beta_{11} EDUHHH_i + \varepsilon_{ij}
\end{aligned} \qquad (4.17)
$$

where:

$\boldsymbol{Y_{ij}}$	**=**	The probability of choosing one of the lighting sources instead of another. J= 0, 1, and 2 the various lighting categories namely; electricity semi-electricity and traditional sources.
$HHGEND_i$	=	Gender of the head of household
$HHAGE_i$	=	Age of the head of household
$MSTATUS_i$	=	Marital status of the head of household
$HHSIZE_i$	=	Size of the household
$HHHI_i$	=	Monthly income of the head of household
$LOCATION_i$	=	Home location of the household
$HRSOFELECSS_i$	=	Hours of electricity availability per week for household
$NROOMS_i$	=	Number of rooms in the home of household
$NLFUEL_i$	=	Similarity with the neighbour's main lighting fuel source
$NHAPP_i$	=	Number of vehicles and appliances own by household
$HHEDU_i$	=	Level of education of the household head

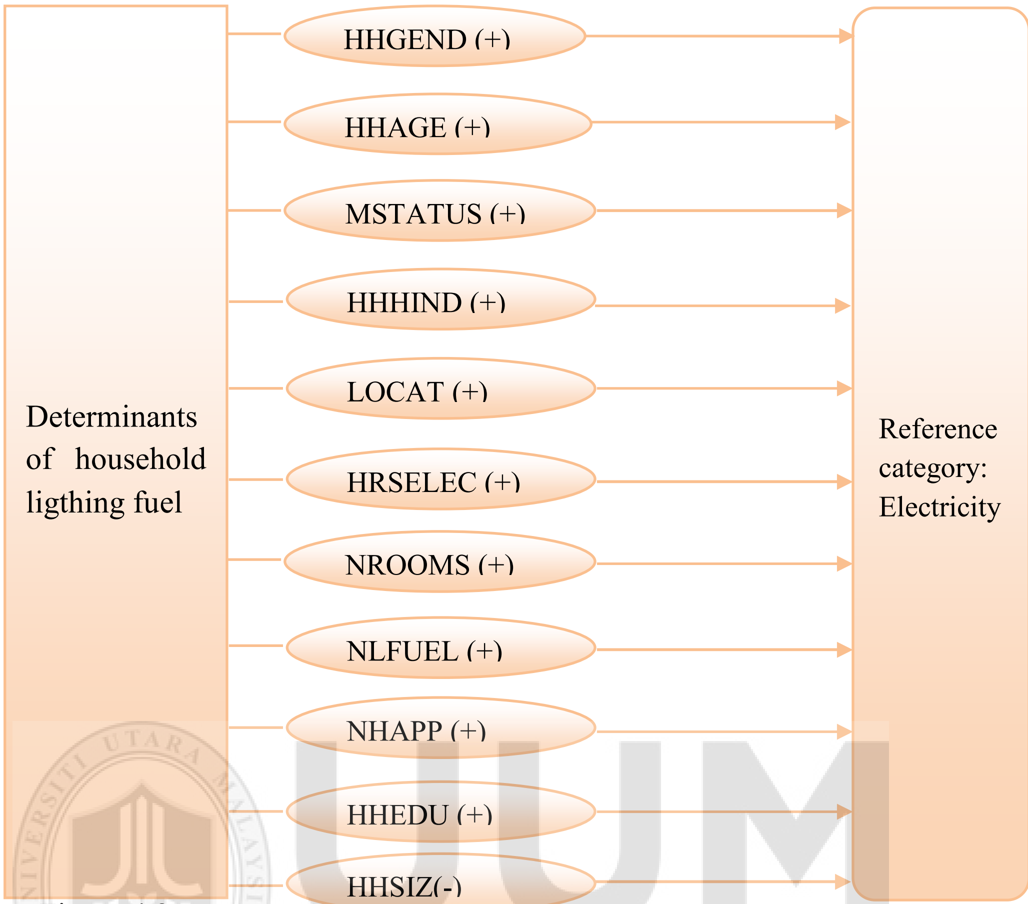

Figure 4.2
Determinants of households' lighting fuel choice
Source: Danlami *et al.* (2015)
Note: Positive sing (+) indicates a positive relationship with adoption of electricity, while the negative sing (-) indicates a negative relationship with electricity adoption.

Figure 4.2, shows how the households' lighting fuel choice is affected by both economic and other non economic factors. Economic factors may include; household income, number of rooms and number of home appliances. On the other hand, the other non economic factors may include a set of household characteristics such as household size, household's head gender, age, marital status and level of education, location of residence, the neighbourhood main lighting fuel source and the hours of electricity supply. The interplay of these factors determines the type of lighting fuel to be chosen by the households.

4.3.2 The Multiple Regression Model

The fourth objective of this study is to assess the determinants of household energy demand, such as the demand for firewood, kerosene and electricity. In this case, OLS regression model was employed to estimate the determinants of demand for firewood consumption and the consumption of electricity in Bauchi State.

OLS model showing the relationship between dependent and independent variables can be expressed as:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + ...+ \beta_k X_k + \in \qquad (4.18)$$

The dependent variable Y and the independent variables (X_1, X_2, X_3 …, X_k) are perceptible irregular scalars, i.e. they can be observed in a random sample of the population. $\in$ is non observable random error and β_0, β_1, β_2..., β_k are the various parameters to be estimated. However, it should be noted that estimation using OLS technique is guided by some assumptions which include: linearity of the parameters of the model, zero mean of the error variable (i.e $E(\in)=0$). Homoscedasticity of the variance of the error term (i.e. ε $N \sim iid(0, \sigma_{\in}^2)$. Zero covariability or relationship between the random error and the explanatory variable (i.e $cov(X_j, \in))=0$. No specification error in the estimated model and absence of perfect multicollinearity among the independent variables.

Following Petersen (1982) and Lee (2013); the implicit form of the relationship between households' consumption of a particular energy and its determinants can be expressed as:

$$Y_{ij} = \beta_0 + \sum_{i=0}^{k} \beta_i X_i \quad (4.19)$$

where; Y_{ij} is household i's consumption of energy type j.

The j = the various sources of households' energy (firewood or electricity).

The estimated empirical OLS model for households' firewood consumption is expressed as:

$$\begin{aligned} FWD_i = {} & \alpha_0 + \beta_1 HHGEND_i + \beta_2 MSTATUS_i + \beta_3 EDUHHH_i + \beta_4 HHSIZE_i \\ & + \beta_5 HHHI_i + \beta_6 LOCATION_i + \beta_7 HOWNS_i + \beta_8 NROOMS_i + \\ & \beta_9 DSHARE_i + \beta_{10} UPFW_i + \beta_{11} UPKERO_i + \varepsilon_{ij} \end{aligned} \quad (4.20)$$

Similarly, the empirical estimated OLS model for households' electricity consumption is shown as:

$$\begin{aligned} ELEC_i = {} & \alpha_0 + \beta_1 HHGEND_i + \beta_2 MSTATUS_i + \beta_3 EDUHHH_i + \beta_4 HHSIZE_i \\ & + \beta_5 LOCATION_i + \beta_6 HSIZE_i + \beta_7 UPFW_i + \beta_8 NROOMS_i \\ & + \beta_9 NLFUEL_i + \beta_{10} HAPP_i + \varepsilon_{ij} \end{aligned} \quad (4.21)$$

where:

FWD_i	=	Quantity of firewood bundle consume monthly.
$ELEC_i$	=	household i, monthly expenditure on electricity
$HHGEND_i$	=	Gender of the head of household
$MSTATUS_i$	=	Marital status of the head of household
$HHEDU_i$	=	Level of education of the head of household
$HHSIZE_i$	=	Size of the household

$HHHI_i$	=	Monthly income of the head of household
$LOCATION_i$	=	Home location of the household
$HMOWN_i$	=	Home ownership of household
$DWELSHARE_i$	=	Sharing dwelling with other households
$UPFW_i$	=	Unit price of firewood per bundle
$HRSOFELECSS_i$	=	Hours of electricity availability per week for household
$NLFUEL_i$	=	Similarity with the neighbour's main fuel source
$NHAPP_i$	=	Number of home appliances own by household
$UPKERO_i$	=	Price of kerosene per litre

4.3.2.1 Diagnostic Checking

However, the validity of OLS estimation is built on some assumptions, therefore the following diagnostic checks were conducted to ascertain the validity of the OLS estimated result. Such tests are: test of heteroskedasticity, variance inflation factor (VIF) test for multicollinearity, omitted variable test and test of normality.

4.3.2.1.1 Test of Heteroskedasticity

The usual OLS standard errors and test statistics are asymptotically valid, provided all of the Gauss-Markov assumptions hold. It turns out that the homoskedasticity assumption, $Var(u_1|x_1, \ldots, x_k) = \sigma^2$, can be replaced with the weaker assumption that the squared error, u^2, is uncorrelated with all the independent variables (x_j), the squares of the independent variables (x_j^2), and all the cross products ($x_j x_h$ for $j \neq h$). This observation motivated White (1980) to propose a test for heteroskedasticity that adds the squares and cross products of all the independent variables (Cited in Wooldridge, 2012). Gujarati (2004) argued that the White does not rely on the normality assumption and is easy to implement. Consider the three-variable regression model (Gujarati, 2004):

$$Y_i = \beta_1 + \beta_2 X_{2i} + \beta_3 X_{3i} + u_i \quad (4.22)$$

The White test can be carried out using the following steps as in Gujarati (2004)

Step 1; given the data, equation (4.22) was estimated to obtain the residuals $\hat{u}_i$.

Step 2; then the following (auxiliary) regression was run:

$$\hat{u}_i^2 = \alpha_1 + \alpha_2 X_{2i} + \alpha_3 X_{3i} + \alpha_4 X_{2i}^2 + \alpha_5 X_{3i}^2 + \alpha_6 X_{2i} X_{3i} + V_i \quad (4.23)$$

That is, the squared residuals from the original regression are regressed on the original *X* variables or regressors, their squared values, and the cross product(s) of the regressors. The this study, the null hypothesis of homoskedasticity was tested based on the Cameron and Trivedi's decomposition of White's Information Matrix (IM) using STATA soft ware and the result is presented in the section of discussion of results.

4.3.2.1.2 Variance Inflation Factor Test

The Variance Inflation Factor (VIF) quantifies the severity of multicollinearity in an OLS regression analysis (Maddala, 1992). It provides an index that measures how much the variance (the square of the estimate's standard deviation) of an estimated regression coefficient is increased because of collinearity. The speed with which the variances and covariances increase can be measured with VIF (Gujarati, 2004).

Based on Maddala (1992) the VIF coefficient can be estimated based on this expression:

$$VIF(\hat{\beta}_i) = \frac{1}{1-R_j^2} \tag{4.24}$$

where:

R_j^2 is the coefficient of determination of the model regressing X_i (one of the independent variables of the model in which the VIF is determined) on the other independent variables. Usually, the VIF value is calculated for each of the independent variables. From the above expression, as R_j^2 approach 1, VIF approaches infinity. The decision rule is that the VIF ≥ 10 indicates severity which needs to be corrected mostly by removing the variable that has high value of VIF.

4.3.2.1.3 Omitted Variable Test

One of the assumptions of the classical linear regression model (CLRM), is that the regression model used in the analysis is correctly specified. If the model is not correctly specified, then there is a problem of model specification error or model specification bias (Gujarati, 2004). Omission of a variable in a linear regression equation may be the consequence of an erroneous exclusion of a variable for which data are available or of exclusion of a variable that is not directly observed (Cameron & Trivedi, 2005). Following Maddala (1992), Cameron and Trivedi (2005) and Wooldridge (2012), supposed that the true model to estimate is

$$y = \beta_1 x_1 + \beta_2 x_2 + u \tag{4.25}$$

Instead, the variable x_2 is removed and the actual estimated model becomes

$$y = \beta_1 x_1 + u \tag{4.26}$$

This is regarded as a misspecified model which makes the estimate of β_1 be

$$\hat{\beta}_1 = \frac{\sum x_1 y}{\sum x_1^2} \tag{4.27}$$

Substituting equation (4.25) in equation (4.27), it gives:

$$\hat{\beta}_1 = \frac{\sum x_1(\beta_1 x_1 + \beta_2 x_2 + u)}{\sum x_1^2} = \beta_1 + \beta_2 \frac{\sum x_1 x_2}{\sum x_1^2} + \frac{\sum x_1 u}{\sum x_1^2} \tag{4.28}$$

Since $\varepsilon(\sum x_1 u) = 0$ then,

$$\varepsilon(\hat{\beta}_1) = \beta_1 + b_{21}\beta_2 \tag{4.29}$$

where:

$b_{21} = \sum x_1 x_2 / \sum x_2$ = the regression coefficient from a regression of x_2 on x_1, therefore, $\hat{\beta}_1$ is a biased estimator for $\beta_1$and the bias can be defined as being equal to the coefficient of the excluded variable multiplied by the regression coefficient in a regression of the excluded variable on the included variable.

STATA software was used to conduct the omitted variable test based on Ramsey (1969). The null hypothesis is that the model does not have omitted-variables bias, if the p-value is higher than the usual threshold of 0.05 (95% significance), then the null hypothesis is not rejected and conclude that no need for more variables.

4.3.3 The Tobit Model

Part of the fourth objective is to estimate the determinants of household demand for kerosene in Bauchi State. However, many of the households in Bauchi State do not use kerosene and therefore significant number of zero '0' values was obtained regarding the use of kerosene fuel as one of the sources for households' energy. Therefore, in this situation, the use of OLS model to estimate the household's kerosene consumption would result in biased and inconsistent estimates. Hence Tobit Model was used to account for such observations. This model has been widely used by many researchers especially studies on household energy use behaviour (Danlami *et al*., 2016; Lee, 2013; Song *et al*., 2012; Jingchao & Kotani, 2011).

In Tobit model, it is assumed that the observed endogenous variables Y_i for observations i = 1, 2, 3,…, n satisfy

$$Y_i = \max(Y_i^*, 0) \tag{4.30}$$

Where; Y_i^*'s are the latent variables generated using linear regression model

$$Y_j^* = \beta' X_i + \varepsilon_i \tag{4.31}$$

where: X_j is the vector of explanatory variables. The model error ε_j is assumed to be normally distributed with zero mean and constant variance εN iid(0 δ^2). The observed value of Y_i is censored below 0, i.e. as is shown below:

$$Y_i = \begin{cases} Y_i^* \; if \; Y_i^* > 0 \\ 0 \; if \; Y_i^* \le 0 \end{cases} \tag{4.32}$$

Regression model based on equation 4.29 is known as censored regression model or Tobit model.

The censored data arises when the information on the dependent variable is obtainable only for some observations or when the significant number of observations in the dependent variables is zero. Given the available data, consisting of several observations on the regressand variable trapped at zero, OLS estimation of this data would give biased and non consistent parameter estimates. In addition, removing such observations that do not have information on the dependent variable and conducting the estimation on the remaining observations or samples, would still result in biased and non consistent estimates. This is because the error term ε_j would not have zero expected value. Not only that, but also would be correlated with the exogenous variable(s) leading to the violation of the assumption of absence of covariance relationship between the random error term and the explanatory variables. Lastly, it should be noted that estimation using Tobit regression model is built upon two important assumptions of homoscedasticity and normality. The hoscedasticity implies that the variance of the random error from the estimated model should be constant. On the other hand, the normality implies that the data has a normal distribution. Violation of these assumptions seriously affects the reliability of the estimation by providing inconsistent and biased estimates (Wooldridge, 2002 and Greene, 2002).

4.4.3.1 Specification of the Empirical Tobit Model

The empirical model can be expressed as:

$$KEROSENE_i = \max\left(0,\ KEROSENE_i^*\right) \tag{4.33}$$

$$\begin{aligned} KEROSENE_i^* &= \beta_0 + \beta_1 HHGEND_i + \beta_2 HHAGE_i + \beta_3 HHEDU_i + \\ &\beta_4 HHSIZE_i + \beta_5 HHHI_i + \beta_6 LOCATION_i + \beta_7 HRSOFELECSS_i + \\ &\beta_8 NFUEL_i + \beta_9 UPFW_i + \beta_{10} UPKERO_i + \varepsilon_i \end{aligned} \tag{4.34}$$

where: the dependent variable represents the quantity of kerosene purchases monthly.

$HHGEND_i$ = Gender of the head of household

$HHAGE_i$ = Age of the head of household

$HHEDU_i$ = Level of education of the head of household

$HHSIZE_i$ = Size of the household

$HHHI_i$ = Monthly income of the head of household

$LOCATION_i$ = Home location of the household

$HRSOFELECSS_i$ = Hours of electricity availability per week for household

$UPFW_i$ = Unit price of firewood per bundle

$NLFUEL_i$ = Similarity with the neighbour's main fuel source

$UPKERO_i$ = Price of kerosene per litre

Based on Greene (2002) the specification tests should be conducted in order to ascertain the validity of the estimated Tobit model such as; the disturbances in the model are not heteroscedastic. The underlying disturbances in the model are normally distributed.

4.3.4 Specification of the model for testing the Relative Income Hypothesis

Verme (2013) after reviewing studies that conducted an empirical test for relative income hypothesis came up with the standard econometric model for testing the relative income hypothesis as:

$$U = \beta_1 \ln(x_i) + \beta_2 \ln(r_i) + \delta Z_i \qquad (4.35)$$

According to Verme (2013) the dependent variable (U) can either be categorical or continuous depending on the model to estimate

Empirically the modified version of this model estimated in this research can be expressed as:

$$Y_{ij} = \beta_0 + \beta_1 INC_i + \beta_2 r_i + \beta_3 r_i LOC_i \qquad (4.36)$$

where:

Y_{ij}	=	main source of fuel (i.e. firewood, kerosene, electricity and gas)
INC	=	income for household
r	=	neighbour main source of fuel
r*LOC	=	is the interaction of r and location.

4.4 Justifications of the Variables included in the Models

The selection of the variables was influenced by some working hypotheses developed. In this study, it is hypothesised that households' decision to adopt and use a particular energy source at a point in time is determined by a joint effects of some factors related to the household energy use and consumption. These are the variables that are hypothesised to influence the type and nature of energy to be adopted by households in Bauchi State. These hypotheses were developed based on a priori knowledge, theories and previous empirical studies on household energy consumptions.

4.4.1 Household Income

This variable represents the monthly income inflow to the households under the study. This variable is measured in Naira value amount. According to Energy Ladder Hypothesis and Energy Stacking model, as income increases, households adopt cleaner source of energy. Furthermore, previous studies have established that there exists a positive relationship between income and adoption of cleaned energy (Mensah & Adu, 2013; Ozcan *et al*., 2013; Couture *et al*., 2012; Jingchao & Kotani, 2011; Osiolo, 2010). The higher the amount of income accruing to households, households tend to switch to the adoption of cleaner energy. Therefore this study hypothesised that incomes of households have a positive relationship with the adoption and consumption of cleaner energy.

4.4.2 Home Ownership

This variable represents the fact whether the dwelling in which the households live is their own or it is for a rent. Home ownership is also one of the indicators of economic status of households which also influence their decision of a type of energy source to adopt. This variable takes a binary value 1, when the households live in their owned home, otherwise 0. Previous studies (Couture *et al*., 2012; Laureti & Secondi, 2012) established that households who live in their owned home tend to adopt cleaner source of energy. Therefore, it is hypothesised in this study that the households that live in their owned home adopt cleaner energy source.

4.4.3 Fuel Cost

This refers to the market value in which a unit measure of a particular energy source is sold. According to the law of demand, the higher the price, the lower the quantity demand and vice versa. This variable is measured in Naira value at which a particular unit of measurement of energy fuel is sold in the market. Furthermore, previous studies (Nlom & Karimove, 2014; Lee, 2013; Ganchimeg & Havrland, 2011; Jingchao & Kotani, 2011; Osiolo, 2010) confirmed such a negative relationship between the adoption of a particular energy source and its price. Therefore, in line with the previous studies conducted in other areas, this study hypothesised that as a price of a particular energy source rises, households in Bauchi State switch to other available alternative sources of energy.

4.4.4 Price of Other Related Fuel

This variable represents the market price value at which a related (whether positive or negative) fuel is sold. In this study, this variable is also measured in terms of Naira value of market price. In the demand theory, it is generally believed that there is a positive relationship between the demand of a particular good and the price of other competitive related commodity, therefore as has been confirmed by previous studies in other areas (Mekonnen & Kohlin, 2008; Onoja, 2012; Song *et al*., 2012), this study hypothesised that the adoption and consumption of a particular energy fuel has a positive relationships with the prices of other fuels since in most cases the various fuel alternatives are substitutes to one another.

4.4.5 Gender of the Household Head

This variable represents the sex category of the household head. This variable is categorised as a dummy variable taking a value of 1 if a household is headed by a male and '0' otherwise. According to Mensah and Audu (2013), households adopt cleaner form of energy when the head is a female. However, contrary to this proposition, this study hypothesized that male headed households tend to adopt cleaner fuels than the households that are headed by females, this is because households that are headed by males tend to be more economically stronger and more buoyant than those headed by females, due to the culture of the people of the study area, that in most cases males earned higher income than females. Also there exists a wide educational gap between male and females in the study area.

4.4.6 Age of the Household Head

This represents the age or how older a household head is, measured by the number of years. This variable is a quantitative variable in this study and it is measured by the number of years of the head of the household. Previous studies (Ozcan *et al*., 2013; Couture *et al*., 2012) found a positive relationship between the age of a household head and the adoption of cleaner energy. In line with these previous studies, this study hypothesized that there is a direct relationship between the age of the head of the household and the adoption of modern energy. This is because as time goes on, the earning of the household head increases which enable the household to afford more costly source of energy.

4.4.7 Education Level of the Household Head

This refers to the highest level of education attained by the household head i.e. in terms of primary, secondary and tertiary levels. This variable is a continuous variable measured by the number of years of formal education of the household head. Previous studies (Nlom & Karimove, 2014; Eakins, 2013; Mensah & Audu, 2013; Ozcan *et al*., 2013; Laureti & Secondi, 2012; Suliman, 2010; Heltberg, 2005) found that there exists positive relationship between the level of education of the household head and the adoption of cleaner energy. The conclusion is that the higher the educated is the households, the more they realised the negative impact of un-cleaned energy and therefore, the less it will be adopted. In line with the previous studies conducted in other areas, this study hypothesized that households in Bauchi State who have more educated members (the household head inclusive) adopt cleaner energy.

4.4.8 Household Size

This variable represents the total number of the household members including the household head. This variable is a quantitative variable measured by per head number of the household members. Previous studies conducted also found that there is a negative relationship between the size of a household and its adoption of cleaned energy (Ozcan *et al*., 2013; Mensah & Audu, 2013; Laureti & Secondi, 2012; Jingchao & Kotani, 2011; Suliman, 2010; Heltberg, 2005). That the larger the size of the household members, the lesser it adopts cleaner energy. In line with these previous studies mentioned above, this study hypothesized that households in Bauchi State with larger size tend to adopt less clean energy.

4.4.9 Location

This variable represents the geographical environmental area in which the households live. That is, whether the household lives in urban or rural area. Furthermore, this variable is a binary variable taking a value of 1 if the household lives in the urban area and 0, otherwise. Previous empirical studies (Eakins, 2013; Ozcan *et al*., 2013; Mensah & Audu, 2013) confirmed that the location where by the households live have significant impact on the nature of the energy source to adopt. The households living in urban areas tend to adopt cleaner energy source than their rural counterparts. In line with this assertion, this study also hypothesized that in Bauchi State, households that are living in urban areas of the State tend to adopt cleaner fuel energy than those living in the rural areas of the State.

4.4.10 Home size

This variable represents the size of the dwelling in which the household lives. It is measured in terms of square-feet (ft^2). Previous studies (Couture *et al*., 2012; Laureti & Secondi, 2012; Song *et al*., 2012) found that the larger the size of the dwellings of the households, the higher the adoption of fuel wood. In line with this assertion and also a priori knowledge, it is hypothesized in this study that households living in larger dwellings tend to consume more firewood than adoption of cleaned energy.

4.4.11 Number of Rooms

This variable refers to the total quantity of rooms available in the home including bedrooms, sitting rooms, kitchens, toilets and dining rooms among others. This variable is a quantitative variable measured by the overall total number of rooms available in the home. Previous studies (Eakins, 2013 and Heltberg, 2005) found that there is a positive relationship between the amount of energy consumption and the number of rooms in a home. Also, this study hypothesized that more number of rooms in a home in which the households live attract higher consumption of energy quantity.

4.4.12 Share of Dwellings

This variable represents whether more than one household live in the same compound. This is one of the factors that affect household energy consumption behaviour. This variable takes a binary value of 1 if the household lives with at least one other household under the same buildings and 0, otherwise. For instance, Couture *et al*. (2012) found that this factor has a positive relationship with the adoption of cleaned energy. Also, in line with the above mentioned previous study, this study hypothesized that share of dwellings by more than one household has a positive impact on the adoption of cleaned energy.

4.4.13 Number of Energy Consumption Device

This variable represents the unit number of energy use devises possess at home. This variable is a quantitative variable as it is measured by the unit number of energy consumption devices owned by the households. Previous studies (Eakins, 2013; Louw *et al*., 2008; Petersen, 1982) established that there is a positive relationship between energy use devices and the adoption of modern energy source as well as the amount of energy consumption at home. Therefore, this study hypothesized that the higher the number of energy consuming devices owned by the household, the higher the quantity of energy consumption.

4.4.14 Neighbour's Main Source of Fuel

This variable refers to the nature or type of the main energy sources adopted by the immediate neighbours of the concerned household. This variable takes a binary value 1, when the main fuel source for immediate neighbouring household is the same with the responding household and 0, otherwise. According to Duesenberry (1949), consumption behaviour of individuals and households is relatively determined, i.e. there exists interdependent and interrelation among the consumption behaviours of households and individuals. In his words "everybody tries to keep up with joneses." Therefore, going by this assertion, households tend to choose an energy source option that is being used predominantly by their immediate neighbours.

4.4.15 Marital Status

This variable represent whether the household head is married, single, divorced or widowed. It is coded; 1 for a married household head, otherwise 0. Previous studies (Danlami *et al*., 2016; Oyekale *et al*., 2012) established that there is a positive relationship between adoption of modern energy source and the marital status of the household head. In line with the assertion of the previous studies, this study hypothesised that household tend to consume more energy when the head is married.

4.4.16 Hours of Electricity Supply

This variable represents the number of hours in a week where by electricity is available for use, measured in number of hours of electricity supply per week. Heltberg (2003) established that there exists a positive relationship between availability of electricity and the household adoption of modern source of fuel. In line with this assertion, this study hypothesised that households in Bauchi State adopt modern source of energy as the number of hours of electricity supply increases.

Table 4.1 shows the summary of these variables and their expected sings

Table 4.1
Summary Description of Variables Estimated

S/N	Variables	Measurement	Hypothesized Signs
1	Household Income	USD/Naira Value	+
2	Marital status	Binary choice; 1 for male, otherwise 0	+
3	Home Ownership	Binary choice; 1 if the household lives in self owned home, otherwise 0	+
4	Fuel Cost (PRICE)	USD/Naira Value	-
5	Price of Other fuels	USDNaira Value	+
6	Household head gender	Binary; 1 if male, otherwise 0	+
7	Age of the household head	Number of years	+
8	Education level of the household head	Years of schooling	+
9	Size of household	Per head number	-
10	Location	Binary choice; 1 if living in urban area	+
11	Size of the home	ft^2	-
12	Number of rooms	Number of rooms	+
13	Share of dwellings	Binary choice; 1 if living with other household in the same compound	+
14	Number of appliances	Per unit quantity	+
15	Neighbour's main fuel source	Binary; 1 if using the same source of fuel with immediate neighbours	+
16	Hours of electricity supply	No. of hours of electricity availability weekly	+

4.5 Population of the Study

This study considers the households living within the boundary of Bauchi State, Nigeria. The total estimated number of households as at 2014 was 769,960 (UNFPA, 2014). These households are spread in the three geopolitical zones of the State namely; Bauchi zone, Ningi zone and Katagum zone.

4.6 Sample Size

After identifying the targeted population of this study, the next step followed was determining the sample size of this study. According to Bartlett, Kotrlik and Higgins (2001), sample size determination is common and usual task for many researchers, in that, it affects and influences the accuracy and quality of research. However, there is not specified percentage of the population set to be accurate for representation. What really matters is the number of the sample size and not a percentage of the study population (Jeff, 2001). Sekaran (2003) argued that when the sample size is too scarce, there will be prone of committing a type I error where the research rejects what should be accepted. On the other hand, too large sample size will lead to committing the type II error whereby the research accepts what should be rejected. Hence, neither too small nor too big sample size help in achieving accurate research conclusions. Roscoe (1975) give a rule of thumb for selecting a good sample size to be larger than 30 and less than 500 for most researches. And that in case of multivariate studies, the sample size should be at least 10 times as large as the number of variables. While, Bartlett *et al*. (2001) gave a rule of thumb for the accurate sample size of at least 5 to 10 times larger than the number of variables.

According to Jeff (2001) the factors to be considered when choosing an appropriate sample size includes; the determined goals, the desired precision of findings, the confidence level, the degree of variability and the estimated response rate.

In this study, the total sample size used was determined based on Dillman (2011). According to Dillman (2011), the formula for determining a good representative sample is as follows:

$$S = \frac{NP(1-P)}{(B/C)^2 (N-1) + P(1-P)} \tag{4.37}$$

where:

S= required sample size.

N= the population size (769,960)

P= the population proportion expected to answer in a particular way (the most conservative proportion is 0.50).

B= the degree of accuracy expressed as a proportion (0.05).

C= the Z statistic value based on the confidence level (in this case 1.96 is chosen for the 95% confidence level)

Some previous studies such as Aminu (2015) Bambale (2013) Just (2008) used this formula to determine their sample sizes. Therefore, the sample size can be determined as:

$$S = \frac{(769{,}960 * 0.5)(1-0.5)}{(0.05/1.96)^2(769{,}960-1)+(0.5)(1-0.5)} = \frac{192490}{501.067+0.25}$$

$$S = \frac{192490}{501.317} = 384$$

This determined sample size corresponds to what is contained in the sample size table by Dillman (2011) for 1,000,000,000 population size. Furthermore, it also corresponds to the sample size as contained in the sample size table by Krejcie and Morgan (1970) for the population size of 1,000,000.

For the purpose of data collection, a total of 750 questionnaires were distributed instead of the pre-determined sample number of 384 households. This was to avoid a problem of non response rate. According to Jeff (2011), since it is not every selected sample that will likely response, there is a need for a researcher to increase the sample size to avoid non response bias. Babbie (1995) argued that at least 50% rate of response is necessary for reporting and analysis (cited in Watson, 1998). The estimated response rate (50%) used in this study is in line with that of the previous studies (Gorondutse, 2014; Maiyaki, 2012). Finally about 548 filled questionnaires were returned back, which is more than 70% of the total number of the issued questionnaires.

4.7 Sampling Technique

The process of choosing sufficient number of units or element from the population of interest for making inferences about the population is known as sampling (Trochim, 2004). So many reasons are behind the use of sample rather than studying the entire population. It saves time especially in the event of tight deadline (Saunders *et al*., 2009). In most cases it is impossible to study the entire population due to the large number of elements under the study. Even if it is possible, time, cost, human resources and other constraints may make the study of the entire population prohibitive. Moreover, the use of sample often produces more reliable result than the census due to less fatigue leading to fewer errors hence more reliable results (Singh, 2006; Sekaran, 2003). Kothari (2004) argued that the researcher needs to prepare sampling technique for the study, the method of how the sample should be selected and in what size must be clearly planned and specified. The method of sampling is usually depends on the research methodology, the research area and the preference of the researcher (Dawson, 2002).

This study has adopted cluster area sampling method. According to Rao (2009), area sampling is a special type of cluster sampling whereby samples are grouped and clustered on the basis of geographical location areas. Area sampling is usually adopted where the research focuses on the population within a specific geographical area like country, State, county and city blocks (Valliant, Kreuter & Dever, 2013; Sekaran, 2003). The reason for adopting this sampling method is that though the sampling frame for the various clusters of Bauchi State is available and was obtained from the National population commission office, there is no available frame containing the list of households living in Bauchi State. Hence in this situation, area sampling is one of the most suitable techniques of data collection. As argued by various scholars that the underlying practical motivation for using area sampling is the absence of complete and accurate list of the universal elements under study since it does not depend upon the population frame (Valliant *et al*., 2013; Rao, 2009;

OECD, 2007; Sekaran, 2003). Moreover, Saunders *et al*. (2009) argued that in the case of cluster sampling, the full list of clusters forms the sampling frame and not the list of individual elements within the population.

The sampling technique used in this study is the multistage cluster sampling. In the first stage, the whole of the study area was divided in to three groups (clusters) based on the geo-political zonal categorisation of the State, the various categories are; Bauchi South, Bauchi Central and Bauchi North. In the second stage, two clusters (Bauchi South and Bauchi North) were selected randomly out of the three clusters. According to Saunders et al. (2009) and Kothari (2004), a researcher makes a random selection of some clusters to represent the total area under study.

In the third stage, these two clusters were further categorised into two sub clusters; urban and rural areas. Then a total of 10 wards were randomly selected from the urban areas while a total of 13 wards were selected randomly from the rural areas. This gives a total of 23 selected wards used as the sampling wards. In the fourth stage, six communities were selected randomly from each of the selected wards of urban areas which made a total of 60 communities from the urban areas. On the other hand, another six communities were randomly selected from the selected wards of the rural areas making a total of 78 communities used from the rural areas. This gives a total of 138 sampled communities used in the study. In the last stage, six households were systematically selected from each of the selected communities of the urban areas making a total of 360 households selected from the urban areas. On the other hand, 5 households were selected systematically from each of the selected communities of the rural areas making a total of 390 households selected from the rural areas. Though finally, a total of 548 households participated in the study (i.e. the number of the returned questionnaires). Figure 4.5 gives the summary of the adopted sampling technique of the study

1st stage: Bauchi State was divided in to three main clusters:
Bauchi North, Bauchi central and Bauchi South

↓

2nd stage: Two clusters were selected to serve as the sampling clusters:
Bauchi North and Bauchi South

↓

3rd stage: The selected clusters were subdivided into two:
Urban areas and rural areas, then the selection of 10 Wards from the urban areas and 13 Wards from the rural areas this gives a total of 23 sample Wards.

↓

4th stage: then 6 communities were selected from each of the chosen urban Wards (i.e. 6*10 = 60 communities from the urban areas)
Also 6 communities were selected from each of the chosen rural Wards (i.e. 6*13 = 78 communities from the rural areas)
This gives a total of 138 sampled communities

↓

Last stage: Selection of 6 households from each of the selected urban communities (i.e. 6*60= 360 households in urban areas)
Selection of 5 households from each of the selected rural communities (i.e. 5*78= 390 households in urban areas)
TOTAL SAMPLES= 360 + 390 = 750 households

Figure 4.3
Sampling Stages of the Study

4.8 Sources of Data

In this study, both the primary and the secondary data were utilised. The secondary data used in this study were mainly sourced from World Development Indicators, National Bureau of Statistics, published works and other sources. However, the analysis of results for this study is solely based on primary data. The primary data related to the socio-demographic features, dwelling characteristics and the information on the pattern of households' energy consumption were obtained using questionnaire from survey conducted on the selected households in Bauchi State Nigeria.

This research adopted questionnaire method because; it is more practical and economical than most of the other data collection techniques. Moreover, information can be solicited easily from many respondents within a short period of time. It also provides the researcher with high degree of flexibility by providing different alternative ways of administering questionnaire. The information generated from the respondents based on questionnaire is easily comparable. Additionally, it offers greater anonymity which makes respondents to provide more responses easily. Large samples that often considered in a questionnaire method makes results to be more reliable and dependable (Kumar, 2011; Mackey & Gass, 2005; Kothari, 2004). Finally, another reason for adopting questionnaire technique is that the targeted respondents of this study are spread over different communities. According to Kumar (2011) a researcher has no option than to use questionnaire method of data gathering in a situation when the respondents are spread over a wide geographical area.

The questionnaire used in this study, was modified and adopted from: (i) World Bank/NBS General Household Survey questionnaire (2012); (ii) Energy Efficiency Centre (EEC) Survey questionnaire in low income Mediterranean area; (iii) Statistical office of the Republic of Slovenia (SORS) survey on household energy consumption (2010) and (iv) Statistics Canada survey of household energy use (2011).

Furthermore, the questionnaire was designed in such a way to appear logically ordered and sequential. It consists of four main parts. The first part consisted of the address of the school, the UUM logo, the title of the study and brief Statement of purpose of the questionnaire which guaranteed the respondents the confidentiality of their responses. This was done to encourage the respondents to provide relevant and useful responses. The second part of the questionnaire (labelled Part A) consisted of the questions on the socio-economic characteristics of the respondents. The third part of the questionnaire (labelled Part B) comprises the questions in relation to the dwelling (home) characteristics. The last part consists of questions on the pattern of energy use and consumption of the respondent's household. Moreover, the questionnaire was written in the simplest possible language for easy understanding of the respondents.

All these were done to ensure sequences and logical order of questions. This is because the nature of arrangements of questions in a questionnaire influences the quality of information, the willingness and interest of the selected respondents' participation in the study. It also reduces the chance of misunderstanding the questions which usually invalidated responses (Kumar, 2011; Kathari, 2004).

Furthermore, it should be noted that originally, the questionnaire used in this study was written in English language, however, due to the fact that it is not all the respondents of this study that can speak English language especially those in rural areas, the translated version of this questionnaire (Hausa version) was used for the respondents that only understand the local language. This is in line with Danielsen *et al*. (2015), Erdivik *et al*. (2015), Shaik *et al*. (2014), Alavi and Ghaemi (2013) and Forsyth *et al*. (2006). Both of the English and the translated version of the questionnaires were cross checked by the experts within and outside UUM to ensure more reliability.

Similarly, after preparing the questionnaire, a pilot study of 30 households was conducted, in order to reconfirm the reliability of instruments and to ascertain the areas which respondents may misunderstood for necessary corrections. According to Kumar (2011), after constructing the questionnaire instruments, it is important to conduct a pre-test of these instruments by conducting a field survey using the questionnaire not for the actual data collection but to ascertain the likely areas which respondents may misinterpret or the Statements that may have ambiguous meaning to rectify the issues before conducting the actual data collection. In this study, Cronbach's alpha was estimated using the data collected in the pilot study. The result of the estimated Cronbach's alpha was presented in the next chapter.

Lastly, after conducting the pilot study and the necessary corrections thereafter, the actual data collection was conducted with the help of some research assistants that personally administered the questionnaire. A total of seven hundred and fifty (750) questionnaires were issued out of which a total of five hundred and forty eight (548) (more than 70% response rate) questionnaires were received back, out of which nine (9) questionnaires were discarded, thereby leaving the analysis to depend on the remaining total of five hundred and thirty nine (539) samples, which is larger than the initially targeted number of four hundred (400) samples. The survey conducted, lasts through July to October, 2015.

4.9 Pilot Study and the Reliability Test

Prior to the conduct of the main data collection, the researcher conducted a pilot study for the purpose of conducting a reliability test of instruments and also to examine the understanding of the respondents towards the designed questionnaire. For the purpose of the pilot analysis, a total number of 30 households were selected to participate in the pilot study. Questionnaires were distributed to collect the data.

Moreover, in order to assess the validity of the variable items that are considered to be related to the adoption of household energy fuel source, the coefficient of the

Cronbach's alpha was estimated. Cronbach Alpha describes the extent to which variables measure a concept. It is connected to the inter-relationship of the variables in the test. According to Santos (1999) Cronbach's alpha examines the average correlations of variables in a survey instruments to gauge its reliability. The value of Cronbach's alpha ranges between 0 – 1, the closer the value is to 1 the better the result. Gliem and Gliem (2003) give a rule of thumb that any value of a Cronbach's alpha below 0.5 is unacceptable. Moreover, Santos (1999) agrees that any value of Cronbach's alpha from 0.7 is acceptable though lower threshold values are used in the literature sometimes. Table 4.2 contains the result of the estimated Cronbach's alpha for this pilot study.

Table 4.2
Croanbach's Alpha Values of Variables Related to Household Cooking Fuel

Items	**Observations**	**Alpha**
Gender	30	0.7136
lnAge	30	0.7147
Marital Status	30	0.7133
Education	30	0.7128
Household size	25	0.6926
Occupation	30	0.7091
lnIncome	30	0.7105
Homeownership	30	0.7132
Homesize	30	0.6707
lnHomesize^2	30	0.6749
Nrooms	30	0.6884
Dwellshare	30	0.7161
Homnature	29	0.7114
Cfuelmainsoure	30	0.7138
Ncfuel	30	0.7157
Homeappliances	29	0.5932
lnHomappliances^2	29	0.6666
lnfirewoodqty	17	0.7112
lnKeroqty	19	0.7116
lnUnitpricefirewood	18	0.7077
lnUnitpricekero	16	0.7099
Test Scale		**0.7127**

From Table 4.2, the average calculated Cronbach's alpha value is 0.71 this shows that the data to be obtained on the variables included in the pilot study is reliable, and acceptable for a valid study and analysis on household fuel adoption in Bauchi State Nigeria, which warranted the researcher to carry out the main data collection exercise.

4.10 Conclusion

This chapter provides the detailed information on the research methodology adopted in this study. The chapter reviews the various energy use theories that served as the theoretical under finings of the study. Furthermore, it was shown that the study considers only households that are living in Bauchi State as the targeted population of the study, out of which about 400 samples were targeted (though more than that actually participated) using a multi stage cluster sampling technique. Additionally, it was shown that different econometric models were specified to serve as the tools of achieving the stated objectives. Lastly, the chapter provides the justification for the included variables of the study and the hypotheses of the study as well.

CHAPTER FIVE

DISCUSSIONS OF RESULTS

5.1 Introduction

This chapter consists of discussions of results. It comprises the descriptive statistics of variables, socio-economic characteristics of households in Bauchi State, correlation analysis of factors influencing household energy choice and consumption in Bauchi State. The analysis of the estimated determinants of household; cooking fuel choice, lighting fuel choice, determinants of firewood, kerosene and electricity consumptions in Bauchi State Nigeria.

5.2 Summary of Descriptive Statistics

This section provides information about the descriptive statistics. The major descriptive statistics are the mean, standard deviation, minimum maximum, skewness and kurtosis (Sekaran, 2003). Whereas mean, minimum and maximum values give information on the descriptive nature of the variables, skewness and kurtosis values, are used to test for normality (Tabachnick & Fidell, 2013; Curran, West, & Finch, 1996; West, Finch, & Curran, 1995). Table 5.1 exhibits the values of the summary statistics.

Table 5.1
Summary of Descriptive Statistics of Variables

VARIABLES	mean	SD	min	max	skewness	kurtosis
HHGEND	-	0.333	0	1	-2.2487	6.0564
HHAGE	36.43	11.74	23	60	0.3372	2.0229
MSTATUS	-	0.440	0	1	-1.0862	2.1799
HHSIZE	7.725	6.040	2	30	1.8272	6.9837
LOCATION	-	0.499	0	1	-0.1531	1.0235
DWELSIZE	52.42	19.28	20	110	0.9448	4.0989
NROOMS	6.515	3.812	2	23	0.9685	4.3327
CFUEL (Y_{ij})	-	0.808	0	3	1.9947	6.3159
HRSOFELECSS	27.30	27.83	0	97	1.2241	3.2710
UPFW	76.67	35.31	30	220	1.5296	6.9072
UPKERO	126.6	27.11	45	200	0.4723	4.9337
NCFUEL	-	0.441	0	1	-1.0734	2.1522
NLFUEL	-	0.371	0	1	-1.8108	4.2791
NHAPP	15.37	13.05	0	57	1.3252	4.1916
HMOWN	-	0.410	0	1	1.4013	2.9638
HHEDU	14.21	6.165	0	22	-1.0270	3.4572
LFUEL (Y_{ij})	-	0.668	0	2	1.2329	3.2324
FWD	34.23	17.12	4	90	1.1863	4.9930
HHHI (USD)	224.0	180.1	77.5	600	0.8523	2.2848

Table 5.1, shows that the average consumption of firewood monthly is about 35 bundles, this implies that on average every household in Bauchi State uses more than one bundle of firewood everyday, which is a clear reflection of high rate of firewood use in Bauchi State, Nigeria. Furthermore, the table indicates that the monthly average income of a household is little bit more than USD200, with the maximum value of USD600. This implies that most of the household in Bauchi State belong to the poor income group. In fact Bauchi State is the third poorest State in Nigeria (NBS, 2012). Furthermore, the table indicates that the average firewood price per bundle is about \$0.40 (about ₦75). Furthermore, the data indicate that on average,

the household size in Bauchi State constitutes about eight members per household. This number approximately is tally to the estimated average household size in Bauchi State, given by Uneze *et al*. (2013). The table shows that the average weekly hours of electricity supply is only 27 hours, this clearly reflects the nature of inadequate supply of electricity in the area, which is one of the factors that likely contributes to high rate of biomass fuel as the main source of energy by households in Bauchi State.

Table 5.2 further shows that the average years of school experienced by the heads of households in the study area is 14 years, representing a schooling experience up to the Diploma/NCE levels of education. Similarly, the reported average number of rooms in the building in which each household lives is six. This number constitutes bedrooms, rest room, sitting rooms and fallows respectively. Additionally, the number of energy use devices possesses at home such as; bulbs, fans, ACs, televisions, radios among others, shows an average value of 15 pieces of these items which is clearly a reflection of low rate of modern energy use by households in the study area. Lastly, the table shows that the average age of household head in Bauchi State measured in terms of years is 36 years, which falls within the age group of working population.

5.3 Socio-Economic Characteristics of Households in Bauchi State and Their Pattern of Energy Consumption

The first objective of this study is to explore the socio-economic characteristics of households in Bauchi State, Nigeria.

Table 5.2
Socio-Economic Characteristics of Households in Bauchi State

Characteristics	Frequency	Percentage	Cumulative Frequencies
Gender			
Male	470	87.36	87.36
Female	68	12.64	100
Age			
16 – 30	187	34.89	34.89
31 – 45	229	42.72	77.61
46 – 60	97	18.10	95.71
Above 60	23	4.29	100
Marital Status			
Single	138	26.14	26.14
Married	390	73.86	100
Level of Education			
Non formal Education	55	10.26	10.26
Primary School	27	5.04	15.30
Secondary	95	17.72	33.02
Diploma/NCE	191	35.63	68.66
B.Sc./HND	124	23.13	91.79
Postgraduate	44	8.21	100
Occupation			
No standard job	59	11.09	11.09
Farmer	68	12.78	23.87
Teacher	106	19.92	43.80
Banker	17	3.20	46.99
Lecturer	18	3.38	50.38
Medical Practitioner	37	6.95	57.33
Businessman	99	18.61	75.94
Others	128	24.06	100
Monthly Income (USD)			
150 and below	277	53.37	53.37
151 - $300	98	18.11	71.48
301 - $450	73	13.10	84.59
451 - $600	56	10.02	94.61
Above 600	32	5.39	100
Household Size			
1 – 5	284	52.99	52.99
6 – 10	140	26.11	79.10
11 – 15	52	9.71	88.81
16 - 20	42	7.83	96.64
21 and above	18	3.34	100

In this section the study explore the socio-economic characteristics of households in Bauchi State and their pattern of fuel consumption, based on the study samples. Table 5.2 indicates the socio-demographic and economic characteristics of the respondents. The Table shows that majority of the respondents (87%) are males. This is because based on the culture of people in the study area, normally males occupy the position of household head, even in a situation when the father (the head) has died, it is the younger brother of the deceased or the first born in the family not the mother that emerges as new head of the family. Because the belief is that, men are stronger than women economically, socially and educationally. Therefore, a woman emerges as a household head only by chance when there is no able man in the family to look after the affairs of the family. Furthermore, most of the respondents (61 %) are within the age of middle adulthood stage (31 – 60 years).

This is because on average, the normal marriage age for males (who are mostly the family head) begins from 25 years and above. Table 5.2 further indicates that about 75% of the respondents are married. Due to the fact that married people are regarded as responsible for overseeing the family affairs. The remaining 25% are regarded as single person comprising the divorced, widowed and separated. Regarding the family size, most of the respondents (approximately, 80%) argued that the size of their family members is within the range of 1-10, the range in which the number of the average family size in Bauchi State reported earlier by Uneze *et al*. (2013) falls (i.e. eight) and this study found the average size of a household to be eight (see Table 5.1).

In addition, the categories of the education level attainment shows that those that attended school up to the Diploma/NCE level has the highest rate (35%) followed by those with the degree certificate (23%). Those who claimed that they did not attend a formal school at all constitute about 10% of the respondents. Only 8% of the respondents claimed to have attended school at a postgraduate level. Regarding the occupation of the respondents, of all those that chosed a Stated category, teaching job (at primary or secondary levels) obtained the highest proportion (about 20%).

This is because teaching job at either primary or secondary school levels is one of the easy to find jobs for both semi-professional (Diploma/NCE) and professional (Degree and above) workers. About 11% of the respondents argued that they do not have a standard job, they are more of casual workers. Lastly, the 24% of the respondents which constitutes the other occupation category as specified by the respondents themselves comprises; tailoring, butcher, mechanic, welding, building construction, civil servant, businessman, journalist, sheep and cattle rearing. Others are; carpenter, porter, sewing, blacksmith, commercial driver, prison service and wood cutter. Lastly, on average, most of the respondents (53%) argued that they usually earned a monthly income that is below $150. This clearly indicates the high rate of poverty in the state especially in the rural areas of the state.

Furthermore, among the factors that can shape the household pattern of energy consumption and switching are the characteristics of the building in which the household live. Table 5.3 contains the information of the home characteristics of the households. Table 5.3 shows that about 79% of the respondents, argued that they live in their self owned home, this is especially in rural areas and some of the urban areas whereby most of the houses are simple and traditional, mostly made of up mud, such kind of houses are easy to possess or built.

Table 5.3
Households' Home Characteristics in Bauchi State

Characteristics	Frequency	Percentage	Cumulative Frequencies
Home Ownership			
Self owned home	421	78.69	78.69
Non self owned home	114	21.31	100
Number of Rooms			
1 – 5	305	56.90	56.90
6 – 10	112	20.90	77.80
11 – 15	106	19.54	97.34
16 and above	13	2.43	100
Home Size (ft^2)			
1 – 24	35	6.53	6.53
25 – 49	138	25.75	32.28
50 – 74	300	55.97	88.25
75 – 99	27	5.04	93.29
100 and above	36	6.72	100
Home Location			
Urban Area	289	53.82	46.18
Rural Area	248	46.18	100

Furthermore, majority of the respondents (about 57%) claimed that the number of rooms in their home is within the range of 1 to 5 rooms. These include; bedrooms, sitting rooms, and any other type rooms that are usually found at homes. On the size of plot in which the home was built, majority of the respondents (56%) argued that the size of the plot in which their homes was built is within the range of 50 – 74 sq feet. This implies that households in Bauchi State live in a relatively large house.

Lastly on the location of the respondents, 53% argued that they live in urban areas while the remaining 47% live in rural areas of the State.

Table 5.4
Household Energy Consumption Pattern in Bauchi State

Characteristics	Frequency	Percentage	Cumulative Frequencies
Main cooking fuel			
Firewood	378	70.65	70.65
Kerosene	114	21.31	91.96
Electricity	12	2.24	94.21
Gas	31	5.79	100
Main Source of Lighting fuel			
Traditional	53	9.96	9.96
Semi-electrical	127	23.87	33.83
Electricity	352	66.17	100
Average firewood consumption monthly(bundle)			
1 – 19	62	13.81	13.81
20 – 39	287	63.92	77.73
40 – 59	43	9.57	87.53
60 and above	57	12.69	100
Average kerosene consumption monthly (litre)			
1 – 15	99	46.70	46.70
16 – 30	84	39.62	90.57
31 – 45	15	7.08	93.40
46 and above	14	6.60	100
Average monthly expenditure on electricity (USD)			
9 and below	366	86.52	86.52
10 - 19	47	11.11	97.63
20 - 29	4	0.95	98.58
30 and Above	6	1.42	100
Number of Energy use devices at home			
zero	10	1.87	1.87
1 – 10	243	45.42	47.29
11 – 20	151	28.22	75.51
21 – 30	54	10.09	85.60
Above 30	77	14.39	100

However, the information on the pattern of household fuel source, quantity of energy consumption and the amount of fuel expenditure is shown in Table 5.4. Based on the responses from the selected samples, majority of the respondents (more than 70%) argued that their main fuel source for cooking is firewood. This is not surprising, but reflects the clear picture of the situation in Bauchi State whereby the majority of households in the State especially rural areas adopt firewood as the main source of cooking fuel. This is also tally with the information provided by Akpan *et al*. (2010). Furthermore, 21% of the respondents argued that they use kerosene as the major source of fuel for cooking, about 6% use gas as the main fuel source, and it is only less than 3% of the respondents claim to be using electricity as their main source of cooking fuel, mainly in the urban areas of the state.

This pattern of main cooking fuel adoption is mostly due to the culture, availability and affordability. On the main source of lighting, about 10% of the respondents argued that they rely majorly on traditional source of lighting such as; traditional lamp, kerosene, charcoal and plant residue. Another category of respondents (24%) argued that they rely mostly on semi-electric source of lighting like; battery torch light and rechargeable lanterns to source light for home use. However, the majority of the respondents argued that they rely mostly on the available electricity as their main source of lighting. This implies that most of households in Bauchi State despite the interruption in the supply of the electricity rely mostly on electricity as their main source of lighting especially urban dwellers.

5.4 Correlation Analysis

In this section, a correlation analysis was conducted in order to explore the nature of the correlation that exist among variables used in this study, and also to ascertain whether there are two or more variables that explain the same phenomena (i.e. multicollinearity of variables). Usually, the value of correlation coefficient ranges between 0 - 1. A correlation value of 0.7 indicates high correlation among variables. Furthermore, a negative value indicates negative relationship between variables and a positive value indicates positive relationship between variables. Table 5.5 exhibits the correlation values for variables in this study.

Table 5.5
Variables Correlation Matrix Cooking Fuel Choice Model

	CFL	**GEN**	**AGE**	**EDU**	**HHS**	**INC**	**LOC**	**HSZ**	**HOS**	**PFW**	**NCF**
CFL	1.00										
GEN	0.06	1.00									
AGE	0.02	-0.15	1.00								
EDU	0.30	0.07	-0.05	1.00							
HHS	-0.16	-0.01	0.29	-0.09	1.00						
INC	-0.20	0.11	0.29	0.26	-0.16	1.00					
LOC	0.20	-0.01	-0.20	0.31	-0.14	0.05	1.00				
HSZ	0.01	0.04	0.19	0.12	0.26	0.25	0.05	1.00			
HOS	0.10	-0.03	0.10	0.08	-0.08	0.03	0.13	-0.14	1.00		
PFW	0.06	-0.07	-0.10	-0.13	0.01	-0.02	0.36	0.03	-0.02	1.00	
NCF	0.27	-0.02	0.03	0.16	0.02	-0.02	0.16	0.002	-0.002	0.06	1.00

Correlation Matrix: Lighting Fuel Choice Model

	LFL	**GEN**	**AGE**	**MST**	**HHS**	**INC**	**LOC**	**HES**	**NRM**	**NLF**	**HPS**	**EDU**
LFL	1.00											
GEN	0.07	1.00										
AGE	-0.12	0.15	1.00									
MST	-0.01	0.18	0.28	1.00								
HHS	0.03	-0.01	0.29	-0.02	1.00							
INC	-0.13	0.12	0.29	0.11	0.16	1.00						
LOC	-0.11	0.01	-0.20	-0.09	-0.14	0.05	1.00					
HOE	-0.18	0.03	-0.03	0.02	-0.06	0.19	0.32	1.00				
NRM	-0.09	0.02	0.19	-0.002	0.42	0.10	-0.14	-0.08	1.00			
NLF	-0.16	0.02	-0.02	0.05	-0.15	-0.11	-0.08	0.03	-0.04	1.00		
HPS	-0.10	-0.06	0.05	0.03	0.06	0.27	0.26	0.36	0.01	-0.13	1.00	
EDU	-0.09	0.07	-0.05	0.02	-0.09	0.26	0.31	0.25	-0.09	-0.12	0.27	1.00

Correlation Matrix: Firewood Consumption Model

	FWQ	GEN	MST	EDU	HHS	INC	LOC	HOS	NRM	DSH	PFW
FWQ	1.00										
GEN	0.04	1.00									
MST	-0.09	0.18	1.00								
EDU	-0.08	0.07	0.02	1.00							
HHS	0.21	-0.01	-0.02	-0.09	1.00						
INC	0.07	0.10	0.09	0.26	0.19	1.00					
LOC	0.13	0.01	-0.09	0.31	-0.14	0.07	1.00				
HOS	-0.07	0.01	-0.08	0.04	-0.16	-0.11	0.12	1.00			
NRM	0.26	0.02	-0.01	-0.03	0.38	0.12	-0.08	-0.27	1.00		
DSH	-0.0002	0.03	0.02	-0.06	0.05	-0.01	0.01	0.27	-0.04	1.00	
PFW	-0.14	-0.06	-0.01	-0.10	0.01	0.02	-0.34	-0.05	-0.01	-0.06	1.00

Correlation Matrix: Kerosene Consumption Model

	KRQ	GEN	AGE	EDU	HHS	INC	LOC	HES	NLF	PFW	PKR
KRQ	1.00										
GEN	-0.02	1.00									
AGE	0.23	0.16	1.00								
EDU	0.04	0.07	-0.03	1.00							
HHS	0.14	-0.02	0.30	-0.10	1.00						
INC	0.16	0.10	0.28	0.26	0.18	1.00					
LOC	-0.02	0.01	-0.20	0.31	-0.11	0.07	1.00				
HES	-0.02	0.03	-0.02	0.25	-0.10	0.19	0.32	1.00			
NLF	-0.17	0.02	-0.02	-0.12	-0.13	-0.12	-0.08	0.03	1.00		
PFW	0.06	-0.04	0.14	-0.05	0.07	0.05	-0.29	-0.06	0.10	1.00	
PKR	-0.18	-0.03	0.05	-0.07	-0.11	-0.04	-0.11	-0.16	0.01	0.14	1.00

Correlation Matrix: Electricity Consumption Model

	ELC	GEN	MST	EDU	HHS	LOC	HSZ	PFW	NRM	NLF	HPS
ELC	1.00										
GEN	-0.002	1.00									
MST	-0.09	0.18	1.00								
EDU	0.19	0.07	0.02	1.00							
HHS	-0.07	-0.01	-0.02	-0.09	1.00						
LOC	0.27	0.01	-0.02	0.30	-0.14	1.00					
HSZ	0.03	-0.04	0.09	0.12	0.26	0.05	1.00				
PFW	-0.05	-0.07	0.002	-0.13	0.01	-0.36	0.03	1.00			
NRM	-0.13	0.01	0.001	-0.05	0.38	-010	0.36	-0.02	1.00		
NLF	-0.06	0.02	0.05	-0.12	-0.15	-0.08	-003	0.07	-0.06	1.00	
HPS	0.13	0.01	0.07	0.03	0.06	0.06	0.16	-0.02	0.10	-0.06	1.00

Correlation Matrix: Verme Model of Neighbourhood Cooking Fuel

	CFL	INC	LOC*NCF	NCF
CFL	1.00			
INC	0.20	1.00		
LOC*NCF	0.03	0.02	1.00	
NCF	-0.27	-0.02	0.45	1.00

Correlation Matrix: Verme Model of Neighbourhood Lighting Fuel				
	LFL	**INC**	**LOC*NLF**	**NLF**
LFL	1.00			
INC	-0.13	1.00		
LOC*NLF	-0.17	-0.03	1.00	
NLF	-0.16	-0.11	0.39	1.00

Note: AGE=Age; EDU = Education; HHS = Household size; INC = Income; RUM = Number of rooms; LEC=Hours of electricity supply; PFW = Price of firewood/bundle; HPS = Home appliances; FWQ = Firewood quantity; PKR= Kerosene price per Littre; KRQ = Kerosene quantity; XEC = Monthly expenditure on electricity; HSZ = Home size.

Table 5.5 indicates that all the variables are weakly correlated. In other words, there is a weak relationship between the variables. This is because none of the variables has a correlation value of up to 0.40 in relation to any other variable. The highest correlation value was r = 0.39; representing a correlation between size of household and the number of rooms in the home. This implies that no any two of the variables that measure the same phenomena. In other words, we can conclude that there is an absence of high multicollinearity among the variables. Therefore all these variables were included in the estimation of household energy consumption models.

Additionally, the correlation matrix exhibits that there is a negative weak relationship between quantity of firewood and the price of firewood (-0.13), firewood quantity and level of education attainment (-0.07), price of kerosene and the quantity of kerosene (-0.07), hours of electricity supply and the kerosene quantity (-0.08). Furthermore, weak negative relationships were found between monthly expenditure on electricity and variables like; household size, price of firewood and price of kerosene (with the correlation values; -0.08, -0.05, -0.05). All these sings conform to a priori expectations.

On the other hand, Table 5.6 indicates that there is a weak positive relationship between firewood quantity and the household size (0.22), kerosene quantity and the variables which include; household size, income and firewood price (with the correlation values; 0.05, 0.08 and 0.01). Additionally, weak positive relationships were found to exist between monthly expenditure on electricity and other variables such as; education, income and kerosene quantity. The values of the correlation coefficients are; 0.19, 0.08 and 0.09, which are clear supports for a priori expectations.

5.5 Estimations of Household Fuel Switching and Consumption

In this section, the results of the various estimations of factors influencing household fuel switching and consumption are presented, discussed and analysed.

5.5.1 Estimations of the Determinants of Household Cooking Fuel Choice

The second objective of this study is to estimate the factors that influence household cooking fuel choice in Bauchi State, Nigeria. This section presents the estimated multinomial logit coefficients of household cooking fuel choice, as well as the marginal effects and the relative risk ratios of the estimated model. Table 5.6 constitutes the estimated coefficients of the MNLM of the household cooking fuel choice in Bauchi State, Nigeria:

Table 5.6
Estimated Coefficients of Household Cooking Fuel Choice

VARIABLES	(Kerosene) 1=0	(Electricity) 2=0	(Gas) 3=0
Gender	0.932*	-1.193	0.006
	(0.564)	(0.781)	(0.780)
Age	0.029*	0.036	-0.001
	(0.015)	(0.028)	(0.025)
Education	0.047	0.189*	0.239***
	(0.042)	(0.097)	(0.091)
Household size	-0.085**	-0.079	-0.200**
	(0.038)	(0.061)	(0.090)
Lincome000	0.598***	0.497	0.793**
	(0.188)	(0.398)	(0.332)
Location	2.263***	-0.788	0.814
	(0.503)	(0.520)	(0.550)
Home size	-0.016	-0.012	0.001
	(0.010)	(0.016)	(0.011)
Home ownership	0.872**	1.241**	0.421
	(0.353)	(0.582)	(0.525)
Firewood price	0.013***	-0.017*	-0.0001
	(0.004)	(0.010)	(0.009)
Ncfuel	-0.945***	-0.514	-1.865***
	(0.347)	(0.629)	(0.450)
Constant	-7.187***	-5.364***	-7.582***
	(1.124)	(1.833)	(1.766)
Observations	465	465	465
Pseudo R^2	0.24		
χ^2 (26) = 110.47			
Prob > χ^2 = 0.0000			

Note: Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Diagnostic Tests

The post estimation tests conducted are; test of joint significant and test of the assumption of independent of irrelevant alternatives (IIA).

Table 5.6 exhibits the result of the joint significant test of all the independent variables included in the model. Based on the result of the test, the null hypothesis that all the coefficients are simultaneously equal to zero is rejected and therefore concludes that the various independent variables estimated in the model, have a joint significant impact on household cooking fuel choice.

Test of IIA Assumption

However, despite that multinomial logit model is built on the assumption of independence of irrelevant alternatives, some scholars such as Aliyu (2010), Cheng and Long (2007) Dow and Endersby (2004), Long and Freese (2001) and even those that developed the various statistical tools of IIA test (McFadden, 1974), questioned the validity and the reliability of the various IIA test statistics, and therefore suggested MNLM to be estimated if the various categories are distinct in the eyes of decision maker and not to rely heavily on the IIA test result. In fact, Cheng and Long (2007) argued that the tests of IIA assumption which are based on estimating the restricted choice set are not satisfactory for applied work. Moreover, IIA violation cannot be corrected by size adjustments or by means of alternative forms of the test. In a various substantive applications, it was found that despite reasonable model specifications, these tests regularly reject IIA when various options seem distinct and they accept IIA when the alternative choices can be reasonably viewed as close substitutes. Furthermore, varieties of IIA tests used on the same data on the same model normally gives inconsistent results regarding the violation or otherwise of IIA in the full model. Therefore, they recommend researchers to follow the suggestions given by McFadden (1974) that MNLM should be used only where the various alternatives are plausibly assumed to be distinct and weighed independently based on the perception of a decision maker.

Therefore, this study conducted the IIA test in order to explore the behaviour of the data, despite that the assumption of IIA is already meet in the categories estimated since none of the four categories appears to be the same with another category. Table 5.7 indicates the results of the IIA test conducted based on seemingly unrelated estimation (SUEST) method

Table 5.7
Results of the IIA Test

Categories	χ^2	**P-Value**	**Evidence**
Firewood	0.00	1.0000	For H_0
Kerosene	0.00	1.0000	For H_0
Electricity	0.00	1.0000	For H_0
Gas	0.00	1.0000	For H_0

The null hypothesis says: H_0: IIA assumption holds.

Based on the result of the IIA test (looking at the P-values), all the χ^2 test statistics are not significance and therefore the null hypothesis of meeting the requirement of IIA assumption is not rejected.

Going back to the estimated model, the discussion of the results of the estimated model (see Table 5.6) for household cooking fuel choice as follows:

GENDER: Based on the result of the estimated MNLM coefficients in Table 5.6, this coefficient was found to be statistically significant at 10% level. The result shows that on average, when other variables are held constant, the household's multinomial log-odds of adopting kerosene instead of firewood is higher by about 0.93 unit when the head is male. This is because in the study area, men are far economically stronger than women and therefore can afford more costly cooking fuel source than female. This conforms to a priori expectation and is in line with the findings of other previous studies (Ogwumike *et al*., 2014; Mekonen & Kohlin, 2008). That is, households that are headed by males are more economically stronger and also the level of education attained by men is far higher than those attend by women due to the culture of the people of the study area and therefore, tend to have higher probability of adopting cleaner fuel compared to women. However, this cooefficient is not statistically significant when it comes to household decision to adopt electricity or gas as the main source of cooking fuel, respectively.

AGE: Based on the estimated MNLM coefficients in Table 5.6, age of the household head was found to be statistically significant at 10% level. Furthermore, the estimated result has shown that the higher the age of the household head, the higher the multinomial log-odd of adopting kerosene fuel instead of firewood. A one year rise in the age of the household head increases the multinomial log-odd of adopting kerosene by 0.03, when all other variables are held constant. This is because as time goes on, income level normally increases which enable the heads of households to afford more expensive source of cooking fuel. This finding is in line with a priori expectation and also supports the findings of other previous studies (Ozcan *et al*., 2013). However, age of the household head is not statistically significant as per as adoption of electricity (in line with Ogwumike *et al*., 2014) or gas as the main source of cooking fuel is concern.

EDUCATION: Based on the estimated model in Table 5.6, education level of the household head was found to be statistically significant at 10% and 1% (for electricity and gas) levels. The result shows that a one year increase in the level of education attainment of the household head increases the multinomial log-odd of adopting electricity (compared to firewood) as the main source of cooking fuel by about 0.19 units. Likewise, one year increase in the level of education attainment of the household head when other factors are held constant; increases the multinomial log-odd of adopting gas as the main source of cooking fuel compared to firewood by about 0.24 units. These findings conform to a priori expectation that the higher the level of education attainment of the household head, the higher the possibility of such household to adopt modern and cleaner source of cooking fuel. This is because when the household head is more educated, he will have more awareness about the negative effects of using biomass cooking fuel energy.

Furthermore, the more educated the household head is, the more economically stronger the household may be, and the more the household afford to use cleaned modern source of cooking fuel, all things being equal. These findings correspond to the findings of the estimated coefficient of this variable and is in line with the findings of Nlom and Karimove (2014), Lee (2013), Mensah and Adu (2013), Maryam (2011), Suliman (2010), Heltberg (2005). It is also in line with the argument of rational choice theory that given perfect information and available resources, households choose one or more of these energy sources available that is believed to provide highest maximum satisfaction.

HOUSEHOLD SIZE: Based on the estimated result of the MNLM in Table 5.6, this coefficient was found to be statistically significant at 5% level. The results have shown that when a family size increase by one individual (other factors held constant) the multinomial log-odd of adopting kerosene instead of firewood as the main source of cooking fuel reduces by about 0.08 units. Likewise, the increase in the size of family by an additional one person reduces the multinomial log-odd of adopting gas compared to firewood by 0.20 units, all things being equal. This conforms to a priori expectation, that the higher the number of persons under the responsibility of one individual, the lower the possibility of adopting cleaned energy. This supports the findings of studies by Lee (2013), Couture *et al*. (2012), Mensah and Adu (2013), Nnaji *et al*. (2012), Maryam (2011), Heltberg (2005). This is because when the number of family members that depend on single person with constant income level increases, the household head find it more difficult to afford higher costly modern and cleaned source of cooking fuel due to increased family responsibility.

INCOME: This coefficient was found to be statistically significant at 1% and 5% (for Kerosene and gas adoption, respectively). The results show that a 1% increase in income of the household head will lead to increase in the multinomial log-odd of adopting kerosene compared to firewood by about 0.6 units all things being equal. Additionally, a 1% increase in the income will cause an increase in the multinomial log-odd of adopting gas as the main source of cooking fuel compared to firewood by about 0.79 units. This is tally with a priori expectation, that is, as income increases, households switch away to the cleaner energy. This supports the assertion of both energy ladder hypothesis and the energy stacking model. Also is in line with the findings of Lee (2013), Couture *et al*. (2012), Link *et al*. (2011), Osiolo (2010) Mekonnen and Kohlin (2008), Heltberg (2003), Hosier and Dowd (1987). This is because, the higher the income, the higher the ability of the household to afford costly modern cleaned source of cooking fuel all things being equal.

LOCATION: The estimated MNLM shows that this coefficient is statistically significant at 1% level. The result shows that households living in urban areas have a higher multinomial log-odd of adopting kerosene compared to firewood than the households living in the rural areas. This is in line with a priori expectations, that the household living in urban areas adopt cleaner cooking fuel source than the households living in the rural areas due to economic, social, educational and availability reasons. This supports the findings of other previous studies (Ogwumike *et al*., 2014; Ozcan *et al*., 2013; Mensah & Adu, 2013; Osiolo, 2010; Suliman, 2010; Hosier & Dowd, 1987). This is because the cleaned and modern cooking fuel facilities are more available in urban areas than the rural areas. Furthermore, the households living in the urban areas are more economically stronger to afford the cost of adopting modern cooking fuel source than the rural dwellers. Also those living in urban areas are in the better position to have awareness and orientation regarding environmental, social and health issues and therefore have higher probability to adopt cleaned source of cooking fuel.

HOME OWNERSHIP: Based on the result of the estimated MNLM in Table 5.6, this coefficient was found to be statistically significant at 5% level. The result indicates that the households that live in their self owned home, have a higher multinomial log-odd of adopting kerosene compared to firewood by about 0.87 units, than those living in non self owned home. Likewise, the result also indicates that the households living in their self owned homes have a higher multinomial log-odd of adopting electricity as the main source of cooking fuel compared to firewood than the households living in non self owned home. This may be viewed from two perspectives. Firstly, living in self owned home is a sign of being an economically strong, being economically strong, household usually adopts cleaned source of cooking fuel respectively. Secondly, living in self owned home encourages the households to avoid all the practice that may likely harm the home in which use of biomass cooking fuel is among, thereby encourages the households to adopt cleaned source of cooking fuel as possible as they can. This is tally with a priori expectation and is in support of the findings of previous studies (Couture *et al*., 2012).

PRICE OF FIREWOOD: The result of the estimated MNLM indicates that this coefficient is statistically significant at 1% and 10% levels (for kerosene and electricity adoption). A USD0.04 (₦10) increase in the price of firewood per bundle will increase the households' multinomial log-odd of adopting kerosene compared to firewood by about 0.1 units. This is tally with a priori expectation because kerosene as a cooking fuel is a substitute to firewood, when the prices of firewood rise, households switch away to the adoption of kerosene assuming (all other factors constant). This supports the demand theory, and is in line with the findings of previous studies (Nlom & Karimove, 2014; Lee, 2013; Couture *et al*., 2012; Oyekale *et al*., 2012) but contradicts the findings of Mekonnen and Kohlin (2008).

Furthermore, the result shows that the higher the price of firewood bundle the lower the multinomial log-odd of adopting electricity as a main source of cooking fuel compared to firewood by about 0.02 units. This does not conform to a priori expectation, since the expectation is that household switch to alternative source of cooking fuel if the price of firewood rises. This may be because of some reasons. Firstly, despite the rise in the price of firewood, it is still cheaper and easier to use compared to the electricity. Secondly, because of availability, households tend to adopt firewood when the price is rising than the electricity because the electricity is very limited in supply or not available. Lastly, culture of massive use of firewood as the main source of cooking fuel in the study area may also encourage them to be sticked to firewood adoption as the main source of cooking fuel because normally, the rise in the price of firewood in the study area is seriously negligible due to availability of supply.

NEIGHBOURHOOD COOKING FUEL SOURCE: Based on the result of the estimated coefficients of the MNLM, this coefficient was found to be statistically significant at 1% levels. The result shows that where the immediate neighbours adopt firewood, the multinomial log-odd of adopting kerosene as the main source of cooking fuel reduces by about 0.95 units. Similarly, where the immediate neighbour use firewood mostly, the household's multinomial log-odd of adopting gas as the main source of cooking fuel reduces by about 1.87 units, all things being equal. This finding conforms to a priori expectation that in most cases, the decision of households' cooking fuel choice is usually influenced by the type of cooking fuel that is predominantly used in their environment. This also conforms the conclusion of the relative income hypothesis, that the consumption behaviour of individuals or households are not only shaped by their income alone but also shaped by the consumption behaviour of the community.

Additionally, Table 5.8 exhibits the results of the estimated marginal effects of the multinomial logit model for household cooking fuel choice. The estimated model is statistically significant at 1% level. The choice categories are four namely; firewood, kerosene, electricity and gas.

Table 5.8

Estimated Marginal Effects of Household Cooking Fuel Choice

VARIABLES	(Firewood) 0	(Kerosene) 1	(Electricity) 2	(Gas) 3
Gender	-0.011	0.049*	-0.038	-0.0001
	(0.044)	(0.025)	(0.033)	(0.014)
Age	-0.002*	0.002*	0.001	-5.71e-05
	(0.001)	(0.001)	(0.001)	(0.0004)
Education	-0.010***	0.003	0.003***	0.004***
	(0.003)	(0.002)	(0.001)	(0.001)
Household size	0.010***	-0.005*	-0.001	-0.003**
	(0.003)	(0.003)	(0.001)	(0.001)
Lincome000	-0.059***	0.038**	0.008	0.012*
	(0.019)	(0.016)	(0.008)	(0.007)
Location	-0.152***	0.161***	-0.019	0.010
	(0.037)	(0.034)	(0.013)	(0.009)
Home size	0.001	-0.001	-0.0002	3.89e-05
	(0.001)	(0.001)	(0.0003)	(0.0002)
Home ownership	-0.106**	0.069*	0.031	0.005
	(0.043)	(0.036)	(0.022)	(0.010)
Fire wood price	-0.001	0.001***	-0.0003	-1.17e-05
	(0.0004)	(0.0003)	(0.0002)	(0.0001)
Ncfuel	0.131***	-0.072**	-0.008	-0.051**
	(0.045)	(0.035)	(0.014)	(0.024)
Observations	465	465	465	465

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1 χ^2 =110.47; Prob(χ^2) = 0.0000

GENDER: The estimated discrete effect of this coefficient in Table 5.8, indicates that; the probability of a household to adopt kerosene as the main source of cooking fuel is higher by about 4.9% when the household head is male than the female headed household. This is for economic and educational reasons. That is, households that are headed by males are more economically stronger and also the level of education attained by men is far higher than those attend by women due to the culture of the people of the study area and therefore, tend to have higher probability of adopting cleaner fuel compared to women. This finding supports the findings of the previous studies (Ogwumike *et al*., 2014).

AGE: Similarly, the estimated marginal effect of this coefficient was found to be statistically significant at 10% level. It shows that a one year increase in the age of the household head increases the probability of adopting kerosene as the main source of cooking fuel by about 0.19%, while reduces the probability of adopting firewood as the main source of cooking fuel by about 0.25%. This is in line with a priori expectation and also supports the findings of Couture *et al*. (2012), Ozcan *et al*., 2013). This is because as time goes on, income level normally increases which enable the heads of households to afford more expensive source of cooking fuel.

EDUCATION: the estimated marginal effects of this variable were found to be statistically significant at 1% level. The results have shown that the marginal effects of this variable are positively related with the probability of adopting electricity and gas as the main source of cooking fuel. A one year more level of education of the household head increases the household probability of adopting electricity as the main source of cooking fuel by about 0.30% and that of gas by about 0.40%. On the other hand, one more year education attainment by the household head reduces the household's probability of firewood adoption as the main source of cooking fuel by about 0.10%.

This is because when the household head is more educated, he will have more awareness about the negative effects of using biomass cooking fuel energy. Furthermore, the more educated the household head is, the more economically stronger the household may be, and the more the household afford to use cleaned source of cooking fuel, all things being equal. These findings conform to the findings of studies by Nlom and Karimove (2014), Ogwumike *et al*. (2014) Oyekale *et al*. (2012), Suliman (2010).

HOUSEHOLD SIZE: The estimated marginal effects of this coefficient were found to be positively related to the probability of firewood adoption and negatively related to the probability of adopting kerosene and gas (significant at 1% and 5% respectively). The results show that when the size of the household increase by one individual, the probability of firewood adoption as the main source of cooking fuel increases by about 1.0% while the probability of kerosene and gas adoption decrease by about 0.5% and 0.3%, respectively. This is because when the number of family members that depend on single person with constant income level increases, the household head find it more difficult to afford higher costly modern and cleaned source of cooking fuel due to increased family responsibility. This is tally with the findings of Couture et al. (2012); Suliman (2010)

INCOME: The estimated marginal effects of this coefficient were found to have significant impacts in influencing the probability of household cooking fuel choice at 1%, 5% and 10% levels (for firewood, kerosene and gas). The results have shown that there is a negative relationship between household income and the probability of firewood adoption. A 1% increase in income reduces the probability of firewood adoption by about 5.9% when other factors are held constant.

On the other hand, a 1%, increase in the income increases the probability of kerosene adoption as the main source of cooking fuel by about 3.8%. Similarly, 1%, increase in income, causes the probability of household adoption of gas as the main source of income to rise by about 1.2%. This is tally with a priori expectation and also conforms to the argument of both energy ladder hypothesis and the energy stacking model. Because, the higher the income, the higher the ability of the household to afford costly modern cleaned source of cooking fuel all things being equal. This further supports the findings of Nlom and Karimove (2014); Ogwumike *et al*. (2014); Ozcan *et al*. (2013); Couture *et al*. (2012).

LOCATION: The estimated discrete effects of this variable were found to be statistically significant at 1% level. The result have shown that the households that live in the urban areas of Bauchi State have a lower probability of adopting firewood as the main source of cooking fuel by about 15.2% compared to the households living in the rural areas of the State. Meanwhile, the probability of households living in the urban areas of the state to adopt kerosene as the main source of cooking fuel is higher by about 16.1% compared to that of rural dwellers. This is because the cleaned and modern cooking fuel facilities are more available in urban areas than the rural areas. Furthermore, the households living in the urban areas are more economically stronger to afford the cost of adopting modern cooking fuel source than the rural dwellers. Also those living in urban areas are in the better position to have awareness and orientation regarding environmental, social and health issues and therefore have higher probability to adopt cleaned source of cooking fuel. This finding is tally with the findings of Ozcan *et al*. (2013), Suliman (2010).

HOME OWNERSHIP: The estimated discrete effects of this coefficient (found to be statistically significant at 5% and 10% for both firewood and kerosene) shows that households that live in their self owned home have a higher probability of adopting kerosene as the main source of cooking fuel by about 6.9% compared to those living in non self owned home. On the other hand, the households living in their self owned home have lower probability of adopting firewood as the main source of cooking fuel by about 10.6% compared to those living in non self owned home. This may be viewed from two perspectives. Firstly, living in self owned home is a sign of being an economically strong, being economically strong, household usually adopts cleaned source of cooking fuel respectively. Secondly, living in self owned home encourages the households to avoid all the practice that may likely harm the home in which use of biomass cooking fuel is among, thereby encourages the households to adopt cleaned source of cooking fuel as possible as they can. This is tally with a priori expectation and is in support of the findings of previous studies (Couture *et al*., 2012).

PRICE OF FIREWOOD: The marginal effect of this coefficient was found to be statistically significant at 1% level. The result shows that a USD0.04 (i.e. ₦10) rise in the price of a firewood bundle, leads to increase in the probability of kerosene adoption as the main source of cooking fuel by about 0.9% holding other factors constant. This is because kerosene serves as a substitute to firewood. This is tally with a priori expectation because kerosene as a cooking fuel is a substitute to firewood, when the prices of firewood rise, households switch away to the adoption of kerosene assuming (all other factors constant). This supports the demand theory, and is in line with the findings of Nlom and Karimove (2014).

NEIGHBOURHOOD COOKING FUEL SOURCE: The estimated discrete effects of this coefficient were found to be statistically significant at 1% (for firewood model) and 5% (for kerosene and gas). The result shows that the probability of firewood adoption as the main cooking fuel source increases by about 13.1% when the household adopts the same source of cooking fuel as the majority of the community (which is firewood). Contrarily it is negatively related to the probability of adopting kerosene as the main source of cooking fuel by about 7.2% lower and also to the probability of gas adoption by about 5.1% lower. This means the community standard has a great impact on the probability of the type of cooking fuel source to be adopted by households. In this case as the majority of the community standard is firewood, the probability of household to adopt firewood goes up while the probability of adopting other source of cooking fuels goes down. This conforms to a priori expectation and is tally to the conclusion of relative income hypothesis that household tries to maintain their consumption pattern at least at their community's consumption standard.

5.5.2 Estimation of the Determinants of Household Lighting Fuel Choice

The third objective of this study was to estimate the factors that influence the household lighting fuel choice in Bauchi State. In this case, multinomial logit model was also estimated in order to assess the impacts of some socio-economic and environmental factors on the household choice of any of the stated lighting source. Table 5.9 exhibits the results of the estimated coefficients of the multinomial logit model.

Table 5.9
Estimated MNLM Coefficients of Household Lighting Fuel Choice

VARIABLES	(Semi-electric) 1=0	(Traditional) 2=0
Gender	0.676*	14.58***
	(0.390)	(0.329)
Age	-0.031**	-0.050**
	(0.015)	(0.021)
Marital status	0.132	0.169
	(0.322)	(0.482)
Households size	0.092***	0.074*
	(0.026)	(0.040)
Lincome000	-0.326*	-0.460*
	(0.194)	(0.254)
Location	0.241	-0.837**
	(0.295)	(0.411)
Hours of electricity supply	-0.013**	-0.002
	(0.006)	(0.009)
Number of rooms	-0.112***	-0.050
	(0.0380)	(0.071)
Nlfuel	-0.958***	-1.337***
	(0.346)	(0.470)
Lnhome appliances	0.097	-0.410
	(0.165)	(0.263)
Education	0.009	-0.019
	(0.021)	(0.032)
Constant	1.026	-10.750***
	(0.879)	(0.970)
Observations	420	420
Pseudo R^2	0.12	

χ^2_{22} = 2973.13
Prob(χ^2) = 0.0000

Note: Robust standard errors in parentheses*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Furthermore, Table 5.10 contains the results of the estimated marginal effects of lighting fuel source in Bauchi State as follows:

Table 5.10
Estimated Marginal Effects of Household Lighting Fuel Choice

VARIABLES	(Electricity) 0	(Semi-electric) 1	(Traditional) 2
Gender	-0.169***	0.078	0.091***
	(0.050)	(0.048)	(0.018)
Age	0.006**	-0.005**	-0.001**
	(0.002)	(0.002)	(0.0003)
Marital status	-0.023	0.021	0.002
	(0.052)	(0.052)	(0.007)
Household size	-0.016***	0.015***	0.001
	(0.004)	(0.004)	(0.001)
Lincome000	0.059*	-0.053	-0.006
	(0.032)	(0.032)	(0.004)
Location	-0.028	0.043	-0.015**
	(0.049)	(0.048)	(0.007)
Hours of electricity supply	0.002**	-0.002**	1.35e-05
	(0.001)	(0.001)	(0.0001)
Number of rooms	0.019***	-0.019***	-0.0004
	(0.006)	(0.006)	(0.001)
Nlfuel	0.205***	-0.180**	-0.026*
	(0.077)	(0.075)	(0.016)
Lnhome appliances	-0.011	0.018	-0.007*
	(0.028)	(0.028)	(0.004)
Education	-0.001	0.002	-0.0003
	(0.004)	(0.004)	(0.001)
Observations	420	420	420

Note: Standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$ Pseudo R^2=0.12; χ^2=2973 Prob=0000

Table 5.9 and Table 5.10 contain the results of the estimated multinomial logit model of household lighting fuel choice in Bauchi State. The estimated coefficients are displayed in Table 5.9 and the marginal effects in Table 5.10 respectively. The overall value of the chi-square of the model shows that the model is statistically significant at 1% level. Additionally, in order to further ascertain the validity of the model, various post estimation tests were conducted and the results were expressed

Diagnostic Tests

Based on the result of the joint significant test shown in Table 5.9, the null hypothesis that the variables included in the model are simultaneously equals to zero is rejected and therefore all the variables are retained as earlier expressed in the model.

Furthermore, Table 5.11 shows that the estimated model meets the IIA assumption and therefore the stated MNLM is maintained as the tool of analyzing household lighting fuel choice in Bauchi State.

Table 5.11
IIA Test

Categories	χ^2	**p-Value**	**Evidence**
Electricity	0.00	1.0000	For H_0
Semi-electric	0.00	1.0000	For H_0
Traditional	0.00	1.0000	For H_0

The discussions and interpretation of the estimated model (Table 5.9) are carried out as follows:

GENDER: Based on the result of the estimated model, the coefficients of gender in Table 5.9, were found to be statistically significant at 10% and 1% (for both semi-electric and traditional lighting sources) levels. The results have shown that the multinomial log-odd of adopting semi-electric source of lighting compared to the electric source is higher by about 0.68 units when the household head is male.

Similarly, the multinomial log-odd of adopting traditional source of lighting compared to electric source is higher by about 14.58 units for households that are headed by male.

In addition, the estimated marginal effects of this coefficient in Table 5.10 were found to be statistically significant at 1% level. The result indicates that the probability of households to adopt electricity as the main source of lighting is lower by about 16.9% when the household head is male. Contrarily, the probability of the household to adopt traditional source of lighting is higher by about 9.1% for households that are headed by male.

AGE: The results have shown that the estimated coefficients of household head age are statistically significant at 5% levels (Table 5.9). Based on the estimated result, there is a negative relationship between age and adoption of semi-electric source of lighting. A one year increase in the age of the household head reduces the household multinomial log-odd of adopting semi-electric source of lighting compared to electricity by about 0.03 units. Similarly, a one year increase in the age of the household head reduces the multinomial log-odd of household's adoption of traditional lighting source compared to electricity by about 0.05 units.

Furthermore, the estimated marginal effects of this variable were found to be statistically significant at 5% levels (Table 5.10). The results have shown that a one year increase in the age of the household head increases the households' probability of adopting electricity as the main source of lighting by about 0.6%. Contrarily, a one year increase in the age of the household head reduces the household probability of adopting semi-electric and traditional lighting sources as the main source of lighting by about 0.5% and 0.1%, respectively. These findings conform to a priori expectation that as time goes on, the earning of the household head increases which enable the household to afford more costly lighting source, all things being equal. This corresponds to the findings of Ozcan *et al*. (2013) and Couture *et al*. (2012).

HOUSEHOLD SIZE: The estimated result has shown that the coefficients of household size are statistically significant at 1% and 10%, respectively (Table 5.9). The result indicates that increase in the size of household by additional one person, increases the multinomial log-odd of adopting semi-electric lighting source compared to the electric source by about 0.09 units when other factors are held constant. On the same vein, additional one person in the family leads to about increase in the multinomial log-odd of adopting traditional source of lighting compared to electricity by about 0.07 units, all things being equal. This is in line with the findings of Lee (2013), Couture *et al*. (2012) and Hosier and Dowd (1987).

Furthermore, the result indicates that the estimated marginal effects of this coefficient are statistically significant at 1% level (Table 5.10). Based on the estimated result, increase in the number of family size by one person reduces the probability of household adoption of electricity as the main source of cooking fuel by about 1.6% when all other factors are held constant. However, on the opposite side, increase in the number of household members by one person increases the probability of adopting semi-electric source of lighting as the main source of lighting by about 1.5% all things being equal. In addition, the result shows that the estimated odd ratios of this variable are statistically significant at 1% and 10% respectively. These findings conform to a priori expectations that as the number of family members increases, holding all other factors constant, the ability of the household head to afford more costly source of lighting reduces due to increase in responsibilities. This corresponds to the earlier findings of Ozcan *et al*. (2013).

INCOME: Based on the result of the estimated model, the coefficients of this variable were found to be statistically significant at 10% level (Table 5.9). The result has shown that a 1% increase in income of the household head reduces the multinomial log-odd of adopting semi-electric lighting source compared to electric source by about 0.33 units, when all other variables are held constant. Similarly, a 1% rise in monthly income of the household head reduces the multinomial log-odd of adopting traditional source of lighting compared to the adoption of electricity. This supports the findings of Lee (2013), Couture *et al*. (2012) and Osiolo (2010).

Furthermore, the estimated marginal effect of this variable shows that there is a positive significant relationship between the probability of electricity adoption as the main source of lighting and the income of the household head (Table 5.10). A 1% rise in income of the household head leads to about 5.9% increase in the probability of adopting electricity as the main source of lighting when other factors are held constant. This is in line with Couture *et al*. (2012). These results correspond to a priori expectation that the higher the level of income the higher the capability of households to adopt electric source of lighting.

LOCATION: Based on the estimated result of the multinomial logit model, the coefficient of this variable was found to be statistically significant at 5% level. The results have shown that the households that are living in urban areas have lower multinomial log-odd of adopting traditional lighting source compared to electricity, than the households living in the rural areas by about 0.84 units when all other factors are held constant. Furthermore, the estimated discrete effect of this variable was found to be statistically significant at 5% level. Based on the estimated result, households that are living in the urban areas of Bauchi State have lower probability of adopting traditional source of lighting compared to electricity by about 1.5% than the households living in the rural areas. This is tally to a priori expectation, because of accessibility, affordability and other social reasons, i.e. households living in the urban areas have more access to the electricity connections, receive more supply of electricity and are more economically powerful to afford the costly electricity than the rural dwellers. Additionally, those living in urban areas are more curious to modern facilities than those living in the rural areas and are therefore have more probability to adopt electricity than their rural counterpart. This is in line with the findings of Ozcan *et al*. (2013) and Hosier and Dowd (1987).

HOURS OF ELECTRICITY SUPPLY: Based on the estimated model, the coefficient of hours of electricity supply was found to be statistically significant at

5% level (Table 5.9). The result has shown that one hour increase in supply of electricity in a week reduces the multinomial log-odd of adopting semi-electric source of lighting compared to electricity by about 0.01 units when other variables are held constant. Furthermore, the estimated marginal effects of this variable were also found to be statistically significant at 5% level (Table 5.10). The result has shown that one hour increase in supply of electricity per week will increase the probability of adopting electricity as the main source of lighting by about 0.2% when other variables are held constant. Contrarily, one hour increase in the availability of electricity in a week reduces the probability of adopting semi-electric source of lighting as the major source of lighting by about 0.2% when other variables are held constant. The estimated findings of this variable conform to a priori expectation that the tendency of households to adopt electricity as the major source of lighting increases when the electricity supply becomes more reliable. This supports the earlier findings of Heltberg (2003).

NUMBER OF ROOMS: The estimated results have shown that this variable is statistically significant at 1% level (Table 5.9). The results have shown that increase in the number of rooms in the home in which the households live by one unit, decreases the multinomial log-odd of adopting semi-electric source of lighting as the main lighting source compared to electricity by about 0.11 units, when other factors are held constant. Similarly, the estimated marginal effects of this variable were found to be statistically significant at 1% level (Table 5.10). The results have shown that one unit increase in the number of rooms in the home in which the households live increases the probability of adopting electricity as the main source of lighting by about 1.9% when other factors are held constant.

On the other hand, one unit increase in the number of rooms in the home reduces the probability of adopting semi-electric source of lighting by about 1.9%, assuming all other factors are held constant. These findings conform to a priori expectation because in most cases, higher number of rooms in the home indicates higher size of home which in turn reflects how economic strong the household is; thereby affording more costly source of lighting. Furthermore, the higher the number of rooms in the home, the higher will be the number of electricity use devices such as bulbs, fans air conditioners and others; which increases the household's desire to use electricity more. This finding also supports the findings of some previous studies (Eakins, 2013; Heltberg, 2005).

NEIGHBOURHOOD SOURCE OF LIGHTING: The result shows that the estimated multinomial logit coefficients of neighbourhood source of lighting are statistically significant at 1% level (Table 5.9). The multinomial log-odd of adopting semi-electric source of lighting compared to electricity decreases by about 0.96 units when both the household and its neighbour adopted the same main source of lighting, assuming other factors are held constant. In the same vein, the multinomial log-odd of adopting traditional source of lighting compared to electricity reduces by about 1.34 units when the household and its immediate neighbour adopted the same source of lighting, if other factors are held constant. Furthermore, the estimated discrete change in this variable (significant at 1% level) indicated that when both the household and its immediate neighbour adopt the same source of lighting, the probability of the household to adopt electricity as the main source of lighting, increases by about 20.5%.

On the other hand, when the probabilities of adopting semi-electric and traditional source of lighting decreases by about 18% and 2.6% when both the household and its immediate neighbour adopted the same (electricity) source of lighting. These findings conform to a priori expectation, that households normally adopt the type of lighting source which most of its immediate neighbours use mostly. This validates the conclusion of relative income hypothesis that the consumption behaviours are usually maintained at least based on the community consumption standard.

HOME APPLIANCES: The results have shown that the estimated marginal effect of this variable was found to be statistically significant at 10% level (Table 5.9). Based on the estimated result, a 10% increase in the number of electricity appliances at home reduces the probability of adopting traditional source of lighting by about 7% when other factors are held constant. This conforms to a priori expectation because electricity appliances are only useful when having electricity. Therefore the greater the items of this kind at home it means the greater the probability of such household to adopt electricity as the main source of lighting, all things being equal. This is in line with the findings of Couture *et al*. (2012).

5.5.3 Estimations of the Determinants of Household consumption of Firewood, Kerosene and Electricity

Unlike the previous section whereby the estimations are for fuel switching, in this section, in order to achieve the fourth objective of the study (which is to estimate the determinants of amount of energy consumption from the various energy sources) estimations were carried out for the factors that influence the amount of energy consumption from each of the energy source (i.e. firewood, kerosene and electricity) using different models.

5.5.3.1 Determinants of Household Firewood Consumption in Bauchi State

In this section, OLS regression model was used to estimate the impacts of some factors on the amount of households' firewood consumption in Bauchi State, Nigeria. Table 5.12 exhibits the result of the estimated model.

Table 5.12
Determinants of Firewood Household Consumption

VARIABLES	Coefficients	Standard error
Gender	0.239*	(0.122)
Marital status	-0.206***	(0.070)
Education	-0.018***	(0.006)
Household size	0.008	(0.005)
Income000	0.001	(0.001)
Location	0.144*	(0.079)
Home ownership	0.008	(0.041)
Lnnumber of rooms	0.167***	(0.059)
Share of dwelling	0.027	(0.066)
Price of firewood	-0.002*	(0.001)
Constant	3.579***	(0.241)
Observations	255	
R^2	0.18	

Ramsey RESET Test (Specification test)
F(3, 244) = 1.23
Prob > F = 0.298

Note: Robust standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1

Based on Table 5.12, the estimated result shows that overall, the model is statistically significant at 1% level with an estimated F-value=4.19 and the corresponding probability value Prob(F)=0.000. Additionally, in order to further ascertain the validity of the estimated OLS model, post estimation tests for multicollinearity, heteroscedasticity, normality and specification of the model were conducted, and the results of these tests are presented below:

Diagnostic Checking

To further ascertain the validity of the estimated OLS model the following post estimation tests were conducted

VIF test for multicollinearity

Table 5.13 contains the VIF test for measuring the extent of multicollinearity among the independent variables

Table 5.13
VIF Test for Multicollinearity

Variable	VIF	1/VIF
home ownership	1.31	0.77
location	1.28	0.78
income000	1.21	0.83
lnnumber of rooms	1.21	0.83
education	1.16	0.86
price of firewood	1.16	0.87
share of dwelling	1.14	0.88
marital status	1.14	0.88
household size	1.14	0.88
gender	1.10	0.91
Mean VIF	1.19	

Based on the result of the VIF test of variable multicollinearity shown in Table 5.13, since none of the VIF value reached a value of 10, there is no problem of multicollinearity among the included variables in the model and therefore, we maintained all our variables for the purpose of estimation.

Specification Test

A specification test was conducted a test to see whether the estimated model is correctly specified or not, using Ramsey RESET test. The result of this test is shown in the bottom side of Table 5.12. Based on the result of the model specification test, the null hypothesis that the estimated model has no omitted variables is not rejected, and therefore concludes that the model has been correctly specified.

Tests of Heteroscedasticity and Normality

In this case, Cameron and Trivedi's tests of heteroscedasticity and normality were conducted. The result of this test is shown in Table 5.14

Table 5.14
Cameron & Trivedi's Decomposition of IM-test

Source	χ^2	**df**	**p – Value**
Heteroskedasticity	63.24	73	0.7854
Skewness	21.17	11	0.0317
Kurtosis	6.39	1	0.0115
Total	90.80	85	0.3135

Based on the overall result of the test statistic shown in Table 5.14 with Prob=0.314, the null hypothesis of normality and the homoskedastic assumptions cannot be rejected. Furthermore, it is important to note that this model was estimated using robust standard error estimates which are free from heteroscedasticity. Therefore, the test was performed in order to further validate the homoscedasticity assumption in the estimated result. The discussions of the result of the estimated model are as follows:

GENDER: Based on the estimated OLS model (Table 5.12), the result has shown that this coefficient is statistically significant at 5% level. It was found to have a positive relationship with the amount of firewood consumption. Households that are headed by male tend to consume firewood by about 23.9% higher than the households that are headed by female when other factors are held constant. This is in line with a priori expectation because households that are headed by a male may be economically stronger to buy firewood for domestic use than female headed households. Additionally, a male household head may not have the strong feeling of replacing firewood with other cooking fuel source because he is not in direct contact with the smoke compared to women. This finding is tally with the earlier findings of Abebaw (2007).

MARITAL STATUS: The result in Table 5.12 has shown that the estimated coefficient of this variable is statistically significant at 1% level. On average, the households that are headed by a married person consume less firewood by about 20% lower compared to the households that are headed by a non married person. This does not conform to a priori expectation because the expectation is that when the head of a household is married, it means more number of household members which necessitates the use of more firewood. However, this may be because the married household head has more responsibility on him making him to have lower budget on firewood purchase to take care for other family responsibilities compare to the non married individual. Or it may be because a married household head in some cases signifies that he is at least more economically stronger to buy cleaner fuel than firewood. This is because based on the culture of the people of the study area, a person usually married when economically can afford the marriage responsibilities of which the purchase of cooking fuel is among. This finding supports the findings of other previous studies (Oyekale *et al*., 2012).

EDUCATION: Based on the estimated regression result in Table 5.12, this coefficient was found to be statistically significant at 1% level. The result established that there is a negative relationship between the level of education of the household head and the amount of the household firewood use. On average, a one year increase in the years of studies of the household head leads to about 1.8% decrease in the amount of firewood consumption when other factors are held constant. This is in line with a priori expectations due mainly to two reasons. Firstly, as more educated is the household head, the more he has health consciousness and also the more he take the danger of using firewood serious which consequently discourage him from using more firewood. Secondly, the level of education attainment usually has serious impacts on earning of individual. The more the household head is educated the higher will be the income and the stronger will be the household to adopt modern cleaned source of energy. This finding supports the earlier findings of Lee (2013) and Abebaw (2007).

LOCATION: Based on the estimated OLS model for firewood consumption in Table 5.12 this coefficient was found to be statistically significant at 10% level. The result indicates that household that live in the urban areas consume higher amount of firewood by about 14.4% compared to the rural areas. This is tally to a priori expectation, because in most cases urban dwellers can afford to buy more quantity of firewood than the rural dwellers. Furthermore, normally the simple to prepare nature of food and drinks items in rural areas makes it to requires less amount of firewood compared to that of urban area.

NUMBER OF ROOMS: The estimated result of the regression in Table 5.12 indicates that this coefficient is statistically significant at 10% level. The variable is positively related to the amount of firewood use, the higher the number of rooms available to the household at home, the higher the amount of firewood consumption when all other variables are held constant. This is because more rooms in the home means more available possible space for household to use firewood, unlike some situations whereby some households are forced not to use firewood because they don't have a space for firewood use at home, because the use of firewood requires relatively more space. This result is tally to the findings of Song *et al*. (2012).

PRICE OF FIREWOOD: Based on the result of the regression in Table 5.12, this coefficient was found to be statistically significant at 10% level. The result has shown that there is a negative relationship between the amount of firewood use and the price per bundle of firewood. The result indicates that USD0.04 (₦10) rise in the price of firewood per bundle reduces the amount of firewood consumption by about 2%. This is tally with a priori expectation because as the price of firewood increases, the household may try to substitute the use of available and cheaper source of fuel thereby reduces its consumption of firewood. Similarly, when the price of a commodity rises, the purchasing power of buyers decreases, leaving the consumer with the ability to buy less of that commodity. This finding is in line with the traditional law of demand and also supports the findings of Lee (2013), Couture *et al*. (2012) and Ganchimeg and Havrland (2011).

5.5.3.2 Determinants of Kerosene Consumption in Bauchi State

Part of the fourth objective of this study is to estimate the determinants of the amounts of kerosene consumption of households in Bauchi State, Nigeria. However, based on the data obtained from the selected samples, more than 50% of the samples do not use kerosene. In this situation, most of the observation tend to have zero values leading to the bias of OLS estimation of this type of data (please refer to the section of model specification for more detail on this). Here the most appropriate model for estimation is Tobit model, and therefore the result of the estimated Tobit model is shown in Table 5.15.

Table 5.15 indicates the estimated Tobit model of kerosene consumption in Bauchi State, Nigeria. The chi-square statistics value (31.69) indicates that overall, the estimated model is statistically significant at 1% with P-value=0.0005. Moreover, various post estimation tests were conducted in order to further ascertain the validity of the estimated model. The results of the post estimation tests are shown below:

Table 5.15

Tobit Model of Household Kerosene Consumption

DV=Quantity of Kerosene Consumption	Coeficient	Standard Error
Gender	0.335	(0.216)
Age	0.011*	(0.006)
Education	-0.012	(0.012)
lnHousehold size	0.005	(0.100)
Income000	0.003*	(0.002)
Location	0.370***	(0.135)
Hours of electricity supply	-0.002	(0.002)
Nlfuel	-0.261*	(0.152)
lnPrice of firewood	0.315**	(0.131)
lnPrice of kerosene	-0.383*	(0.197)
Constant	2.340**	(1.129)
Pseudo R^2	0.12	

Note: Robust standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1

Diagnostic Checking

The following diagnostic checkings were conducted in order to ascertain the validity of the estimated Tobit model

Tests of Heteroskedasticity and Normality

The test of heteroskedasticity and normality were conducted using Cameron and Trivedi Im-test. The results of these tests are contained in Table 5.16

Table 5.16

Cameron & Trivedi's decomposition of IM-test

Source	χ^2	**df**	**p-Value**
Heteroskedasticity	62.29	62	0.4659
Skewness	17.97	10	0.0555
Kurtosis	2.27	1	0.4021
Total	80.95	73	0.2450

Based on the result of the heteroscedasticity and normality in Table 5.16, the null hypothesis of homoscedasticity and normality is not rejected. The discussion of the estimated Tobit model for household kerosene consumption in Bauchi State is expressed below:

AGE: The result of the estimated Tobit model in Table 5.15 has shown that this coefficient is statistically significant at 10% level. The result established that there is a positive significant relationship between the intensity of household kerosene use and the age of the household head. Based on the estimated Tobit coefficients, 1 years increase in the age of the household head brings about 1.1% rise in the intensity of kerosene use when other factors are held constant. This is in line with a priori expectation because as time goes on, normally income of the household head increases thereby enabling the household to afford more quantity of kerosene fuel. Additionally, as time goes on the size of household become large due to additional marriage by the household head (since Bauchi State people practices polygamy marriage system) or due to new born sons and daughters to the household, that necessitates the expansion of consumption items in the household of which kerosene is inclusive.

INCOME: The result of the estimated Tobit model in Table 5.15 has shown that this coefficient is statistically significant at 10% level. The positive relationship between the intensity of kerosene use and income implies that the higher the income of the household head, the higher the intensity of kerosene use by the household. Based on the estimated coefficient of this variable, a USD5 (₦1000) rise in income leads to about 3% increase in the intensity of kerosene use as a source of fuel to the household when other variables are held constant. This is tally to a priori expectation, because as the income of the household head increases, the ability to adopt kerosene as the main source of fuel to the household also increases all things being equal. This supports the earlier findings of Lee (2013) and Dubin and Daniel (1984).

LOCATION: The result of the estimated Tobit model in Table 5.15 has shown that this coefficient is significant in influencing the household intensity of kerosene use at 1% level. This coefficient indicates that households that are living in the urban areas of Bauchi State, tend to use more kerosene by about 37% higher than those in the rural areas of the state, when all other factors are held constant. This is in line with a priori expectation, because, kerosene is more available in urban areas of Bauchi State than the rural areas. Similarly, the cost of kerosene in Bauchi State is relatively high whereby most of the rural dwellers cannot afford to use it as their main source of fuel.

Furthermore, people living in the urban areas are more aware of the environmental dangers of tree cutting than their rural counterpart, which make those that can afford to use kerosene as their main fuel source in the urban areas to use it more than those in the rural areas. Lastly, the different varieties of foods and cooking styles that are found in urban areas far exceed those that are found in rural areas. Most of the foods found in rural areas of the State are traditional and simple to cook foods, thereby making consumption of kerosene to be higher for households that are living in urban areas than in the rural areas. This conforms to the findings of Mensah and Adu (2013)

NEIGHBOURHOOD MAIN LIGHTING SOURCE: This coefficient was found to be statistically significant at 10% level. Based on the estimated Tobit model in Table 5.15, the coefficient of this variable was found to have a negative relationship with the household intensity of kerosene use. When both the household and its neighbour adopt the same source of lighting (mostly electricity) the intensity of kerosene use decreases by about 26%, assuming other factors are held constant. This is tally with a priori expectation and also confirms the conclusion of the theory of relative income hypothesis, that consumption behaviour of individuals and households is influenced by the nature of consumption standard of the community in which they live, hence households use in most cases the most widely use type of fuel source by their community.

PRICE OF FIREWOOD: The estimated result from the Tobit model indicates that this coefficient which was found to be statistically significant at 5%; has a positive relationship with the intensity of household kerosene use. The higher the price of firewood, the higher the intensity of kerosene uses. Based on the value of this coefficient, a 1% rise in the price of firewood leads to about 0.31% increase in the intensity of kerosene use when other factors are held constant. This is tally with a priori expectation, because as the price of firewood rises, households substitute the use of firewood with kerosene, because firewood and kerosene in most cases are close-substitute. This supports the findings of Lee (2013) and Koshal *et al*. (1999).

PRICE OF KEROSENE: The result of the estimated Tobit model indicates that this coefficient is statistically significant at 10% level. The result shows that there is an inverse relationship between the intensity of kerosene use and the price of kerosene. A 1% increase in the price of kerosene leads to the decrease in the intensity of the household kerosene use by about 0.38% when other variables are held constant. This is tally with a priori expectation, that as price of a commodity rises, the purchasing power of the user decreases leading to the reduction in the quantity purchased. This confirms the theory of demand and supports the findings of Lee (2013); Couture *et al*. (2012); Koshal (1999) and Dubin and Daniel (1984).

In this model, the coefficient of this variable is the price elasticity of demand for kerosene (both the dependent variable and the variable of kerosene price are in log values).

5.5.3.3 Determinants of Electricity Consumption in Bauchi State

Part of the fourth objective of this study is to estimate the determinants of electricity consumption in Bauchi State. In this section, the result obtained from the estimation of electricity consumption is presented and discussed. The result of the estimated OLS model for electricity consumption is presented in Table 5.17.

Table 5.17
Estimated OLS Model for Household Expenditure on Electricity

VARIABLES	Coefficients	Standard Error
gender	0.027	(0.287)
marital status	-0.364*	(0.187)
education	0.026**	(0.010)
household size	-0.001	(0.014)
location	0.591***	(0.173)
home size	0.001	(0.003)
price of firewood	0.003*	(0.002)
lnnumber of rooms	-0.162	(0.109)
Neighbour lighting fuel	-0.094	(0.207)
home appliances	0.013**	(0.007)
Constant	1.640***	(0.394)
Observations	350	
R^2	0.11	
Ramsey RESET Test (specification test)		
F(3, 239) = 1.96		
Prob > F = 0.1197		

Note: Robust standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1

Table 5.17 contains the result of the estimated OLS model for household electricity consumption in Bauchi State, Nigeria. The overall test statistic (F-value) of the model indicates that the estimated model is statistically significant at 0.1% (p-value = 0.000). Moreover, in order to further ascertain the validity of the model, various post estimation tests were conducted.

Diagnostic Checking

In this section, diagnostic checks for heteroskedasticity, normality, multicollinearity and specification tests were conducted to ascertain the validity of the estimated OLS model of household expenditure on electricity.

Test of Heteroskedasticity and Normality

The test of heteroskedasticity and normality were conducted using Cameron and Trivedi Im-test. The results of these tests are contained in Table 5.18. The results of the heteroscedasticity and normality tests failed to reject the null hypothesis of homoscedasticity and normality.

Table 5.18
Cameron & Trivedi's Decomposition of IM-test

Source	χ^2	df	P-value
Heteroskedasticity	52.05	61	0.7859
Skewness	13.73	10	0.1857
Kurtosis	2.27	1	0.1317
Total	68.05	72	0.6100

Test of Multicollinearity

Table 5.19 contains the VIF test for measuring the extent of multicollinearity among the independent variables as shown in Table 5.19.

Table 5.19
VIF Test of Multicollinearity

Variable	VIF	1/VIF
lnnumber of rooms	1.34	0.75
home size	1.32	0.76
location	1.31	0.76
household size	1.26	0.80
price of firewood	1.22	0.82
education	1.13	0.89
marital status	1.09	0.92
gender	1.08	0.92
home appliances	1.06	0.94
Nlfuel	1.05	0.95
Mean VIF	1.19	

Based on the result of the VIF test of variable multicollinearity shown in Table 5.19, since none of the VIF value reached a value of 10, there is no problem of multicollinearity among the included variables in the model and therefore, the study maintained all the variables for the purpose of estimation.

Specification Test

Here a test to see whether the estimated model is correctly specified or not, was conducted using Ramsey RESET test. The result of this test is shown in the bottom side of Table 5.17. Based on the result of the model specification test, the null hypothesis that; the estimated model has no omitted variables was not rejected, and therefore, the model is correctly specified.

MARITAL STATUS: The result of the estimated OLS model in Table 5.17 has shown that this coefficient is statistically significant at 10% level. The result further shows that there is a negative relationship between this variable and expenditure on electricity. The household that are headed by a married individual have less expenditure on electricity by about USD1.35 (₦365) lower compared to the household whereby the head is not married. This result does not conform to a priori expectation, because the expectation is that households that are headed by a married person have higher expenditure on electricity due to the fact that they are larger in size requiring higher expenditure on electricity than otherwise.

However, the justification of this finding is that a married household head normally have more responsibilities on him than the single one, the condition which may make him to have lower budget on electricity consumption than the non married household head especially the fact that the people of the study area practice polygamy marriage system which makes them to have more responsibilities to shoulder leading to the cutting down of expenditure on electricity to other basic life necessities. This finding corresponds to the findings of Cayla *et al*. (2011).

EDUCATION: The result in Table 5.17 has shown that this coefficient is statistically significant at 5% level. Based on the estimated OLS result, an additional one year level of education attainment by the household head increases the household monthly expenditure on electricity by about USD0.09 (₦26) when other variables are held constant. This is tally with a priori expectation, because higher education level means higher income which results in increase in expenditure on electricity. Furthermore, the higher the level of education attained by the household head, the higher the minimum living standard to be maintained by the household leading to the rise in the household expenditure on electricity. This finding supports the findings of previous studies (Lee, 2013; Labandeira *et al*., 2010).

LOCATION: The result in Table 5.17 has shown that this coefficient is statistically significant at 1% level. Based on the estimated result, households that are living in urban areas have higher monthly expenditure on electricity than those living in the rural areas by about USD2.14 (₦600) when other factors are held constant. This conforms to a priori expectation because expenditure on electricity tends to be higher for urban dwellers than for rural dwellers due to so many reasons. Firstly availability, the number of hours in which electricity is available in urban areas is higher than that of rural areas which make the expenditure on electricity in the urban areas higher. Secondly, the electrical appliances own and use by households living in the urban areas far outweigh that of those living in rural areas which result in higher expenditure in the urban areas than the rural areas. Lastly, affordability, the households living in urban areas mostly have more income than those living in the rural areas and therefore afford to pay more on electricity consumption than those living in the rural areas. This finding corresponds to the earlier findings of previous studies (Eakins, 2013; Labandeira et al., 2010; Diabi, 1998).

PRICE OF FIREWOOD: The result from the estimated model (Table 5.17) has shown that this coefficient is statistically significant at 10% level. The result has shown that there is a positive relationship between the household expenditure on electricity and the price of firewood. Based on the estimated coefficient; USD0.04 (₦10) increase in the price of firewood bundle leads to increase in the household expenditure on electricity by about USD0.11 (₦30) when other factors are held constant. This is tally with a priori expectation because in most cases especially for cooking purposes, firewood and electricity are close substitute hence as the price of firewood rises, households switch away to consumption of electricity by increasing their expenditure on the electricity. This is tally with the findings of Svoboda and Br (2013) and also in line with the argument of the theory of demand, that the price of a commodity has a positive relationship with the amount of demanding the other close substitute good, so that as the price rises, people substitutes to the consumption and use of the other commodity or service.

HOME APPLIANCES: This variable represents the number of home electrical appliances such as bulbs, fluorescents, televisions, radio, refrigerators etc, possess at home measured in terms of number of unit quantity. Based on the estimated result, this variable was found to be statistically significant at 5% level. The result has shown that an addition to the stock of electrical appliance use at home, brings about increase in household expenditure on electricity by about USD0.05 (₦13) when other factors are held constant. This is in line with a priori expectation, because the higher the number of electrical device owned, the higher the consumption of electricity, consequently the higher the expenditure on electricity. This finding is tally with the findings of some previous studies (Eakins, 2013; Louw *et al*., 2008; Petersen, 1982)

5.5.4 Relative Income Hypothesis and the Household Energy Choice and Consumption

The last objective of this study is to test the relevance of relative income hypothesis on household energy choice and consumption in Bauchi State, Nigeria. In this case, the relevance of the theory of relative income hypothesis to the two dimensions of household energy choice (i.e. cooking fuel and lighting fuel consumption choices) were tested separately.

5.5.4.1 Relative Income Hypothesis and the Household Cooking Fuel Choice

In this case, the validity of the theory of relative income hypothesis was tested in relation to household cooking fuel consumption choice. In order to conduct such test, the study employs two approaches namely; statistical and econometric estimation approaches. The statistical tests consist of testing the relevance of the variable representing relative income hypothesis in the previous estimated MNLMs. The estimation method has to do with estimating a modified model of testing relative income hypothesis proposed by Verme (2013). The results of the tests are discussed below:

5.5.4.1.1 Statistical Tests of RIH and the Household Cooking Fuel Choice

The various statistical tests of RIH in relation to the households' source of cooking fuel choice were conducted, the results of the tests are explained as follows.

5.5.4.1.1.1 Test of a Specific Variable (NCFUEL)

From the earlier estimated model of household cooking fuel choice, a likelihood ratio test of the variable representing neighbourhood cooking fuel was conducted. The procedure is that firstly, the full model was estimated and called it unrestricted model. Then the variable representing relative income hypothesis was removed and re-estimated the model again (the second model is known as; restricted model). Then the likelihood ratio test was conducted for the following hypothesis:

H_0: the restricted and unrestricted models are non nested models.

The result of the test is shown in Table 5.20

Table 5.20

Likelihood-Ratio Test of a Specific Variable (NCFUEL)

LR χ^2 (2)	=	21.88
Prob(χ^2)	=	0.0001

Assumption: restricted nested in unrestricted

Table 5.24 indicates the result of a specific variable test 'NCFUEL' in the estimated multinomial logit model (see Table 5.6). The result has shown that the LR Chi-square statistic is significant at 0.1%. This implies that the variable NCFUEL is relevant in explaining household cooking fuel source choice. Meaning that the full model (unrestricted) which has the variable 'NCFUEL' in its has an additional information in explaining household cooking fuel choice than the restricted model which has the same variables as the unrestricted model except the variable 'NCFUEL'. This signifies that the theory of relative income hypothesis is relevant in explaining the cooking fuel consumption pattern of households.

5.5.4.1.1.2 Fit Statistics of the Model

Similarly, post estimation test of fit statistic was used to further ascertain the relevance of the theory of relative income hypothesis in explaining the household cooking fuel consumption pattern. The procedure followed in conducting this test was that, firstly, the full model was estimated based on multinomial logit model and saved it using fitstat command. Then the partial model was estimated by removing the variable 'NCFUEL'. Then the fit statistics of these models were established in order to see which of these two estimated models better fit the data. The results obtained from the fit statistics are shown in Table 5.21

Table 5.21

Test of Model Fit

	Current	Saved	Difference
Model:	mlogit	mlogit	
D:	550.425(428)	528.546(421)	21.879(7)
AIC:	630.425	616.546	13.879
BIC':	19.771	17.658	2.113

Table 5.21 indicates the various fit statistics of the two estimated models. The saved model is the full model containing all the variables together with the variable 'NCFUEL'. On the other hand, the current model contains all the variables (as in the full model) except the variable 'NCFUEL' which is the focal of the analysis. The result shows that all the three test statistics i.e. the LR (D), the AIC and the BIC established that the full model (saved model) has better fits than the partial (current) model. This is further evidence that the theory of relative income hypothesis can be used to explain households cooking fuel consumption pattern.

5.5.4.1.1.3 Wald Test of Individual Variable (NCFUEL)

This is the third statistical method followed to re-examine the validity or relevance of the theory of RIH in explaining household cooking fuel choice behaviour. The result of the Wald test is shown in Table 5.22.

Table 5.22

Wald Test of NCFUEL

χ^2 (3)	=	20.06
Prob(χ^2)	=	0.0002

H_0 [0]o.ncfuel = [1]ncfuel = [2]ncfuel = [3]ncfuel = 0

Table 5.22 exhibits the result of the Wald test for the variable 'NCFUEL' which is one of the explanatory variables in the estimated model. The result of the test rejected the null hypothesis of non relevance and therefore the variable is strongly relevance (significant at 0.1%) in the model. This is a further validation of the theory of relative income hypothesis in describing household cooking fuel use behaviour.

5.5.4.1.2 Econometric Approach of Testing the Relevance of RIH and the Household Cooking Fuel Choice

In this case, various estimations were conducted to ascertain the validity of relative income hypothesis based on the model (modified) of testing relative income hypothesis as proposed by Verme (2013). Multinomial logit model estimation was conducted to see the relationship between household cooking fuel choice and the variables representing the theory of relative income hypothesis. The result of the estimated model is shown in Table 5.23.

Table 5.23
Estimated Model of RIH and Household Cooking Fuel Choice

VARIABLES	(Kerosene) 1=0	(Electricity) 2=0	(Gas) 3=0
Lincome000	0.393***	0.634**	0.971***
	(0.142)	(0.300)	(0.262)
Loc*Ncfl	1.713***	0.682	1.434**
	(0.332)	(0.603)	(0.683)
Ncfuel	-2.337***	-0.829	-2.919***
	(0.347)	(0.704)	(0.649)
Constant	-1.663***	-5.023***	-4.754***
	(0.529)	(0.992)	(1.015)
Observations	530	530	530

Note: Robust standard errors in parentheses, Pseudo R^2 = 0.12 *** p<0.01, ** p<0.05, * p<0.1 Wald χ^2 (9) = 76.04, Prob > χ^2 = 0.0000

Furthermore, the estimated marginal effects of the model are shown in Table 5.24

Table 5.24
Marginal Effects of the Estimated Model of RIH and Household Cooking Fuel Choice

VARIABLES	(Firewood) 0	(Kerosene) 1	(Electricity) 2	(Gas) 3
Lincome000	-0.095***	0.049**	0.016*	0.031***
	(0.024)	(0.021)	(0.008)	(0.009)
Loc*Ncfl	-0.316***	0.270***	0.006	0.039
	(0.055)	(0.055)	(0.018)	(0.029)
Ncfuel	0.494***	-0.368***	0.002	-0.127**
	(0.058)	(0.067)	(0.018)	(0.050)
Observations	530	530	530	530

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

As can be seen from Table 5.23 and Table 5.24 the various coefficients and the marginal effects of the estimated model for testing the relationship between the theory of relative income hypothesis and the household cooking fuel choice. The probability of the model shows that the overall fit of the estimated model is statistically significant at 0.1% level. From the estimated results, variables (the independent variables) representing the theory of relative income hypothesis were found to be statistically significant mostly at 1% and 5% levels. Furthermore, all the coefficients have the sign that conform to a priori expectation which is further evidence of the relevance of the theory (RIH) to household cooking fuel choice.

For instance, based on the result from the estimated model, the coefficient of income (Table 5.23) has a positive relationship with kerosene adoption, a 1% increase in income leads to increase in the multinomial log-odd of adopting kerosene by about 0.39 units compared to firewood. Similarly, 1% rise in income, increases the multinomial log-odd of adopting electricity by about 0.63 units compared to firewood when other variables are held constant. Furthermore, a 1% increase in income leads to about increase in the multinomial log-odd of adopting gas compared to firewood by about 0.97 units. Additionally, the marginal effects of this coefficient (Table 5.24) indicate that 1% increase in income decreases the probability of adopting firewood as the main source of cooking fuel by about 9.5%, while increases the probabilities of adopting kerosene, electricity or gas by about 4.9%, 1.6% and 3.1% respectively.

Furthermore, the result indicates that the coefficients of neighbour source of cooking fuel-location interaction (Table 5.23) are statistically significant at 1% and 5% respectively. Based on the estimated result, households that live in urban areas and who have the same main source of cooking fuel with their neighbours, have higher multinomial log-odd of adopting kerosene compared to firewood than otherwise by about 1.7 units. Similarly, the multinomial log-odd of adopting gas as the main source of cooking fuel compared to firewood for households that live in urban areas and adopt main cooking fuel source similar to their neighbours is higher than otherwise by about 1.43 units, when the rest variables are held constant. Similarly, the estimated marginal effects of this variable are statistically significant at 1% level. The result has shown that the interaction between living in urban areas and adopting main source of cooking fuel similar to that of immediate neighbour, reduces the household probability of adopting firewood as the main source of cooking fuel by about 31.6% while increases the probability of adopting kerosene by about 27%. This implies that the location where the household lives and the type of cooking fuel mostly adopted in their community have a joint significant effect on the type of cooking fuel to be adopted and used. This validates the significant relationship between the argument of the theory of relative income hypothesis and the household cooking fuel choice.

Lastly, the coefficient 'NCFUEL' which also represents the argument of the relative income hypothesis was found to be significant at 1% level. Based on this coefficient (Table 5.23), the multinomial log-odd of adopting kerosene compared to firewood is lower by about 2.3 units when the neighbouring households adopt similar main source of cooking fuel. Also the multinomial log-odd of adopting gas compared to firewood is less by about 2.9 units when the neighbouring households adopt similar main source of cooking fuel. Similarly, the estimated marginal effects of this coefficient (Table 5.24) were significant at 1% and 5% respectively. The result has shown that the probability of adopting firewood is higher by about 49.4% when the neighbouring household adopt similar source of main cooking fuel.

On the contrary side, the probability of adopting kerosene as the main source of cooking fuel is lower by about 36.8% and for adopting gas by 12.7% when the neighbouring households adopted firewood as their main source of cooking fuel. All these findings support the relevance of the theory of relative income hypothesis to household cooking fuel source and consumption. Also it is in line with the previous studies' (Khan, 2014; Torgler *et al*., 2006; McBride 2001; Kosicki, 1987) validation of the application of relative income hypothesis in other aspects (non energy consumption) of households' consumption.

5.5.4.2 RIH and the Household Lighting Fuel Choice

The validity of the theory of relative income hypothesis was tested in relation to household lighting main fuel choice. In order to conduct such test, the study employs two approaches namely; statistical and econometric approaches. The statistical tests consist of testing the relevance of the variable representing relative income hypothesis in the previous estimated multinomial logit models. On the other hand, the estimation method has to do with estimating a modified model of testing relative income hypothesis proposed by Verme (2013). The results of the tests are discussed below:

5.5.4.2.1 Statistical tests of RIH and the Household Lighting Fuel Choice

Here the various statistical tests of relative income hypothesis in relation to the households' source of lighting fuel choice were conducted based on the previous estimated multinomial logit model of household lighting fuel choice (Table 5.9). The results of the tests are explained below:

5.5.4.2.1.1 Test of a Specific Variable (NLFUEL)

Here from the earlier estimated model of household lighting fuel choice, a likelihood ratio test of the variable representing neighbourhood lighting fuel was conducted. The procedure was that firstly the full model was estimated and called it unrestricted model. Then the variable representing relative income hypothesis was removed and re-estimated the model again (the second model is known as; restricted model). Then the likelihood ratio test of the following hypothesis was conducted:

H_0: the restricted and unrestricted models are non nested models.

The result of the test is shown in Table 5.25

Table 5.25
Likelihood-Ratio Test of a Specific Variable (NLFUEL)

LR χ^2 (2)	=	13.22
Prob(χ^2)	=	0.0013

(Assumption: restricted nested in unrestricted)

Table 5.25 indicates the result of a specific variable test which NLFUEL in our estimated multinomial logit model of household lighting fuel choice (see Table 5.9). The result has shown that the LR Chi-square statistic is significant at 1% level. This implies that the variable NLFUEL is relevant in explaining household cooking fuel source choice. Meaning that the full model (unrestricted) which has the variable 'NLFUEL' in it has an additional information in explaining household lighting fuel choice than the restricted model which has the same variables as the unrestricted model except the variable 'NLFUEL'. This signifies that the theory of relative income hypothesis is relevant in explaining the pattern of households lighting fuel choice.

5.5.4.2.1.2 Fit Statistics of the Model

Similarly, post estimation test of fit statistic was used to further ascertain the relevance of the theory of relative income hypothesis in explaining the household lighting fuel consumption pattern. The procedure followed in conducting this test is that, firstly, the full model was estimated based on the multinomial logit model and saved it using fitstat command. Then the partial model was estimated by removing the variable ‘NLFUEL’. After that, the fit statistics of these models were established in order to see which of these two estimated models better fit the data. The results obtained from the fit statistics are shown in Table 5.26.

Table 5.26
Test of Model Fit

	Current	**Saved**	**Difference**
Model:	mlogit	mlogit	
D:	615.999(408)	602.781(384)	13.219(6)
AIC*n:	681.999	674.781	7.219
BIC':	49.035	49.988	-0.953

Table 5.26, indicates the various fit statistics of the two estimated multinomial logit models of household lighting fuel choice. The saved column indicates the various test statistics for the full model. The full model contains all the variables together with the variable ‘NLFUEL’. On the other hand, the column titled ‘current’ displays the test statistics of the partial model. This model contains all the variables (as in the full model) except the variable ‘NLFUEL’ which is the focal of our analysis. The result shows that both the LR (D) and the AIC established that the full model (saved model) has better fits than the partial (current) model. This is further evidence that the theory of relative income hypothesis can be used to explain households lighting fuel consumption pattern.

5.5.4.2.1.3 Wald Test of Individual Variable (NLFUEL)

This is the third statistical method followed to re-examine the validity or relevance of the theory of relative income hypothesis in explaining household lighting fuel choice consumption behaviour. Some previous studies (Kosicki, 1987) used t-test to test the validity of the theory of relative income hypothesis. The result of the Wald test is shown in Table 5.27.

Table 5.27
Wald Test of NLFUEL

χ^2 (3)	= 11.78
Prob(χ^2)	= 0.0028

H_0 [0]o.ncfuel = [1]ncfuel = [2]ncfuel = 0

Table 5.27 exhibits the result of the Wald test for the variable 'NLFUEL' which is one of the explanatory variables in the estimated multinomial logit model of household cooking fuel choice source. The result of the Wald test rejected the null hypothesis of non relevance and conclude that the variable is strongly and significantly (1%) relevance in the model. This is a further validation of the theory of relative income hypothesis in describing household lighting fuel choice behaviour.

5.5.4.2.2 Econometric Approach of Testing the Relevance of RIH and the Household Lighting Fuel Choice

Here, the test of relative income hypothesis in relation to household lighting fuel choice was conducted by estimating the modified Verme model. The result of the estimated model was shown in Table 5.28.

Table 5.28
Coefficients of the Estimated Modified Verme Model for Testing RIH

VARIABLES	(Semi-electricity) 1=0	(Traditional) 2=0
Lincome000	-0.430***	-0.382*
	(0.146)	(0.196)
Loc*Nlfl	-0.102	-1.094***
	(0.243)	(0.366)
Nlfuel	-1.061***	-0.494
	(0.302)	(0.398)
Constant	1.390**	0.270
	(0.572)	(0.818)
Observations	507	507

Note: Robust standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1

Furthermore, the marginal effects of the estimated model are shown in Table 5.29

Table 5.29
Marginal Effects of the Estimated Modified Verme Model for Testing RIH

VARIABLES	(Electricity) 0	(Semi-electricity) 1	(Traditional) 2
Lincome000	0.092***	-0.069***	-0.023
	(0.028)	(0.025)	(0.016)
Loc*Nlfl	0.084*	0.006	-0.089***
	(0.047)	(0.043)	(0.028)
Nlfuel	0.218***	-0.207***	-0.012
	(0.066)	(0.067)	(0.035)
Observations	507	507	507

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table 5.28 and Table 5.29 contain the estimated model for testing relative income hypothesis in relation to household lighting fuel choice. The overall model is statistically significant at 0.1% level. The estimated model consists of variables representing the theory of relative income hypothesis that are regressed on the type of lighting fuel source to be chosen by the household based on multinomial logit model. The lighting fuel source has three categories namely; electric, semi-electric and traditional sources of lighting. The result indicates that all the coefficients are statistically significant mostly at 1% level. Based on the estimated coefficient of the household income (Table 5.28), a 1% rise in income of the household head reduces the multinomial log-odd of adopting semi-electric lighting source compared to electricity by about 0.43 units. Also it reduces the multinomial log-odd of adopting traditional source of lighting compared to electricity by about 0.38 units when other variables are held constant. Additionally, the estimated marginal effects of this coefficient (Table 5.29) indicate that a 1% increase in the income of the household head increases the probability of adopting electricity as the main source of lighting by about 9.2%, while reduces the probability of adopting semi-electric sources of lighting by about 6.9%. This is in line with the argument of relative income hypothesis that income of households also has significant impact on the pattern of their consumption behaviour.

Furthermore, based on the result of the estimated model, the coefficient of the interaction variable between households' adopting similar source of lighting as their neighbours and the location in which the household lives, indicates that households that are living in urban areas and also that adopted similar main source of lighting as their neighbours, has lower multinomial log-odd of adopting traditional source of lighting by about 1.094 units compared to electricity than the other type of households. Moreover, the estimated marginal effects of this interactive variable (Table 5.29) indicate that the probability of adopting electricity as the main source of lighting fuel for households that are living in urban areas of Bauchi State and also who have similar main source of lighting as their immediate neighbours is higher by about 8.38% compared to the otherwise households. Also, their probability of adopting traditional source of lighting is lower by about 8.94% than the otherwise households. This is in line with a priori expectation and also supports the argument of the theory of relative income hypothesis that the interaction of the environment and the immediate neighbours of households have significant impact in shaping the consumption pattern of households.

Lastly, the estimated model has shown that the variable representing the similarity of the type of lighting fuel source adopted by the household to that of its immediate neighbour; is significant and therefore relevant to the analysis of household energy choice (Table 5.28). The result has shown that the multinomial log-odd of adopting semi-electric lighting source compared to the electricity is lower by about 1.061 units when the household adopt similar (electricity) lighting fuel to that of its immediate neighbour. Similarly, the estimated marginal effects have shown that the probability of adopting electricity as the main source of lighting fuel is higher by about 21.8% when the household and its immediate neighbour adopted similar source of lighting fuel. Moreover, the probability of adopting semi-electric source of lighting (Table 5.29) is lower by about 20.7% when the household and its immediate neighbour adopted the same source of lighting. This is because, the most widely use source of lighting is electricity, that is why the odd and probability of adopting electricity increases while for other sources decreases which is in line with the conclusion of the theory of relative income hypothesis that consumption pattern of households is influenced by the consumption behaviour of their immediate neighbours. Also it is in line with the previous studies' (Khan, 2014; Torgler *et al*., 2006; McBride 2001; Kosicki, 1987) validation of the application of relative income hypothesis in other aspects (non energy consumption) of households' consumption.

5.6 Conclusion

This chapter gives a detail discussion on the estimated results using different models. Two different MNLM were estimated and analysed in order to examine the factors that influence households' choice of cooking and lighting sources of fuels. Additionally, two different OLS models were estimated and analysed in order to explain the determinants of households' consumption of firewood and electricity. Moreover, Tobit model was estimated and analysed to discuss the factors that determine the inyensity of kerosene consumption by households. In the same vein, two Verme models were estimated, presented and analysed in this chapter in order to assess the validity of the axiom of relative income hypothesis in explaining the behaviour of household energy choice and consumption. Lastly, the various results of the diagnostic checks for the various estimated models discussed in this chapter, validated all the estimated results analysed in this chapter.

CHAPTER SIX

CONCLUSIONS AND POLICY RECOMMENDATIONS

6.1 Introduction

This chapter constitutes the last part of this study. The main aim is to present the conclusions of the research, the various theoretical, methodological and practical contributions of the study, policy recommendations based on the findings of the study, limitations of the study and the suggestions for further research.

6. 2. Summary of Findings

This study was conducted with the main aim of assessing the factors that influence household energy choice and consumption in Bauchi State Nigeria. Specifically; to examine the determinants of household cooking fuel choice in Bauchi State; to assess the determinants of the household lighting fuel choice in Bauchi State; to identify and assess the determinants of the quantity of consuming the various fuel sources (firewood, kerosene and electricity) and to test the relevance of the theory of relative income hypothesis in relation to household energy consumption. To achieve these objectives, a total of 750 questionnaires were distributed out of which a total of 548 questionnaires were returned back and from which nine questionnaires were discarded.

The various models used to analyse the data are; MLNM, Tobit regression model, OLS regression model and the Verme model for testing relative income hypothesis.

Furthermore, three different statistical tests were conducted to further ascertain the validity of the argument of the relative income hypothesis in relation to household energy consumption. These are; Wald test, test of fit statistics and the likelihood ratio test. Based on the estimated models, the findings of the study can be summarised as:

6.2.1 Determinants of Household Cooking Fuel Choice in Bauchi State

Multinomial logit model was used to estimate the determinants of household cooking fuel choice in Bauchi State, Nigeria. The various sources of the cooking fuel were classified into four main categories namely; firewood (the reference category), kerosene, electricity and gas. The result has shown that the higher the income, the higher the households' adoption of kerosene and gas as the main source of cooking fuel than firewood. This supports the arguments of energy ladder hypothesis and energy stacking model.

Similarly, the higher the level of education of the household head, the more the household adopts electricity and gas, as the main source of cooking fuel than firewood. This is in line with the arguments of rational choice theory. Households that are living in the urban areas and those that are headed by a male tend to adopt kerosene as the main source of cooking fuel than firewood. Moreover, the households that live in their self owned home, have higher probability of adopting kerosene and electricity as the main source of coking fuel than those living in non self owned home. The result further indicated that the higher the age of the household head, the higher the probability of adopting kerosene as the main source of cooking fuel compared to firewood. In addition, the new discovery of this study is that the conclusion of relative income hypothesis is relevant in explaining the pattern of household cooking fuel choice.

Moreover, the findings indicated that the larger the size of family, the lesser the probability of the household to adopt kerosene and gas as the main source of cooking fuel compared to firewood. Finally, out of the ten variables included in this model, only one variable (home size) was found to be irrelevant as per influencing the household choice of cooking fuel in Bauchi State.

6.2.2 Determinants of Household Lighting Fuel Choice in Bauchi State

Here, multinomial logit model was also used to analyse the factors that influence the household choice of their main source of lighting fuel. One of the unique contributions of this study from the previous studies on household energy choice and consumption is that the various lighting fuel main sources were grouped into main three categories; traditional, semi-electric and electric sources of lighting. The traditional category comprised of firewood, kerosene and traditional lamps. The semi-electric category consisted of battery torch lights and rechargeable lanterns. The electric category consisted of the public electricity and private generators. The result indicated that the household head being male and the size of family have positive impacts on the adoption of traditional and semi-electric source of lighting compared to electricity.

On the other hand, age of the household head and the income level, have negative impact on the probability of adopting traditional and semi-electric sources of lighting compared to the adoption of electricity as the main source of lighting fuel. Similarly, the result indicated that the households that live in the urban areas have lesser probability of adopting the traditional source of lighting compared to the electricity than those living in the rural areas. Additionally, the higher the number of hours of electricity availability, the lesser the adoption of the semi-electric source of lighting compared to the electric source. Similarly, the higher the number of rooms in the house, the lower the adoption of the semi-electric source of lighting compared to the electric source. Finally, another unique discovery of this study is that it was discovered that the argument of relative income hypothesis is valid in explaining the pattern of household lighting fuel choice and consumption.

However, the variables that were included in the model and were found to have insignificant impact on households' choice of lighting fuel sources are; marital status, level of education and the number of home appliances at home.

6.2.3 Determinants of Firewood Consumption in Bauchi State

OLS regression model was used to estimate the factors that influence the households' consumption of firewood in Bauchi State, Nigeria. In this case, the dependent variable is the monthly average quantity of the consumed firewood bundles. The study found that households that are headed by a male consume more firewood than the households headed by females. Similarly, the number of rooms in the home was also found to have positive significant relationship with the household consumption of firewood. On the other hand, level of education has a negative relationship with the consumption of firewood. The higher the level of education of the household head, the lower the amount of firewood consumption by such household. Moreover, marital status of the household head was found to have a negative relationship with the amount of firewood consumption. The study also found that price of firewood is negatively related to the amount of firewood consumption. This lends support to the argument of the theory of demand. However, the variables that were found to be statistically insignificant are; household size, income, home ownership and share of dwelling.

6.2.4 Determinants of Kerosene Consumption in Bauchi State

In order to estimate the factors that influence the households' consumption of kerosene in Bauchi State, Tobit regression model was used in the study to achieve this objective. The result has shown that the higher the age of the household head, the higher the intensity of kerosene consumption. Likewise income was found to have positive significant impact on the intensity of kerosene use. Similarly, the price of firewood per bundle has a positive relationship with the intensity of household kerosene use. In the same vein, households living in the urban areas have higher intensity of kerosene consumption than their rural counterpart. On the other hand, the price of kerosene far litre has a negative relationship with the intensity of kerosene use. This supports the argument of the theory of demand. Similarly, the new discovery of this study is that the argument of relative income hypothesis is valid in explaining the intensity of household kerosene use.

However, the variables that were also included in the model but were found to be statistically insignificant in explaining the intensity of household consumption of kerosene in Bauchi State are; gender of the household head, level of education, household size and hours of electricity supply.

6.2.5 Determinants of Electricity Consumption in Bauchi State

OLS regression model was also used to estimate the factors that influence the household consumption of electricity in Bauchi State, Nigeria. The dependent variable here is the average monthly expenditure on electricity for the household. The study found that the higher the level of education of the household head, the higher the level of expenditure on electricity. Similarly, households that are living in the urban areas of Bauchi State have more expenditure on electricity than those living in the rural areas. Price of firewood was found to have a positive significant relationship with the electricity expenditure. Similarly, the study found that the higher the number of energy use devices at home, the higher the amount of electricity expenditure. Contrarily, marital status was found to have a negative impact on the electricity expenditure, the households that are headed by a married person have less expenditure on electricity than otherwise. However, the variables that were found to have insignificant relationship with the household expenditure on electricity are; gender, household size, number of rooms and home size.

6.2.6 Relative Income Hypothesis and the Household Energy Consumption in Bauchi State

One of the unique contributions of this study (also one of the specific aims of this study) was to test the relevance of the relative income hypothesis in explaining household energy consumption in Bauchi State. In order to achieve this aim, apart from the inclusion of variables representing the argument of the theory of relative income hypothesis in the various estimated models, separate tests of this theory were conducted using both the statistical and the econometric methods. The results of the various statistical tests namely; Wald test, likelihood ratio test and the fit statistics have shown that the conclusion of relative income hypothesis is relevance to the pattern of household fuel choice in Bauchi State. Moreover, the modified estimated verme model for testing the relative income hypothesis has shown that the argument of the theory is relevant for both cooking and lighting fuel choice respectively.

6.3 Contributions of the Study

The main choice of energy sources remains one of the most important aspects of households' living. This study attempted to carry out a rigorous analysis of households' energy choice and consumption in Bauchi State, Nigeria. The study was able to empirically explore, identify and assessed the significant socio-economic and geographical factors that influence the pattern of household energy choice and consumption in Bauchi State, Nigeria. The attempted contributions of this study appear in form of theoretical contribution, methodological and practical contributions as follows:

6.3.1 Theoretical Contributions of the Study

This study attempted to make a number of theoretical contributions. In the first place, the study was able to relate the argument of the theory of relative income hypothesis to household energy choice and consumption. Using different variables and methods, the study found that the argument of relative income hypothesis is relevant in explaining household energy consumption behaviour. Though, so many empirical tests of this theory were conducted earlier by previous studies in different aspects of households' living (household saving behaviour by Kosicki, 1987; individual health and mortality by Mangyo & Park, 2011; Lindley & Lorgelly, 2005; household commodity consumption by Khan, 2014; individual performance on the work place and job satisfaction; by Card *et al*., 2012; Torgler *et al*., 2006; depression by Hounkpatin, *et al*., 2014; Cuadrado & Long, 2011; and life satisfaction and well being by Brown *et al*., 2015; Senik, 2008; Carbonell, 2005; Senik, 2003; Mcbride, 2001; Clark & Oswald, 1996).

However, to the best of my knowledge, no attention was given by these studies to conduct such test specifically in relation to household energy choice and consumption. However, establishing a valid relationship between the theory of relative income hypothesis and household energy choice consumption has a policy relevance especially in developing countries, were by the government is not financially strong. The relevance is that when government embark on policy of reducing the use of firewood, the government can decide to select some households on which the policy will be implemented directly, which in turn due to relative influence, other households will also reduce the use of firewood to other alternative cleaned source of energy. In this way, the resource and time needed for implementing such policy on the whole households are saved, which can be used for another useful purpose.

Similarly, this study has successfully able to relate the axiom of energy ladder hypothesis using household data in Bauchi State. Though there are many studies (Hosier & Dowd, 1987; Leach, 1992; Masera *et al*., 2000; Campbell *et al*., 2003; Mensah & Adu, 2013) that relate the axiom of energy ladder hypothesis in other areas, there are only few studies (only Maryam, 2011) within the Nigerian context. Additionally, this study was also able to relate household energy choice with energy stacking model using household data of Bauchi State. So many studies (Heltberg, 2004; Leiwen & O'Neill, 2003; Mekkonnen & Kohlen, 2009; Risseeuw, 2012) established the relevance of energy stacking model to household energy choice outside the Nigerian context. Whereas only few studies (Ogwumike *et al*., 2014) that has done so within the Nigerian context. Therefore, taking a new and specific environment, this study is an additional literature to the existing studies.

Another theoretical contribution of this study is that, based on the a priori knowledge of the study area and the review of relevant theories and related empirical studies in other areas, this study was able to develop and tested a total of 16 hypotheses, out of which 13 hypotheses were accepted and three hypotheses were rejected. For instance the study found that gender, age, level of education and income of the household head. household size, location, home size, and homeownership, bundle price of firewood and the nature of main cooking fuel source use by immediate neighbours have (positive or negative) significant impacts in discouraging households in Bauchi State from using firewood as the main source of cooking fuel towards the adoption of cleaner cooking fuel (Kerosene, electricity and gas). Furthermore, the study found empirically that household head's age and income, weekly hours of electricity supply, residing in urban areas, number of rooms and neighbours' adoption of electricity as their main lighting source, have significant positive impact in encouraging households to adopt electricity as the main source of lighting fuel.

On the other hand, gender of the household head and the household size, were found to have negative significant impacts on households' adoption of electricity as the main source of lighting in Bauchi State. Similarly, gender, marital status, education, home location, number of rooms, prices of firewood and kerosene, age, income, neighbourhood main lighting source and home electrical appliances; were empirically proved to have significant impact on the amount of firewood, kerosene and electricity consumptions. Though these hypotheses were developed from a priori knowledge, relevant theories and the review of past empirical literature that the researcher was able to come across, none of a single previous study attempted to test exactly the same hypotheses.

Furthermore, another contribution of this study is that the study was able to estimate the determinants of household lighting source from wider perspective. The study grouped the main household lighting sources into three categories namely; Electric (comprising public electricity and private generators), semi-electric (consists of battery torch lights and rechargeable lanterns) and traditional (such as firewood, kerosene, candles and traditional lamps). Based on the literature that the researcher was able to come across, none of the previous studies on household energy studies (both within and outside Nigeria) carried out similar estimation on household lighting fuel sources, though Ogwumike et al. (2014) considered only public electricity and kerosene in their study. Lastly, a new interaction variable was created to see the impact of the interaction between environment and neighbourhood type of main fuel source on the household energy choice. This variable was found to be statistically significant and relevant in explaining household energy choice in Bauchi State.

6.3.2 Methodological Contributions of the Study

This study has also attempted to make some methodological contributions in its attempt to analyse households' energy choice in Bauchi State, Nigeria. One of the methodological contributions of this study is its wider application of econometric models to analyse household energy choice using micro households' data of Bauchi State, Nigeria. To achieve the stated objectives of this study, seven different models were estimated. Though there are some previous studies (Eakins, 2013; Lee, 2013; Couture *et al*., 2012; Osiolo, 2010; Mekonnen & Kohlin, 2009) that have a wider application of econometric techniques to analyse household energy choice outside the Nigerian context, none of the studies conducted within the context of Nigeria has wider econometric application. Most of the studies within the Nigerian context (Abdurrazak *et al*., 2012; Desalu *et al*., 2012; Nnaji *et al*., 2012; Onoja, 2012; Oyekale *et al*., 2012; Maryam, 2011) are limited to descriptive analysis or estimated only one model to analyse household cooking fuel choice for some specific areas.

Furthermore, although some previous studies (Hosier & Dowd, 1987; Leach, 1992; Masera et al., 2000; Mensah & Adu, 2013; Heltberg, 2004; Mekkonnen & Kohlen, 2009; Risseeuw, 2012) on household energy choice conducted test of some relevant theories (energy ladder hypothesis and fuel stacking model) their approach of such tests is limited to conducting an econometric estimation alone. However, this study in addition to the econometric estimation, three different statistical test methods were used to further ascertain the relevance of the theory of relative income hypothesis to household energy choice. The various statistical tests adopted are; Wald test, likelihood ratio test and test of fit statistics, and were all found to support the argument of the relative income hypothesis in relation to household energy consumption.

Another contribution of this study is that the study was able to estimate Verme model using household data of Bauchi State, Nigeria. Verme (2013) after reviewing various studies that tested the validity of relative income hypothesis in different aspects of households' living, developed an econometric model for testing the theory of relative income hypothesis. Based on the literature that the researcher was able to come across, the researcher hoped that this is the first study to empirically estimate verme model for testing relative income hypothesis and the results obtained from such estimations produced valid and acceptable results.

Similarly, though there are many studies on household energy choice and consumption, most of these studies are general in nature trying to estimate determinants of household energy choice without conducting separate estimation for each dimension of household fuel choice. However, this study adopted a unique pattern from those of most previous studies by conducting separate estimation for each of cooking and lighting fuels individually, though similar approach was adopted by Ogwumike *et al*. (2014) in their studies. Lastly, despite that the questionnaire used in this study is modified and adopted from four different sources (already mention earlier), however this study at least contributed by estimating cronbach's alpha as a means for testing the reliability of the instruments in the questionnaire using micro household data of Bauchi State, Nigeria.

6.3.3 Practical Contributions of the Study

The itemised attempted practical contribution of this study is that the discovery and findings of this study provided a clear picture and information on household energy use pattern in Bauchi State, Nigeria. The results and analysis carried out by this study can serve as first hand information to the relevant stakeholders. Similarly, other previous studies (Danlami *et al*., 2016; Kowasari & Zerriffi, 2011; Niemeyer, 2010; Joon *et al*., 2009; Pachauri, 2007) recommended the conduct of more researches on household energy choice that are more especially micro based analysis for better understanding of the issue and absorbing the heterogeneity nature of households. Hence considering such recommendations, this study has contributed to more empirical exploration in this area. Lastly, the recommendations offered by this study based on the empirical findings may be useful to the relevant authorities when making and implementing household energy policies in the study area. The overall goal is to encourage households to shift from the use of less cleaned energy sources (that jeopardise public health and environment) to the adoption of cleaner energy sources.

6.4 Policy Recommendations

Having conducted empirical investigation of household energy choice and consumption in Bauchi State, Nigeria, the following recommendations were offered based on the study findings, in order to discourage the use of firewood for cleaned energy.

It was found that there is an interdependent in the pattern of energy choice and consumption among households. Therefore, a sound policy that will introduce some households with cleaned source of energy will have strong and wider impact on more households that will move towards the use of the cleaned energy source through the relative influence or influence of immediate neighbourhood. As some households are introduced with cleaned modern energy sources, soon other households will adopt it due to neighbourhood influence. In this way the resources, energy and time that should be wasted when executing the policy on all the targeted households are saved and can be used for other developmental purposes.

Since increase in income was found to have significant impact in discouraging households' adoption of firewood as the main source of cooking fuel and also discourages adoption of traditional source of lighting, policies and programmes aimed at raising income earnings of individuals should be embarked upon to discourage the adoption of firewood and other traditional sources of lighting, especially considering the fact that Bauchi State is the third poorest State in Nigeria (NBS, 2012). Income can be increased via employment generation, wealth creation, increase in government expenditure, empowering small and medium scale industries and skills development

The study finds that households that live in urban areas have higher probability and odd of adopting modern cleaned fuel sources. In line with this finding, government should try to turn some rural parts of the State into urban areas especially considering the fact that presently, the number of rural communities in the State far outweighs the number of urban communities. This will encourage more adoption of modern cleaned fuel sources.

The study found that the level of formal education attainment by the household head has significant influence on adopting modern cleaned fuel sources. The higher the level of education, the higher the probability of adopting cleaned source of fuels.

Therefore, government should embarked upon policies to encourage higher education attainment of people leaving in the study area, especially rural areas whereby there are large number of illiterate people. High rate of school enrolment can be increased via policies like; free education policies, education enrolment at a subsidised rate, construction of more schools near to the people especially in rural areas, provision of more scholarships at higher levels, employing adequate number of teachers to meet the growing number of pupils and increase in expenditure on educational facilities. The curriculum of the educational system should emphasize on the danger of high rate of deforestation in the environment. Moreover, as part of education, strong and continuous awareness campaign should be embarked upon regarding the health and environmental danger of high rate of firewood use especially in rural areas whereby the rate of awareness is very low.

Furthermore, the study has found that adequate supply of electricity has significant impact on electricity use. Therefore, provision of cheap and adequate electricity supply to households will encourage many households to use electricity as their main source of cooking and lighting, thereby reducing the rate of firewood use.

6.5 Limitations of the Study and Suggestions for Further Researches

Although this study attempted to make some contributions, the study suffers some limitations.

Firstly, despite that this study tried to conduct an analysis of household energy choice and consumption using Bauchi State household data, the study cannot offer any explanation about the influence of time dimension on the pattern of household energy choice and consumption in the study area. Therefore, a study that will incorporate the influence of time dimension in its analysis is a welcome development. Secondly, the data analysed in this study were collected from households living within Bauchi State, Nigeria, therefore all the findings and conclusions from this study are for the study area alone and cannot be made to another areas due to geographical, environmental, social and other differences that usually invalidates generalisations.

Thirdly, although the sampling frame of the names of areas and communities are available, the sampling frames for the households living in Bauchi State which are the units of analysis for this study are not available. Therefore despite that some element of random selections of households were applied when selecting the respondents, however as this selection is not based on a full sampling frame (due to non availability) generalisations to the total population of the study has to be made with cautious. Lastly, this study cannot analyse the determinants of gas consumption in Bauchi State due to inadequate and inconsistent observations regarding the households' quantity of gas consumption and expenditure.

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Appendix A
RESEARCH QUESTIONNAIRE

RESEARCH QUESTIONNAIRE
SCHOOL OF ECONOMICS FINANCE AND BANKING
UNIVERSITI UTARA MALAYSIA
MALAYSIA.

Sir/madam, I`m a student of the above mentioned department, I`m carrying out my research study titled `**An analysis of the determinants of household energy choice and consumption in Bauchi State, Nigeria**` for the fulfilment of the award of Doctor of Philosophy in Economics. Kindly assist by responding to the following questions. Your responses are guaranteed to be treated confidentially. Thanks for your cooperation and contribution.

PART A: SOCIO-ECONOMIC FEATURES OF THE HOUSEHOLD

1. GENDER (Household head):
   a. Male ( )
   b. Female ( )

2. Age (Number of years) ……………..

3. MARITAL STATUS (Household head):
   a. Single ( )
   b. Married ( )
   c. Widow ( )
   d. Divorced ( )
   e. Separated ( )

4. LEVEL OF EDUCATION:

a. Non formal education/Qur`anic school. ( )

b. Primary school. ( )

c. Secondary school. ( )

d. Graduate. ( )

e. Postgraduate. ( )

5. Number of the household members (including the head) ..…………..

6. OCCUPATION:

Unemployed ( )

Farmer ( )

Teacher ( )

Banker ( )

Lecturer ( )

Medical Practitioner ( )

Businessman ( )

Others (please specify) ……………………………………. ( )

7. Average Monthly Income (Naira) ………………

PART B: DWELLING CHARACTERISTICS

1. We are living in:

   a. Self owned dwelling ( )

   b. Rented dwelling ( )

   c. Dwelling provided by employer ( )

   d. Free dwelling but owned by another non h/h member ( )

2. If living in a renting home; specify the annual cost of rent (Naira) ………..

3. DWELLING LOCATION:

   a. Urban Area ( )

   b. Rural Area ( )

4. Dwelling size …………

5. Please choose the measurement used for measuring the dwelling size:
   a. Feet ( )
   b. Meter square ( )
   c. Centimetre square ( )
   d. Other (specify)……………………… ( )

6. Number of rooms …………..

(Such as; bedrooms, sitting rooms, reading rooms, kitchens, etc., excluding toilets)

7. SHARING OF DWELLING

   Does your household lives with another household in the same building

   a. Yes ( )
   b. No ( )

8. NATURE OF THE DWELLING (TICK AS APPROPRIATE)

Traditional home made of mob	
Single detached house	
Semi detached house	
Row house	
Apartment or flat in a duplex	
Apartment in a building	
Single attached house	

Brief description of the above categories:

Single-detached house – A single dwelling not attached to any other dwelling or structure (except its own garage or shed.) A single-detached house has open space on all sides, and has no dwellings either above it or below it.

Semi-detached house – One of the two dwellings attached side by side (or back to back) to each other, but not attached to any other dwelling or structure (except its own garage or shed.) A semi-detached dwelling has no dwellings either above it or below it and the two units, together, have open space on all sides.

Row house – One of three or more dwellings joined side by side (or occasionally side to back), such as a town house or garden home, but not having any other dwellings either above it or below.

Apartment or flat in a duplex – One of two dwellings, located one above the other.

Apartment in a building that has storeys – A dwelling unit attached to other dwelling units, commercial units, or other non-residential space in a building that has storeys.

Single-attached house – A single dwelling that is attached to another building.

PART C: ENERGY USE AND RELATED INFORMATION

1. What is the Main Source of Your Cooking Fuel (Tick only one option)

Firewood	
Kerosene	
Electricity	
Gas	

2. Choose the Second Alternative of Cooking Fuel Source (Tick only one option)

Firewood	
Kerosene	
Electricity	
Gas	
Other (Specify) ……………………………	

3. Select the main source of lighting fuel (tick only one)

Firewood	
Kerosene	
Electricity	
Petroleum	
Diesel	
Candles/	
Traditional lamp	
Rechargeable lantern	
Battery/Dry/Cell torch light	
Others (specify)	

4. For how many hours do you get electricity supply in a day …………….

5. Select your second (2nd) and third (3rd) alternative sources of lighting by writing appropriately against any two of the following lighting fuel sources (i.e. chose two options) Write 2nd against your second alternative and 3rd against your third alternative

Firewood	
Kerosene	
Electricity	
Petroleum	
Diesel	
Candle	
Traditional lamp	
Rechargeable lantern	
Battery/Dry/cell torch light	
Other (specify)	

6. Specify the total monthly quantity of each of the following fuel sources as used by your household

FUEL	MEASUREMENT	QUANTITY
Firewood	Bundle	
Kerosene	Litre	
Electricity	Unit/kwh	
Petroleum	Litre	
Gas	Litre	
Candle	Unit	
Traditional lamp	Unit	
Rechargeable lantern	Unit	
Battery/Dry/cell torch light	Unit	
Other (specify)		

7. Specify the total average monthly expenditure on each of the following fuel source by your household

FUEL SOURCE	AMOUNT (₦)
Firewood	
Kerosene	
Electricity	
Petroleum	
Diesel	
Gas	
Candle	
Traditional lamp	
Rechargeable lantern	
Battery/Dry/cell torch light	
Other (specify)	

8. For each of the following fuel sources, indicate the unit price (based on each fuel's measurement) at which you buy each of them.

FUEL	**MEASUREMENT**	**Price per measurement**
Firewood	Bundle	
Kerosene	Litre	
Electricity	Unit/kwh	
Petroleum	Litre	
Diesel	Litre	
Gas	Litre/cylinder	
Candle	Unit	
Traditional lamp	Unit	
Rechargeable lantern	Unit	
Battery/Dry/cell torch light	Unit	
Other (specify)		

9. Select the major means of transportation for the household
    a. Commercial taxi/okada ( )
    b. Private owned motor car ( )
    c. Private owned motorcycle ( )
    d. Bicycle ( )
    e. Other (specify)……………………….. ( )

10. Number of cars owned by the household
    a. 1 – 3 ( )
    b. 4 – 6 ( )
    c. 7 – 9 ( )
    d. 10 and above ( )

11. Number of motorcycles owned by the household
    a. 1 – 3 ( )
    b. 4 – 6 ( )
    c. 7 – 9 ( )
    d. 10 and above ( )

NOTE

All the cars and/or motorcycles owned by each member of the household should be considered.

12. Select the main fuel source for transport purposes by your household
    a. Petroleum ( )
    b. Diesel ( )

13. Specify the total average quantity of fuel use **MONTHLY** for transportation purpose

		LITRE
a.	Petroleum (Litre)	…………
b.	Diesel (Litre)	…………

14. Specify the total monthly expenditure on fuel for transport purposes by the household

		₦
a.	Petroleum	………
b.	Diesel	………

15. Indicate whether the main fuel cooking source for your immediate neighbour is similar to that of yours
    a. Yes ( )
    b. No ( )

16. If the above is 'No' please from the following options, choose the main fuel source of cooking for your immediate neighbour (i.e. other household)
    a. Firewood ( )
    b. Kerosene ( )
    c. Electricity ( )
    d. Gas ( )

17. Indicate whether the main lighting fuel sources for your immediate neighbours are similar to yours
    a. Yes ( )
    b. No ( )

18. If the above is 'No' please from the following available options choose the main lighting fuel source by most of your neighbours (please tick only one option)

Firewood	
Kerosene	
Electricity	
Petroleum	
Diesel	
Candle	
Traditional lamp	
Rechargeable lantern	
Battery/Dry/cell torch light	
Other (specify)	

19. Select the total number of energy consumption devices possess at home (such as; fans, televisions, AC, fridge, iron, electric cooker, gas cooker, water heater, washing machine, dryer, bulbs, cylinder, DVD, radio, exercise machines, etc.) each of these item should be counted as one and use the following options to show the aggregate number as possess by the household (e.g. if you have 6 bulbs and 3 fans in the home, the total number of your home appliance is 6 + 3 = 9)
    a. 1 – 25 ( )
    b. 26 – 50 ( )
    c. 51 – 75 ( )
    d. 76 – 100 ( )
    e. 101 and above ( )

Thank you very much for spending your valuable time to respond to my questionnaire

ABUBAKAR HAMID DANLAMI

(95977)