ENERGY USE PATTERNS AND TRENDS: THE IMPACT OF ENERGY POLICY IN SOUTH AFRICAN LOW-INCOME HOUSEHOLDS

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ABSTRACT

Energy poverty is a growing concern especially amongst low-income populations in developing countries. The transition to modern energy carriers is associated with welfare improvement and it is considered as an important developmental goal to achieve, in order to eradicate energy poverty. As such, the South African government has made energy poverty an issue of policy focus. Literature abounds with different measures of energy poverty; energy programmes and policies are also aimed at improving the welfare of the low-income households in terms of basic services such as electricity.

As a point of entry into this study, this thesis explored energy use patterns and trends in low-income South African households. The research objectives addressed in the study included investigating the extent of energy poverty through a multidimensional energy poverty index, examining the extent to which the 'energy ladder' and 'energy stacking' models explains energy transition patterns and to examining whether the Free Basic Electricity Policy has impacted on energy choices and energy poverty. In order to contribute to energy poverty and energy policy discussion in South Africa, this study has investigated the dimensions of energy poverty amongst low-income South African households from these three different perspectives (objectives).

A positivist approach, by using a quantitative method was used to underpin the study. The study utilised secondary data, which were from the National Income Dynamics Survey and Income and Expenditure Survey. The former was used for the analysis of the multidimensional energy poverty index and energy transition patterns whilst the latter was used for the analysis of the impact of the Free Basic Electricity Policy. The four waves of the National Income Dynamics Survey, with 2008 as the base year and the 2010/2011 version of the Income and Expenditure Survey were used whilst the data were processed through the quantitative software package, STATA version 12. The data were then analysed using the multidimensional energy poverty framework by Nussbaumer *et al.* (2011) and econometric models, which best fit the objectives.

The result of the panel analysis, which assesses the multidimensional energy poverty for low-income households in South Africa showed that low-income households in both urban and rural areas are in a moderate state of energy poverty but different levels. However, the cross-sectional analysis revealed that the percentage of low-income households that are energy poor is reducing for the rural households but increasing for their urban counterparts from 2008 to 2014. The panel and cross-sectional results of the contribution of the energy dimensions in multidimensional energy poverty shows that the low-income households are especially energy poor in terms of heating fuel.

The findings from the econometric estimates partly confirmed an energy ladder behaviour for the energy choice for cooking. An energy stacking behaviour was confirmed for the low-income households for these energy services - heating and lighting. Moreover, it was found that with respect to cooking and heating, low-income households living in a modern dwelling, having a small household size and residing in an urban area are less likely to use transitional or traditional energy carriers but most likely to use modern energy carriers. In addition, low-income households are more likely to use modern energy carriers for their cooking and heating in 2010, 2012 and 2014 than in 2008. For lighting energy service, low-income households living in a modern dwelling in an urban settlement are most likely to use modern energy carriers for lighting and less likely to use transitional energy carriers or candles. Only in 2014 were low-income households more likely to use modern energy carriers for lighting than in 2008. The results further showed that modern energy carriers have the highest probability of being preferred for lighting followed by cooking and lastly heating.

Also emerging from the findings are that more urban low-income households are receiving the Free Basic Electricity (FBE) grant than their counterparts in the rural areas. The probability of low-income households owning entertainment/education appliance and food preserving appliance is positively influenced by access to Free Basic Electricity. The low-income households living in an urban settlement and in a modern type of dwelling supported this result. However, household size does not seems to support this result should it grow larger.

The study concludes that the Multidimensional Energy Poverty Index (MEPI) is able to provide information on the depth of energy poverty and on the energy dimension, which shows how energy poor the low-income houseolds are. Thus, policy makers could track improvements of energy poverty over time. The study also conclude that the adoption of modern energy carriers are subject to rurality (urban), type of dwelling (modern) and household size (small). Besides, the energy intensity of each energy services or the scale of preference could govern the choice of modern energy carriers being most preferred for cooking, heating and lighting. The findings on the FBE imply that the policy is effective for the low-income households that have access to it. The challenge is that only few low-income housholds that are qualified access FBE.

The study recommends, among other things, that ways to promote and support the use of modern energy carriers for heating, for example, is by upgrading the appliance (heater) to a more efficient appliance, which can save the consumer money and energy. Suitable measures to combat energy poverty should be urban-rural specific, taking into consideration the rapid population growth in the informal settlements. Access to the FBE, to address affordability, for the low-income households in the informal settlements needs intervention from the government. The factors preventing qualified low-income households from using FBE allocation is highlighted for further research. Issues to deliberate on, emerging from the study, among other things is that there is a need for a systematic and comprehensive outlook in the alignment of policies between departments and between spheres of government.

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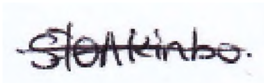
DECLARATION

I, Sylvia Olawumi Israel-Akinbo, hereby declare that this thesis work submitted for the degree of Philosophiae Doctor in the Faculty of Commerce, Department of Economics and Economic History at Rhodes University, is my own independent work, and has not previously been submitted by me to any other university.



April 2018

Sylvia Olawumi Israel-Akinbo — Date

Grahamstown

DEDICATION

In all humility and with a heart full of gratitude, I dedicate this work to the ALMIGHTY GOD, who has given me the health, opportunity and inspiration to undertake and complete this research study.

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LIST OF ACRONYMS

AGECC	Advisory Group on Energy and Climate Change
BMR	Bureau of Market Research
CIA	Central Intelligence Agency
COSATU	Congress of South African Trade Unions
CPI	Consumer Price Index
CURES	Citizens United for Renewable Energy and Sustainability
DFID	Department for International Development
DME	Department of Minerals and Energy
DoE	Department of Energy
ECG	Electricity Company of Ghana
EDI	Energy Development Index
EEPCo	Ethiopian Electric Power Corporation
EIA	Energy Information Administration
EREC	European Renewable Energy Council
ERHS	Ethiopian Rural Household Survey
Escom	Electricity Supply Commission
ESMAP	Energy Sector Management Assistance Programme
FAO	Food and Agriculture Organisation

FBE	Free Basic Electricity
GDP	Gross Domestic Product
GHG	Greenhouse Gas
ICS	Interconnected System
ICTs	Information and Communication Technologies
IEA	International Energy Agency
IES	Income and Expenditure Survey
IEP	Integrated Energy Plan
ILRIG	International labour Resource and Information Group
IMF	International Monetary Fund
INE	Instituto Nacional de Estatistica
INEP	Integrated National Electrfication Programme
IPPs	Independent Power Producers
IRENA	International Renewable Energy Agency
KDI	Kerosene Distribution Improvement
KNBS	Kenyan National Bureau of Statistics
LBPL	Lower Bound Poverty Line
LPG	Liquefied Petroleum Gas
MCA	Multiple Correspondence Analysis
MEPI	Multidimensional Energy Poverty Index
MEM	Ministry of Energy and Minerals

MPI	Multidimensional Poverty Index
NEP	National Electrification Programme
NIDS	National Income Dynamics Survey
OECD	Organisation for Economic Cooperation and Development
OPHI	Oxford Poverty and Human Development Initiative
PHCN	Power Holding Company of Nigeria
PMG	Parliamentary Monitoring Group
PSIA	Poverty and Social Impact Assessment
REA	Rural Electrification Agency
RSA	Republic of South Africa
SALDRU	South Africa Labour and Development Research Unit
SCS	Self Contained System
SEA	Sustainable Energy Africa
SONABEL	Société Nationale Burkinabè d'Electricité
SALGA	South African Local Government Association
TANESCO	Tanzania Electric Supply Company
TEA	Total Energy Access
TEIT	Total Energy Inconvenience Threshold Approach
UBOS	Uganda Bureau of Statistics Projections
UBPL	Upper Bound Poverty Line
UCT	University of Cape Town

UN-AGECC	United Nation Secretary General Advisory Group on Energy and Climate Change
UNDP	United Nation Development Programme
UNEP	United Nation Environmental Programme
VRA	Volta River Authority Act
WEF	World Economic Forum
WHO	World Health Organisation

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Chapter 1

INTRODUCTION

1.1 Context of the Research

Energy is one of the basic elements of social and economic development (Bekele *et al.* 2015). Energy poverty is considered one of the factors contributing to the slowing down of social and economic development most especially in developing countries (Mekonnen *et al.* 2016; United Nation Development Program, UNDP 2010). In developing countries, the provision of electricity is recognised as a critical foundation for the eradication of energy poverty (International Energy Agency 2010; Nussbaumer *et al*. 2012). Unfortunately, the current state of electricity access, particularly in Africa, remains critically low (Hailu 2012; International Energy Agency, IEA 2010). Nevertheless, the reality is that a large proportion of the population, especially low-income earners, in developing countries exist under conditions of energy poverty (Matsika *et al.* 2013; Pereira *et al.* 2011b; Sokona *et al.* 2012).

Defining energy poverty, especially at the micro-economic level of the residential sector, is central to any effort to alleviate it (Pachauri and Spreng 2011). Most definitions of energy poverty for developing countries emphasise accessibility to electricity or the electrification of low-income households in rural or urban settlements (Dinkelman 2011; Pachauri and Spreng 2011). The World Economic Forum, WEF (2010), defined energy poverty as a lack of access to sustainable modern energy services and products. Another definition describes energy poverty as a descriptor of the problems of household energy consumption in the face of the lack of access to electricity and clean cooking facilities (Li *et al.* 2014; Sovacool 2012). According to Parajuli (2011), the lack of clean cooking facilities is an indication of the need to expand energy services.

Energy poverty in South Africa has been defined as a lack of access to those modern energy services necessary for human development (Ismail 2015; Kohler *et al.* 2009). These services are defined as household access to electricity, clean cooking, and space heating facilities (e.g. fuels and stoves that do not cause air pollution in houses) (Ismail

2015; Kohler *et al.* 2009). Although South Africa boasts lower rates of energy poverty than most neighbouring countries, it remains a country struggling to develop its economy to provide opportunities for people to extract themselves from energy poverty (Adam 2010; Ismail and Khembo 2015). Adam (2010) stated that there are 12.5 million rural and urban houses in South Africa not connected to the national electricity grid in addition to the millions that are connected to the grid but are unable to pay for electricity. Households at the low-income level (those classified as earning R0 – 18 000 per annum or with an income below R1 500 per month) are mostly those that cannot afford sufficient electricity to improve their welfare (Ismail and Khembo 2015). Thus, houses without electricity (in both rural and urban settlements) primarily depend on traditional fuels for cooking and space heating requirements (Kimemia *et al.* 2014; Matinga *et al.* 2014). Even houses connected to the grid still use traditional fuels because of the high cost of electricity in relation to household income (Bhide and Monroy 2011; Demurger and Fournier 2011).

An important goal of the post-apartheid South African Government is to increase accessibility to modern energy resources, particularly electricity, in low-income houses because this access leads to the eradication of energy poverty (Department of Energy, DoE 2013). The Department of Minerals and Energy (DME), by providing for effective energy utilisation hopes to ensure energy poverty alleviation. Despite increased efforts by government, the social well-being of poor South African households, in general, has not greatly improved more than two decades after the end of apartheid (Godfrey *et al.* 2016). The national electrification program intends to encourage newly electrified houses to shift from wood, paraffin, candles, and batteries to electricity (DoE 2015; Swart and Bredenkamp 2012). There is a need therefore to understand the state of energy poverty, most especially, in low-income households, in both rural and urban areas.

Metrics that can be used quantitatively to assess and track progress on energy poverty among low-income households represents an essential support tool. The metrics that have been applied in South Africa include: the access based approach (Leibbrandt *et al.* 2005); the headcount index approach combined with the income based approach (Poverty and Inequality 2007); the access adjusted energy measure approach (Vermaak

et al. 2009), and the expenditure approach (DoE 2012; South African Local Government Association (SALGA) Energy Guideline Series 2014). A new tool developed to evaluate energy poverty is the multidimensional energy poverty index (MEPI) which captures the set of energy deprivations that may affect an individual or a household (Nussbaumer *et al.* 2012). MEPI is composed of five dimensions representing basic energy services, including cooking/space heating, lighting, and household electrical appliances, entertainment, and communication (Nussbaumer *et al.* 2012). One important advantage of MEPI over all other energy poverty measures is its decomposability (allowing for a wide range of analyses focussing on sub-groups like wealth classes) (Nussbaumer *et al.* 2012). This unique advantage allows the determination of the incidence and intensity of energy poverty in low-income households, and therefore the more accurate evaluation of policies aimed at reducing energy poverty.

Determining household energy consumption patterns in the presence or absence of electricity, is important for an understanding of the interventions that could be introduced (Daioglou *et al.* 2012; Kaygusuz 2012). There are a number of theories explaining the energy consumption patterns of households. The 'energy ladder' was the first model explaining household energy choice in developing countries (Hosier and Dowd 1987; Leach 1992; Van der Kroon *et al.* 2013); describes the way in which households will normally behave (following the utility maximising neoclassical model) by identifying income as the most important determinant of energy choice (Heltberg 2003; Kowsari and Zerriffi 2011). The energy ladder hypothesis states that households move up the ladder as income increases; or move down the ladder as income decreases (Arnold *et al.* 2006; Gebreegziabher *et al.* 2010; Hosier and Dowd 1987; Van der Kroon *et al.* 2013). According to Chen *et al.* (2006) and Lay *et al.* (2013), fuel price and accessibility to the market are also important factors for moving up or down the energy ladder. At the top of the ladder are the modern fuels perceived to be superior, such as electricity from the grid, and liquefied petroleum gas (LPG) (Heltberg 2004; Leach 1992; Van der Kroon *et al.* 2013). Transitional fuels, like kerosene or paraffin, coal and charcoal, form the middle of the list (Van der Kroon *et al.* 2013). At the lower end of the range are traditional fuels such as wood, dung or crop wastes (Hosier and Dowd 1987; Van der Kroon *et al.* 2013).

Contrary to the energy ladder theory, many studies find that households in developing countries tend to consume a combination of fuels, referred to as "energy stacking" (or multiple fuels) (Heltberg 2003; Joon *et al.* 2009). Thus, a household chooses from a portfolio of high and low cost fuel types constrained by income and preferences (Ekholm *et al.* 2010; Nansaior *et al.* 2011), or urban/rural locations (Ekholm *et al.* 2010; Pachauri *et al.* 2004). Based on the energy stacking theory, once a household adopts a modern fuel, traditional fuels and devices are retained which means that households only partially switch from one fuel type to another.

One common way to alleviate energy poverty is through energy subsidies (Hailu 2012; Lin and Jiang 2011). From a theoretical point of view, energy subsidies can be justified when they correct a market failure or produce gains in social welfare (Bazilian 2010a; Gillingham *et al.* 2009). The success of a subsidy aimed at correcting a market failure can be determined by the extent to which the subsidy reduces or completely neutralises the market failure (Backlund *et al.* 2012; Fattouh and El-Katiri 2013). If a subsidy aims to accomplish a social objective, for example, increasing social welfare, its success can be evaluated by the extent to which gains in social welfare exceed economic cost (Lin and Jiang 2011; Gillingham *et al.* 2009). Questions of who, what, and how to subsidise need to be carefully assessed (Vagliasindi 2012; World Bank 2010).

One South African government programs that aims to support low-income households in meeting basic energy needs is the Free Basic Electricity (FBE) Act (Adam 2010; Ruiters 2009). Eskom, the national electricity provider in South Africa, introduced FBE after suggestions made by the Department of Minerals and Energy (DME) in 2001 (DME 2003). FBE is a basic service support that allocates an allowance of 50kWh of free electricity each month to low-income households. One of the aims of the subsidy electricity is to address affordability problems related to electricity for low-income households (Makonese *et al.* 2012; Malzbender and Kamoto 2005). It was assumed that the introduction of FBE would diversify household energy choices and encourage a move from traditional energy sources to electricity. The free 50kWh, according to the government, was to meet the need for basic lighting, ironing, cooking, black and white television, a small radio, and the boiling of water using an electric kettle (DME 2003, 2004, 2005).

Various studies have focused on FBE in South Africa. Howells *et al.* (2006) explore the role of the FBE in distortion of energy choices; Mapako and Prasad (2005) in FBE policy with regard to national electric grid and solar home system; Davies *et al.* (2008) look at the impact of FBE on electricity demand by households. Recent studies by Makonese *et al.* (2012) and Ruiters (2011) have assessed the FBE in connection with pre-paid metres and the complexities and contradictions of the policy act. These studies all contribute to South African energy research. There has, however, been much debate about the amount of free basic electricity that is supplied, with some authors arguing that the FBE is insufficient to have an effect on the energy choices of low-income households (Dugard 2009; Howells *et al.* 2006; Ruiters 2009). The Congress of South African Trade Unions (COSATU), and some other organisations, have called for an increase of the FBE amount from 50kWh to 100kWh or more per month (Urban Seed Daily News 2008; Makonese *et al.* 2012). Howells *et al.* (2006) and Ruiters (2009) agree that the 50kWh free electricity complicates household energy choices and is inadequate in making a meaningful contribution to low-income households. A counter-argument from Gaunt (2003), Inglesi-Lotz (2011) and Ruiters (2011) is that the provision of free 50kWh has the potential to increase a household's welfare through access to clean energy. Cowan and Mohlakoana (2004) and Dugard (2009) argue that the FBE does not take into account larger households, thus discriminating against them. Makonese *et al.* (2012: 3), in reply to the argument by Cowan and Mohlakoana (2004) and Dugard (2009), consider FBE to be a 'token' from the government but that the costs of extra electricity consumption have then to be borne by the household.

While there have been a number of studies examining the impact of FBE policy (Howells *et al.* 2006; Mapako and Prasad 2005; Davies *et al.* 2008; Makonese *et al.* 2012; Ruiters 2011), the debate continues on its effectiveness in alleviating energy poverty over time. To date, the MEPI has not been used to examine the impact of the FBE program on energy consumption and energy poverty in low-income households in South Africa.

1.2 Objectives of the Research

The main objective of the study is to evaluate energy use patterns and trends among low-income South African households. The main objective was achieved through the following sub-objectives:

Sub-Objective 1: To investigate the extent of energy poverty among low-income households in South Africa using a multidimensional energy poverty index.

The National Income Dynamics Survey (NIDS) provides the most comprehensive datasets for the analysis of energy poverty. Following the approach of Nussbaumer *et al.* 2011, an MEPI was constructed for low-income households in South Africa. The MEPI technique was derived from the literature on multidimensional poverty measures from the Oxford Poverty and Human Development Initiative (OPHI) (Alkire and Foster 2007, 2009, 2010; Alkire and Santos 2010). The multidimensional energy poverty approach measures the proportion of the population that is multi-dimensionally energy-poor (incidence) and the average intensity of their deprivation of energy (intensity). Multidimensional poverty was estimated by multiplying the incidence of poverty by the intensity of energy deprivation. For this study, the choice of six dimensions of energy deprivation is assumed to reflect the essential household energy services in order to reveal the multidimensional nature of energy poverty. The six dimensions representing basic energy services include cooking, heating, lighting; services provided by means of household appliances, entertainment/education, and telecommunication appliances. Energy poverty indicators related to appliances address the notion of affordability and also capture elements related to the end-use which are commonly not included in energy access metrics. Relative weights were assigned to various energy poverty indicators so that a household is considered to be energy deprived if the primary cooking, lighting, and heating fuel is not a modern energy carrier, does not have a fridge (basic household appliance), radio (entertainment/education appliance), and cell phone (telecommunication appliance).

Sub-Objective 2: To examine if the 'energy ladder' or 'energy stacking' models explains the energy transition patterns among South African low-income households.

The NIDS datasets were also used to examine the prevalence of the different energy choices made by low-income households by showing the extent to which various energy sources are being used. The energy choices by households were disaggregated by different end-use (cooking, space heating, and lighting) allowing for an examination of the extent to which modern, transitional, or traditional carriers are being used. Therefore, if low-income households move up the energy ladder as their income increases, the 'energy ladder' model is confirmed. This is assessed if income is statistically significant in relation to a household's decision concerning the energy choices for cooking, heating and lighting. The 'energy stacking' model, on the other hand, was assessed whether modern energy carriers are used in combination with transitional or traditional energy carriers when there is an increase in income. Therefore, if income is not statistically significant in relation to the household's decision concerning energy choices for cooking, heating, and lighting, "energy stacking" is confirmed. An ordered logistic regression was carried out to test the above assessment because energy choice do follow a meaningful sequential order where one energy choice is superior to others. The marginal effect was used to determine, firstly, which of the energy models describes the transition pattern of the low-income households and secondly, to determine and then to examine the influence of some endogenous characteristics in the energy transitioning.

Sub-Objective 3: To examine whether access to FBE policy significantly influences the probability of low-income households owning food preserving or entertainment devices.

The objective of the FBE policy is to bring relief to poor households enabling them to benefit from access to electricity as the main energy source for their basic energy requirements of lighting, ironing, cooking, and the use of a television. In order to analyse if access to FBE policy influence the possession of these electrical appliances, the study used the Income and Expenditure Survey (IES) 2010/2011, which comprises the following elements: availability of free electricity, electricity connection, and the types of appliances used in the household. The proportion of low-income households receiving and not receiving the FBE was estimated. A binary logit regression was used to examine the significance of the FBE policy through the ownership of entertainment and foo-preserving appliance.

1.3 Overview of the Thesis and Structure

The thesis is organised into nine chapters. Chapter 2 reviews the concept of energy poverty. The chapter recognises the importance of identifying energy poor households and the economic measures of energy poverty. Quantitative approaches to measuring energy poverty are discussed with an overview that highlights the new metric to measure and report energy poverty.

Chapter 3 is a review of household energy consumption and patterns with particular reference to developing countries. It reveals the important endogenous and exogenous characteristics influencing household energy choice decisions. The energy models that govern household energy transition as well as case studies to demonstrate the energy models are presented.

Chapter 4 provides a review of empirical literature on energy subsidy. It outlines both the benefits and negative implications of energy subsidy. The problems and benefits posed by the removal, or reduction, of energy subsidy provides additional insights into the ways in which economic theory proves the nature of the subject matter. Electricity subsidy, the privatisation of electricity in developing countries and a comparative discussion of electricity subsidies in some selected countries is also presented in the chapter.

Chapter 5 discusses energy poverty, household energy consumption patterns, and electricity subsidy in South Africa. Historical origins and measures as they relate to each main version are discussed. The chapter also discusses issues relating to the energy system of the country with special attention to the electricity policy.

Chapter 6 presents the research methods comprising the sources of the data, procedures, techniques, and specific methods used in the analysis.

The results of the study are presented in chapters 7 and 8. In Chapter 7, the descriptive statistics of the sample (low-income households) are provided. The chapter is also devoted to the discussion of results based on energy poverty, using concepts discussed in chapter 2. Chapter 8 presents the results of the energy models and the impact of the electricity policy, and uses concepts gathered from chapters 3 and 4.

The key arguments presented in the thesis are summarised in Chapter 9, which provides conclusions to the study. The chapter offers recommendations and suggests areas for future research in the area of energy policies.

Chapter 2

THE CONCEPT OF ENERGY POVERTY

2 Introduction

In this chapter, the concept of energy poverty, which is often considered synonymous with fuel poverty, is discussed. Firstly, energy poverty and fuel poverty are discussed as descriptors of problems of household energy consumption. Energy poverty has become significant, especially in developing countries, because of an understanding that access to electricity is fundamental to the eradication of energy poverty. After a brief discussion to identify those households in energy poverty, the economic and quantitative measures of energy poverty are reviewed. The description and components of the new composite index to measure energy poverty are provided in this chapter. Country case studies to demonstrate the applicability of the new energy poverty index ends the chapter.

2.1 Defining Energy or Fuel Poverty

Defining energy or fuel poverty especially at the micro-economic level of the residential sector identifies the nature of need, which then serves as a basis for pinpointing the actions required to address the need (Hills 2012; Pachauri and Spreng 2011). For developing countries, energy poverty has been defined with respect to accessibility to electricity which is widely recognised as central to most aspects of sustainable development including agricultural and industrial developments, health care, portable water, communication, and education (Bazilian *et al.* 2010; United Nation Development Program 2010).

The International Energy Agency (IEA) (2010) defines energy poverty as a lack of access to electricity and a reliance on traditional fuels. Bouzarovski *et al.* (2012), Buzar (2007) and Pachauri *et al.* (2012) define energy poverty as a condition of household being unable to access, or unable to afford, electricity for its basic needs. Energy poverty can

therefore be described as a concept that addresses issues of electricity access and affordability (Li *et al.* 2014; Pereira *et al.* 2010).

Fuel poverty, the same phenomenon as energy poverty, is the common term used in most developed nations (Boardman 1991, 2010; Hills 2011). For developed countries, fuel poverty has been defined with respect to satisfactory space heating, since this is a significant determinant of winter deaths and ill-health (Dear and McMichael 2011; Hills 2012; Liddell and Morris 2010). In the early 80's in the United Kingdom, fuel poverty was defined as the inability of a household to ensure an adequate thermal regime in its living space (Boardman 1991, 2010; Hills 2011; Schuessler 2014). Thermal regime represents energy demand for space and water heating, cooling, lighting, and powering appliances (Golubchikov and Deda 2012; Ürge-Vorsatz and Herrero 2012). Pachauri *et al.* (2004) and Barnes *et al.* (2011) define fuel poverty as the need for households having to spend more than 10 percent of their monthly income to ensure adequate heating. The recommended acceptable temperature is 21^{0}C in the living areas and 18^{0}C in other parts of the house (Boardman 2010; Hills 2011; World Health Organization 1987). Fuel poverty, therefore, quantifies issues of affordability (Hills 2011; Li *et al.* 2014).

2.1.1 The Concept of Energy Poverty

Energy poverty pervades many, if not all dimensions of poverty (Srivastava *et al.* 2012; Vermaak *et al.* 2009) as one of the major social problems of the 21st century (Boardman 1991, 2010). According to Pachauri and Spreng (2011), energy poverty is caused by a complex combination of factors, including the lack of the physical availability of electricity and the lack of income in the face of the high costs associated with using electricity. Both developed and developing nations face challenges of energy poverty, but developing nations are more severely and directly affected (Bouzarovski *et al.* 2012; Dagoumas and Kitsios 2014; Kammen and Kirubi 2008). The overall scale of energy poverty is especially severe in Africa and developing countries (Kaygusuz 2011; Ürge-Vorsatz and Herrero 2012). It is estimated that one-third of the world's population, amounting to 2 billion people, suffer from energy poverty (Bhide and Monroy 2011; Kaygusuz 2011; Sagar 2005). Half of this population lives on the African continent (International Energy Agency 2012; Kaygusuz 2011). The concept of energy poverty is an

important determinant of household welfare in terms of its capacity for energy consumption (Barnes *et al.* 2011).

In developing countries, having no access to electricity, or not being able to afford it results in a reliance on traditional fuels (International Energy Agency *et al.* 2010; Jones 2010; Sovacool 2012). Modern fuel use is positively correlated with electrification of the household (Bhutto and Karim 2007; Pereira *et al.* 2011) as indispensable for basic activities such as lighting, refrigeration, and the running of household appliances which cannot be easily replaced by other forms of energy (Apergis and Payne 2011; Mazur 2011). In both developing and developed countries, electricity, according to Dilaver and Hunt (2011) and Nui *et al.* (2011), is more convenient for the acquisition of comfortable heating, air conditioning, and entertainment, thus greatly increasing quality of life. Electricity consumption is regarded as a reference of well-being and a measurable indicator of life quality (Petterssona *et al.* 2012; Pinheiro *et al.* 2011). The aim of extending access to electricity however has been slow to progress worldwide due to high cost of extending grids (Kaygusuz 2011; Zhou *et al.* 2008). Extending the national grid network, according to De Gouvello (2002) and Yadoo and Cruickshank (2012), has economic advantage if the population to be served is close to reaching the full capacity of the existing grid. Those populations needing to gain access to electricity are distinguished from those, which are high-end users; energy poverty applies to households whose basic needs are compromised by poor incomes that are unequal to the cost of electricity (Advisory Group on Energy and Climate Change, AGECC 2010; Kaygusuz 2012; Khandker *et al.* 2012).

2.2 Identifying Energy/Fuel Poor Households

According to Hills (2012), a good indicator of energy/fuel poverty should help identify energy/fuel poor households, which is crucial for the efficient implementation of policies to combat energy poverty (Dubois 2012; Morestin *et al.* 2009). Understanding the characteristics of energy/fuel poor households is a major step towards identification (Hills 2012).

2.2.1 Low-Income and Rurality

Low-income is the most commonly used indicator of energy-poor households (Hills 2012; Ürge-Vorsatz and Herrero 2012). Low-income households are often located in rural areas (Hills 2012; Mainali and Silveira 2013) and have a restricted budget for energy (Hills 2012; Ürge-Vorsatz and Herrero 2012). Furthermore, in most developed and developing countries, low-income households are unable to afford connection to the national electricity grid due to high up-front costs and energy usage costs (Bouzarovski *et al.* 2012; Brew-Hammond 2010). The unit cost of electricity delivery in rural areas of both developed and developing countries is high because of remote geographical location and difficulty in accessibility (Ahlborg and Hammar 2014; Mainali and Silveira 2011). Thus, the extent of energy poverty is much greater in rural than in urban areas (Hills 2012; Mondal *et al.* 2010).

Khandker *et al.* (2012) conducted an energy poverty survey in India, a developing country, to determine if energy-poor households are also income-poor households. India is the sixth largest electricity generating country as well as the sixth largest electricity consumer in the world (Bhide and Monroy 2011; Kamalapur and Udaykumar 2011). Despite this, the population census conducted in 2011 in India revealed that 700 million people lack access to electricity (Census of India 2011; Reddy and Nathan 2013). Ninety percent of people without electricity live in the rural areas (Pachauri 2014; Rao 2013) where traditional fuels still provide 80-90 percent of energy needs (Census of India 2011; Palit *et al.* 2014).

In the Khandker *et al.* (2012) study, cross-sectional data from a household survey representing both urban and rural households were used. A simplified approach identified energy poor-households by dividing the households sampled into ten income groups. Energy consumption for the lowest income groups were observed and used to define the energy poverty line. Findings showed that, for rural households, energy consumption corresponded to income until after the fifth decile, therefore estimating the poverty line for Indian rural households at the fifth income decile. For urban households, energy consumption corresponded to income until after the second income decile. That the urban energy poverty line emerged as lower than the rural indicates

greater access to modern energy and a wider range of available energy services in urban households than rural households. The conclusion that there were more energy-poor households in rural India than in urban areas also shows the importance of using different measurements for rural and urban areas (Miah *et al.* 2011).

2.2.2 House Type and Age of Property

House type is another identifying factor of energy-poor households in developed countries (Hills 2012; Ürge-Vorsatz and Herrero 2012). House type indicates whether dwellings are semi-detached, terraced, detached, flats, or bungalows (Hills 2012; Palmer and Cooper 2011). The type of dwelling is significant as heating energy is related to external wall and window areas (Hills 2012; Palmer and Cooper 2011). Fuel poor households usually live in semi-detached or terraced housing (Hills 2012; Ürge-Vorsatz and Herrero 2012) which are larger and have more windows than equivalent houses of other types (Palmer and Cooper 2011). Since heating energy is correlated to window and floor areas, increased heating energy is necessary in such dwellings (Palmer and Cooper 2011; Ürge-Vorsatz and Herrero 2012). The age of a property is also significant in energy costs because insulation and efficient heating systems determine heating energy in old properties (Hills 2012; Palmer and Cooper 2011). According to Hills (2012), Palmer and Cooper (2011), and Saunders *et al.* (2012), poor quality buildings and energy inefficient housing are key guides to the likelihood of a household's being energy/fuel poor.

2.2.3 Payment methods

Payment methods for electricity vary: prepayment metres, standard credit; or direct debit (Hills 2012; O'Sullivan *et al.* 2014). Prepaid metres have been widely adopted by utilities in different countries across the globe (Hills 2012; Makonese *et al.* 2014). This allows energy consumption only when the electricity supply is in credit (Casarin and Nicollier 2009, 2010; Makonese *et al.* 2014). Prepaid metres have been well received by consumers in both developed and developing countries, because being in control of household electricity spending obviates high monthly electricity accounts (Anderson *et al.* 2012; Boelman *et al.* 2010).

Low-income households, however typically use less electricity, so prepayment metering increases the difficulties of energy hardship (Hills 2011; O'Sullivan *et al.* 2014). Low-income energy usage is dependent on dwelling and appliance characteristics, and is usually less energy efficient than in higher-income households (O'Sullivan *et al.* 2014). This is problematic for households as they are unable to afford efficient appliances that might allow for savings (Dubois 2012; O'Sullivan *et al.* 2014). Therefore, prepayment metering cannot provide the benefits of budgetary management for low-income households (Hills 2011; O'Sullivan *et al.* 2014).

In the United Kingdom, a developed country, Price *et al.* (2012) explored low-income households to determine the households that are fuel-poor; low-income households using prepayment metres for household fuel were specifically targeted following the "remediableness approach" advocated by Williamson (1996) in applying the target principle, which states that:

> "…targeting should be as precise as possible, in order to help those who need it most"

It was assumed that households using prepayment or standard payment rather than direct debit to settle their energy bills are likely to be fuel-poor (Department of Energy and Climate Change 2009; Hills 2011).

The data was collected through an extensive survey of low-income households. Respondents were chosen as being representative of prepayment electricity consumers. Questionnaires were administered in face-to-face interviews in respondents' homes. The data included, among other information on heating method, the extent to which households were fully heated, affordability of fuel bills, issues associated with using prepayment metres, and charging prepayment cards, whether prepayment metres installation involved payment in arrears, and the experience of disconnection from prepayment metres. The conclusion was that low income households that use prepayment meters are typically in fuel poverty (Hills 2011; Price *et al.* 2012).

2.3 Economic Measures of Energy Poverty

The extent of energy poverty can be estimated by measuring how far a target population is from a reference point (Bhanot and Jha 2012; Pachauri and Spreng 2011). Only when energy poverty is properly measured can progress towards alleviating it be measured (Hills 2012; Pachauri and Spreng 2011). The concept of a poverty line is a well-known tool generally accepted for measuring energy poverty (Barnes *et al.* 2011; Khandker *et al*. 2012).

2.3.1 The Energy Poverty Line

The aim of determining an energy poverty line is to distinguish energy-poor households from non-energy poor households (Chidebell-Emordi 2015; Pereira *et al.* 2011). Several approaches have been used. For example, the energy poverty line can be defined as the minimum quantity of physical energy needed to perform basic tasks such as cooking and lighting (Barnes *et al.* 2011; Khandker *et al.* 2012). Above this minimum, energy contributes to greater welfare and higher levels well-being, while below this, households consume a bare minimum level of energy (Barnes *et al.* 2011; Pereira *et al.* 2010). Another approach defines the level of energy used by households below the known income poverty line (Barnes *et al.* 2011; Foster *et al.* 2000). The underlying assumption of this approach is that households below the poverty line may or may not be energy poor due to the local availability of natural resources (e.g. trees from the local environment) (Barnes *et al*. 2011). A third approach is based on energy expenditure as a proportion of total income (Boardman 1991; Pereira *et al.* 2010). According to Barnes *et al.* (2011) and Sovacool (2012), poor households spend a higher percentage of their income on energy than do wealthier households. A cut-off point of 10 percent of income spent on energy is considered to be the poverty line (Hills 2011; IEA 2010).

Based on these approaches, there is no international agreement for the definition of the energy poverty line. For instance, those based on the minimum quantity of physical energy needed have been found to be location specific due to differences in climatic conditions (Barnes *et al.* 2010; Hills 2011). Others based on expenditure have often been found to be arbitrary in establishing what defines essential energy services (Barnes *et al.* 2010; Pereira 2010). Thus, it has been difficult to get an agreement considering

the methodological and conceptual issues in defining an energy poverty line. However, once an energy poverty line is identified, it will help ascertain the extent of energy poverty.

2.3.2 The Headcount Index and Poverty Gap Index Approaches

The Headcount Index approach is the most intuitive energy poverty measure used in both developed and developing countries (Heindl 2014; Miniaci *et al.* 2014; Nussbaumer *et al.* 2012). The headcount index is based on scrutinising the number of households that fall below a defined energy poverty line relative to the overall population (Khandker *et al.* 2012; Miniaci *et al.* 2014). While this approach is easy to interpret, it does not incorporate information about a desirable amount of energy consumption either for utilities or for other goods nor does it reveal the distribution of income below the poverty line (Heindl 2014; Miniaci *et al.* 2014).

Similar to the headcount index is the Poverty Gap Index approach, which measures the depth of energy poverty by adding up the extent to which a household falls below the poverty line, considering the average energy expenditure, and expresses it as a percentage of the poverty line (Heindl 2014; Ivanic *et al.* 2012). The approach gives limited information about the severity or depth of energy poverty within the group of the energy poor (Ivanic *et al.* 2012; Miniaci *et al.* 2014).

2.4 Approaches to Quantitative Estimate of Energy Poverty

The complex combination of the lack of the physical availability of certain energy types, the lack of income and the high costs associated with using energy, among other things, have been identified as causing energy poverty (Bazilian *et al.* 2010; Pachauri and Spreng 2011). Any approach to measuring energy poverty, according to Nussbaumer *et al.* (2012, 2013) and Pachauri and Spreng (2011), needs to show shifts in the composition of energy poverty over time so that progress, or the lack of it, can be monitored. The consistent measurement of energy poverty on a regular basis is therefore crucial to provide a benchmark of relative change or progress that can guide international and national agencies in setting priorities (Pachauri and Spreng 2011; Poverty and Inequality

Institute 2007). Quantitative assessments of energy poverty have yielded several metrics, especially at the micro level (Dagoumas and Kitsios 2014; International Energy Agency 2010; Practical Action 2010). First, the Minimum Energy Consumption approach proposed by Modi *et al.* (2005) and the United Nation Secretary-General Advisory Group on Energy and Climate Change (UN-AGECC 2010), second, Total Energy Inconvenience Threshold approach (TEIT), third, the Demand-based approach; fourth, the Expenditure approach; fifth, an Income-invariant Energy Demand approach introduced in Barnes *et al.* (2011); sixth, the Multidimensional Energy Poverty Index (MEPI) by Nussbaumer *et al.* (2012) and lastly the Total Energy Access (TEA) standard, presented in Practical Action (2012). This section reviews the way energy/fuel poverty is being measured and the implications of different measurement approaches.

2.4.1 The Minimum Energy Consumption Threshold Approach

The Minimum Energy Consumption Threshold approach, also called the UN-AGECC metric, seeks to identify households, not able to fulfil their basic energy needs (Bensch 2014; Modi *et al.* 2005; UN-AGECC 2010). Energy poverty, using this approach, is based on two energy poverty indicators or thresholds- rate of electrification and household use of non-solid cooking fuels (Barnes *et al.* 2010; Bensch 2014; UN-AGECC 2010). It was assumed that these two energy poverty indicators gave a snapshot of energy access in developing countries (Bensch 2014; UN-AGECC 2010). An energy poverty cut-off point is proposed for each of the chosen energy poverty indicators in terms of consumption per year and capita (Bensch 2014; Modi *et al.* 2005; UN-AGECC 2010). Thus, a minimum amount of final energy used (non-solid cooking fuels), or any other fuel(s) used, and the minimum amount of electricity used for all other services determine the energy poverty cut-offs (Bensch 2014; Modi *et al.* 2005; UN-AGECC 2010). A household is defined as energy poor if the energy poverty cut-offs are not exceeded (Bensch 2014; Modi *et al.* 2005; UN-AGECC 2010).

The drawbacks of the Minimum Energy Consumption Threshold approach lie in the fact that energy poverty is measured only in a quantitative sense and only implicitly takes account of types of energy by including efficiencies of each energy type (Barnes *et al.* 2010; Bensch 2014). Thus, according to Barnes *et al.* (2010) and Bensch (2014), it is

conceivable that the Minimum Energy Consumption Threshold approach would classify a household with very high biomass consumption as energy non-poor, even if the household lacks electric light and burns the biomass in inefficient and polluting stoves. In addition, the Minimum Energy Consumption Threshold approach depends crucially on the concept of clean versus traditional cooking stoves, which may be the case in rural areas of less developed or developing countries but not in an urban setting, even among the energy poor (Barnes *et al.* 2010; Bensch 2014).

Bensch and Peters (2012) carried out a survey in rural Senegal to cover households among whom improved cooking stoves had been randomly distributed. Energy poverty cut-offs were assigned for electrification and clean cooking access rates with an estimate of 50 kilowatt hours and 40 kilograms of oil equivalent respectively (Bensch and Peters 2012). The results revealed 62 percent of households are energy poor for the clean cooking access rate (Bensch and Peters 2012).

2.4.2 The Total Energy Inconvenience Threshold Approach

Mizra and Szirmai (2010) developed the Total Energy Inconvenience Threshold (TEIT) to measure energy poverty, focussing specifically on the monetary and non-monetary costs involved in using specific types and amounts of energy consumed, and the inconveniences associated with using different energy sources in the household. Mizra and Szirmai (2010) measured inconvenience in terms of the time and effort and adverse impact associated with the use of alternative fuels. Inconveniences include using inefficient and polluting energy sources and equipment (Mizra and Szirmai 2010; Pachauri 2011; Pachauri and Spreng 2011). Energy poverty is measured under the TEIT approach as the point beyond which all households measured as suffering inconveniences are defined as energy poor (Mizra and Szirmai 2010; Pachauri and Spreng 2011). In other words, the TEIT approach takes into account the shortfall in energy consumption (the extent to which energy use lies below a threshold energy requirement) and the inconveniences of using different energy sources. The limitations of the TEIT approach are having to account for direct costs of particular energy mixes and/or the affordability of the energy required for the end-use of equipment in the household (Mizra and Szirmai 2010; Pachauri and Spreng 2011). Furthermore, the

approach requires detailed household survey data which may be difficult to collect on a routine basis in many instances (Mizra and Szirmai 2010; Pachauri and Spreng 2011).

2.4.3 A Demand-Based Approach

The demand-based approach is established on the level of energy demand as it relates to household income and not on energy expenditures alone (Barnes *et al.* 2010; Khandker *et al.* 2010). The assumption underlying the measure of energy poverty is that household consumption of energy and other non-energy goods and services is related to overall well-being (Barnes *et al.* 2011; Khandker *et al.* 2010). The basic intention is to determine minimum energy needs after taking into account the price of energy used and the availability of different energy types (He and Reiner 2014; Khandker *et al.* 2012). The need is determined by observing changes in household energy consumption according to flunctuation of income (Barnes *et al.* 2010; Khandker *et al.* 2012). The energy poverty line is drawn at the point at which energy consumption begins to rise with increases in income (Barnes *et al.* 2010; He and Reiner 2014). At or below this point, households consume a bare minimum level of energy and should be considered as energy poor (Khandker *et al.* 2012; Liddell *et al.* 2011). The attractiveness of this approach lies in the definition of energy poverty, which is based on how a household actually consumes energy, and on local resource conditions, energy prices, and policies (Barnes *et al.* 2010; He and Reiner 2014). One disadvantage of the approach however is that it is data intensive, requiring a household survey that covers details of energy consumption (Barnes *et al.* 2010; Khandker *et al.* 2012).

Khandker *et al.* (2012) used the Energy Demand approach to estimate energy poverty for rural households in India. The underlying assumption of the approach is that a household's energy demand is influenced by a range of factors at the level of the household (including income, education, etc.); and the community (energy price, village infrastructure, commodity prices, etc.) (Khandker *et al.* 2012). Energy poor households display a weak relationship between their energy use and their income (Barnes *et al.* 2010; Khandker *et al.* 2012). An energy poverty line was defined on this central basis, and estimated as the point at which energy consumption for households rises almost monotonically with income (Barnes *et al.* 2010; Khandker *et al.* 2012). Data on the

monetary value of energy expenditure, energy consumption, and income (in deciles) provided a balanced position to estimate energy poverty (Barnes *et al.* 2010; Khandker *et al.* 2012). For the surveyed rural households in India, the energy poverty line was drawn at the fifth income decile (Khandker *et al.* 2012). The number of households in a state of energy poverty was determined by using the energy poverty headcount, which counts the number of households below the fifth income decile (Khandker *et al.* 2012).

2.4.4 The Expenditure Approach

The Expenditure approach is the most commonly used for measuring energy/fuel poverty in both developed and developing countries (Khandker *et al.* 2010; Thomson 2013). Adopting the Expenditure approach classifies households according to their financial ability to meet basic energy needs (Barnes *et al.* 2011; He and Reiner 2014). The Expenditure approach includes both the Expenditure method and the Expenditure Share method (Liddell *et al.* 2011; Thomson 2013).

The Expenditure approach measures the average energy demand for households at the income poverty line and equates that demand with the level of basic energy needs (Khandker *et al.* 2010; Liddell *et al.* 2011). Households that are poor in terms of income are also energy-poor (Barnes *et al.* 2010, 2011). The Expenditure method does not need to measure types of energy used by individual households (Barnes *et al.* 2011; He and Reiner 2014). As Khandker *et al.* (2010) and Liddell *et al.* (2010) point out, the usefulness of measuring average energy demand is clear, the resulting definition of basic need is precise, and the measurement technique is relatively simple. A drawback is that the method assumes that energy poverty follows exactly the same pattern as expenditure or income poverty, thus the income poor are defined as energy poor regardless of access to energy supply, climatic conditions, or societal norms (Barnes *et al.* 2011; Khandker *et al.* 2010; Liddell *et al.* 2011). The Expenditure approach is similar to the Energy Demand based approach (Khandker *et al.* 2010; Liddell *et al.* 2011).

The Expenditure Share method examines the proportion of household income spent on energy (Boardman 2011; Fahmy *et al.* 2011; Hills 2012, Liddell *et al.* 2012) classifying it as energy poor if energy expenditure exceeds a specific percentage of income

(Boardman 2010; Fahmy *et al.* 2011). The idea is that households forced to spend a large proportion of their income on energy are deprived of other basic goods and services, and their welfare is lessened (Barnes *et al.* 2011; He and Reiner 2014). A cut-off point of 10 percent of a household's total income spent on energy services is commonly used as a benchmark for determining energy poverty (Barnes *et al.* 2010; Moore 2012). According to Hills (2012), Khandker *et al.* 2010 and Liddell *et al.* (2011), the 10 percent decision rule is an arbitrary figure. Moore (2012) criticised the 10 percent threshold, pointing out that it is based on observations made more than twenty years ago by Boardman (1991) and therefore not sensitive to current changes in energy prices.

The Expenditure Share method was used to estimate fuel/energy poverty in households in England. The energy services considered include space and water heating, lights, electrical appliances, and cooking (Hills 2012; Moore 2012). Any household that needed to spend more than 10 percent of its income on the aforementioned energy services were defined as being energy poor (Heindl 2013; Hills 2012; Moore 2012). Importantly, income was measured based on full income, before housing costs or benefits, and was not adjusted for household size and composition (Hills 2012; Moore 2012). Data from the English Housing Survey and modelled utility bills of households were used to assess fuel/energy poverty (Hills 2012; Moore 2012). In the year 2011, based on the 10 percent energy poverty line, 15 percent of households in England were identified as fuel/energy poor, 25 percent in Scotland, 29 percent in Wales, and 42 percent in Northern Ireland (Department of Energy and Climate 2013).

2.4.5 The Multidimensional Energy Poverty Index Approach: A New Metric to Measure and Report Energy Poverty

The multidimensional energy poverty index (MEPI) is an adaptation of the general Multidimensional Poverty Index (MPI) (Nussbaumer *et al.* 2012; United Nation Development Programme, UNDP 2010). The MPI is based on the methodology described in Alkire and Foster (2007, 2011). Measuring poverty on a multidimensional basis necessitates evaluating whether people succeed in achieving minimum thresholds

of well-being in a narrow set of dimensions and indicators which are usually selected with reference to the type of poverty to be addressed (Alkire *et al.* 2014; Santos 2013).

The Alkire-Foster method also involves a combination of counting and axiomatic traditions (Alkire and Foster 2007, 2011). The counting tradition identifies the poor by the number of deprivations that affect them while the axiomatic tradition sets out a group of desirable properties that poverty measures must satisfy at the identification and aggregation stages (Alkire and Foster 2007, 2011). For the process of identification, the authors suggest a cut-off level for the number of weighted deprivations suffered by an individual (Alkire and Foster 2007, 2011). The methodology involves assigning the value of zero when there is no deprivation and the value of one when there is (Alkire and Foster 2007, 2011; UNDP 2010). The method involves choosing dimensions and indicators and weighting them, setting the multidimensional cut-off for the proportion of deprivations that an individual must suffer in order to be considered poor, then calculating the deprivation score for each individual (Alkire and Foster 2007, 2011).

The Alkire-Foster measurement to construct MPI is the headcount ratio (the proportion of individuals identified as poor) and the poverty intensity rate (the weighted average of the deprivations suffered by people identified as poor) (Alkire and Foster 2007, 2011). The MEPI is a slight adaptation of MPI, but designed to capture and evaluate a set of energy deprivations that affect an individual or household (Nussbaumer *et al.* 2012, 2013). Fundamentally, MEPI takes into account the incidence (or headcount ratio) and the intensity (or average intensity) of energy poverty (Bekele *et al.* 2015; Edoumiekumo *et al.* 2013; Nussbaumer *et al.* 2013; Sher *et al.* 2014). The incidence of energy poverty (or the headcount ratio), on one hand, is defined as the proportion of the population identified as energy poor (Nussbaumer *et al.* 2012, 2013). On the other hand, the intensity of energy poverty (or average intensity) is defined as the average percentage of dimensions in which energy poor people are deprived (Nussbaumer *et al.* 2011, 2012 and 2013; Sher *et al.* 2014). In other words, the intensity of energy poverty measures the set of energy deprivations that may affect an individual or household (Nussbaumer *et al.* 2012, 2013). The MEPI merges these two features of energy poverty measures (Nussbaumer *et al.* 2011, 2012 and 2013). The unique advantage of the MEPI, as

opposed to other metrics for measuring energy poverty, is that it allows for decomposability (allowing for a wide range of analyses focussing on sub-groups like wealth classes) (Nussbaumer *et al.* 2012, 2013).

The MEPI captures and provides detailed and accurate information on energy poverty, in the choice and structure of its variables (Nussbaumer *et al.* 2012, 2013). Variables should be carefully selected on the basis of their relevance to the issue at hand and measurability (Nussbaumer *et al.* 2012, 2013). In other words, MEPI can capture the occurrence and magnitude of energy poverty (Mensah *et al.* 2014; Nussbaumer *et al.* 2013). The MEPI, therefore, has the potential to be a tool in monitoring improvement and in influencing the design and execution of policy and to contribute to regulatory and financial strategies to address energy poverty (Nussbaumer *et al.* 2013; Sher *et al.* 2014).

In line with the multidimensional nature of energy poverty, the MEPI is composed of five dimensions representing basic energy services and six indicators of these dimensions (Nussbaumer *et al.* 2013; Sher *et al.* 2014). The basic energy services demanded in households include cooking, space heating/cooling, lighting and entertainment/education (radio, television, computer) services provided by household appliances (e.g. refrigerator, washing machine, and geyser), and telecommunication (Nussbaumer *et al.* 2011; 2012 and 2013). The indicators represent the set of energy deprivations that affect a person in the dimensions mentioned above and which assign energy poverty to an individual or household if the sum of deprivations exceeds a predetermined value (Iddrisu and Bhattacharyya 2015; Nussbaumer *et al.* 2012). The deprivation index is measured by assigning a score based on the intensity of the importance of each indicator (Edoumiekumo *et al.* 2013; Nussbaumer *et al.* 2012, 2013). When designing a national multidimensional poverty or energy poverty measure, the selection of dimensions and indicators is necessary. There is no fixed list of what should be included. The five dimensions and their six indicators with cut-offs is presented in Table 2.1.

Table 2:1: Dimensions and Indicators with Respective Cut-offs

Dimension	Indicator	Variable	Cut-off (Situation of deprivation)
Cooking	Modern cooking fuel	Type of cooking fuel	A household is considered poor/deprived if it made use of any fuel beside electricity, LPG, kerosene, natural gas or biogas for cooking purposes.
	Indoor pollution	Food cooked on stove or open fire (no hood /chimney), indoor, if using any fuel beside electricity, LPG, natural gas or bio-gas	A household is considered poor/deprived if it does not make use of modern cooking stove, or if using three stone cook stove or any fuel for cooking beside electricity, LPG, kerosene, natural gas or bio-gas
Lighting	Electricity Access	Has access to electricity	A household is considered poor/deprived if it has no electricity connection or access to electricity facilities
Services provided by household appliances	Household appliance ownership	Has a refrigerator or washing machine or geyser	A household is considered poor/deprived if it has no refrigerator, washing machine or geyser
Entertainment/education	Entertainment/education appliance ownership	Has a radio or television or computer	A household is considered poor/deprived if it has no radio or television or computer
Communication	Telecommunication means	Has a cell phone or landline or internet service	A household is considered poor/deprived if it has no cell phone or landline or internet service

Adapted from : Nussbaumer *et al.* 2013 and Sher *et al.* 2014

Nussbaumer *et al.* (2011; 2012 and 2013), argues that an ideal energy poverty metric should shed light on the issue of energy poverty through energy services which are important in making a difference to lives and can track of the demand side of energy. It is noteworthy that any energy poverty metric is likely to be constrained by data scarcity. Therefore, this study reviews the indicators that could underpin a measure of energy poverty and at the same time be adapted to the South African context. The

different dimensions of the basic energy services demanded by households is discussed next.

2.5 Dimensions of the Multidimensional Energy Poverty Index

Access to basic energy services is often regarded as a universal human right (Bradbrook and Gardam 2006; He and Reiner 2014). Basic energy services, represented by dimensions, are assumed to determine the standard of living, and summarise the social policy priorities of any government (Alkire *et al.* 2011; Angulo *et al.* 2016). Further, Sen (2004) suggests that focusing on dimensions that are important to the society in question is an appropriate focus for public policy. Improvements in energy services play a crucial role where energy poverty is concerned.

2.5.1 Dimension of Household Energy for Cooking

The provision of energy for cooking is a basic need. Cooking is amongst the very basic needs. Rural households use different forms of energy to minimise the cost and risks arising from unstable supply and technologies (Kaygusuz 2011; Practical Action 2010). A heavy reliance on the use of traditional fuels (firewood, charcoal, dung, etc) for cooking has an important opportunity regarding the time spent collecting fuel (Edoumiekumo *et al.* 2013; Nussbaumer *et al.* 2011).

The cooking dimension is composed of two elements: cooking fuel and indoor pollution. Following the approach of Nussbaumer *et al.* (2013), in instances wherein information on indoor pollution is not available, data on the type of stove can be an imperfect proxy for the cooking dimension to monitor household access to clean and efficient cooking fuels (electricity, LPG, solar and biogas) (Dagoumas and Kitsios 2014; Kaygusuz 2011).

2.5.2 Dimension of Household Energy for Lighting

Lighting is a fundamental human need irrespective of class, income, or gender (Legros *et al.* 2009; Practical Action 2010). People without access to electricity use poor sources of light (transitional energy carriers) and lose productive hours as the sun sets (Khandker *et*

al. 2010; Practical Action 2010). Access to lighting extends household activities beyond daylight hours so households without electricity resort to lamps that are polluting, dangerous, and provide low quality light (Kaygusuz 2011; Practical Action 2010). In rural households, the major use of electricity is for lighting whilst in urban households, use of electricity extends well beyond lighting (Barnes *et al.* 2011; Khandker *et al.* 2012). According to Barnes *et al.* (2011), rural households that have electricity use it for lighting with kerosene wick lamp or candle as backup sources. Kaygusuz (2011), however, noted that rural households take only a small share of their energy consumption for lighting. The use of lighting illustrates the joint relationship between income and energy (Kaygusuz 2011; Khandker *et al.* 2010).

2.5.3 Dimension of Household Ownership of Appliance(s)

Ownership of appliances brings in the notion of affordability (Kaygusuz 2011; Nussbaumer *et al.* 2011). The use of household appliances, such as television sets, microwaves, refrigerators or washing machines, depends first on the availability of electricity (IEA 2008; Kaygusuz 2011). Secondly, income levels of rural populations influence the acquisition of such appliances (IEA 2008; Kaygusuz 2011). It was argued at times that the use of household appliances by rural populations is not necessarily to meet basic needs, but rather to achieve a sense of belonging to the mainstream of development (Kaygusuz 2011; Yüksel 2010). The same was said of household appliances that helped reduce the labour intensity of rural life and allow people to redirect the time saved to other activities for self-improvement or the improvement of household income (IEA 2008; Kaygusuz 2011). The lack of purchasing power for appliances has been described as a major inhibiting factor in rural equity (IEA 2008; Kaygusuz 2011). Access to electricity, or modern fuels, is of limited use if the potential user has no financial means to pay for the fuel or invest in the appliance, which would deliver the desired service (Kaygusuz 2011; Nussbaumer *et al.* 2012). Thus, variables related to the possession, for instance, a washing machine and refrigerator are included for analysis.

2.5.4 Dimension of Household Entertainment/Education and Communication

Entertainment/Education, information, and communication are intrinsic to social and economic relationships (Nussbaumer *et al.* 2011, 2012; Practical Action 2010). Information and communication technologies (ICTs) have been established as important tools for alleviating poverty because they enable the widening of information and communication beyond the immediate environment (Kaygusuz 2011; Practical Action 2010). ICTs include a wide range of technologies: radio and television, telephones (landline or mobile), computers, and the internet (Kaygusuz 2011; Practical Action 2010). The use of a landline or mobile telephone plays a crucial role in socio-economic development (Nussbaumer *et al.* 2011, 2012; Practical Action 2010). With internet access, people can communicate electronic information beyond the locality in which they live (Kaygusuz 2011; Practical Action 2010). Radio or television can provide access to information relevant to people's lives and livelihoods (Marker *et al.* 2002; Practical Action 2010). ICTs and its benefits is contingent on electricity access (Kaygusuz 2011; Nussbaumer *et al.* 2011). Entertainment/education and communication, according to Nussbaumer *et al.* (2011, 2012, and 2013) and Practical Action (2010), can improve the efficiency of business practices and enable wide access to customers, suppliers, partners, sources of capital, and global information.

2.6 The Indicators' Deprivation Cut-Offs and the Weighting Structure

Indicators are useful as proxies for the analysis of performance by extending understanding of the main issue (e.g. energy); and they highlight important relations that are not evident when using basic statistics (Iddrisu and Bhattacharyya 2015; Nussbaumer *et al.* 2011). Indicators are essential tools for communicating energy issues related to sustainable development to policy makers and to the public, and for promoting institutional dialogue (Iddrisu and Bhattacharyya 2015; Nussbaumer *et al.* 2011). Thus, indicators capture the set of energy deprivations that affect a person/household in the above named dimensions and can assign energy poverty to a person/household if the sum of deprivations exceeds a pre-defined, adjustable energy poverty threshold (Bazilian 2012; Iddrisu and Bhattacharyya 2015). Once the indicators'

deprivation cut-offs have been selected, the next step is to define the weights each indicator will have.

Weights are central in determining the trade-offs between dimensions of well-being, in that they reflect particular value judgements by assigning a higher value to some dimensions and a lesser to others (Decancq and Lugo 2013; Nussbaum 2000; Sen 2009). According to Nussbaumer *et al.* (2011; 2012), the issue of weight is described as controversial. It was argued that all the indicators and dimensions considered need not necessarily have the same relative importance or symmetrical importance (Angulo *et al.* 2016; Nussbaumer *et al.* 2011; 2012). There is reason to believe that the energy poverty variables of the MEPI are of, or not of, equal importance, particularly in the case of conflicting objectives (Angulo *et al.* 2016; Nussbaumer *et al.* 2011). That notwithstanding, the theoretical frameworks to derive rational weighting approaches are difficult to construct (Freudenberg 2003; Nussbaumer *et al.* 2011). Various methods have been suggested to assign weight to the dimensions that make up a multidimensional index. For example, Decancq and Lugo (2013) suggest three options: firstly, that weight is assigned to the function of distribution on the achievements in society and is not based on any value judgments about how the trade-off between dimensions should be data-driven weight. Secondly, that weights could be assigned based on only the value judgements about trade-offs and not on the actual distribution of the achievements in the society under analysis: a normative approach (Decancq and Lugo 2013). The third option suggested by Decanq and Lugo (2013) is that weights could be assigned based on a data-driven approach but with some form of valuation of these achievements. Angulo *et al.* (2016) suggest that equal weights could be assigned to each dimension and the weight received by the indicators could be set according to the household deprivation rates in each indicator. In other words, a higher weight is assigned to indicators with high deprivation rates (Angulo *et al.* 2016). The weighting structure, used by Nussbaumer *et al.* (2013), is that more importance is given to the energy services deemed to be essential. On the contrary, according to Nussbaumer *et al.* (2011), weights were defined based on expert opinion. From the various suggestions, Angulo *et al.* (2016) and Nussbaumer *et al.* (2011; 2013) consider, there is no definitive procedure of assigning weights over dimensions and indicators in a multidimensional

measure of poverty or energy poverty. Angulo *et al.* (2016) affirm that, since there is no consensus on the weighting scheme that should be used, weight selection is in the hands of the researcher.

2.7 The Evaluation of the Multidimensional Energy Poverty Index in Some Developing Countries

Many empirical studies relating to energy consumption, poverty, and the environment have been carried out (Bhidey and Monroy 2011; Pachauri and Spreng 2004; Quedraogo 2006; Srivastava *et al.* 2012). Empirical works on energy poverty are still relatively few and include Barnes *et al.* (2011); Nussbaumer *et al.* (2011, 2012 and 2013) and Sher *et al.* (2014). The MEPI has been used to inform some countries they are energy poor, from the direct measurement of useful energy requirements at the various demand sectors of households (Bekele *et al.* 2015; Iddrisu and Bhattacharyya 2015; Nussbaumer *et al.* 2011). According to Nussbaumer *et al.* (2013), energy poverty is arbitrarily qualified as acute when the MEPI exceed 0.7, moderate between 0.3 and 0.7, and low when below 0.3. The city and the zone selected for the evaluation were based on the degree of energy poverty ranging from acute energy poverty (South-South zone of Nigeria) to moderate energy poverty (Addis Ababa, Ethiopia) (Nussbaumer *et al.* 2012). Furthermore, any energy poverty metric is likely to be constrained by data paucity (Nussbaumer *et al.* 2011, 2013). Selection was also based on availability of datasets that allows for the analysis of the MEPI. The selection of a city and a zone, however, was made with the objective of deriving insights from the structure and selected determinants of energy poverty in a number of different capacities.

2.7.1 Energy Poverty Evaluation in Addis Ababa, Ethiopia

The residents of Addis Ababa, the largest city in Ethiopia, use modern, transitional, and traditional energy carriers for their domestic energy activities (Bekele *et al.* 2015; Mekonnen and Kohlin 2009). This is as a result of the strategic location of the city enabling the access of various and different kinds of energy carriers such as wood, charcoal, kerosene, LPG, electricity, animal dung, leaves, and barks (Bekele *et al.* 2015; Mekonnen and Kohlin 2009). In addition, people of a range of income groups inhabit

the city, which makes it a market place for diverse kinds of energy carriers (Bekele *et al.* 2015; Mekonnen and Kohlin 2009). Some peri-urban residents have no access to electricity because of limited expansion of the electricity grid, price fluctuations in the different energy carriers, and the physical inaccessibility of kerosene and LPG (Bekele *et al.* 2015; Mekonnen and Kohlin 2009).

Bekele *et al. (*2015) used primary data and employed a multistage stratified random sampling technique to identify data sources. Bekele *et al.* (2015), following the work of Nussbaumer et al. (2011) and Edoumiekumo *et al.* (2013), constructed a MEPI for the residents of the city. The MEPI was determined by using the five dimensions and by having five energy poverty indicators, which include energy for cooking activities, indoor air pollution, access to electricity, owning energy appliances, and using energy appliances (Bekele *et al.* 2015). Higher weights were assigned to the indicators of more importance (dimension of energy for cooking) while other dimensions were assigned equal weight (Bekele *et al.* 2015). The combination of the deprivation counts has to exceed a pre-defined threshold line (which is 0.3 for the study) so that a household is identified as being energy poor if it does not use a modern energy carrier for cooking and is affected by indoor air pollution from burning traditional energy carriers and by not using improved cooking stoves (Bekele *et al.* 2015). Furthermore, energy poor households have no electric metre, no electric devices, and do not use energy appliances, or entertainment, education or, indeed, any telecommunication appliances (Bekele *et al.* 2015).

Their findings revealed the incidence of energy poverty to be 49.57% while the energy poverty intensity was estimated at 1.17 (Bekele *et al.* 2015). The MEPI was calculated by multiplying energy poverty incidence and energy poverty intensity giving a value of about 58%. This implies that those households have little or no access to modern energy for cooking, do not have their own appliances and do not use energy appliances (Bekele *et al.* 2015). The remaining 42% households are therefore classified as multidimensionally energy non-poor, implying that they have access to modern energy carriers for cooking and they use different energy appliances thereby benefiting from modern energy supplies (Bekele *et al.* 2015). Household heads educated to post-secondary level, households with a refrigerator, with electric metre and having to spend

more on energy are less likely to be identified as energy poor in the study (Bekele *et al.* 2015).

The study demonstrated the importance of enhancing household income, education, and ownership of an electric metre, since they are instrumental for households' transition from traditional energy carriers to modern energy carriers.

2.7.2 Energy Poverty Evaluation in South–South Zone of Nigeria

The South-South Zone of Nigeria is a geopolitical zone comprising six states- Akwa-Ibom, Bayelsa, Cross-River, Delta, Edo and Rivers (Edoumiekumo *et al.* 2013, 2014). The zone has been the hub of the Nigerian monotonic economy since the discovery there of crude oil in 1956 (Edoumiekumo *et al.* 2013, 2014). Inhabitants of the zone depend mostly on wood and sawdust (wood shavings) and other biomass fuels as the major source of cooking fuel (Edoumiekumo *et al.* 2013). Most households in the zone also use open lanterns and candlesticks for lighting (Edoumiekumo *et al.* 2013).

Edoumiekumo *et al.* (2013) used secondary data collected during the National Standard Survey (NLSS) of households and adopted a multi-stage stratified sampling technique. Following the work of Nussbaumer *et al.* (2011), a MEPI was constructed using two dimensions and having three energy poverty indicators which include modern cooking fuel, indoor pollution, and access to the main electricity grid or to electricity from a generator (Edoumiekumo *et al.* 2013). A high weight was assigned to indicators of importance (for example, dimension of energy for cooking) while the other indicator was assigned a low weight (such as the dimension of energy for lighting) (Edoumiekumo *et al.* 2013). The combination of the deprivation count has to exceed a pre-defined threshold line (which is 0.5 for this study) so a household is identified as energy poor if it does not use a modern energy carrier for cooking and is affected by indoor air pollution from burning traditional energy carriers and for not using improved cooking stoves (Edoumiekumo *et al.* 2013). Furthermore, energy poor households have no access to the main electricity grid or to electricity from a generator (Edoumiekumo *et al.* 2013).

The zonal multidimensional energy poverty incidence is 83.2% while the energy poverty intensity was estimated to be 0.903 (Edoumiekumo *et al.* 2013). The MEPI for the zone

was estimated to be 75.1%, implying that most households in the zone have no access to modern energy for cooking, no access to electricity, and no access to electricity from a generator (Edoumiekumo *et al.* 2013). The remaining 24.9% households are therefore classified as energy non-poor, implying that they do have access to modern energy carriers for cooking and have access to electricity or to a generator (Edoumiekumo *et al.* 2013). In addition, female household heads older than 60 who have attained primary and secondary education are likely to be moderately energy poor. In addition, household heads who are employed (excluding students and retirees), living in rural areas and having high per capita expenditure and a large share of food expenditure as a percentage of the total expenditure of the household are also likely to be moderately energy poor as identified in the study (Edoumiekumo *et al.* 2013).

The study concluded that education and employment opportunities should be put in place to tame the menace of energy poverty were suggested by Edoumiekumo *et al.* (2013). In addition, efforts to curb energy poverty was suggested by Edoumiekumo *et al.* (2013) in an attempt to target rural dwellers.

2.8 Conclusion

This chapter outlines the definition of energy/fuel poverty. Fuel poverty is a term commonly used for developed countries to describe the situation of a household, which is unable to afford basic levels of energy for adequate warmth. This definition of energy poverty establishes that the provision of access to electricity in developing countries be central to facilitating the eradication of energy poverty. The role of electricity in the economic and social development of a country is a reference of well-being for its populace, so that the reality of billions of people worldwide not having access to electricity reveals the magnitude of the challenge. The particular challenge for Africa is to extend the national power grids to multiple populations.

Designing energy poverty policies that will achieve a reduction of energy poverty begins with identifying those households, which are actually energy poor. The chapter illustrates how low-income, rurality, dwelling type, age of the property, and the method used to pay for electricity are practical identification variables of energy poor households. The economic tools for measuring energy poverty, with respect to the

poverty line, headcount, and poverty gap indexes, are important tools that allow for statistical reporting of poverty levels and patterns.

The chapter further provides an overview of methodologies used to measure energy poverty. The main characteristics, scopes, and limitation of these methodologies are highlighted. A new tool to evaluate energy poverty, the Multidimensional Energy Poverty Index (MEPI), is reviewed. The MEPI, based on the concept of multidimensional poverty, is composed of two components: the incidence of energy poverty, and a quantification of its intensity. The MEPI focuses on deprivation in terms of energy, and places energy services at the centre of its analysis. The MEPI captures the multidimensionality of energy poverty by incorporating five dimensions (cooking, lighting, ownership of appliance, education/entertainment, and communication) and six indicators (modern cooking fuel, indoor pollution, electricity access, household appliance ownership, education/entertainment appliance ownership, and telecommunication).

The indicators' deprivation cut-offs define a household as being in a state of energy poverty if the above named dimensions are exceeded. The meaning of weights as crucial factors determining the trade-off between dimensions is also discussed. Three categories of approaches (data-driven, normative, and hybrid) for setting weights are reviewed.

Finally, the applicability and measures of MEPI to reflect the energy poverty situation were explored in three selected countries. The country case studies provide insights into how energy poverty manifests in each dimension, which should be individually addressed in order to reduce overall multidimensional energy poverty.

The next chapter presents the energy transition patterns of households and their energy choices, especially in developing countries.

Chapter 3

HOUSEHOLD ENERGY CHOICES AND TRANSITION PATTERNS

3 Introduction

In this chapter, the energy choice(s) and the consumption patterns adopted by households in developing countries with respect to some endogenous and exogenous factors are presented. These choices are a crucial factor in the adoption of modern energy carriers such as electricity. It is assumed that transition patterns of energy are not uniform, so the two principal energy models that are likely to govern household consumer behaviour are reviewed. The relevance of the energy models are explored by using Zimbabwe, Kenya, Uganda, Ethiopia, Mozambique, and Burkina Faso as case studies.

3.1 Household Energy Choices and Consumption Patterns in Developing Countries

Electricity and other modern energy carriers, and the methods by which energy is delivered to the end user, play an important role in economic and social development (IEA 2010; Zhao 2012). Access to modern forms of energy provides great benefits through the provision of reliable and efficient services for lighting, heating or cooling, mechanical power, transport and telecommunication services (Lay *et al.* 2013; Niu *et al.* 2012). Billions of people in developing countries lack access to electricity and to other modern energy carriers (Hodge 2010; IEA 2010; Kaygusuz 2012). It is estimated that 1.4 billion people lack such access and that 2.7 billion people rely on the traditional use of biomass for cooking (IEA 2010; Kaygusuz 2012). The projection suggests that 1.2 billion people will still lack access to electricity in 2030, and that 87 percent of them live in rural areas (IEA 2010; Kaygusuz 2012). In the same situation, the number of people relying on traditional energy carriers for cooking will rise to 2.8 billion in 2030, 82 percent of them in rural areas (Abbasi and Abbasi 2010; IEA 2010). The greatest challenge, however, is in Sub-Saharan Africa, where only 31 percent of the population has access to electricity, the lowest level in the world (IEA 2010; Kaygusuz 2012). Kaygusuz (2012) acknowledges

that, if South Africa is excluded, the percentage declines further to 28 percent. Furthermore, residential electricity consumption in Sub-Saharan Africa, excluding South Africa, is roughly equivalent to consumption in New York (IEA 2010; Kaygusuz 2012).

The lack of access to modern energy carriers is a serious hindrance to economic and social development (IEA 2010; Sokona *et al.* 2012). Sufficient supplies of modern energy sources are the basis for the raising of standards of living, improving the quality and quantity of human capital, enhancing business and the natural environment, and increasing the efficiency of government policies (Birol 2007, Greenpeace and the European Renewable Energy Council, EREC 2010 and IEA 2010).

The demand for energy is growing in developing countries due to rapid population growth, especially in Africa (Jain 2010; Kaygusuz 2011, 2012). With increasing population, household energy is an important issue for developing countries; access, however, is predicted to continue to worsen (Cai and Jiang 2008; Niu *et al.* 2012). Despite limited access, the choice of energy made by households is an important issue for developing countries (Lay *et al.* 2013; Mekonnen and Köhlin 2009; Niu *et al.* 2012).

Energy choices have a major impact on the energy system of a country and its economic development (Joyeux and Ripple 2007; Lay *et al.* 2013). In addition, Niu *et al.* (2012) mentions that quality of life could be assessed by observing energy consumption. If a household relies mainly on traditional fuels for cooking, space heating or lighting, economic activities may be hindered (Lay *et al.* 2013; Liu *et al.* 2013; Van der Kroon *et al.* 2013). Shifting to modern energy carriers, according to Heltberg (2004) and Lay *et al.* (2013) can improve productivity in significant ways.

Kowsari and Zerriffi (2011) and Takama *et al.* (2012) suggest that households in developing countries might switch from traditional energy carriers to electricity or other modern energy alternatives if available and affordable, and that this transition is an important developmental goal towards the eradication of energy poverty (Kowsari and Zerriffi 2011; Liu *et al.* 2013). Furthermore, the transition from one set of energy choices to another is a crucial area of inquiry, according to Joyeux and Ripple (2007) and Niu *et al.* (2012), in that moving from traditional energy carriers to modern energy

carriers is associated with welfare improvement; thus, it is an area for policy makers especially. As a result, for policy makers to design appropriate policy interventions to encourage energy transition from traditional or transitional energy choices to modern energy choices, the factors influencing household energy choice (s) are vitally important.

3.2 Endogenous Determinants of Household Energy Choice in Developing Countries

There have been many debates about factors determining energy choices and transition (Kowsari and Zerriffi 2011; Mekonnen and Köhlin 2008; Pachauri and Jiang 2008; Van der Kroon *et al.* 2013), and a number of factors have been identified in the literature to describe the circumstances in which households make their decisions. Van der Kroon *et al.* (2013) refer to this as the household decision environment; the term represents a complex and interactive web of factors that influence. Understanding the factors that enable or prevent certain energy uses provides insights into the motivations behind certain decisions, which can then be used to design and deploy targeted measures to eliminate energy poverty. Endogenous factors are inherent in the household (or the internal opportunity set), and influence household energy choice decisions (Kowsari and Zerriffi 2011; Van der Kroon *et al.* 2013). Endogenous determinants are summarised as economic characteristics such as income and consumption expenditure (Barnes *et al.* 2010; Gebreegziabher *et al.* 2010; Mekonnen and Köhlin 2008; Pachauri 2004; Van der Kroon *et al.* 2013). Non-economic characteristics include education, family size, gender, age composition, and dwelling status (Arnold *et al.* 2006; Cooke *et al.* 2008; Mekonnen and Köhlin 2009; Miah *et al.* 2011; Rao and Reddy 2007; Van der Kroon *et al.* 2013). Some literature also argues that factors influencing household energy choices are not purely either economic or non-economic decisions. It was proposed that cultural characteristics, such as preferences, for example in cooking practices and tastes, often drive household energy choices (Farsi *et al.* 2007; Masera *et al.* 2000; Stern 2014; Takama *et al.* 2011). Table 3.1 summarises those factors that determine household energy choice.

Table 3:1 Summary of Factors Determining Household Energy Choice in Developing Countries

Endogenous Factors
Economic Characteristics – income and household consumption expenditure
Non-Economic Characteristics – education, household size, gender, age and dwelling status (ownership of dwelling and type of dwelling)
Cultural Characteristics – food tastes and cooking practices
Exogenous Factors
Energy prices
Policies and regulations (energy subsidies)
Energy conversion technology

Adapted from: Kowsari and Zerriffi 2011 and Van der Kroon *et al.* 2013

3.2.1 Economic Characteristics Influencing Household Energy Choice Decisions

A large body of literature points to income as the main factor influencing energy choices by households (Barnes *et al.* 2010; Kowsari and Zerriffi 2011; Leach 1992; Pachauri 2004; Van der Kroon *et al.* 2013; Wuyuan *et al.* 2008). The theory is that each household makes its own energy choices based on available income; so that the higher the income level, the greater is the tendency for households to choose modern energy carriers (electricity and/or liquefied petroleum gas (LPG) etc.) over traditional or transitional energy (kerosene, paraffin, wood, charcoal etc.) (Hosier and Dowd 1987; Lee 2013). This suggests that there is a strong correlation between increase in income and the uptake of modern energy carriers was suggested (Barnes *et al.* 2010; Leach 1992; Pachauri 2004; Van der Kroon *et al.* 2013; Wuyuan *et al.* 2008). Van der Horst and Hovorka (2008) found that in Maun, Botswana, households primarily choose wood (a traditional energy carrier) across the income spectrum. At the same time, there is an example of low-income households using modern energy carriers such as electricity and LPG (Campbell *et al.* 2003). Campbell *et al.* (2003) administered a household questionnaire in Zimbabwe in urban locations in 1994 and 1999 which ascertained the energy carriers used for cooking and lighting by households with the intention of investigating variations in energy choice with income (Campbell *et al.* 2003). Over 90% of high-income

households were reported to use electricity for cooking and lighting while 68% of low-income households use electricity for lighting and cooking (Campbell *et al.* 2003). As the study was conducted in urban locations, it may not be representative for rural households. The way households earn their income may be important (Rao and Reddy 2007; Van der Kroon *et al.* 2013). Households that derive income from wages or salaries have a higher likelihood of using modern energy carriers compared to farm households which derive their income from agricultural work or the informal selling of goods (Rao and Reddy 2007; Van der Kroon *et al.* 2013). For this reason, the expectation, according to Rao and Reddy (2007) and Van der Kroon *et al.* (2013), is that households with a stable regular income are more likely to choose modern energy carriers than those with unreliable income sources.

Household consumption expenditure is often used as a proxy for income (Gebreegziabher *et al.* 2010; Mekonnen and Köhlin 2009; Mestl and Eskeland 2009). Gebreegziabher *et al.* (2010), Mekonnen and Köhlin (2009), and Pachauri and Jiang (2008) found that increased consumption expenditure is associated with an increased likelihood of choosing modern energy carriers. Mekonnen and Köhlin (2009) conducted a survey in Ethiopia on urban households using a panel data collected in 2000 and 2004. A random effect logit model was used to analyse the factors that determine choice of a particular fuel type (Mekonnen and Köhlin 2009). It was suggested that households generally increase their spending on all energy carriers as their income increases and that they spend more on modern and transitional energy carriers compared to traditional energy carriers (Mekonnen and Köhlin 2009). Pachauri and Jiang (2008) discovered a difference in their case study in the rural and urban areas of India and China using secondary data, where the transition to modern energy carriers does not increase as household expenditure rises. Nevertheless, among urban households, the transition to modern energy types does occur with increases in household expenditure (Pachauri and Jiang 2008). The differences in energy choice decisions across rural and urban households, according to Ekholm *et al.* (2010) and Gebreegziabher *et al.* (2010), provides insights into differing levels of affluence in the rural and the urban populations.

3.2.2 Non-Economic Characteristics Influencing Household Energy Choice Decisions

On the non-economic factors, education, especially of the household head, has a significant tendency to influence energy choice (Pundo and Fraser 2006; Rao and Reddy 2007; Van der Kroon *et al.* 2013). Pundo and Fraser (2006) in their case study in Kenya, specifically from the rural settlement, Kisumu, examined factors influencing a household's choice of cooking fuel; the household survey was conducted in 2001. The perspective of education influencing energy choice was explained in the study by means of the increasing opportunity costs of fuel collection time (Pundo and Fraser 2006; Van der Kroon *et al.* 2013). This helps to explain why it is that those households in which there are educated members tend to use modern energy carrier/s even after controlling for income or fuel prices (Heltberg 2005; Pundo and Fraser 2006). Heltberg (2005) and Pundo and Fraser (2006) argue that when households use wood they collect themselves or other biomass they produce themselves, which do not have a monetary cost, their collection and use is determined by opportunity costs, which depend on the productivity of labour in wood collection relative to the opportunity cost of time in alternative employment. In other words, education increases the opportunity cost of time and therefore renders attractive the time saved from using modern energy carriers (Guta 2014; Heltberg 2005).

Rao and Reddy (2007), in the rural and urban areas of India, also examined the energy choice decisions for cooking by using national sample survey data collected in 2001. With an increase in education levels, households are increasingly likely to prefer modern energy carriers to traditional energy carriers (Rao and Reddy 2007). The awareness of the negative effects of traditional energy sources on health was identified in both studies (Pundo and Fraser 2006; Rao and Reddy 2007). It was assumed that education increases household awareness of both opportunity costs and health impacts of traditional energy use (Pundo and Fraser 2006; Rao and Reddy 2007; Van der Kroon *et al.* 2013). The effect of education on choices of energy carrier, according to Pundo and Fraser (2006) and Rao and Reddy (2007), is the same in both rural and urban areas.

Household size has been identified as one of the factors that may affect household energy choice (Barnes *et al.* 2005; Guta 2012; Heltberg 2004; Lay *et al.* 2013; Rao and

Reddy 2007; Van der Kroon *et al.* 2013). Barnes *et al.* (2005) observed that large households of five or more persons tend to select traditional energy carriers, whereas smaller households of one to four persons tend to choose relatively modern energy carriers. Guta (2012) also found that large households generally choose traditional energy carrier/s and in greater proportion but that such large household usually consume less total energy per capita than do smaller households. In other words, household size directly affects energy use by influencing the amount of energy consumed, although larger households have higher total energy consumption but lower per capita energy consumption due to returns to scale (Barnes *et al.* 2005; Guta 2012; Kowsari and Zerriffi 2011; Wuyuan *et al.* 2008). Van der Kroon *et al.* (2013) also found that increasing family size suggesting abundant labour available for fuel collection, limits the need to use modern energy purchased in the markets. Rao and Reddy (2007) mention that larger households in developing countries are often related to lower incomes, hence explaining the limited capacity to purchase modern energy sources. A contrasting finding, however, from Heltberg (2005) and Hosier and Dowd (1987), is that larger households are likely to move away from traditional energy carriers such as wood and to move towards transitional energy carriers such as kerosene, but there is a lesser likelihood that such households will choose electricity over either wood or kerosene. A possible reason for the finding is that household size was not measured as number of residents but by the number of rooms, which according to Heltberg (2005) is an indicator of the wealth of the household. So large household size, measured by the number of rooms is associated with a move away from wood but towards exclusive LPG use (Heltberg 2005).

Gender findings have mainly focused on the labour situation of women (Israel 2002; Lay *et al.* 2013; Njong and Johannes 2011; Lewis and Pattanayak 2012; Van der Kroon *et al.* 2013). Within the household labour economy, especially in developing countries, women are often responsible for cooking and collecting firewood (Lay *et al*. 2013; Njong and Johannes 2011; Van der Kroon *et al.* 2013). The number of women in a household constrains a switch to modern energy carriers, as the more women there are in a household, the more labour there is available to fetch wood (Heltberg 2005; Njong and Johannes 2011). Heltberg (2005) and Njong and Johannes (2011) argue, households

headed by women are likely to use firewood for cooking. On the other hand, Israel (2002) and Lewis and Pattanayak (2012) claim that women might have stronger preferences for using a modern energy carrier given their involvement in cooking. Rao and Reddy (2007) and Van der Kroon *et al.* (2013) mention that since the negative effects of firewood use directly affects women, switching to a modern energy carrier is likely to be preferred in households by them. This agrees with the findings of Mekonnen and Köhlin (2008) that women choose energy carriers to improve their collecting and cooking conditions. In some studies, women's income is understood to be an important determinant of modern energy choice, not only in terms of the opportunity costs in time but also because it translates into powerful bargaining position in terms of energy choices (Gupta and Kohlin 2006; Israel 2002; Lewis and Pattanayak 2012; Van der Kroon *et al.* 2013).

The age of the household head, also an influence, has led to two opposing effects. Age can function as an indicator for lifecycle (Quedraogo 2006; Van der Kroon *et al.* 2013). Quedraogo (2006) argues that the further a household moves up in its lifecycle, the wealthier it becomes and enables financial assets allowing the choice of modern energy carriers over traditional or transitional energy carriers. On the other hand, according to Demurger and Fournier (2011) and Rao and Reddy (2007), older household heads may be conservative, having developed the habit of traditional cooking, thereby restraining the move away from this practice. Mekonnen and Köhlin (2008) were unable to find evidence of a relationship between the ages of household heads and choice of traditional or modern energy carriers.

Energy consumption was found to vary with household dwelling status, explained in terms of ownership of dwelling or type of dwelling (Miah *et al.* 2011; Rao and Reddy 2007). Ownership of dwelling is a determinant for the use of biomass energy: households that share their dwelling with other people, either as tenants or co-owners, have relatively limited space for storing wood, and are therefore expected to adopt more efficient energy types with low space requirements (Mensah and Adu 2013; Miah *et al.* 2011). Mensah and Adu (2013), using the Ghana Living Standards Survey conducted in 2005 and 2006 observed that shared households have a higher chance of

adopting modern fuels than householders that live alone in their dwelling. Shared dwellings have a 60 percent greater chance of adopting LPG as cooking fuel than do households that do not share dwellings (Mensah and Adu 2013). Quedraogo (2006) investigated the determinants of household energy choice in Ouagadougou, Burkina Faso. The data collected included the characteristics of the households and their expenditures showeing that a household head, who is the owner of the house, is likely to be in charge of the management of space of in his dwelling with the marginal effect of increasing the chance of the adoption of traditional energy carriers (Quedraogo 2006).

Suliman (2013) assessed the influence of the type of dwelling on cooking energy carrier in Sudan, using graphic and contingency tabulation analyses. Suliman (2013) identified the quality of the dwelling by type of roofing and expected that the dwellers in a house roofed by durable materials like metal, cement fibre, concrete, or brick, avoid roof stain by adopting modern or transitional energy carriers. The estimate indicated the probability of choosing LPG by 8% and charcoal by less than 1% (Suliman 2013). Baiyegunhi and Hassan (2014), in a study conducted in rural households in Kaduna State, Nigeria, used a different approach to define type of dwelling as either traditional or modern: traditional houses are built with mud bricks and without an internal kitchen while modern houses are built with concrete bricks and have an internal kitchen. The study showed that households living in traditional houses are unlikely to choose natural gas and electricity over wood. The marginal effect suggests that for households living in traditional houses, the likelihood of transition from wood to natural gas and electricity decreases by about 37% and 38% respectively, the likely reason being that most rural households use an external kitchen which discourages the use of modern energy carriers which require expensive equipment (Baiyegunhi and Hassan 2014).

3.2.3 Cultural Characteristics Influencing Energy Choice Decisions

Cultural factors can influence the choice of energy decisions but are difficult to capture theoretically and to assess quantitatively so are not emphasised in most empirical literature (Kowsari and Zerriffi 2011; Masera *et al.* 2000; Stern 2014). Nonetheless, some proxy indicators have been used to reveal the effect of culture on energy choice. Preferences and habits (such as food tastes and cooking practices) and cooking time

have been identified as important indicators of energy choice because meals taking a long time to cook are mostly prepared using firewood whereas those taking less time are prepared with charcoal or kerosene (Fitzgerald *et al.* 1990; Taylor *et al.* 2011).

Taylor *et al.* (2011), using ethnographic work and survey data, investigated cooking fuel choices in Guatemalan rural households in 2001, 2006, and 2010. Ethnographic material included participant observation, field notes, multiple informal interviews, and in-depth tape-recorded semi-structured interviews (Taylor *et al.* 2011). Results demonstrated that many households continue to cook with wood because food tastes better when cooked on firewood and water can be kept on the boil or warm. Guatemala's two staple foods of beans and corn require many hours of cooking for which propane gas would be expensive (Taylor *et al.* 2011). Moreover, the burners on conventional gas stoves cannot generate enough power to handle the quantity of food cooked and the size of the pots used. Interviews reveal that the rising price of LPG makes the preferred alternative for domestic energy (Taylor *et al.* 2011).

Pundo and Fraser (2006), using the Kisumu household survey of 2001 covering rural areas in Kenya found that even in relatively well-off households, cultural styles of cooking have kept working women using wood because of common cultures and societal lifestyles. Masera *et al.* (2000), utilising data from a four-year (1992-1996) case study conducted in a Mexican village, showed that people persist with traditional energy sources to cook the flat cake tortilla, even when they can afford modern energy sources. The income status and family size of the surveyed households in the empirical studies described are typical of a rural settlement of low-income and large family size (Masera *et al.* 2000; Pundo and Fraser 2006; Taylor *et al.* 2011). Farsi *et al. (*2007), in their study of urban Indian households, found wood stoves to be a preference for baking traditional bread (Farsi *et al.* 2007; IEA 2006; Njong and Johannes 2011). Culture has proved a significant variable in urban households that are assumed to have a wide choice and free availability and accessibility to modern energy carriers.

3.3 Exogenous Determinants of Household Energy Choices in Developing Countries

Literature has revealed the need to look beyond the endogenous characteristics of households, suggesting that the energy portfolio of households could depend on external conditions or exogenous factors such as those external to household decision-making (Kowsari and Zerriffi 2011; Van der Kroon *et al.* 2013). External conditions influence household decisions regarding their energy portfolios by the choices available and the incentive to choose one energy technology or fuel over another (Kowsari and Zerriffi 2011; Van der Kroon *et al.* 2013). Exogenous determinants of household energy choice decisions are summarised as price influences demand, which is often reflected in energy prices (Arthur *et al.* 2012; Heltberg 2005), policies, and regulations (Barnes *et al.* 2005; Kowsari and Zerriffi 2011), and energy conversion technology (Barnes *et al.* 1994; Takama *et al.* 2012).

There has been an ongoing debate over the role of energy prices in household energy decision making. While some identify energy prices as factors restricting the choice of modern energy (Fisher 2004; Heltberg 2005; Van der Kroon *et al.* 2013), others consider it a factor rarely affecting energy selection although quantities used may be affected (Arthur *et al.* 2012; Brouwer and Falcao 2004; Campbell *et al.* 2003; Foley 1985; Hosier and Dowd 1987). Heltberg (2005), for example, using the data set of Guatemala's National Survey of Living Conditions in 2000, found that high LPG prices increased the consumption of wood in rural areas so that LPG was no more than an occasional complement. In urban areas, the high price of wood increases the probability of using LPG only with wood as a complement (Heltberg 2005). The results reveal the impact of prices on choice behaviour (Heltberg 2005).

Arthur *et al.* (2012) assessed the factors influencing domestic energy transition in Mozambique. Using data collected in a household survey carried out in 2002 and 2003, they found that for lighting, consumers in all income groups are unlikely to substitute electricity for other carriers (kerosene or candles) when electricity prices rise (Arthur *et al.* 2012). Possible explanations are that lighting uses relatively little electricity relative

to other uses of electricity such as cooking or space heating and that electrical lamp and bulbs are relatively cheap (Rantlo and Fraser 2015).

Across the range of perspectives, however, the dominant underlying position has been that price differentials are likely to influence consumer preferences or active choices (Akabah 1990; Karakezi and Majoro 2002; Arthur *et al.* 2012). In addition, energy prices are likely to reduce the range of affordable energy choices and prevent low-income consumers using modern energy carriers (Akabah 1990; Karakezi and Majoro 2002; Arthur *et al.* 2012). This affirms the notion of Heltberg (2003) that low-income households are more vulnerable to fuel price fluctuations

Government policies to control the production and distribution of energy carriers indirectly affect household energy choices (Barnes *et al.* 2005; Kowsari and Zerriffi 2011). Modern energy is often too expensive for low-income households, thus discouraging the uptake of modern energy or slowing the pace of household energy transition (Heltberg 2005; Kowsari and Zerriffi 2011; Pachauri and Jiang 2008). Most energy intervention strategies have focused on increasing the availability of modern energy, the reliability of the energy distribution network, and reducing the price of modern energy through subsidy (Kowsari and Zerriffi 2011; Mirza and Kemp 2009). In urban India, government policies that increase access to LPG through both public and private distribution channels cause a significant transition from wood to LPG (Barnes *et al.* 2005). Similarly, the government of Nepal gave priority to rural electrification through the definition of specific policies to promote electrification using renewable technologies which policies have had the effect of activating electricity demand in rural areas (Mainali and Silveira 2011). Awareness about the benefits of electrification has increased followed by the demand for modern energy technologies in rural areas (Mainali and Silveira 2011).

Subsidies have also been used to improve affordability and to facilitate energy access and have not led to increased costs for consumers (Mainali and Silveira 2011). In fact, the government of India, intending to make kerosene and LPG affordable to the poor, provided a significant price subsidy on these products in rural areas (Jain 2010). Kerosene was sold at a discounted price through public distribution shops and LPG

cylinders were sold through dealers of oil companies (Jain 2010). Despite the government's having spent a large amount of money, the objective of the subsidy programme was not achieved (Jain 2010). In the case of kerosene, although the subsidy was provided with the aim of promoting the use of kerosene as cooking fuel, a major proportion of the subsidised kerosene was used for lighting (Jain 2010). As kerosene is an inefficient source for lighting, the diversion resulted in kerosene resulted in the misapplication of the subsidy (Jain 2010). Due to the wide disparity between diesel and kerosene prices, large quantities of kerosene is siphoned off either to the black market or for adulterating diesel (Jain 2010). According to Jain (2010), it was estimated that 40 percent of the total kerosene supplied was not used for its intended purpose. Consequently, some rural households buy kerosene from the black market at a price more than double that of the subsidised price (Jain 2010). Possible reasons for this are that kerosene from the black market is available at all times and there is no queue at the point of purchase (Jain 2010). The overall objective of the programme of providing kerosene at lower prices was therefore defeated (Jain 2010).

Energy conversion technology or end use appliance is also a key aspect of household energy use (Barnes *et al.* 2003; Kowsari and Zerriffi 2011). Despite the advantages of using efficient technologies, the high capital cost of energy end-use appliances as well as additional costs, such as connection fees, associated with using modern energy conversion technologies is a major barrier to using modern energy systems (Kowsari and Zerriffi 2011; Takama *et al.* 2012). A survey in India found that the high initial cost of LPG and electric stoves particularly relative to low cash incomes in rural areas, is a major barrier to choosing modern energy carriers (Reddy 2003). Furthermore, in Ouagadougou, the equipment required for cooking with LPG costs almost nine times as much as does a 12-kilogram supply of the fuel itself (Quedraogo 2006). Because of this initial outlay, a household having limited disposable income is unlikely to make such an investment (Quedraogo 2006). In Malawi, where a Bluwave stove (a millennium gel fuel initiative compatible with a clean cooking fuel) was invented, the purchase of the stove would consume more than a quarter of average monthly income (Robinson 2006). Such an investment is likely to deter a transition to modern or clean cooking fuel (Schlag and Zuzarte 2008). Barnes *et al.* (1994) found that when the end use appliances are

affordable, households might still not adopt them due to their incompatibility with their existing energy service equipment. For example, in Nepal, a new stove design was introduced, on the assumption that consumers have a singular preference for higher efficiency stoves (Barnes *et al.* 1994). On the contrary, the stoves were not welcomed because they were not technically adapted to or compatible with various environments having being designed and tested in the laboratories without field-testing (Barnes *et al.* 1994). It was assumed erroneously that if a stove was adopted in one part of a country, it would be acceptable in other areas (Barnes *et al.* 1994).

There are already covered factors that are important in explaining the energy transition behaviour of households in developing countries. These include landholding, reliability of energy supplies, climatic conditions, rurality, and cost and payment methods of energy carriers. Some of these, such as climatic conditions, geographical locations (rurality), and cost and payment methods are discussed in Chapter 2 as factors identifying energy poor households.

3.4 Models Explaining Energy Transition in Developing Countries

Having described household behaviour in the light of energy choices and having identified determinants driving household energy choices, studies have attributed varying degrees of importance to these variables (Farsi *et al.* 2007; Heltberg 2005; Kowsari and Zerriffi 2011; Masera *et al.* 2000; Mekonnen and Kohlin 2009; Van der Kroon *et al.* 2013). While considerable uncertainty remains in the literature on the energy choices and transition patterns of households, two key models have been identified: Energy Ladder and Energy Stacking Models.

3.4.1 The Energy Ladder Model

The traditional view on household energy choices has been the Energy Ladder Model which describes the way in which households will normally behave as utility maximizing neoclassical consumers in adopting the most ideal energy carrier (Akabah 1990; Gebreegziabher *et al.* 2010; Hosier and Dowd 1987; Van der Kroon *et al.* 2013). The Energy Ladder Model conceptualises a linear transition of household energy choices from traditional energy carrier to transitional energy carrier then to modern energy

carrier (Hosier and Dowd 1987; Lee *et al.* 2015; Van der Kroon *et al.* 2013). Thus, as households advance in socio-economic status, the model assumes that those traditional energy choices that are inefficient, less costly, and more polluting are abandoned for transitional energy choices first and then, in the last phase, to modern energy choices, as shown in Figure 3.1 (Lay *et al.* 2013; Lee *et al.* 2015; Van der Kroon *et al.* 2013).

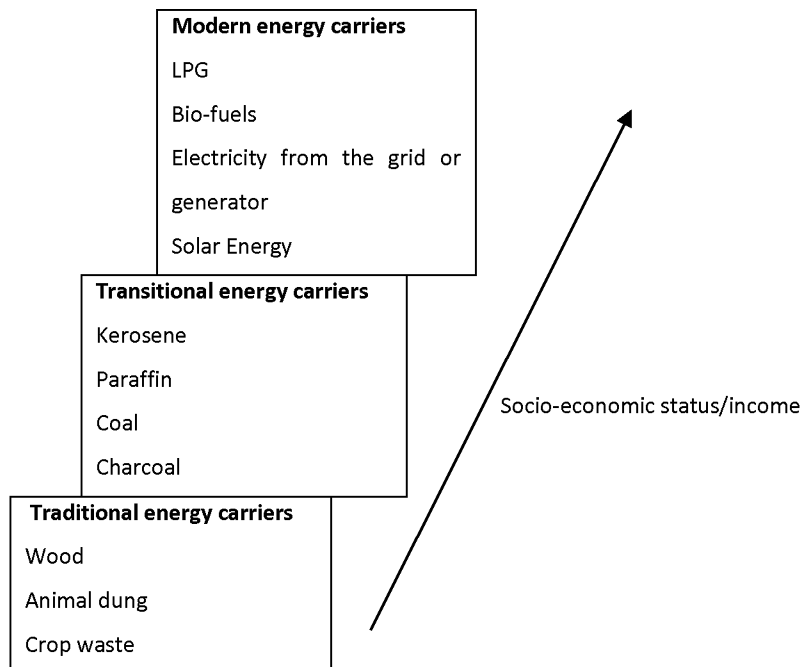

Figure 3:1 The Energy Ladder Model

Adapted from: Nissing and Blottnitz 2010 and Van der Kroon *et al.* 2013

Modern energy carriers are generally perceived to be superior to traditional or transitional energy carriers in efficiency, ease of use, and comfort (Farsi *et al.* 2007; Van der Kroon *et al.* 2013). In addition, it is widely recognised that modern energy carriers are preferred by households in comparison to traditional energy carriers (Elias and Victor 2005; Farsi *et al.* 2007; Nasaiour *et al.* 2011; Nissing and Von Blottnitz 2010). For these reasons, traditional energy carriers have been regarded as an inferior economic good, that is to say, as fuel for the poor when the poor are assumed to be those who are

unable to afford alternatives (Akabah 1990; Campbell *et al.*2003; Leach 1992; Van der Kroon *et al.* 2013).

Masera *et al.* (2000) and Van der Kroon *et al.* (2013) mention that the Energy Ladder Model also assumes that the most expensive energy technologies are perceived as signifying higher social status. Households move up the ladder, not only for the purpose of energy efficiency but as an indication of increased social status. The energy ladder thus aligns with the economic theory of the consumer stating that as income rises, consumers not only demand a larger amount of the good, but also change their consumption pattern towards higher quality goods (Hosier and Dowd 1987; Van der Kroon *et al.* 2013).

The observed differences in energy choice patterns between low, middle, and high-income households in developing countries motivates the energy ladder model (Gebreegziabher *et al.* 2010; Heltberg 2004). The findings of nearly all studies have confirmed that income is one of the main determinants of household energy choice and the transition towards modern energy use (Barnes *et al.* 2010; Hosier and Dowd 1987; Lay *et al.* 2013; Pachauri and Jiang 2008). Lay *et al.* (2013) explain that modern energy often involves a relatively large upfront investment in equipment, which hinders households from using them. In addition, the adoption of modern energy might require knowledge and a certain level of education; both factors correlating to income (Lay *et al.* 2013). Therefore, Lay *et al.* (2013) and Van der Kroon *et al.* (2013) infer a strong correlation between income and energy choice.

Contrary to previous findings, a growing body of empirical studies on household energy use show that, with increasing income, households can afford to purchase a variety of appliances, each of which may require a specific energy source (Heltberg 2003; Van der Horst and Hovorka 2008; Martins 2005; Van der Kroon *et al.* 2013). Masera *et al* (2000) state:

> ...it is unusual for households to make a complete fuel switch from one technology to another; rather they begin to use an additional technology without abandoning the old one' (2000:2085).

Thus, the Energy Ladder Model was described as being able only to provide a very limited view of reality (Kowsari and Zerriffi 2011; Masera *et al.* 2000). The major achievement of the Energy Ladder Model is its ability to capture the strong income dependency of energy choice of households, particularly in urban areas (Kowsari and Zerriffi 2011; Masera *et al.* 2000). The next section proposes the new energy model.

3.4.2 The Energy Stacking Model

The Energy Stacking Model or Multiple Fuel Use Model was developed on the basis of findings that households choose to use a combination of energy carriers on both upper and lower stages on the energy ladder (Arnold *et al.* 2006; Davis 1998; Kowsari and Zerriffi 2011; Lee *et al.* 2015; Martins 2005). Thus, once a modern energy carrier is adopted, traditional or transitional energy carrier(s) are kept, and households only partially switch (Lee *et al.* 2015; Mensah and Adu 2013).

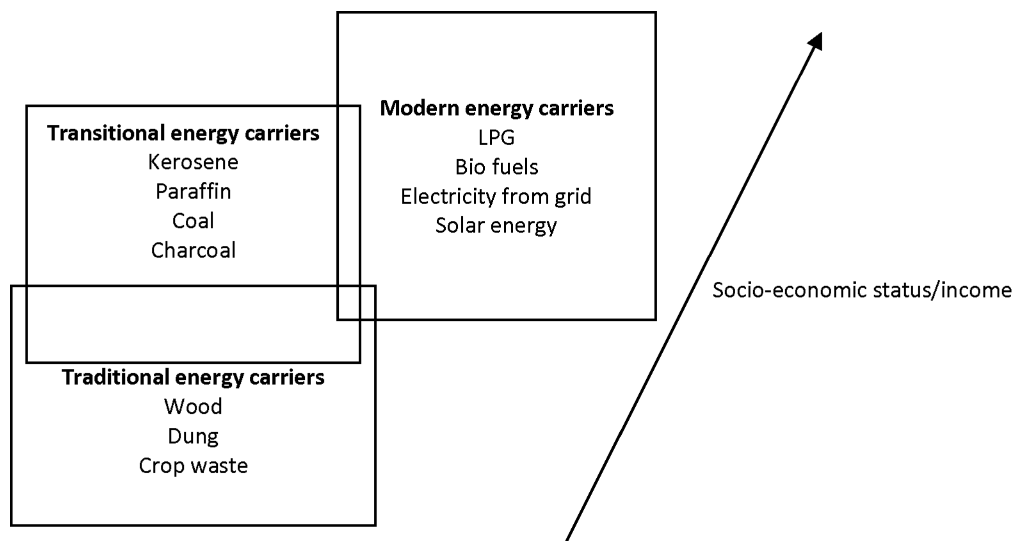

Figure 3:2 The Energy Stacking Model

Adapted from: IEA 2002 and Van der Kroon *et al.* 2013

The Energy Stacking Model has gained support in the literature (Van der Horst and Hovorka 2008; Lee *et al.* 2015; Mekonnen and Kohlin 2008; Mizra and Kemp 2009; Van

der Kroon *et al.* 2013). Complementary reasons have been put forward to explain the energy stacking behaviour of households in both rural and urban areas. Davids (1998) and Liu *et al.* (2013) argue that energy stacking is inherent to the livelihood strategies of the poor, following the irregular and varying income flows derived from agricultural work or the informal selling of goods (Nansaior *et al.* 2011; Van der Kroon *et al.* 2013). It was surmised that households applied a specific budget strategy in order to maximise energy security (Davids 1998; Van der Kroon *et al.* 2013). Also, energy stacking behaviour was observed due to energy supply problems. Thus, households tend to diversify their energy carriers by having a back-up in the event of temporary unavailability (Hosier and Kipyonda 1993; Joon *et al.* 2009). Leach (1992) agreed that given that a household has overcome the income barrier, other devices further down the ladder are normally maintained as insurance against supply failure. Also, Campbell *et al.* (2003), Leach (1992) and Soussan *et al.* (1990) suggest energy stacking by households as a risk minimization strategy since irregularity in energy prices might occur that might lead to fuel's being unaffordable for some time.

3.5 Case Studies of the Energy Ladder Model in Developing Countries

Having established by means of the Energy Ladder Model, that households use a more sophisticated energy carrier as their economic status increases either as a result of a rise in income or a fall in the fuel price, the case studies of three developing countries are here reviewed. Zimbabwe, Kenya, and Uganda are middle-income countries and their energy system is typically dependent on traditional and transitional energy sources. For these developing countries in Africa the energy ladder model has been applied.

3.5.1 The Zimbabwean Energy System and the Energy Ladder Model

Having gained independence in April 1980, Zimbabwe is a landlocked country and the energy supply options are a mixture of hydroelectricity, coal, and renewable sources (Dube 2003; Jingura *et al.* 2013). Biomass supplies about 66 percent of total energy consumption in Zimbabwe (Chambwera 2004; Jingura *et al.* 2013). Over 76 percent of the country's population, that is about 10 million people, relies on biomass. Some estimates indicate that biomass use for energy purposes in Zimbabwe would increase

through to 2020, at the same rate as population growth (Jingura *et al.* 2013; Zimbabwe Department of Mine and Power 2009). The major biomass materials found in Zimbabwe are wood, crop, and forestry residues, animal dung, energy crops, and municipal and industrial waste (Jingura *et al.* 2013; Zimbabwe Department of Mine and Power 2009). Basic sources of electricity are from hydro and thermal power with much of the electricity produced by Kariba Dam, the country's flagship hydroelectric power station (Davidson and Mwakasonda 2004; Jingura *et al.* 2013). Rusitu Hydro, a mini hydro plant of 750kW, operated privately, also sells power to the state-owned company, Zimbabwe Electricity Supply Authority Holdings (ZESA) (Davidson and Mwakasonda 2004; ZESA 1999). Thermal power comes from the Hwange coal power station with a capacity of 496 megawatts (Davidson and Mwakasonda 2004; Zimbabwe Department of Mine and Power 2009). The country also imports 35 percent of its power requirement from South Africa's Eskom, Mozambique's Hydroelectrica Cahora Bassa and the Democratic Republic of Congo's Société Nacional d'Électricité (SNEL) (Mbohwa 2003; Zimbabwe Department of Mine and Power 2009). Solar power is thought to have enormous potential both on a small and large scale (Jingura *et al.* 2013; Zimbabwe Department of Mine and Power 2009).

In urban households, electricity, wood, and kerosene are the main energy sources with wood as the main energy source for cooking and space heating in low-income households in both rural and urban areas (Campbell and Mangono 1994; Jingura *et al.* 2013). Gas is used in a minority of urban households (Chambwera and Folmer 2007; Zimbabwe Department of Mine and Power 2009). Campbell *et al.* (2003), Chambwera (2004) and Hosier and Dowd (1987) describe the complexity of the Zimbabwean energy system as an ideal platform from which to explore the energy ladder theory.

Hosier and Dowd (1987) and Campbell *et al.* (2003) conducted empirical research on Zimbabwean households. The database used by Hosier and Dowd (1987) was taken from the National Energy Survey used by the Central Statistical Office (CSO) covering the period from March to May of 1984. Campbell *et al.* (2003) administered questionnaires in 1994 to households in larger cities and in 1999 to households in smaller towns. Both studies ascertained what fuels were used by households as well as investigating

variations in fuel choice according to income (Campbell *et al.* 2003; Hosier and Dowd 1987).

The findings presented by Hosier and Dowd (1987), with various multinomial logit specifications, revealed that, as economic status improves, the use of wood for fuel declines and households consuming kerosene increases. As income increases for households initially using kerosene, the use of kerosene declines and the percentage of households using electricity increases. Thus, the evidence supports the concept of the energy ladder. From the findings of Campbell *et al.* (2003), budget and income constraints of households are the chief determinants of the overall pattern of consumption expenditure. Findings further revealed that reducing the price of kerosene induced households to shift from wood to kerosene, thus, as real income rises, transition from wood to kerosene and later to electricity is induced (Campbell *et al.* 2003).

Campbell *et al.* (2003) confirm the tendency towards complete substitution of one fuel type for another in both smaller towns and larger cities and established that, at the top of the energy ladder, among households who use mainly electricity for cooking, mixtures of fuels of mainly electricity plus kerosene do exist (Campbell *et al.* 2003). The suggestion is that fuel security is valued, or necessitated, by unreliable or insufficient electricity supplies. Hosier and Dowd (1987), on the other hand, found that urban residential households display a trend towards complete substitution of electricity for other fuels as income rises. Inevitably, the very highest income groups in Zimbabwe were found to use electricity only (Attwell *et al.* 1989; Hosier and Dowd 1987).

3.5.2 Energy System and Energy Ladder Theory in a Ugandan Context

Uganda is endowed with an abundant renewable energy potential from sources such as biomass, water, wind, and sun although this potential has not been fully utilised (Energy Report for Uganda 2015; Heffner *et al.* 2010). The public electricity supply in Uganda began in 1954, and was sourced from Owen Falls dam (Heffner *et al.* 2010; Keating 2006). Until 2005, electricity in Uganda was exclusively from a state owned company providing more than 98% of the country's electricity when about 5% of Ugandan

households were reported to have access to electricity (Heffner *et al.* 2010; Keating 2006). The government, in an attempt to meet growing demand and reduce poor hydroelectricity performance, appointed an independent power producer to supply 150 megawatt capacity to the grid based on diesel (Kiza 2006; Modi *et al.* 2006). This dramatically raised the percentage of the Ugandan population who have access to electricity to about 12% (Buchholz and Da Silva 2010; Murphy *et al.* 2014). A wide gap in the electrification rates persisted with 48% of households in urban areas and only 3.8% in rural areas having access to electricity (Rural Electrification Agency, REA 2010; Uganda Bureau of Statistics Projections, UBOS 2010).

The result is that households rely heavily on solid biomass for basic energy needs, especially in rural areas (Rural Electrification Agency, REA 2010; Uganda Bureau of Statistics Projections, UBOS 2010). More specifically, in urban households, 78 percent of their energy comes from solid biomass while the share of solid biomass in rural households is 99 percent (Lee 2013; UBOS 2010). The Uganda Bureau of Statistics Projections, UBOS (2010) stated that in 2015 more than 75% of total energy consumption would still come from wood. Uganda is typical of an under-electrified country (Buchholz and Da Silva 2010; Murphy *et al.* 2014).

Lee (2013) conducted empirical research in Uganda to test the correlation between household characteristics and the use of various fuels. Data from the Ugandan National Household Energy Survey of 2009 and 2010 were used for this econometric analysis and data on energy expenditure was used to proxy income with a focus on expenditure on energy types (Lee 2013).

Lee (2013) presented evidence that household energy use in Uganda conforms to the energy ladder theory. The trends in Ugandan households' energy mix shows electricity, gas, and charcoal being used for domestic needs in urban areas while kerosene and firewood are mainly used in rural areas. Households increase modern fuel consumption such as electricity with increasing affluence, while transitioning away from traditional energy sources such as wood and transitional fuels such as kerosene (Lee 2013). The importance of electricity to households is reflected as economic status changes for the

better and a direct relationship with income is shown to be in line with the energy ladder theory.

Mixed energy use was prominent for lower income households in both urban and rural areas (Lee 2013). Transitioning the lower income households to the upper rungs of the energy ladder, according to Burke (2010) and Lee (2013), means that the nation's electricity is affordable, because the major driver for continuing to climb the ladder away from traditional fuel is ultimately income.

3.5.3 The Kenyan Energy System and Evidence of the Energy Ladder Theory

Kenya is the world's 47th largest country bordered by Somalia to the east, Ethiopia to the north, Sudan to the northwest, Tanzania to the south and Uganda to the west. According to Kiplagat *et al.* (2011), the country has the most developed economy in East Africa. Its main source of modern energy is grid electricity generated from hydropower, thermal, and geothermal sources (Kiplagat *et al.* 2011; Mutua *et al.* 2012). Kenya is also one of the leading off-grid solar markets worldwide and the biggest in Africa. Kenya has been used as a case study in the analysis of the adoption of solar home systems (Jacobson 2007; Ondraczek 2013). By 2010, at least 320,000 solar home systems had been installed providing 4.4% of rural households with solar energy; also, solar energy has been the primary source of electricity in rural areas, especially for lighting (Lay *et al.* 2013; Ondraczek 2013).

The Kenyan electricity generating company, a state owned company, produces 75% of the total installed capacity, making it the largest power generator in the country (Kiplagat *et al.* 2011; Ondraczek 2013). Despite having the biggest economy in East Africa and the biggest market for solar energy, the energy system of Kenya is not exceptionally different from other developing countries where there are high levels of dependence on traditional fuels (Ondraczek 2013; Pundo and Fraser 2006). Kerosene is used by more than 80% of residential households (Kenya Institute of Public Policy Research and Analysis, KIPPRA 2010; Kiplagat *et al.* 2011). According to Mutua *et al.* (2012), there have been challenges in the electricity sub sector that have affected the quality of service delivered to the populace, including many intermittent outages and

low electricity access rates. Empirical studies on household energy use in Kenya have confirmed that rural households use liquefied petroleum gas (LPG) for cooking and lighting and use wood for cooking, while urban households use LPG only when electricity is not available (Karekezi *et al.* 2008; Kiplagat *et al.* 2013; Mutua *et al.* 2012; Pundo and Fraser 2006).

Lay *et al.* (2013), using data from the Kenyan Integrated Household Budget Survey (KIHBS), tested for the existence of energy ladder in the context of lighting fuel choice and found that transition from traditional to transitional, and then to modern energy carriers, mainly driven by rising incomes according to the energy ladder theory, is likely to provide useful insights into what happens to poorer households when they become richer (Lay *et al.* 2013). Overall patterns of energy use of ruraland urban households were first assessed before investigating lighting fuel choices (Lay *et al.* 2013). The options for lighting given in the questionnaire included collected wood, purchased wood, grass, kerosene, electricity, LPG, solar energy, dry cell (torch), candles, and biogas (Kenyan National Bureau of Statistics, KNBS 2006; Lay *et al.* 2013).

The study is clear that there are pronounced differences between rural and urban households with respect to lighting fuel (Lay *et al.* 2013). While most rural households mainly use kerosene, about 10 percent use wood for lighting (Lay *et al.* 2013). Few households were reported to be using electricity, dry cells, or solar energy for lighting (Lay *et al.* 2013). By contrast, urban households mainly choose between kerosene and electricity for lighting and rarely use other fuels (Lay *et al.* 2013). In both rural and urban houses, the use of wood and dry cells decreases with rising relative income while the use of electricity, solar energy, and LPG increases (Lay *et al.* 2013). The use of kerosene first increases and at a higher income level decreases again (Lay *et al.* 2013). In part, this has confirmed the energy ladder study by Lay *et al.* (2013) that income is a determinant for modern energy use including solar energy.

3.6 Case Studies of Energy Stacking Model from Previous Research in Developing Countries

Studies have demonstrated that energy switching is not unidirectional and households may switch back to traditional or transitional energy carriers even after adopting modern energy carriers. Ethiopia, Mozambique, and Burkina Faso are middle-income countries as classified by the World Bank using the GNI per capita and whose Energy Development Index (EDI) measuring energy system transition towards modern energy), according to IEA (2010b) and Nussbaumer *et al.* (2012), are in the lower level of energy development category. Similarly, following the results of the Multidimensional Energy Poverty Index (MEPI) for developing countries, Ethiopia, Mozambique and Burkina Faso are in a state of acute energy poverty (MEPI > 0.9) (Nussbaumer *et al.* 2012). The energy-stacking model has also been tested in households in these countries.

3.6.1 The Energy Stacking Model in Ethiopia

Ethiopia, located in the horn of Africa, is endowed with huge amounts of hydro, wind, geothermal, and solar power potential (Bekele and Palm 2010; Department for International Development, DFID 2009). In spite of this, the Department for International Development (2009) records that only a small portion of these resources has been utilised and the country suffers from a very low consumption of electricity. The Ethiopian Electric Power Corporation (EEPCo), a state owned company, is the major supplier of electricity; there are, in addition, a few community and privately owned systems (Gebreegziabher *et al.* 2012; Mekonnen and Köhlin 2009). There are two power supply systems: the interconnected system (ICS) which has grid connections and is mainly supplied from hydropower plants and the self-contained system (SCS) made up of isolated power-generating units operating with diesel (Gebreegziabher *et al.* 2012; IEA 2010). According to EEPCo (2009), the electrification rate of the country is about 37% but this electrification rate measures the number or proportion of towns and

villages connected to the grid-system but does not indicate anything about the electricity consumption level (EEEPCo 2009; Gebreegziabher *et al.* 2012).

Electricity is found in urban areas while kerosene is the principal energy carrier used in rural areas for illumination purposes in households (Central Intelligence Agency, CIA 2011; Gebreegziabher *et al.* 2012). The energy consumption for cooking in Ethiopia is reported to be predominantly reliant on solid biomass fuel resources (Guta 2012; Mekonnen and Köhlin 2009). In both urban and rural areas, the baking of *injera,* which is the staple bread of Ethiopia, consumes the most wood and accounts for about 60 percent of total household energy consumption (Gebreegziabher *et al.* 2012; Guta 2012). This means that electricity for cooking is limited to a very few households in larger towns, meaning that there is a persistent increase in the demand for wood and a growing pressure on local forests (FAO 2010; Gebreegziabher *et al.* 2012; Guta 2014).

For the empirical analyses by Guta (2012), the Ethiopian Rural Household Survey (ERHS) data of 2000 and 2004 was used; it is a longitudinal survey that started in 1989 and is repeated every four years (Guta 2012). Energy choice decision was analysed in the context of a mixed-energy model because because in any one period, rural households use multiple sources of energy (Guta 2012). The econometric tool used for the research was the multinomial logit model the objective of which was to examine household fuel stacking or multiple energy use behaviour (Guta 2012). The dependent variable was discret fuel choice, traditional energy carrier, or a mix of traditional and modern energy carriers with response variables by comparison with modern energy sources and only with reference choice (Guta 2012). Notably the study classified kerosene as a modern energy source.

Findings show that rural households exhibit energy stacking behaviour, as opposed to supporting the energy ladder hypothesis, whereby modern and traditional energy carriers are consumed concurrently and simultaneously (Guta 2012). The result is similar to the study of Mekonnen and Köhlin (2009) in which panel data collected in 2000 and 2004 was used and which explored urban households. Consumers were grouped into three categories according to the main fuel used by individual households: those whose main fuel was only fuelwood and/or charcoal, only kerosene and/or

electricity, and a mixture of fuelwood or charcoal and kerosene or electricity (Mekonnen and Köhlin 2009). A multinomial logit model was used to analyse energy stacking; results suggest that even in urban areas households tend to increase the number of fuels they use as their incomes increase instead of completely switching over from the consumption of traditional fuels to modern fuels (Mekonnen and Köhlin 2009). Thus, households tend to switch to a multiple fuel-use strategy, or to energy/fuel stacking, as their incomes rise, perhaps as result of preferences, taste, dependability of energy supply, and the availability of technology.

3.6.2 The Energy Stacking Model in Mozambique

Mozambique has one of the highest hydroelectric potentials in Africa and is home to the Cahora Bassa Dam, one of the largest hydro dams in Africa (Cipriano *et al.* 2015; Ministry of Energy 2011). The dam produces electricity for Mozambique, South Africa, Zimbabwe, Botswana, and the Southern African Power Pool (the International Renewable Energy Agency, IRENA 2012; Ministry of Energy 2011). The country is also endowed with significant renewable energy resources such as biomass, solar, and wind, as well as fossil fuels such as natural gas and coal (Cipriano *et al.* 2015; IRENA 2012). Despite these renewable energy sources, Mozambique's national grid, according to Cipriano *et al.* (2015) and IRENA (2012), only serves about 18% of the population and suffers from transmission and distribution losses totalling up to 27% of power that is generated. The country constantly ranks amongst those with the lowest electricity access rate (IRENA 2012, Ministry of Energy 2011). Electricity generation, transmission, and distribution in Mozambique is controlled by the state owned company - Electricidade de Moçambique (Cipriano *et al.* 2015). Private and municipal small generators (mostly diesel engines) and a few installations of renewable energy account for less than 1% of the total electricity supply (Arthur *et al.* 2012; Cipriano *et al.* 2015).

The main sources of domestic energy in Mozambique are wood, charcoal, kerosene, LPG, and electricity (Arthur *et al.* 2010; Instituto Nacional de Estatistica, INE 2007). To satisfy household energy needs, Mozambicans largely depend on traditional biomass such as wood and charcoal for cooking and heating (Arthur *et al.* 2010; Ministry of Energy 2011). Kerosene and wood are predominantly used for lighting (Brouwer and

Falcao 2004; Ministry of Energy 2011). In the capital, Maputo, 71% of the population rely on charcoal and wood for their cooking energy needs (Arthur *et al.* 2012; Ministry of Energy 2011).

Atanassov (2010) administered a questionnaire to households in the Municipal district of Catembe, located less than a kilometre from the city of Maputo. The research adopted a case study approach to investigate factors determining household cooking energy sources and the implications they are for the introduction of modern energy alternatives (Atanassov 2010). The surveyed households were ddivided among the three income strata of low, middle, and high and their respective energy choices were examined (Atanassov 2010). The type of transportation ownership such as car, motorcycle, or bicycle, the electrical appliances owned by household, house type, such as size and location, furniture type, and household occupation were taken into account in order to ascertain income level (Atanassov 2010). The ownership of a car, a house with three bedrooms or more, and a well-furnished interior were generally signs of a high-income household (Atanassov 2010). Beachside residents were classified as high income as well (Atanassov 2010). Low-income households resided in thatch reed houses or in non-renovated brick houses with limited living space (Atanassov 2010). The study noted that high and middle-income households do not abandon the use of wood as is suggested by the energy ladder model (Atanassov 2010). Furthermore, irrespective of economic status, all income groups make use of charcoal (Atanassov 2010). On the other hand, the lower income household energy usage pattern was the only one that corresponded to the energy ladder model in that wood usage increases as income decreases (going down the energy ladder) and there is an increase in LPG usage as household income levels rise (Atanassov 2010).

3.6.3 Energy Stacking Model in Burkina Faso

Burkina Faso, a landlocked country in the middle of the West African Sahel region, is one of the least advanced countries in the world (Quedraogo 2006; United Nations Development Programme, UNDP 2010). The country's economy is predominantly based on agriculture and has limited industrial facilities (Quedraogo 2006; Wethe 2009). Energy in Burkina Faso is derived mainly from the use of biomass such as wood and

charcoal, followed by hydrocarbons, hydroelectricity, and renewables such as solar energy (Briceno-Garmendia and Dominguez-Torres 2011; Wethe 2009). Constraints on the utilisation of hydropower have led the country to set up thermal power generation plants, which have high production costs, to meet a fast growing demand (Energici 2010; Helio International 2009). The national electricity company, Société Nationale Burkinabè d'Électricité (SONABEL), which generates 83 percent of power from thermal sources and 16.7% from hydropower, provides electricity (Energici 2010; SONABEL 2010). SONABEL is a privately owned company, responsible for the generation and distribution of electricity in the country's urban centres (Energici 2010; SONABEL 2010).

Access to electric power in Burkina Faso is characterised by a national access rate of up to 14% in urban areas with only 1.2% in rural areas (Energici 2010; Quedraogo 2013). In Ouagadougou, the capital of Burkina Faso, only 29% of the population have access to electricity as a source of lighting energy (Quedraogo 2006). The majority of the population, about 85%, use kerosene for lighting (Bensch *et al.* 2013; Energici 2010). The dominant cooking energy carrier in the capital is wood which is used by 76% of households (Bensch *et al.* 2013; Energici 2010). In rural areas, nearly all energy is biomass-based (Bensch *et al.* 2013; Energici 2010). Quedraogo (2013) mentions however, that LPG usage is slowly increasing, and supplies almost 30% of the cooking energy needs in Ouagadougou.

Quedraogo (2006) aimed to identify the determinants of household fuel choice, using an extensive survey of household expenditure in Ouagadougou. The data collected relate to the characteristics of the households and their expenditures (Quedraogo 2006). A multinomial logit was used for the analysis (Quedraogo 2006). The study found that the surveyed households' adoption probability of LPG for cooking was significantly related to the household standards of living of high income, high level of education, and low household size (Quedraogo 2006). The surveyed households were found to be using LPG in combination with wood (Quedraogo 2006). Utilisation rates of wood decrease from low income households to households with high incomes (Quedraogo 2006).

Quedraogo (2006) argued that wood appears as a transitional energy carrier just as kerosene is typically seen as a transitional energy carrier in the energy ladder, for

households that aim at other cooking energy carriers that are suitable for urban consumption. The utilisation rate of charcoal grows from low-income households to households with higher incomes thus demonstrating ways in which households using charcoal for cooking energy have different characteristics from those which use wood (Quedraogo 2006). Indeed, the results does indicate that the users of wood as the main energy carrier for cooking have the lowest per capita income, because of large household size compared to the users of charcoal and LPG (Quedraogo 2006). These results led Quedraogo (2006) to suggest that energy stacking could not be confirmed in the surveyed households because wood remains the primary carrier of energy for households in Ouagadougou and it is likely to do so for a long time to come.

3.7 Conclusion

This chapter discusses factors influencing energy choice decisions and the transition patterns in the households of developing countries. Considering the economic factors, income was identified as the most important influence on the choice of energy use, especially the move towards modern energy. Besides income, household consumption expenditure, which is a proxy of income, yielded contrasting information based on differing levels of affluence in rural and urban settings, in that while increased household consumption expenditure is likely to cause urban households to switch to modern energy carriers, the transition is not the same for rural households.

Most authors stress the importance of non-economic factors as determinants of household energy choice. Households that include educated members are more likely to have modern energy carriers as their main fuel than those with less educated members. Family size is an influence on the choice of which energy carrier is used: small household size is more likely to use modern energy carriers as their only fuel whereas a large family tends to use traditional or transitional energy carriers. On the contrary, when the number of rooms is used to describe household size, large households tend to use modern energy carriers, as many rooms reflect affluence. The gender composition of the household has a similar effect. A high share of females in a household, significantly reduces the need to abandon traditional energy carrier, as it increases the ability to collect wood and in cooking labour time.

Age is also a determining factor in household energy use and can lead to two opposing effects: older people tend to retain the habit of using traditional energy types. On the other hand, it is assumed that, as one advances in age, the wealthier one becomes and the more likely one is to have accumulated financial assets, thus encouraging the use of modern energy carriers. Dwelling type and ownership of dwelling are other factors examined in the existing studies. Being the owner of a house provides freedom of space management and this tends to increase the probability of using traditional energy carrier such as wood but tenants must adhere to occupancy rules which can limit their energy options.

Beside the influence of economic and non-economic characteristics, cultural factors such as cooking habits also play a role in constraining a complete transition to modern energy carriers. Traditional methods of cooking have been identified as an influence on the diversification of energy sources, and in some households, irrespective of economic status, traditional energy carriers for cooking are preferred because of traditional culinary preferences in cooking methods.

External conditions such as energy prices, modern energy conversion technologies, and the environmental policy were shown to have an important influence on choices of energy made by households. Some consider energy prices unlikely to affect energy selection but acknowledge the effect of price on the quantities of energy used, while others consider energy prices to be an important constraint alongside other issues such as availability and the cost of appliances. Intervention strategies and policies on energy and subsidies by governments have had mixed results regarding the energy choice behaviour of households. Policies designed to encourage low-income households especially to switch to a modern energy carrier rarely manage effectively to achieve the aims of the intervention. Nevertheless, some energy subsidies are reasonable and necessary in specific instances, especially when they are aimed at encouraging sustainable energy use. Modern energy conversion technologies have also posed some significant difficulties in influencing energy transition patterns of households. The high initial cost to the consumer of modern appliances such as LPG and electric stoves,

particularly relative to the low cash incomes in many rural areas have caused households to move towards the cheapest and least convenient energy carriers. On the other hand, no matter how efficient or cheap is a modern energy conversion technology, households have proved reluctant to adopt it if it is difficult to install and maintain or less convenient and less adaptable to local preferences than its traditional counterpart.

Finally, the energy ladder is the central model that conceptualises household energy transition patterns and choices in developing countries, but the fact is that, on the contrary, it became apparent to some authors that multiple fuel use, otherwise known as energy stacking, is the norm for most households. Energy stacking allows households to have the advantages of traditional, transitional, and also modern energy carriers as is seen in case studies which are in support of the energy stacking, model.

The next chapter discusses the theory of energy subsidy.

Chapter 4

THE THEORY OF ENERGY SUBSIDY

4 Introduction

In this chapter, an overview of the concepts of subsidy and energy subsidy, where they arise, how they are financed, whom they affect and the size, in terms of the financial budgetary cost, is presented. In order to have a broad notion of the categories of energy subsidies, the supply side subsidy and the demand side subsidy are discussed. The discussion on the benefits of energy subsidy centres on social and environmental benefits; arguments regarding the negative implications of energy subsidy, removing or reducing energy subsidies, and benefits of such action are highlighted. A brief review on the channel of consumer energy subsidy focussing specifically on residential electricity consumption and subsidy is presented. The strategy of the privatisation of the electricity industry is considered. Finally, a summary of the findings that demonstrate specificities of the energy sector in particular countries are explored.

4.1 An Introduction to Energy Subsidy

Subsidies comprise all measures that keep prices for consumers below market level, or keep prices for producers above market level, or reduce costs for consumers and producers (Badcock and Lenzen 2010; De Moor 2001). A cash payment to producers or consumers was identified as the simplest and most transparent form of subsidy (El Katiri and Fattouh 2015; Mmadu and Akan 2013). Ways in which governments may choose to subsidise is usually dependent on several factors which include the overall cost of a programme, the transaction and administrative cost thereby involved, and ways in which the cost of the subsidy affects different social groups (Dansie *et al.* 2010; Mmadu and Akan 2013). A subsidy involves a complex set of changes in economic resource allocation through its effects on costs and/or prices (Mmadu and Akan 2013; United Nation Environmental Programme, UNEP 2002).

Subsidy measures on the demand side, that is consumers, are mainly price controls, transfer payments, and consumer tax relief, etc., and are prevalent in developing countries (Mmadu and Akan 2013; Ouyang and Lin 2014). This kind of subsidy exists when consumers are assisted by the government to pay less than the prevailing market price of a given commodity (El Katiri and Fattouh 2015; Mmadu and Akan 2013). For example, the government may provide goods or services at no cost or below market price, such as university education or public transport (El Katiri and Fattouh 2015; Mmadu and Akan 2013). Such subsidies, however, involve high costs for the government which has to reimburse organisations for the cost of the subsidy (Mmadu and Akan 2013; Rao 2012).

Subsidies on the supply side, that is producers, are aimed at increasing the income of energy producers, for example by lowering taxes, and/or supporting research and development or by reducing the cost for energy producer by increasing their supply price (Mmadu and Akan 2013; The Oxford Institute for Energy Studies 2015). Supply-side subsidies are prevalent in developed countries especially in those that are shifting from fossil fuels to renewable energy (Ouyang and Lin 2014; Srinivasan 2009). Subsidies to producers also involve considerable accounting, and transaction costs, as well as the cost to the national treasury (Mmadu and Akan 2013; The Oxford Institute for Energy Studies 2015). According to the International Energy Agency (IEA 2011), subsidies for renewable energy in France in 2010 were about US$ 66 billion and likewise the United States Energy Information Administration (EIA 2013) indicated that energy subsidies amounted to US$ 37.2 billion in 2010.

A common reason for justifying a subsidy is market failure (Fattouh and El Katiri 2012; Lin and Jiang 2010). Chang (2001) defined market failure as that situation in which the market does not work as is expected of an ideal market. Gillingham and Sweeney (2010) also define market failures as deviations from perfect markets due to some elements in the functioning of the market structure. Economic theory explains that government intervention in the economy should occur in the case of market failure and in cases wherein this intervention would result in an improvement in social welfare (Buera *et al.* 2013; Lockwood 2013; White *et al.* 2013). Externalities are an example of a market failure (IEA 2011; Robert 2010). Thus, if some costs or benefits are associated with an

economic activity which is not borne by the agent undertaking the activity the cost or benefit is called an externality (IEA 2011; Robert 2010). Pigou (1920) formulated the idea that market failure from externalities can be solved if policy makers internalise the externality, that is, they make the producers of the externality face the true price, including the externality. Externalities can be addressed both with subsidies or taxes and, according to IEA (2011) and Robert (2010); subsidies are most prevalent in the areas of energy and technology policy.

Finding a commonly agreed definition of energy subsidy has been a major challenge but the most common definition is a direct cash payment by a government to an energy producer or consumer to stimulate the production or use of a particular fuel or form of energy (Fattouh and El Katiri 2012; OECD 1998). Some definitions attempt to capture other types of government interventions that affect prices or costs, either directly or indirectly. For example, The United States EIA (2010) has defined an energy subsidy as any government action designed to influence energy market outcomes, whether through financial incentives, regulation, research and development, and/or public enterprise. The IEA (2010) defines energy subsidies as any government action that concerns primarily the energy sector, which lowers the cost of energy production, raises the price received by energy producers, or lowers the price paid by energy consumers. Given these definitions, there are two aspects of energy subsidies that are of interest to researchers: the size of energy subsidy, and the effects of energy subsidy removal or reduction (Lin and Ouyang 2014; Mourougane 2010).

High budgetary costs are associated with subsidies especially energy subsidies (Beaton and Lonton 2010; IEA 1999; Iwaro and Mwasha 2010; Jiang and Tan 2013). Fossil fuel subsidies are most commonly found in developing countries (Iwaro and Mwasha 2010; Jiang and Tan 2013). Fossil-fuel subsidies worldwide in 2011 was $523 billion, and a report by the IEA acknowledged that in the absence of the removal or reduction of the subsidy, spending on fossil-fuel subsidies is likely to reach $900 billion by 2017 (IEA 2012). Subsidies to renewable energies, for example, wind, solar, and geothermal (all grouped together) received approximately $673 billion of federal incentives in the United States in 2015 (Energy Information Administration 2014/2015; Renewables-Global Status Report 2016)

Globally, electricity, natural gas, and petroleum products are the most heavily subsidised energy types, each receiving more than a quarter of total energy subsidies (Iwaro and Mwasha 2010; Lin and Jiang 2010). More than half of all energy subsidies are attributable to petroleum products in Egypt, while one-third is accounted for by electricity, and 15% by natural gas (Castel 2012; Fattouh and El Katiri 2013). In Russia, subsidies amounting to about $40 billion per year go to natural gas and electricity (Dansie *et al.* 2010; IMF 2015). Iranian energy subsidies for natural gas and electricity are almost as large, at an estimated $37 billion per year (IMF 2015; Sdralevich *et al.* 2014). According to Lin and Li (2012), subsidies for oil products account for 53%, natural gas subsidies account for 10.7%, and subsidies for electricity account for 21.4% of the Chinese government budget. Notably, China, Russia, India, Indonesia, and Egypt have subsidies amounting to $10 billion each per year (Dansie *et al.* 2010; Whitley and van der Burg 2015). These countries are among the top five in subsidy spending worldwide thus representing a large proportion of the world's energy subsidies (Dansie *et al.* 2010; Whitley and van der Burg 2015).

4.2 Categories of Energy Subsidy

The outcome of energy subsidies, in general, depends on where the government positions these subsidies, which could be either on the supply side or on the demand side (Lester 2009; World Economic Forum, WEF 2013). Demand side subsidies are those designed to reduce the cost of consuming energy, called Consumer Subsides while supply side subsidies are aimed at supporting domestic production, and are called Producer Subsidies (Burniaux *et al.* 2009; Ellis 2010).

4.2.1 Demand Side Subsidy: Consumer Subsidies

In developing countries, subsidies in the energy sector are much more weighted towards consumers and have the primary objective of reducing the cost of energy for low-income households (International Monetary Fund, IMF 2010; World Bank 2010). Consumer subsidies arise when the price paid by consumers is below a benchmark market price (Clements *et al.* 2013; Coady *et al.* 2015). The calculation for the benchmark price for traded energy products, such as natural gas and petroleum

products, is different from non-traded energy product like electricity (Coady *et al.* 2015; International Monetary Fund, IMF 2014). For internationally traded energy products, where there are no import or export restrictions, the benchmark price used to calculate subsidies is the international price adjusted for distribution and transportation costs (Coady *et al.* 2015; World Bank 2010). The international price is used as a reference point at which energy is traded, and this is based on arguments of opportunity cost (IMF 2010; World Bank 2010). Therefore, according to the IMF and the World Bank (2010), for a country that can export energy the true value of production at the margin is that which it obtains on the international market, while for an importing country, the true cost of the energy is the import price.

The benchmark price for a non-traded energy product is the price at which the domestic producer recovers costs, including a normal return to capital (Coady *et al.* 2015; World Bank 2010). In most developing countries, electricity is a non-traded good, since there are rarely sufficient interconnections to permit substantial import or export (IMF 2010; World Bank 2010). The IMF (2010, 2014) argued that, where substantial amounts of electricity can be traded, the border price could be used in calculations of subsidies, while the domestic costs of supply are usually used as the reference price when there is little effective trade. Thus, for the non-traded good, there is no international transport cost adjustment to be made (IMF 2010; World Bank 2010). According to World Bank (2010), the particular nature of the power sector and its commercial arrangements may lead to other adjustments to take into account any difference between the amount of electricity produced and the amount paid for. The utility or the government usually covers any shortfall in payments which also constitutes a subsidy (IMF 2010; World Bank 2010).

Consumer subsidy includes three components: these are the Pre-tax consumer subsidy, the Tax consumer subsidy, and the Post-tax consumer subsidy (Clements *et al.* 2014; Coady *et al.* 2015). The Pre-tax consumer subsidy exists when energy consumers pay prices below the costs incurred to supply them with this energy; that is to say deviations of consumer prices from marginal supply costs (Coady *et al.* 2010; IMF 2014). The benchmark price for Pre-tax consumer subsidy is taken as the supply cost which is the opportunity cost to a country of supplying the energy product either to companies or

households (Coady *et al.* 2015; IMF 2010, 2014; World Bank 2010). Taking gasoline as an example of an internationally traded energy product, the supply cost is the international price for gasoline adjusted for distribution and transport costs (IMF 2010, 2014; World Bank 2010). Pre-tax subsidy is therefore the international price for gasoline less the final price paid by consumers at the pump (Coady *et al.* 2015; IMF 2014). For goods that are not internationally traded, the supply cost is the domestic cost of production or the cost recovery price with costs evaluated at efficient prices (Coady *et al.* 2015; IMF 2014). If, for example, electricity is produced using natural gas purchased at a price below its export price the cost recovery price should be based on the export price of natural gas (Coady *et al.* 2015; IMF 2014).

On the other hand, Tax consumer subsidy exists if taxes for energy are below their efficient level (Clements *et al.* 2014; Coady *et al.* 2015). Energy is expected to be taxed in the same way as are any other consumer products, so, if the energy tax is lower than that of other consumer products, then there is likely to be a tax subsidy (Clements *et al.* 2014; Coady *et al.* 2015). Similarly, some energy products contribute to pollution and global warming, and it is a requirement that a tax subsidy should reflect those adverse effects on society in the price of energy (Coady *et al.* 2015; IMF 2014).

Post-tax consumer subsidies arise when the price paid by consumers is below the supply cost of energy plus an appropriate Pigouvian or corrective tax (Coady *et al.* 2015; Clements *et al.* 2014). Pigouvian tax usually reflects the environmental damage associated with energy consumption and an additional consumption tax that is applied to all consumption goods for raising government revenues (Coady *et al.* 2015; IEA 2014; Parry *et al*. 2014). Thus, Post-tax consumer subsidies are typically higher than Pre-tax and Tax consumer subsidies, primarily due to the environmental cost of energy production (Coady *et al.* 2015; Clements *et al.* 2013, 2014). Post-tax consumer subsidies are pervasive in both developed and developing economies and among oil producing and non-oil producing countries (Coady *et al.* 2015; Parry *et al.* 2014). Figure 4.1 provides a diagrammatic illustration of these notions of energy subsidies for a single energy product.

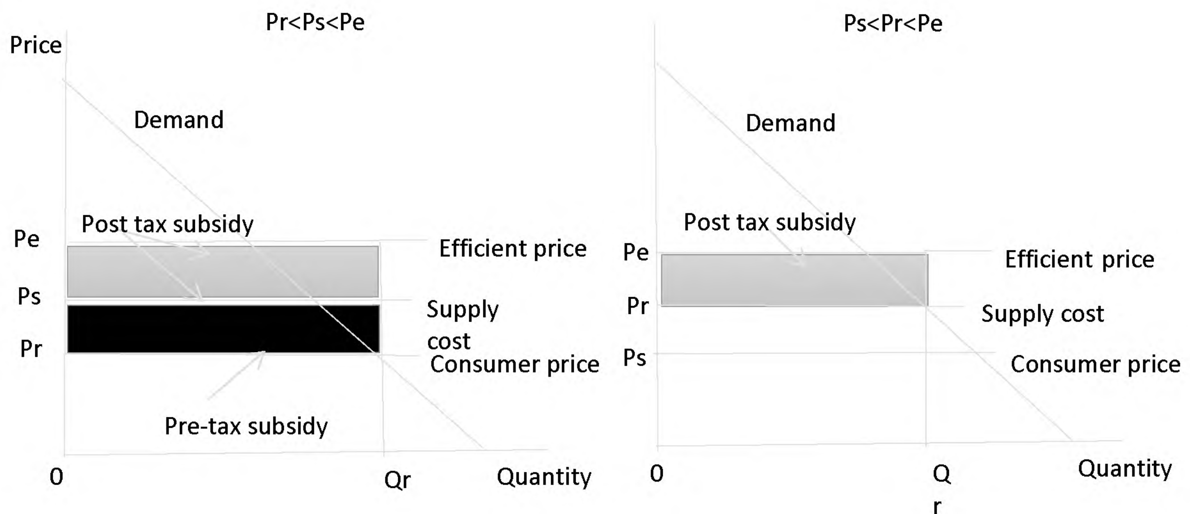

Figure 4:1 Consumer energy subsidies

Source: Coady *et al.* 2015:11

From Figure 4.1, P_s denotes the supply cost, P_r the consumer price, P_e the efficient price and energy consumption by Q_r. In the left panel, in which $P_r < P_s < P_e$, the Pre-tax consumer subsidy is indicated by the black rectangle calculated as energy consumption times the gap between supply and consumer prices. The Post-tax consumer subsidy is the sum of the Pre-tax subsidy and the tax subsidy, calculated as energy consumption multiplied by the gap between efficient and retail prices.

In the right panel, in which $P_s < P_r < P_e$, the Post-tax consumer subsidy is the grey rectangle, and there is no Pre-tax consumer subsidy.

In Figure 4.1, Post-tax consumer subsidies represent the amount by which the cost borne by the consumers falls short of the total economic cost of consumption. The excess cost, or subsidy, is either covered by the government in the form of budgetary support or foregone revenues or it is passed onto society in the form of environmental damage. On the other hand, Pre-tax consumer subsidies capture only a part of the excess cost that is sufficient to cover the supply cost and are thus an incomplete measure of the total economic subsidy.

4.2.2 Supply Side Subsidy: Producer Subsidies

In developed countries, subsidies are usually directed to energy production (Huot and Grant 2012; Jiang and Tan 2013). Producer Subsidies exist when producers receive either the direct or indirect support that increases profitability above that which it otherwise would be (Coady *et al.* 2015; IMF 2014). This can take many forms, including receiving a price for the output above the supply cost, paying a price for inputs below supply costs, receiving preferential tax treatment, or receiving a direct transfer from the government's budget (Fattouh and El Katiri 2013; OECD 2013). Producer subsidies, according to IMF (2014) could also arise when prices received by suppliers are above a benchmark price or when producers make losses at the benchmark price. The loss experienced by energy producers who are usually state-owned enterprises could be because of the high costs involved in energy production though low prices are charged; even so, a producer subsidy might come from the government's budget or might be financed by the state-owned enterprise itself (Fattouh and El Katiri 2013; IMF 2014).

4.3 The Benefits of Energy Subsidy

Despite energy subsidies weighing heavily on a country's finances, many developing-country governments rely on energy subsidies as an essential component of macroeconomic policy to offer social, environmental, and economic support (El Katiri and Fattouh 2015). The energy challenges that developing countries face are significant and increasing (Ahuja and Tatsutani 2009; El Katiri and Fattouh 2015). At the heart of the debate about the future of energy in developing countries is how to expand supplies and access ways that meet the needs of both the current generation and future generations (World Bank 2010). For this reason, energy subsidies exist to support a variety of social or environmental goals (El Katiri and Fattouh 2015; OECD 1998).

4.3.1 Social Benefits of Energy Subsidy

Social reasons are one of the main arguments for subsidising energy in order to facilitate access to basic fuels by reducing the cost of kerosene/paraffin, higher quality or modern fuels such as liquefied petroleum gas (LPG) or electricity (Fattouh and El Katiri 2012; Iwaro and Mwasha 2010). Low energy prices, particularly for electricity and higher

quality fuels have been found to help low-income households gain access to modern fuels thereby improving their living standards (Fattouh and El Katiri 2012; Mainali and Silveira 2010). A small modern energy input could realise a great improvement among low-income households in rural areas thereby minimising the gap between those who have access to modern forms of energy and those who do not (Jiang *et al.* 2015; Rubens *et al.* 2006). Where subsidies have resulted in low-income households switching from traditional to modern energy carriers, less indoor air pollution and a reduction in the time women and children spend gathering fuel are additional social benefits (Lin and Jiang 2011; OECD 2010). As a result, more time could be spent on productive activities such as farming and education (Mainali and Silveira 2010; Mourougane 2010). For such reasons do Jiang *et al.* (2015) and Rubens *et al.* (2006) argue that energy subsidies are an effective policy tool that may assist poor groups.

Gassmann (2014) and Lin and Jiang (2011) point out that energy subsidies support energy consumption and encourage connection to the energy grid by means of connection subsidies. The direct benefit for households is the gain in disposable income due to lower prices for energy while the indirect gain is lower prices paid for other goods and services because of lower cost of fuel-based inputs of production (Dansie *et al.* 2010; Mourogane 2010). In the opinion of Fattouh and El Katiri (2012) and Lin and Jiang (2011), energy subsidies help governments protect the incomes of those in the lowest groups of income distribution and contribute to poverty alleviation.

4.3.2 Environmental Benefits of Energy Subsidy

It has been noted that subsidising modern energy use brings some environmental benefits (IEA 2010; Lin and Jiang 2011; OECD 2010). For example, subsidies for oil products and electricity in developing countries can reduce the pressure on forests especially where there is a dependency on firewood (Lin and Jiang 2011; OECD 2010). This is one of the reasons why some developing countries maintain subsidies for kerosene and LPG (IEA 2010; OECD 2010) Public funding of fossil-fuel research and development can yield positive environmental effects if it results in the use of efficient and clean-burning technologies in the long term (OECD 2010; UNEP 2008). Subsidies to support renewables and energy-efficient technologies may help to reduce harmful

emissions depending on market conditions and how they are structured (OECD 2010; UNEP 2008). Denmark, for example, for environmental reasons encourages electricity production from wind turbines in order to reduce carbon dioxide emissions (OECD 2010; UNEP 2008). Wind power is promoted by the government through a combination of voluntary agreements with electricity utilities and subsidies to non-utility generators (OECD 2010; UNEP 2008). Most industrialised countries have introduced subsidies to renewables or energy-efficient combustion technologies for environmental reasons (IEA 2010; Lin and Jiang 2011). For example, grants are provided if electricity is produced by or if transport fuels based on, renewables, and if energy-efficient combustion plant and equipment are bought (IEA 2010; Lin and Jiang 2011).

4.4 The Negative Implications of Energy Subsidy

It is widely acknowledged that energy subsidies could have a number of negative effects (Bárány and Grigonytė 2015; Clements *et al.* 2013, 2014; Fattouh and El Katiri 2013; Mourogane 2010, Parry *et al.* 2014). Depending on the type of subsidy provided either to the producer or the consumer, the negative effects can have social, environmental, and economic implications (Bárány and Grigonytė 2015; Clements *et al.* 2013, 2014; Fattouh and El Katiri 2013).

4.4.1 The Social Implications of Energy Subsidy

The social implications of energy subsidies vary according to the type of subsidy (UNEP 2008). Subsidies on cooking and space heating fuels, for the preservation of low energy prices, have been found to benefit industries and households that are well-off especially those in the towns and cities, more than they do low-income households (Dube 2003; Fattouh and El-Katiri 2012, 2013; Gangopadhyay *et al.* 2005; Jiang *et al.* 2015; Kebede 2006). Jiang *et al.* (2015) found that in some cases low energy prices might not even reach the poor because the poor may be unable to afford even the subsidised energy or they may have no physical access to it, as when a rural community is not connected to the electricity grid (Fattouh and El-katiri 2012, 2013; Jiang *et al.* 2015). Fattouh and El-Katiri (2013) and Jiang *et al.* (2015) claim that even if low-income households do benefit from an energy subsidy, the financial value is limited because might consumption is

generally modest. Middle and higher income households tend to benefit in nominal terms, since they consume more of the subsidised fuel than do the poor (Fattouh and El-Katiri 2013 and Jiang *et al.* 2015). Jiang *et al.* (2015), for example, found in India, that the bottom 40% of the population ranked by income received only 15% of the benefits of the diesel subsidy and 20% of the benefits of the liquefied petroleum gas subsidy. On the other hand, 40% of rich households received 65% of the benefits of the diesel subsidy and 70% of the liquefied petroleum gas subsidy. Lin *et al.* (2009) observed a similar phenomenon in household electricity subsidies in China where 22% of the low-income households received 10.1% of household electricity subsidies and 27% of the high-income households received 45% of the total subsidies.

The interests of poor people, especially those living in remote areas are further compromised by energy subsidies which are observed as often going to large capital-intensive projects such as constructions of hydroelectric dams, large-scale thermal plants, oil refineries, and gas-processing plants (IEA 2010; UNEP 2008). These projects usually involve displacing communities and could affect poor households close to those facilities since they are usually unable to move to avoid local pollution and safety risks (IEA 2010; UNEP 2008).

4.4.2 The Environmental Implications of Energy Subsidy

A number of studies have reported the environmental consequences of energy subsidies (Bárány and Grigonytė 2015; Clements *et al.* 2013, 2014; Coady *et al.* 2015). The IEA, for example, found in estimates from OECD countries that subsidies that encourage the production and use of fossil fuels inevitably have harmful consequences for the environment (Bárány and Grigonytė 2015; Coady *et al.* 2015). Consumer energy subsidies that lower the price to end-users normally increase consumption of the respective fuels which can lead to high air-borne emissions of noxious and greenhouse gases (Coady *et al.* 2015; Fattouh and El Katiri 2012). A study conducted in India, reported by UNEP (2008), pointed out that indoor air pollution caused by burning fossil fuels, accounts for about a half-a-million premature deaths per year of women and of children under five years of age. An OECD (2010) report demonstrated that higher fossil-fuel production could damage the environment by polluting water supplies and

spoiling the landscape. For example, subsidies for biofuels in Iran, according to Coady *et al.* (2015) and OECD (2010), triggered intensive farming, which resulted in an increased use of fertilisers and pesticides, thereby damaging local eco-systems and intensifying both soil and water pollution. Figure 4.2 demonstrates how production and consumption subsidies on fuel production can be bad for the environment. The assumption is that the supply and/or use of the fuel results in some air pollution or greenhouse-gas emissions.

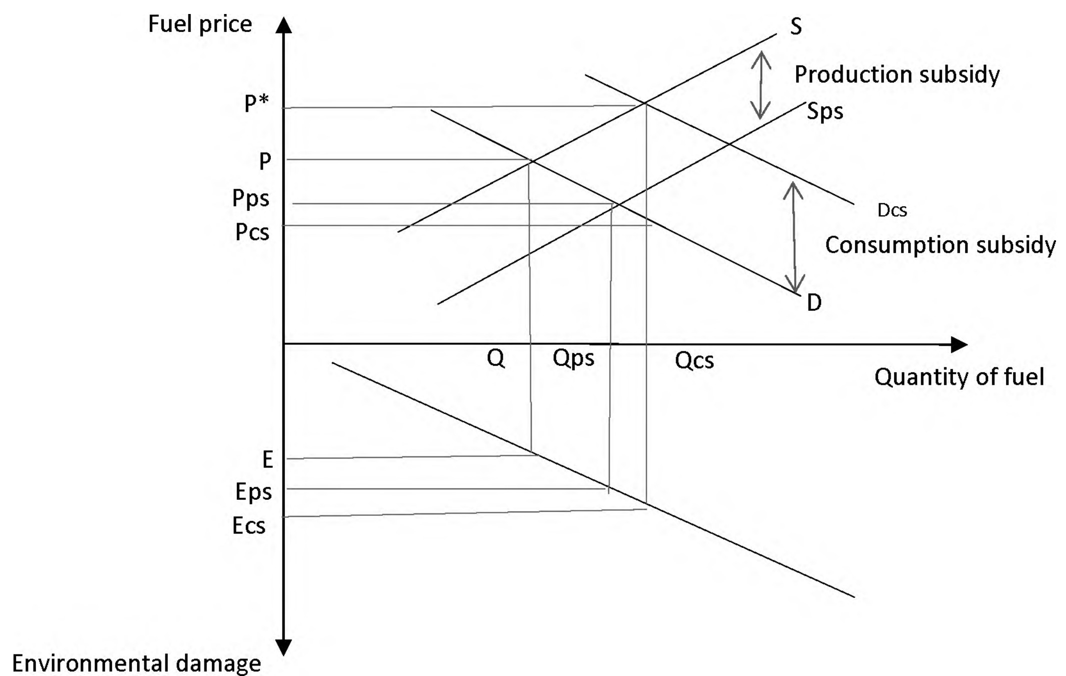

Figure 4:2 Environmental impact of energy subsidy

Source: UNEP 2002:28

Figure 4.2 shows that there is a direct relationship between fuel consumption/production and environmental damage. Point P is the original price of fuel before subsidy is introduced and P^* is the new equilibrium price.

From Figure 4.2, on the supply side, the introduction of a production subsidy shifts the supply curve from S to Sps, causing a reduction in fuel price from P to Pps. The quantity of fuel supply increases from Q to Qps and the environmental damage as a result increases from E to Eps.

On the demand side, the introduction of a consumption subsidy shifts the demand curve from D to Dcs. The net price paid by consumers falls from P to Pcs and a movement along Q to Qcs occurs as demand increases. The environmental damage increases from E to Ecs.

The increase in fuel consumption and production is on account of energy subsidy intervention by the government. The increase in supply of energy can be explained by the reduction in the cost of producing fuel while the increase in demand is due to the decrease in the effective price paid by consumers. Producer and consumer subsidies are explained in detail in the next section.

4.4.3 The Economic Implications of Energy Subsidy

Some studies point out that subsidies to specific energy types can undermine the development and commercialisation of other energy sources that might ultimately become economically attractive, most especially to households (Fattouh and El Katiri 2013; Mourogane 2010). Thus, Fattouh and El Katiri (2013) and Mourogane (2010) argue that subsidising a specific energy type, especially for households, could lock out the use of other clean, safe, and environmentally-friendly energy sources. For example, subsidies on kerosene in Iran encourages a shift away from LPG for which reason, Mourogane (2010) pointed out, energy subsidies hinder competition as non-subsidised fuel(s) will appear more expensive than do subsidised fuel/s. In addition, subsidies, by lowering end-use prices to consumption and/or production, lead to higher energy use and reduced incentives to conserve or use energy efficiently (Clements *et al.* 2013; Fattouh and El Katiri 2013). By reducing the price received by producers, a subsidy may diminish the ability and incentive to invest in new infrastructure and production processes and this can lead to deterioration in the financial circumstances of energy companies (Inglesi-Lotz 2011; Ruiters 2011). As a result, subsidy may encourage reliance on outdated and unclean energy (Inglesi-Lotz 2011; Ruiters 2011).

Subsidies to producers to protect them from competitive market pressures, tend to reduce incentives to minimise costs and this results in less efficient plant operation and investment that may otherwise not be economic (Clements *et al.* 2013, 2014). For

example, subsidies on coal production in some OECD countries have hindered efforts to improve productivity (Clements *et al.* 2013, 2014). Bárány and Grigonytė (2015) and Clements *et al.* (2013, 2014) state that subsidising some energy forms, such as renewable energy sources, could discourage much needed investments in energy efficiency, renewable energy sources, and energy infrastructure thereby increasing the vulnerability of countries to volatile international energy prices. Furthermore, energy subsidies, according to UNEP (2008), impose large fiscal costs that need to be financed by various combinations of higher public debt, higher tax burdens, and the crowding out of other public spending, for example on health, education, and infrastructure. Volatile international energy prices and large fiscal costs have been identified as a hindrance to economic growth (Bárány and Grigonytė 2015; Clements *et al.* 2013, 2014; UNEP 2008).

4.5 The Impact of Removal or Reduction of Energy Subsidies

Subsidy removal or reduction involves the government in reducing or abolishing the subsidies on goods and services, thereby forcing its citizens to pay more for those goods and services (Akinwale *et al.* 2013; Widodo *et al.* 2012). Once subsidies are in place and people get used to low prices, subsidy removal or reduction becomes difficult for the government (Whitley and van der Burg 2015). Price hikes, hampered growth, speculation, hoarding, and political turmoil have been identified as problems arising from the removal of energy subsidies to any fuel (Widodo *et al.* 2012; World Bank 2010). Regarding price hikes and hampered growth, a report by Hassanzadeh *et al.* (2012) shows that the removal of fuel subsidies on petroleum products in Iran and for which a neighbouring country charges lower prices, created a strong incentive to smuggle for resale at domestic higher prices and as a result hindered the growth of the economy of the country. Widodo *et al.* (2012) pointed out that the result of the Indonesian government's having signalled beforehand that they would reduce fuel subsidies, was extra purchasing and hoarding in anticipation of the policy's being implemented; this meant a significant drop in purchasing immediately after the price rise took effect. Historically, the public respond negatively to plans involving fuel subsidy removal, which sometimes has resulted in social and political chaos (Akinwale *et al.* 2013; George *et al.* 2014).

Specifically, the impact of energy subsidy removal or reduction has direct and indirect effects on household welfare (Coady *et al.* 2014; Widodo *et al.* 2012; World Bank 2010). The direct effects include higher costs for energy for cooking, space heating, and lighting (Coady *et al.* 2014; World Bank 2010). Increases in the cost of transport, in turn increase the cost of travel particularly to and from places of work which also has direct effects on households (Coady *et al.* 2014; World Bank 2010). Indirect effects occur through increases in energy costs for energy-intensive products and services due to increases in the cost of production and raw materials (Coady *et al.* 2014; Fattouh and El Katiri 2012; Jiang *et al*. 2015). Producers pass on increased production costs to households by increasing retail prices (Coady *et al.* 2014; Widodo *et al.* 2012). Indirect effects on the cost of living for households can be as significant as are the direct effects as is demonstrated by Coady *et al.* (2014) in their analyses in Ghana. Coady *et al.* (2014), adopting a price-shifting model, estimate the direct effect of fuel subsidy removal for each income population by multiplying the respective budget shares for each of the fuel products (diesel, LPG, petrol, and kerosene) purchased at the increased price of the fuel. The indirect effect, on the other hand, using the same model, is estimated by the input-output data combined with a formulation of the household demand for each product. The results for the direct effects showed that households in the lowest income quintile experienced a 2.1% decline in their real spending, followed by a 1.56% decline for middle-income quintile, and a 1.86% for the highest income quintile (Coady *et al.* 2014). The indirect impact results obtained, following a price increase in transport and communication (8.06%), in trade, in restaurants and hotels (1.2%), and fisheries (2.06%), showed that household welfare reduced for the lowest income quintile by 32% and 81% for the highest income quintile (Coady *et al.* 2014). The two results point out that the direct impact of the removal of fuel subsidy for Ghanaian households has the biggest impact on the household welfare of the lowest income quintile while the indirect impact on household welfare was biggest for the highest income quintile (Coady *et al.* 2014).

Granado *et al.* (2010), Fattouh and El Katiri (2012) and Jiang *et al.* (2015) argue that removing an energy subsidy affects the competitiveness of domestic industries and firms. Higher energy prices associated with pricing reform have the effect of increasing the cost of industrial inputs, which include input fuels of natural gas, electricity, crude

oil, and gasoline or oil-based products such as raw materials for plastic industries, asphalt for the construction sector, and chemical fertilisers for agricultural activities (Fattouh and El Katiri 2012; Jiang *et al.* 2015). As a result, the output price of other industries increases, which, in turn, causes a new round of indirect expenses (Fattouh and El Katiri 2012; Jiang *et al.* 2015). The increase in the cost structure reduces the profit margins of domestic industries, and erodes their global competitiveness (Fattouh and El Katiri 2012; 2013). Industries with high-energy intensity and those that face strong competition, such as the petrochemical industries, are mostly affected by such pricing reform (Fattouh and El Katiri 2013; IMF 2014). Abouleinein *et al.* (2009) and Fattouh and El Katiri (2012) point out that the impact of energy pricing reform on industry can also operate through the demand side. The cost shock associated with energy pricing reform may result in the underutilisation of capacity, which in turn lowers employment and therefore reduces overall demand, causing a reduction in economic activity (Abouleinein *et al*. 2009; Fattouh and El Katiri 2012).

4.6 The Benefits of Removal or Reduction of Energy Subsidies

Despite the challenges involved in removing subsidies, as listed above, a review of studies has shown that removing or reducing energy subsidy could be beneficial (Whitley and van der Burg 2015; World Bank 2010). According to IEA (2010), the removal of fossil fuel subsidies in developing countries between 2011 and 2020 would lead to reduced fossil fuel consumption and thence to reduced emissions of air pollutant such as sulphur dioxide (SO_2), nitrogen oxide (NO_x), and particulate matters, all of which are harmful to public health and the environment.

Furthermore, the removal or reduction of energy subsidies has been shown to be an improvement on a country's fiscal and macroeconomic performance in terms of an increase in global real income or gross domestic product (GDP) (Whitley and van der Burg 2015; World Bank 2010). These gains are the result of a more efficient allocation of resources across sectors which are saved by the subsidy removal or reduction (Burniaux and Chateau 2011; Whitley and van der Burg 2015). For example, Ellis (2010) argues that the GDP impact of subsidies on fossil fuel consumption arises from their role in distorting energy prices. Thus, when fossil fuels are sold below the market level, their

use imposes a burden on the economy which can be expressed as the increase in growth that would occur if subsidies were removed and resources efficiently redeployed (Ellis 2010).

Another justification for reducing or removing a fuel price subsidy in order to promote the development and use of renewable energy (Burniaux and Chateau 2011; Guerrerio 2010). A rapid transition from fossil fuels to renewable energy would be possible if fossil fuel subsidies are reduced or removed because removing or reducing fossil fuel subsidies would free funds that could be directed to clean energy subsidies and other environmental programs designed for the mitigation of environmental degradation.

There are circumstances in which it would be advantageous to reduce or remove energy subsidies and, on the other hand, there are circumstances that justify the introduction or retention of an energy subsidy (UNEP 2002; World Bank 2010). According to a UNEP report, a balance may be required between the benefits and impacts of energy subsidy removal or reduction (UNEP 2002). This acknowledgment justifies reports by Vagliasindi (2012) and the World Bank (2010) that the questions of whom, and what, and how to subsidise need to be assessed carefully in order to minimise the social and economic cost of energy subsidy reduction or removal. Removing or reducing energy subsidies without commensurate compensation entails the risk of an increase in energy poverty (Gassmann 2014; Mourogane 2010). It was therefore suggested that the removal of subsidies be supported by other policies that would limit the adverse impacts on industries, particularly energy intensive industries and households, and especially low-income households (Nwachukwu and Chike 2011; World Bank 2010).

4.7 Electricity Residential Consumption Subsidies

Worldwide, a well-functioning electricity sector is essential for growth and improvements in the quality of life (Amoakor-Tuffour and Asamoah 2015; IMF 2013). Electricity powers modern society and the energy sector is important because of the versatility of the end-use of electricity when compared to other forms of energy (Akpan 2014; Gyamfi *et al.* 2015). Thus, without electricity, economic transformation through enhanced productivity in manufacturing and services, technological innovations, and promoting value-addition in resource-based economies would not be possible (Emodi *et*

al. 2014; Niekerk 2012). Because electricity access is an important factor in the acceleration of development in most of the economies of the world, policy makers endeavour to formulate suitable plans for the management of the potential challenges posed by electrification, as well as ensuring short, medium, and long-term energy security for the country and its citizens in a positive and sustainable manner ((Emodi *et al.* 2014; IMF 2013).

Africa is home to the world's largest off-grid populations, approximately 590 million people, have no connection to the national electric grid and a lack of access is particularly stark in rural areas (IMF 2013; Niekerk 2012). Over the last decade, however, several countries in Africa have set up rural electrification agencies or bodies to extend access in these areas (IMF 2013; Niekerk 2012). On average, greater progress in access has been made in rural areas of countries in which there are rural electrification agencies (IEA 2011; IMF 2013). Most electricity production in Africa relies on large hydropower systems or fossil fuels, as well as gas-fired power stations, which are operated by private independent power producers under long-term contracts (IEA 2011; Niekerk 2012). Diesel generators are used more and more to provide a temporary increase in power supply to the grids for businesses and some households especially those not connected to the grid (Niekerk 2012; Szabo *et al.* 2011).

Many governments in developing countries consider electricity subsidies to be an essential ingredient for the alleviation of energy poverty (Hailu 2012; Jiang *et al.* 2015). As the population is often poor, the need to make electricity affordable is paramount (Cooke *et al.* 2014; Hailu 2012). Electricity is widely perceived to have important externalities for education and health outcomes and to contribute in a decisive way to economic growth (Gyamfi *et al.* 2015; Sokona *et al.* 2012). The cost of a standard electricity bill may not be affordable for many households (Brew-Hammond 2010; Tsimpo and Wodon 2012). Considering that in many cases, 60% of a household's budget must be devoted to food, it is difficult for such a household eventhough it may be connected to the electricity network to pay for electricity without having to sacrifice other necessities (Brew-Hammond 2010; Tsimpo and Wodon 2012). As for those households which do not have a connection to the electricity network, the share of total expenditure that they would have to allocate if they were to become connected could

be even prohibitive, especially for low-income households in rural areas (Hailu 2012; IEA 2011).

Electricity tariff increases in many developing countries do not often keep pace with general increases in the cost of living resulting, most utilities not being able to maintain their network properly, let alone expand it (Gyamfi *et al.* 2015; IMF 2013). At the same time, it is politically awkward for governments and regulatory agencies to increase tariff rates (IMF 2013; IEA 2011). First, such an increase in tariffs would be highly visible for electricity consumers who feel it right away especially as bills are paid only once a month, and amount to relatively large sums of money for lower income households/consumers, who also may not be informed about the cost structures of their utilities and/or the need for such tariff increases (Brew-Hammond 2010; Tsimpo and Wodon 2012). In addition, increases in tariffs affect urban populations disproportionately, although these are the populations most likely to demonstrate against such increases (Brew-Hammond 2010; Tsimpo and Wodon 2012).

The need to solve the energy-poverty problem of electricity access remains critical in developing countries especially in Africa, for the prevailing solution of electricity subsidies has been recognised as unsatisfactory (Zerriffi 2011; Zhang *et al.* 2005). The push for privatisation of the electricity sector has been embraced in some developing countries on the basis of public sector managers often being thought to be inefficient and corrupt (Estrin and Pelletier 2015; Zerriffi 2011).

4.8 Privatisation of Electricity in Developing Countries

Privatisation requires a transfer of the provision of goods and services from the public to the private sector (Estrin and Pelletier 2015; Roland 2013). Privatisation covers the sale of public assets to private owners, the contracting out of services formerly provided by state organisations to private producers, and the entry of private producers into markets that were formerly public monopolies (Goodman and Loveman 1991; Roland 2013). According to Kay and Thompson (1986), privatisation is a way of changing the relationship between the government and the private sector in terms of denationalisation, deregulation, and contracting out. Allen (2004) pointed out that privatisation has different meanings in different countries depending on the country's

need, and the form it takes should be in line with government policies of promoting economic growth and development.

Privatisation is favoured over nationalisation because of the conviction that private companies are efficient and competitive and that a private company has to respond to pressure from shareholders to perform efficiently, for if the firm is inefficient, it could be subject to take over (Estrin and Pelletier 2015; Kousadikar and Singh 2013). A state-owned company does not have this pressure and so there is possibility of inefficiency creeping in (Estrin and Pelletier 2015; Kousadikar and Singh 2013). The privatisation of state owned monopolies allows more firms to enter the industry and extend competitiveness in the market (Ahmad 2011; International Labour Resource and Information Group, ILRIG 2014). Competition will encourage a non-performing company to work hard and the monopolistic behaviour of companies that enjoy individual supremacy can be challenged (Ahmad 2011; Estrin and Pelletier 2015). Privatisation, however, and depending on the nature of the market does not necessarily increase competition (Estrin and Pelletier 2015; ILRIG 2014). For example, there is more competition in telecoms and gas and electricity distribution while there is little competition in the rail industry (Estrin and Pelletier 2015; ILRIG 2014).

The main arguments against privatisation in developing countries are natural monopoly and profiteering (Boubakri *et al*. 2008; Estrin and Pelletier 2015; Zhang *et al.* 2008). A natural monopoly occurs when the there is only one efficient firm in an industry (Estrin and Pelletier 2015; Zhang *et al.* 2008). Privatisation will not result in truly productive competitiveness if a natural monopoly exists. It can create a private monopoly which might seek to set higher prices which exploit the consumer (Estrin and Pelletier 2015; Zhang *et al.* 2008). The goal of private companies is to maximise profit, and in this way would serve the needs of those who are most willing to pay, or to provide services in regions where their services will be most profitable (Boubakri *et al*. 2008; Estrin and Pelletier 2015).

Privatisation of electricity generation in most developing countries results from historical, political, technological, and institutional factors (Eberhard and Gratwick 2011; Zhang *et al.* 2005). The poor performance of many state-owned firms in terms of costs

of production, service quality, and expansion have led many governments in developing countries to turn to private investors for solutions, especially as a means of achieving improved services and lower prices (Boubakri *et al.* 2008; Zhang *et al.* 2005). Privatisation of the electricity sector has taken many forms in Africa; these include: the complete sale of state utilities; long term concessions; management contracts; and the entry of independent power producers (IPPs) (Kessides 2012; Niekerk 2012). The most common form of privatisation in Africa is IPPs (Eberhard and Gratwick 2011; Niekerk 2012).

IPPs generally involve the state-owned power utility retaining its position as the dominant generator while the IPPs generate the electricity, which they then sell to the state utility under the terms of power purchase agreements (Kessides 2012; Niekerk 2012). IPPs are privately financed and their major role and purpose is to enhance a country's generating power capacity (Eberhard *et al.* 2014; Niekerk 2012). Some major problems with some IPPs is their inability to meet their contractual obligations consistently and their tendency to be vulnerable to corruption (Kessides 2012; Niekerk 2012).

4.9 Country Case Studies of Electricity Subsidy

Electricity subsidies vary according to the country (Iwaro and Mwasha 2010; Nierkerk 2012). Case studies made in three countries - Ghana, Nigeria and Tanzania are examined here. These case studies show the specificities of the energy sector in these countries and highlight common themes and issues throughout the African continent. Ghana, Nigeria, and Tanzania are middle-income countries, as is South Africa, and have experienced significant economic growth in the past decade with the inevitable result of corresponding increases in energy demand (Akpan 2014; Cooke *et al.* 2014; Rugabera *et al.* 2013). These countries, due to their rapid development, have the potential to serve as growth models for poorer developing countries, so their electricity policy has implications for many other governments. Table 4.1 gives a summary of the electricity sector in the three countries.

Table 4:1 Overview of the Electricity Sector in Ghana, Nigeria and Tanzania

Variable	Ghana	Nigeria	Tanzania
Rural electrification rate Urban electrification rate	Access rate at less than 30% Access rate at 66%	Access rate at 35% Access rate at 84%	Access rate at 7% Access rate at 39%
Electricity programme(s)	Ghana energy development and access project initiated in 2000 Strategic national energy plan initiated in 2006	Rural electrification programme initiated in 1981 National energy policy initiated in 2003 Renewable energy master plan initiated in 2005 National energy master plan and renewable electricity action programme initiated in 2000	Energy and water utilities regulatory authorities initiated in 2006 Rural energy agency initiated in 2007 New electricity act initiated in 2008
Kind of energy regulator	State	State	State
Type of subsidy	Consumer	Consumer and Producer	Consumer
Kind of electricity subsidy and mode	In 2002, the government introduced a subsidy for low-income households. A direct payment to households consuming 50KWh or less per month	In 2005, the government subsidised electricity by paying a lump sum amount to the electricity agencies to carry out all activities. In 2008, a multi-year electricity tariff for households was introduced. Households that consume 50KWh or less were assigned a fixed charge. In addition, households with electricity demand above 50kWh but less than 200KWh were charged a different fixed charge	In 2003, the government introduced and electricity tariff for low-income households Connection fees were subsidised for households consuming 50KWh or less

Source : Bauner *et al.* 2012 ; Emodi and Yusuf 2015 ; Kemausuor *et al.* 2011

Electrification rates in Ghana, Nigeria, and Tanzania, indicate the existence of a huge disparity in electricity access between urban and rural areas (Bauner *et al.* 2012; Emodi and Yusuf 2015; Kemausuor *et al.* 2011). Tanzania suffers most from low coverage of the electricity grid (Bauner *et al.* 2012; Ministry of Energy and Minerals, MEM 2013). According to the Tanzania Ministry of Energy and Minerals (2013), the country's power sector is heavily dependent on hydro reserves, which are increasingly diminishing because of unreliable rainfall patterns and frequent and prolonged droughts. This situation has induced power crises and increased dependence on the importation of expensive, environmentally polluting fossil fuels (Bauner *et al.* 2012; MEM 2013). Low rural electrification rates in the three countries could result from low population densities, which makes grid extension an enormously challenging and expensive way to electrify rural areas (MEM 2013; Mensah *et al.* 2013).

To support electricity access, the case study countries have implemented various electricity programmes to ensure the long-term reliability and security of energy supply for the sustainable social and economic development of their countries. Electrification programmes were initiated with good intentions, such as the desirability of providing reliable electricity support which would enhance the delivery of essential social services and facilitate the use of modern energy services (Kankam and Boon 2009; Kemausuor *et al.* 2011). Provision and use of affordable modern energy carriers as the major cooking fuel at the household level were encouraged (IEA 2009; Kankam and Boon 2009). Even so, in many African countries, including the three that are discussed here, providing access to modern energy has proved difficult and efforts made by the government have yielded declining results over the years (Ackah *et al.* 2014; Eleri *et al*. 2011; Rugabera *et al.* 2013). In the case of Ghana, growing demand for energy and constraint in supply as well as inadequate financing are cited as being key to poor results (Kankam and Boon 2009; Kemausuor *et al.* 2011). Aliyu *et al.* (2013) and Emodi and Boo (2015) argue that lack of available policy options to address the changing energy situation in Nigeria where present policies intended to address the current situation in the energy sector are ineffectual. Similarly, in the case of Ghana, inadequate funding is listed as a determining factor in causing a setback in the electrification program (Emodi and Boo 2015; Idris *et al.* 2013). The MEM (2012) also cited a similar case for Tanzania where government

budget constraints and the lack of financial resources have led to delays in the implementation of several programmes under the aegis of the power sector.

Most electricity production in Africa is provided by state-owned utilities, although many of these utilities have been dismantled over the years; some have been commercialised, which involves different forms of contract arrangements, and some have been privatised necessitating a complete divestiture of assets from public to private ownership (Marful-Sau 2009; Niekerk 2012). The most common forms of privatisation in African countries include independent Power producers (IPPs) and management contracts with very few complete sales of utilities (Marful-Sau 2009; Niekerk 2012). Ghana's electricity sector is largely comprised of state-owned companies and the Electricity Company of Ghana (ECG) is the country's main electricity distribution company (Amoakor-Tuffour and Asamoah 2015; Fritsch and Poudineh 2015). In order to streamline the operation and development of the power stations and to ensure speedy growth of the electricity industry, the Volta River Authority Act (VRA) was established in 1961 (Gyamfi *et al.* 2015; Kemausuor *et al.* 2011). The ECG now operates on a commercial basis, purchasing electricity from VRA in bulk for distribution (Gyamfi *et al.* 2015; Kemausuor *et al.* 2011). In the context of Nigeria, the Power Holding Company of Nigeria (PHCN) was formed in 2005 and is now being privatised (Aliyu *et al.* 2013; Niekerk 2012). The Tanzania Electric Supply Company (TANESCO), an entirely state-owned utility, is the country's main electricity producer (Bauner *et al.* 2012; MEM 2013). The World Bank planned to privatise TANESCO but this was rejected by the government in 2006 (Niekerk 2012; World Bank 2009). Full privatisation did not take place, but the Electricity Act of 2008 did liberalise electricity generation, transmission, and distribution, and opened up the way for IPPs to compete with TANESCO in generating electricity (Niekerk 2012; MEM 2013).

Consumer subsidies, most common in developing countries, are designed to achieve social, economic, and environmental objectives (Bazilan and Onyeji 2012; IMF 2013). The wish to expand energy supplies and extend access to energy for the poor, both for current and future generations, result in policy interventions in the form of subsidies (Ahuja and Tatsutani 2009; World Bank 2010). Consumer subsidies are important

sources of social protection in developing countries and their governments devote significant resources to lowering consumer prices for basic goods and services such as electricity (Iwaro and Mwasha 2010; Vagliasindi 2010). Ghana, Nigeria, and Tanzania, as with other developing countries, employ consumer subsidies as a tool of socio-economic policy (Mensah and Adu 2013; Siddig *et al.* 2014; Rugabera *et al.* 2013). In Ghana, for instance, the Kerosene Distribution Improvement (KDI) and LPG programs sought to enable efficient utilisation of biomass fuels and influence a switch from the use of traditional biomass to clean alternatives through the provision of subsidies (Kankam and Boon 2009; Mensah and Adu 2013). The program specifically increased rural affordability of kerosene and encouraged the adoption of LPG as the major cooking fuel at household level (Kankam and Boon 2009; Mensah and Adu 2013).

The Ghanian government, in addition to kerosene and gas subsidies, subsidises electricity at household level (Coady *et al.* 2006; Vagliasindi 2012). Similarly, the Nigerian government justifying its objective of alleviating energy poverty, introduced fuel and electricity subsidies at the producer and consumer levels (Rice 2012; Siddig *et al.* 2014). The electricity subsidy helps the poor by keeping electricity prices at an affordable level while the subsidy targeted to the producer helps to maintain a stable consumer price (Oni 2012; Siddig *et al.* 2014). Similar to the Ghanaian energy subsidy is the Tanzanian government's employment of a consumer subsidy of kerosene and electricity for household consumption (MEM 2013; Rugabera *et al.* 2013). The unconnected rural houses in Tanzania are paying less for kerosene than are connected rural houses, while the connected rural houses are paying less for electricity than are unconnected rural houses (MEM 2013; Rugabera *et al.* 2013).

Residential electrical use is the most difficult to provide because households use much of their electricity in the morning and evening (Energy Sector Management Assistance Programme, ESMAP 2005; Gyamfi *et al.* 2015). There are different electricity tariffs for industrial, commercial, and residential consumers (Cooke *et al.* 2014; Gyamfi *et al.* 2015). In Ghana, the tariff for residential consumers has a 'lifeline tariff' for low consumption (Cooke *et al.* 2014; ESMAP 2005). The lifeline tariff is a common slogan used in most developing countries to quantify a flat rate tariff for the monthly consumption of electricity (DoE 2013; Poverty and Social Impact Assessment, PSIA

2005). The Government of Ghana offers a flat rate to customers consuming 50kWh per month or less (Cooke *et al.* 2014; ESMAP 2005). The subsidy act as a tool to ensure that lower income households are protected from high electricity tariffs with the underlying assumption of the tariff scheme being that households are individually metered and billed (ESMAP 2005; PSIA 2005). In compound houses in which different tenants who are not necessarily related but share the same meter, there are variations in how well people understand, or have access to, the bills (PSIA 2005). Delays in payment by some residents and internal disputes over bill payment were some highlighted problems (PSIA 2005).

Nigeria's electricity tariff is similar to that of Ghana. The Power Holding Company of Nigeria (PHCN) also offers a lifeline to residential consumers who use 50kWh of electricity or less (Alike 2012; Foster and Pushak 2011). Residential consumers, whose demand is above 50kWh but less than 200kWh, also enjoy partial subsidies on tariff rates (Alike 2012; Foster and Pushak 2011). A large proportion of residential houses, however, are unmetered therefore electricity bills are based on average consumption which means that in the absence of proper metering, the amount billed is at best an estimate (Adenikinju 2005; Tallapragada 2009). The electricity agency is provided with a lump sum from the government each year to cover the activities of generation, distribution, and transmission (Alike 2012; Foster and Pushak 2011). In Tanzania, low-income residential households pay about US$ cents 3.8/kWh for electricity consumption of less than 50kWh per month (Rugabera *et al.* 2013; Tanzania Electric Supply Company 2012). Another method in Tanzania to increase access to electricity of low-income households to electricity is to subsidise connection fees to the electricity grid (Rugabera *et al.* 2013; TANESCO 2012).

4.10 Conclusion

The chapter provides an overview of energy subsidies, discussing the rationale behind government's subsidizing of energy. It deals with the huge costs expended on energy subsidies designed to lower the price of energy products for consumers and the two different ways, of supply-side subsidy and demand-side subsidy, of implementing the subsidy plan.

The chapter further identifies the social, economic, and environmental benefits of energy subsidies and also the negative implications of energy subsidy alongside the implication of the poor design of any energy subsidy.

The chapter also reviews the potential impact of subsidy removal or reduction in terms of their benefits and negative implications. Price hike, hampered growth, speculation and hoarding, and political turmoil are identified as problems resulting from the removal of energy subsidy. Some benefits include: a reduction in fossil fuel consumption leading to reduced emissions of air pollutant; the improvement of a country's fiscal and macroeconomic performance in terms of an increase in global real income and/or gross domestic product which means the freeing funds which could be useful in environmental programs designed to mitigate environmental degradation. Different policy options to mitigate the adverse effects of subsidy removal or reduction are examined.

Finally, electricity subsidy is discussed as an essential ingredient for the alleviation of energy poverty. The push for the privatisation of the electricity sector to solve energy-poverty issues is considered as are reasons for the privatisation of electricity generation in most developing countries which are historical, political, technological, and institutional. The IPPs as the most common form of privatisation in Africa is also explored. The chapter ends with comparative case studies of three countries with the intention of showing the specificities of the energy sector in these countries and to highlight common themes and issues on the African continent at large.

The next chapter discusses energy poverty, energy transition patterns, and energy subsidy in South Africa.

Chapter 5

ENERGY POVERTY, TRANSITION PATTERNS, AND ELECTRICITY POLICY IN SOUTH AFRICA

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5 Introduction

The definition of energy poverty in South Africa is explored in the first section. Enquiry into measures of energy poverty among South Africans is not new. This chapter deals with possible measures of energy poverty, as applied in this country. The energy sources that households generally use, with details on energy sources for lighting, cooking, and heating are explored followed by a section on South Africa's energy system, and its electricity sector. Initiatives of energy programs and policies launched by the South African government is outlined as are programs aimed at improving the welfare of South African households in terms of basic services such as electricity was outlined. Lastly, the explanation of one of the policy initiatives the South African government has implemented, the benefits and challenges of its implementation, are considred in detail.

5.1 Energy Poverty in South Africa

In the South African context, energy poverty is defined as the lack of access to modern energy services necessary for human development (Ismail 2015; Kohler *et al.* 2009). The services are defined as access to electricity and clean cooking and space heating facilities such as fuels and stoves that do not cause air pollution in houses (Ismail 2015; Kohler *et al.* 2009). Without these modern energy services, low-income households are cut off from basic amenities and therefore have to live and work in unhealthy, polluted conditions (Citizens United for Renewable Energy and Sustainability, CURES 2009; Ismail and Khembo 2015). The lack of access to adequate, reliable, safe, and environmentally friendly energy services describes the way energy poverty manifests itself (Sustainable Energy Africa, SEA 2014, United Nation Development Programme, UNDP 2000).

The South African government has acknowledged that energy poverty deepens general poverty and contributes to an erosion of health and education outcomes (Ismail and Khembo 2015; Republic of South Africa, RSA 1998). It has made progress in addressing energy poverty and has made it an issue of policy focus which is evidenced in the integrated resources plan that was developed in 2010 to bring about additional electricity capacity between 2010 and 2035, under a policy-adjusted plan that is a compromise between low-carbon and low-cost strategies (Fisher 2014; IEA 2013). The aim is to promote energy efficiency while diversifying the energy mix of 42% renewable, 23% nuclear, 21% gas and imported hydroelectric, and 6.3% coal (Fisher 2014; IEA 2013). Household electrification nationwide has increased from 36% in 1994 to 87% in 2012 (DoE 2012; Vermaak *et al.* 2014). It is noteworthy that this speed of increase access is unprecedented internationally (DoE 2012; Integrated Energy Plan, IEP 2013).

Although South Africa boasts lower rates of energy poverty than do most of her neighbouring countries, it remains an example of a country struggling to develop its economy and to provide opportunities for people to extract themselves from energy poverty (Adam 2010; Ismail and Khembo 2015). IEP (2013) stated that, there are 1.5 million rural and urban households not connected to the national electricity grid in addition to the millions that are connected but are unable to pay for electricity. Households at the low-income level cannot afford sufficient electricity to improve their welfare (Ismail and Khembo 2015; Mapako and Pasad 2005). At a provincial level, 34% of households in KwaZulu-Natal and 40% in the Eastern Cape are not connected to the electricity grid (DoE 2009; Vermaak *et al.* 2014). Electrification backlogs in these provinces are among the highest in the country (DoE 2009; Vermaak *et al.* 2014). The country has also been experiencing rolling electricity blackouts due to rapid growth in demand and insufficient investment in generation capacity (Baker *et al.* 2014; de la Rue du Can *et al.* 2013). The strategic remedy for the inadequacy of supply was scheduled interruptions in electricity supply, otherwise known as 'load shedding' and was intended to avoid a total power system failure (Baker *et al.* 2014; de la Rue du Can *et al.* 2013; Inglesi-Lotz and Blignaut 2013). Despite being more or less predictable, load shedding causes immense disruption to the economy and to everyday life (Baker *et al.* 2014; Eberhard 2008).

5.2 Measures of Energy Poverty in South Africa

Being able to measure energy poverty is essential for the design of policy and government interventions as it provides for geographical mapping of locations of severity to which resources can be directed accordingly (DoE 2012; Ismail and Khembo 2015). Some scholars argue that understanding the various dimensions of deprivations experienced by households in a state of energy poverty could help government focus on specific programmes (Ismail and Khembo 2015; Kohler *et al.* 2009; Vermaak *et al.* 2014). Finally, an energy poverty measure at appropriate intervals assist in the assessment of the effectiveness of energy poverty relief programmes by moving households out of energy poverty and by improving household's welfare in both the short term and over an extended period of time (DoE 2012; Ismail and Khembo 2015).

Attempts have been made to measure energy poverty in South Africa in terms of quantification and assessment. Approaches used to measure energy poverty include the energy expenditure approach, the thermal efficiency approach, and the subjective approach.

5.2.1 The Energy Expenditure Approach

The energy expenditure approach of energy poverty measurement is an internationally accepted measure (DoE 2013; Hills 2012). Energy expenditure is calculated as the share of total household income or expenditure spent on energy (DoE 2009; Fahmy 2011). The South African DoE (2009, 2010) recommend that a household is energy-poor if it spends 10% or more of its income on domestic energy needs. According to Statistics South Africa's 2010 and 2011 Income and Expenditure Survey, expenditure on electricity, gas, and other energy carriers accounts for 2.6% of annual consumption expenditure on average for households in the country (Statistics South Africa 2012). Therefore, assuming a 10% energy expenditure for low-income households seems a reasonable assumption; which puts such household at approximately four times the national average and defines them as energy poor (DoE 2013; World Health Organisation, WHO 2004).

The energy expenditure approach is often linked conceptually to the measurement of affordability (Lahimer *et al.* 2013; Moore 2012), which measure sees energy poverty as the level of energy used by households that are below the energy expenditure poverty line (Khandker *et al.* 2012; Tirado and Ürge-Vorsat 2010). Thus, affordability represents that situation in which households cannot afford the costs they have to bear for the comfortable exploitation of modern energy carriers which would satisfy their energy service needs (Moore 2012; Ürge-Vorsat and Tirado 2012). Such households are likely to be confronted with the choice of meeting energy requirements on the one hand and forgoing other important competing spending priorities on the other (DoE 2013; WHO 2004). The DoE (2012), using this approach in 2012 found that, 47% of South African households are energy poor because they have to spend on average 14% of their total monthly household income on domestic energy needs.

Some scholars (Fahmy 2011; Kohler et al. 2009) have considered the estimation and assessment of energy poverty based on the expenditure approach to be inaccurate. They argue that low-income households in South Africa typically rely on cheap but inferior biomass for their domestic energy needs, therefore the energy expenditure approach would completely underestimate the extent of energy poverty in the country (Fahmy 2011; Kohler *et al.* 2009). Kohler *et al*. (2009) put forward this demonstration to buttress this fact: he assessed two households both spending 15% of their monthly income on energy, both of which are classified as energy poor according to the energy expenditure approach. If one of the households bought paraffin and candles while the other bought electricity, the household that bought electricity obtained a greater quantity of useful energy because electricity is the more efficient energy carrier (Kohler *et al.* 2009). Therefore, the household that bought paraffin and candles should be considered poorer than the one that bought electricity; this analysis takes into account the quantity of energy used by the household rather than just its cost (Kohler *et al.* 2009). In addition, if the household that bought electricity gained access to free basic electricity (FBE- is an energy subsidy for low-income households in South Africa which will be discussed in a subsequent section), it follows that that household should be classified as energy non-poor, even though it would be classified as an energy-poor household according to the energy expenditure approach (Kohler *et al.* 2009).

5.2.2 The Thermal Efficiency Approach

The thermal efficiency approach is commonly used in European countries (Fahmy 2011; Hills 2012). This measure relies on an assessment of the condition of a place of residence in terms of thermal comfort levels relative to social needs (Fahmy 2011; Hills 2012). In other words, the approach involves the evaluation of the physical structure and the conditions of a dwelling unit focussing on the amount of energy required to heat the home to an acceptable standard, which typically represents a notable determinant of domestic energy costs (DoE 2013; Fahmy 2011). The South African Department of Energy used this approach in 2012 and found that 49% of households were thermally inefficient (DoE 2013). Following the method of the Hills Fuel Poverty Review in the United Kingdom, a household having both a low income and a thermally inefficient dwelling was considred energy poor (Hills 2012). The DoE (2013) and Human Science Research Council (2012) measured energy poverty, choosing a 60% of median per capita monthly income or R642 (the 2012-rand value) for the threshold of a lower income. This means that a household was defined as energy poor if thermally inefficient with a per capita monthly income of less than R642 per month (DoE 2013; Human Science Research Council 2012). The result showed that in 2012, 26% of South African households were energy poor. The implications of these results are that thermal inefficiency does not necessarily constitute a measure of energy poverty and many non-poor households could be thermally inefficient out of choice even though they possess the material resources to ensure that this is not the case (Fahmy 2011; Hills 2012).

5.2.3 The Subjective Approach

The subjective approach is another way energy poverty has been measured and examined in South Africa (DoE 2012; 2013; Ismail and Khembo 2015). This involves using indicators to survey questions concerning whether households are experiencing difficulty in affording the cost associated with meeting basic energy requirements (DoE 2013; Fahmy 2011). The question asked is, is the amount of energy the household has less than adequate, just adequate, or more than adequate for lighting, cooking, heating rooms, and keeping warm (DoE 2013; Fahmy 2011). The responses were put together in a summated scale ranging from 0 (adequate for all four energy needs) to 4 (inadequate

for all four energy needs) (DoE 2013; Fahmy 2011). Following this approach, 66% of South African households were identified as being energy poor in 2012 (DoE 2013).

According to the DoE (2013), the advantage of this method is its usefulness in tracking levels and trends in energy poverty, that is, it focusses on the problems associated with energy poverty as the people themselves feel and acknowledge their state of being energy poor. Further, as the questionnaire does not include detailed questions on household income, it is relatively easy to administer the questionnaire (DoE 2013). Using the subjective approach, the South African case yielded a considerable degree of variance in those households identified as energy poor relative to the previously discussed energy expenditure and thermal efficiency approaches (DoE 2013; Human Research Development Council 2012). The weakness of this approach is the likelihood of misreporting because of the possible stigma associated with declaring oneself to be in energy poverty, and the robustness of results based on the use of different subjective indicators as well as the choice of household respondent (DoE 2013; Seth 2011). Hills (2012), on an evaluation of the relative strengths and weaknesses of the subjective approach, argued that questions relating to the indicators are probably useful as a way of complementing more objective approaches, giving a real sense of the poverty experienced by households. The DoE (2013) concluded that the subjective approach makes intuitive sense in the South African context as it enhances the understanding of the nature, extent, and temporal dynamics of energy poverty in the country.

5.3 Energy Consumption Patterns of Households in South Africa

The energy consumption patterns of South African households are influenced by both macro determinants, or those external to the household and micro determinants which are within the household (SEA 2014; UNDP 2003). The major macro-determinants of household energy consumption in South Africa are geographic location, climatic and seasonal variation, and access to cheap coal (Eberhard and Van Horen 1995; SEA 2014). These macro-determinants are largely related to space heating and they affect energy use especially in low-income households (SEA 2014; UNDP 2003). The micro-determinants on the other hand include household income and expenditure, household

size, gender, age, education, dwelling type (that is, household construction and insulation), access to water supplies, and energy supplies (SEA 2014; UNDP 2003).

The country's household energy mix includes electricity, LPG, coal, wood, paraffin and solar energy (DoE 2012; Swart and Bredenkamp 2012). It is evident that considerable differences in patterns of energy mix are likely to exist between electrified and non-electrified houses (Swart and Bredenkamp 2012; Vermaak *et al.* 2014). Households that have electricity use this source for lighting, cooking, and space heating; it was reported that other sources such as candles, paraffin, wood, and LPG continued to be used in at least a fifth of cases (DoE 2012; SEA 2014). On the other hand, non-electrified houses were found to rely primarily on candles for lighting and on paraffin, coal, gas, and wood for cooking and space heating (DoE 2012; SEA 2014). Dry cell batteries are used for powering appliances and car batteries or generators and solar energy are common in both electrified and non-electrified houses (DoE 2012; SEA 2014).

The patterns of energy use by low-income houses, electrified or non-electrified, also show a mix of different energy carriers (DoE 2012; Statistics South Africa 2008). The energy carriers chosen by low-income households depend on budget, need, availability, and preferences (DoE 2012; SEA 2014). Low-income households often experience erratic cash flow, giving rise to expenditure patterns that do not allow for large amounts of income to be spent on energy, such as regularly paying an electricity bill at the end of the month or buying a large quantity of fuel each month (DoE 2012; SEA 2014). So energy is usually purchased in small amounts, for example, a bucket of coal, a litre of paraffin, or purchase on a prepaid electricity card for a minimum amount of R20 (2012-rand value) (DoE 2012; SEA 2014). Traditional and transitional energy carriers generally are used for domestic activities such as cooking, lighting, and space heating, and this in spite of some households having electricity connections (DoE 2012; Statistics South Africa 2008). In addition, increases in the cost of electricity coupled with interruptions in electricity supply can force the use of use candles as a means of lighting (DoE 2012; Swart and Bredenkamp 2012). The energy use patterns of low-income households clearly reflect a complexity of social and economic factors (SEA 2014; Swart and Bredenkamp 2012).

The consumption of traditional and transitional energy carriers by low-income households could affect their health, welfare, and development (Swart and Bredenkamp 2012; Vermaak *et al*. 2014). Each year, thousands of South Africans die due to respiratory illnesses caused by indoor air pollution especially if they come from low-income households (Barnes *et al.* 2011; Swart and Bredenkamp 2012). Using candles, paraffin, or wood can lead to devastating shack fires (Kimemia *et al.* 2014; Swart and Bredenkamp 2012). Paraffin poisoning is common in low-income settlements when sometimes children drink paraffin, because it is usually stored in an innocent-seeming beverage or cool drink bottle (Kimemia *et al.* 2014; Swart and Bredenkamp 2012). Approximately 80 000 children are poisoned each year in South Africa from accidentally drinking paraffin and paraffin related incidents cost the economy R204 billion annually (2012 Rand value) (Kimemia *et al.* 2014; Vermaak *et al.* 2014). Lastly, school children who need to study at night have to do so by the dim glow of a candle (Swart and Bredenkamp 2012). Kohler *et al.* (2009) emphasise the fact that access to efficient and affordable energy carriers are vital to alleviating the effects of energy poverty, and that policies need to be developed which would encourage the use of efficient energy at the household level, so that the use of paraffin, biomass, and charcoal, for example, are minimised (SEA 2014; Vermaak *et al.* 2014).

If a principal objective of the government of South Africa is the alleviation of energy poverty by encouraging a shift to modern energy carriers its energy systems and policies requires discussion as being crucial to energy use, economic growth, and development (Fisher 2014; Nkomo 2006).

5.4 An Introduction to South Africa's Energy System

South Africa is a middle-income developing country with an uneven social and economic development due to apartheid which was abolished in 1994 (Winkler and Marquand 2009; Ziramba 2009). The South African economy is energy intensive compared to other African countries, and energy has been a key factor in the shaping of its social and economic development (Aitken 2007; Bugaje 2006; Lin and Wesseh 2014). On the supply side, energy predominantly is derived from coal, contributing 72% of the country's primary energy in 2012, followed by oil (22%), natural gas (3%), nuclear (3%),

and renewables (less than 1%) (Lin and Wesseh 2014; Tait and Winkler 2012). On the demand side, energy emissions from fuel combustion in 2011 were driven primarily by industry and mining which is over 60% of final energy consumption (Lin and Wesseh 2014; Winkler and Marquand 2009). The inclusion of commerce increases this figure to about 75% while residential energy use makes up 16%-18% of the total energy supply (Lin and Wesseh 2014; Winkler and Marquand 2009).

Renewable energy plays a limited but significant role in power generation (Krupa and Burch 2011; Ziramba 2009). Solar and wind power are attractive and have good potential for development (Energy Research Centre 2010; Oladiran and Meyer 2007). Wind power is being exploited increasingly on a large scale and electricity from wind turbines is widely spread (DoE 2015; Walwyn and Brent 2015). Solar energy is a steadily contributing additional capacity to the power system for the technology is well suited to the country's abundant sunshine (DoE 2015; Walwyn and Brent 2015). On the other hand, hydropower potential is limited due to the country's low rainfall level (Inglesi-Lotz and Pouris 2012; IEA 2011). A growing number of projects are being proposed for South Africa under the project title of "Waste to Energy" where waste such as anatomical hospital wastes, bio-hazardous wastes, electronic scrap, municipal/domestic, and industrial wastes is burned instead of coal (Energy Information Africa, EIA 2014; Gumbo 2013).

By international standards, South Africa is deficient in natural gas and its consumption is therefore low (Eberhard 2011; Ziramba 2009). Given the small reserves, little has been done to establish industrial gas networks (Eberhard 2011; Ziramba 2009). Biomass, especially wood, is also an important fuel in South Africa but supplies less than 20% of the national final energy consumption (Davidson 2006; Matsika *et al.* 2013). Biomass is a critical energy source for rural households who collect most of the household fuel wood from areas in and around settlements, though this has resulted in the degradation of large areas of otherwise potentially arable land (Davidson 2006; Matsika *et al.* 2013). South Africa's coal consumption is mainly for electricity production accounting for 93% of electricity generation (Eberhard 2011; Winkler and Marquand 2009). After the end of apartheid, electricity was seen as one of the main components of socio-economic development and was prioritised as a basic service (Kessides *et al.* 2007; Tait and

Winkler 2012). Electrification in the broad sense became a primary symbol of modernisation worldwide (Tait and Winkler 2012; Winkler *et al.* 2011).

5.4.1 The Structure of South Africa's Electricity Sector

The electricity sector plays a pivotal role in the South African economy (Inglesi-Lotz and Pouris 2012; Spalding-Fecher and Matibe 2003). Prior to 1994, the majority of South African households had little access to electricity and other basic services due to apartheid policies (Inglesi-Lotz and Pouris 2012; Louw *et al.* 2008). Then the focus of the electricity sector was on industry and mining known as 'minerals-energy complex' and on white households who comprised 12% of the total population; while the rest of the population, of mainly black households, was largely excluded (Kessides *et al.* 2007; Winkler and Marquand 2009). The minerals-energy complex was the key configuration of the social-technical regime in terms of the concrete form of accumulation of capital taken in the country and in which the country's electricity sector and the coal that was used to generate it is embedded (Baker 2015; Fine 2010; Fine and Rustomjee 1996). South Africa's minerals-energy complex was central to the economy then, leaving a legacy of uneven development (Baker *et al.* 2014; Winkler and Marquand 2009). As a result, there was a large backlog of households requiring electrification at the start of 1990 and by 1993, only 36% of the country's population, mostly in the urban areas, was connected to the electricity grid (Kessides *et al.* 2007; Louw *et al.* 2008; Winkler and Marquand 2009).

Following the new government's commitment to universal electrification, 'Access to electricity for all' was a key slogan of the African National Congress, the ANC (Dinkelman 2011; Kessides *et al.* 2007; Van Dijk *et al.* 2014). With a massive and rapid electrification programme, advanced and financed largely by Eskom, residential electrification rates grew to 73% in 2006 (Department of Minerals and Energy, DME 2006; Winkler and Marquand 2009). Eskom's strategic interest was the provision of electricity for consumption with special emphasis on extending services to areas neglected by apartheid planning schemes (Tsikata and Sebitosi 2010; Winkler and Marquand 2009).

The Electricity Act, No 42 of 1922 created the Electricity Supply Commission: Escom, which became 'Eskom' in 1992 (Gaunt 2008; Pegels 2010). Eskom is a state-owned national utility and dominates South Africa's electricity sector; its electricity supply rests upon three functions: generation; transmission; and distribution (DoE 2012; Kenny 2015). Generation is the production of electricity in power stations with Eskom providing over 95% of electricity generation and the rest coming from municipal power stations and some independent power producers (IPPs) (Eskom 2011; Kenny 2015). Transmission is the bulk transfer of electricity from power stations to centres of demand and Eskom supplies all South Africa's transmission (Eskom 2011; Kenny 2015). Distribution is the transfer of electricity from substations to final consumers, such as factories, offices, and households (Eskom 2011; Kenny 2015). Eskom delivers 50% of the distribution and the remaining 50% is delivered by municipalities (Amra 2013; Kenny 2015). Eskom provides electricity directly to about 3 000 industrial customers, 1 000 mining customers, 48 000 commercial customers, 84 000 agricultural customers, and more than 4 million mostly prepaid residential customers (Eskom 2011; Newberry and Eberhand 2008). It imports electricity from Lesotho, Mozambique, and Namibia, and sells electricity to Botswana, Lesotho, Mozambique, Namibia, Swaziland, Zambia, and Zimbabwe (Amra 2013; Eskom 2011). Imports and exports constitute about 5% of total electricity on the Eskom system (Amra 2013; Eskom 2011).

Since 2008, South Africa has been experiencing challenges in meeting its electricity needs (Amra 2013; Dippenaar 2015). Economic challenge, ageing infrastructure, poor planning and lack of investment were identified as the contributing factors that compromise the ability of South Africa to meet its electricity demands (DoE 2015; Eskom 2011). According to Steyn (2011), the inability of Eskom to come to terms with uncertainty about the future demands on its electrical power system and about the risks entailed in its technology and investment choices, were pointed out as causes of the problems in South Africa's electricity sector. In addition, it was argued that delays in bringing in new generating capacity from Medupi and Kusile which are new coal-fired power stations is the reason for the electricity crises of 2008-2010 (Eberhard 2012; Urbach 2012). Dippenaar (2015) pointed out that Medupi and Kusile power stations should have provided nearly 10 000 Megawatts of electricity in 2014 but failed to do so.

Furthermore, the energy system, during the apartheid regime, was structured to serve a particular race and not the majority. Because there was, as a result of apartheid, a backlog of houses in need of electrification, the pre-1994 policies are pointed to as being largely responsible for the electricity challenges in the country (Eberhard 2012; Newberry and Eberhard 2008; Trollip *et al.* 2014). Attempts to reform the electricity sector in South Africa have yielded a number of programmes and policy interventions (Ismail and Khembo 2015; Mvondo 2010; Prasad *et al.* 2006).

5.4.2 South Africa's Electricity Programmes and Policies

Programmes and policies in South Africa are initiated to comply with the provisions of the Constitution of the Republic (DoE 2015; 2016). In 1998, the White Paper on Energy Policy was implemented which provides the basic direction for energy service delivery strategies and their enactment with the intention of achieving the country's national goals (DME 1998; Ziramba 2008). In addition, the policy document placed significant emphasis on an integrated approach to household energy problems which emphasise the importance of electrification (DoE 2013; Gaunt 2005). The government acknowledges that household access to adequate energy services for cooking, heating, lighting, and communication is a basic need in its recognition that while various fuel-appliance combinations could meet these needs, without access to electricity, human development potential is severely undermined (Bekker *et al.* 2008; DME 1998).

In addressing the energy imbalance and demand in the domestic sector, the National Electrification Programme (NEP) was implemented between 1994 and 1999 (DoE 2003, 2015). One of the objectives of the programme was to electrify those rural and urban low-income houses which had been deprived of access to electricity during the apartheid period (Davidson 2006; DoE 2015). The programme expected that newly electrified households would switch from using wood, candles, and batteries to using electricity (DoE 2015; Gaunt 2005). A successor to the NEP was implemented in 2001, the Integrated National Electrification Programme (INEP) (DoE 2015; Eskom 2011)- the role of which was to plan, implement, and monitor energy projects effectively (Parliamentary Monitoring Group, PMG 2012; DoE 2015). The programme creates new infrastructure while ensuring that existing infrastructures are rehabilitated and well

maintained (DME 2008; Mzini and Lukamba-Muhiya 2014). In addition, INEP addresses the extent of the backlog of households following the Energy White Paper recommendations of 1998 and connects newly built houses and informal settlements to electricity (DoE 2013; PMG 2012).

The Republic of South Africa's government has been implementing the drafted post-apartheid framework for the suppy of energy (DME 2008; Mzini and Lukamba-Muhiya 2014). In 2000, the government announced a policy to provide free basic services of water, sanitation, and energy to poor households (Adam 2010; Bhorat *et al.* 2012; DME 2003). Following this, the DME developed the Free Basic Energy policy as complementary to the INEP in order to ensure poverty alleviation by providing for effective energy utilisation (DME 2004; Lemaire 2011; Mapako and Prasad 2005). To cater for the provision of basic energy, the DME considered the supply of liquid fuels and electricity (Bhorat *et al.* 2012; DME 2003; Mapako and Prasad 2005). Concerning electricity, the policy document concerns itself with supplying support to grid and non-grid poor households (DME 2003; Lemaire 2011; Mapako and Prasad 2005).

5.5 The Free Basic Electricity Policy

Free Basic Electricity (FBE) is an official government social welfare policy launched in South Africa in 2003 (DME 2003; Ruiters 2011); its sets out ways in which government interventions can bring relief to poor households with access to electricity in order to ensure optimal socio-economic benefits from the Integrated National Electrification Programme (Bhorat *et al.* 2012; DME 2003; Eskom 2011). As discussed in Chapter 4, the FBE is a demand side subsidy, otherwise called a consumer subsidy, as the policy ensures free access to basic electricity for those poor households that are connected to the national electricity grid (Eskom 2011; SALGA Energy Guideline Series 2014). The DME, in the guidelines for the FBE policy, points out that the provision of electricity supply enhances the well-being of the poor, especially women and female children, affects the health of the populace positively, and reduces the use of fossil fuels (DME 2003; DoE 2013).

The estimation of the amount of electricity required for the basic needs of poor households is important as representing the minimum amount of free electricity

available to qualifying customers (Bekker *et al.* 2008; Eskom 2011). The FBE policy states that an allocation of 50kWh of electricity per month be provided free of charge to poor households connected to the national electricity grid (DME 2003; Inglesi 2010; Ruiters 2009). The amount is based on research carried out by the Energy Research Centre, University of Cape Town, which reported that 56 percent of poor households consume no more than 50kWh per month (Adam 2010; University of Cape Town, UCT 2003). This study pointed out that 50kWh per month is deemed sufficient to provide basic services such as lighting, ironing, cooking, the boiling of water using an electric kettle, black and white television, and a small radio (Adam 2010; UCT 2003). The justification of the 50kWh by the government is that poor households have a low demand for electricity and that energy efficient lighting interventions and other energy saving appliance would increase the utility level of the subsidy (DME 2003; Eskom 2011). Households that consume more than the allotted 50kWh per month imply an ability to pay the normal electricity tariff and could be charged for any unit above the free allocation (DME 2003; Eskom 2011).

The implementation of the FBE policy for grid-connected poor households occurs by means of two approaches: a broad-based approach and a self-targeted approach (Adam 2010; DME 2003; SEA 2014). The broad-based approach refers to the implementation of an agreed allocation of free basic electricity to all poor households that have a legal connection (Adam 2010; DME 2003). The self-targeted approach has two possible methods of implementation (Adam 2010; SEA 2014). The first gives poor households the option of restricting the electricity current drawn from their supply whereupon they become eligible for the free basic electricity allocation (Adam 2010; DME 2003). It was expected that poor households with low consumption would apply for the current limited electricity supply (Adam 2010; DME 2003). This method ensures accurate targeting of the poor and reduces the incidence of overloads on rural electricity power lines (Adam 2010; DME 2003). The second option requires that the electricity service provider, either Eskom or the local authority should identify household that consume, an average of less than a pre-determined amount of electricity per month and automatically apply the free basic electricity allocation to such households (Adam 2010; DME 2003). The DME recommended the self-targeted approach, or the second option,

for the implementation of the first phase of the FBE as it is supposedly more accurately able to target the poor and less costly to implement for municipal electricity distributors since it can be easily applied to credit or prepayment meter services (Adam 2010; DME 2003). The preconditions for households to receive FBE are proof of their monthly income, a legal connection to the national grid, and agreement that a prepaid metre be installed (Ruiters 2009). Households that have a record of non-payment of electricity bills are excluded from having free electricity until all bills are paid (DME 2003; Makonese *et al.* 2009).

Importantly, the government in 2002-2003 initiated a trial phase during which households were offered 50kWh of free electricity per month for a 1-year period (Dekenah *et al.* 2009; UCT 2003). The response to the trial, documented by the Eskom Load Research Programme, revealed an average monthly consumption of 35kWh per month (Dekenah *et al.* 2009; Eskom 2007). The proceedings for final implementation was through partnerships between municipalities and Eskom (Howells *et al.* 2007; Ruiters 2009).

5.5.1 The Benefits of the FBE Policy

The benefits of consumer subsidies, discussed in Chapter 4, were that it facilitated access through subsidy to modern fuels as the cost of the fuel is reduced and thereby enables an improvement in the living standards of the low-income households. The introduction of the FBE policy has delivered basic services to communities that were previously disadvantaged (Makonese *et al.* 2009; Mapako and Prasad 2014). The FBE policy has enabled the extended use of better quality lighting than the candles on which they had previously depended (Mapako and Prasad 2014; Mzini and Lukamba-Muhiya 2014). Good lighting, according to Sparknet (2010) is important for learners and teachers for reading and studying at night. Furthermore, the use of wood for cooking or space heating has declined significantly (Bekker *et al.* 2008; Mapako and Prasad 2014; UCT 2003). Mapako and Prasad (2014) found that the majority, about 77%, of those households that benefitted from the FBE policy in the Western Cape Province indicated their preferance for electricity for cooking. Wentzel (2005) pointed out some benefits of the FBE from a study of two rural areas reporting that household expenditure is being

transferred from energy to other household priorities, such as food preparation, and the saving of time and labour in fuel collection, as well as gains in efficiency and also cleanliness.

Franks (2014), using the Income and Expenditure Survey 2005/2006 and 2010/2011 in a comparative study of FBE and non-FBE households in the city of Cape Town found variations in their energy expenditure. Without FBE, individually metered households who used less than 150kWh per month, paid at least R115 (2013 Rand value) for electricity while households with FBE, who used above the free 50kWh but less than 150kWh, spent R77 (2013 Rand value) on electricity per month.

In research conducted by Prasad (2003), over 90% of households use electricity for more days per month than they did before the FBE policy was introduced and this has led to a reduction in the use of other energy carriers. These households were able to use fewer candles than hitherto and less paraffin, which was the other significant fuel affected by the acquisition of the FBE (Prasad 2003). Many households relate their extended electricity access to increased safety and security because of being able to leave on outside lights, as they are no longer constrained by the use of candles or paraffin which they had to put off once their productive hours for the day had ended (Mapako and Prasad 2014; Prasad 2003).

Furthermore, the provision of the 50kWh of electricity has lowered expenditure on respiratory related diseases which had been caused by indoor air pollution (Howells *et al.* 2010; Kimemia *et al.* 2014; UCT 2003). Mvodo (2010), in a study in Buffalo City, Eastern Cape province found that the FBE policy had positive impacts on health: 92% of households indicated they had not experienced any respiratory related illness in the past 9 months until the time of the survey (Mvodo 2010). Adam (2010) also proves that the FBE policy improves the welfare of the poor by eliminating the health risks of using wood for cooking.

Davis *et al.* (2008) examined the effect that the monthly free allocation of 50kWh had had on the electricity consumption and fuel used in two rural villages: Antioch and Garagapola, in South Africa. The study shows that FBE influences electrical appliance

ownership, such as electric stoves, and/or perhaps more electrical appliance usage (Davis *et al.* 2008). Cooking appliances are major consumers of electricity and are thought to be an important indicator of of levels of electricity usage in households taking advantage of the FBE policy (Davis *et al*. 2008). Furthermore, access to electronic media, through television, has broadened the exposure of rural communities to news and current affairs as well as to entertainment (Mapako and Prasad 2014; Mzini and Lukamba-Muhiya 2014). The use of luxury appliances such as food processors, washing machines, toasters and sandwich makers was also observed (Mapako and Prasad 2014; Mzini and Lukamba-Muhiya 2014).

5.5.2 The Challenges of the FBE Policy

The major social implication of consumer subsidy policy as discussed in Chapter 4 is the inability of the subsidy to reach the poor. The registration for the FBE was aided by the Department of Social Development whereby the South African government ensured that poor households were targeted to receive the FBE. Other challenges, however, have been highlighted in connection with the FBE among poor households in South Africa.

Some authors have argued that the size of the FBE allocation of 50kWh of free electricity is insufficient for the improvement welfare and fails to have a significant impact on the energy choices of poor households (Howells *et al.* 2006; Mapako and Prasad 2005; Ruiters 2009). According to Howells *et al.* (2006) and Ruiters (2009), the 50kWh subsidy of electricity reflects the apartheid legacy, in that it is characterised by a minimal understanding of needs, which led to a low-consumption of energy by households. It was pointed out that households, as a result of the size of the FBE, have to make choices about what to use energy for and thus limit their sense of how needs can be defined and satisfied (Howells *et al.* 2006; Ruiters 2009). In addition, as stated previously, most low-income households rely on more than one source of energy (Davis *et al*. 2008; Liu *et al.* 2013). Thus, the possibility of these households using the 50kWh for lighting but continuing to use paraffin, coal, and wood, which have a negative impact on their health and safety (Mapako and Prasad 2005; Ruiters 2011).

Eberhard (2004) argued that the 50kWh electricity allowance is probably not suitable for low-income urban households, which typically have large household sizes and require high energy. Cowan and Mohlakoana (2004) describe the 50kWh of electricity as discriminating against larger households. A study by the National Treasury (2006) estimated that an average small household, though no specification is offered of how small, spends R213 (2003-rand value) on electricity by consuming 498kWh per month whilst a large household is expected to spend R414 (2003-rand value) consuming 1000kWh per month on electricity (National Treasury 2006). The intention of the policy was to ensure that even a limited amount of electricity could improve the lives of low-income households and could reduce the health and fire risks of using other fuel sources such as wood or paraffin (Howells *et al.* 2006; Ruiters 2009). The trial phase, conducted by UCT, disregarded household size or larger households which share their electricity connection with other households, a common practice among backyard dwellers, and households which run a small business from home (Ruiters 2009; SEA 2014). Because of these limitations, the UCT research raised concerns about the appropriateness of its findings in regards to informing decisions about what constitutes a suitable amount of free electricity (Howells *et al.* 2005; Ruiters 2009).

Another challenge of the FBE policy is the use of prepaid meters as a means of getting FBE to households (Adam 2010; Makonese *et al.* 2012; Kimemia *et al.* 2014). The FBE policy stipulates that poor homes applying for free basic electricity would have to be fitted with a prepaid metre, the imposition of which is arguably a further source of inequality in the accessing of energy (Kimemia *et al.* 2014; Ruiters 2009). The purchase of vouchers are necessary for the activation of the free basic electricity allowance, but, given the uncertainty of income frequent among low-income households, sometimes they are unable to afford these, so their homes are left without any electricity (Adam 2010; Malzbender and Kamoto 2005). Furthermore, Malzbender and Kamoto (2005) agree that the installation of prepaid electricity metres for low-income households has resulted in financial difficulties for some, as they have to pay in advance for electricity from the date of installation.

The effectiveness of the FBE policy is also affected by the limits in the electrical current being provided (Adam 2010; Ruiters 2009). The assumption from the trial phase was

that poor households generally have a low demand for electricity and their needs could be met adequately by restricting the electrical current drawn from their supply to 20 Amperes (Adam 2010; Ruiters 2009). The limited electrical current restricts what appliances can be used and the risk of tripping the electricity supply occurs when several appliances are used simultaneously (Adam 2010; Ruiters 2009). Adam (2010) contends that the 20 Amperes is likely to inconvenience low-income households in the performance of domestic tasks. Giving an example, Adam (2010) pointed out that when thermostatically controlled geysers are used, there may be frustrations due to clients not knowing when the geyser is consuming electricity, with the result that the concurrent use of other electrical appliances would result in tripping off the electricity. Another consequence of a limited electrical current highlighted by Kimemia *et al.* (2014); Ruiters (2009) is that frequent power failures, which are possible fire hazards, can lead to the damaging of electrical appliances.

Some studies have reported a high level of inconsistency, in terms of the FBE policy implementation, based on the different agents who administer the project (Adam 2010; Makonese *et al*. 2012; Ruiters 2009). As already mentioned, the municipality and Eskom are the agents responsible for implementation in different areas or regions across the country (Howells *et al.* 2006; Ruiters 2009). In those cases in which the municipality acts as the agent, FBE remains pegged at the proposed 50kWh, while in Eskom supply areas, qualifying households receive up to 100 kWh of FBE per month (Adam 2010; Makonese *et al*. 2012). The uneven allocation is as a result of the implementation of the project, with the municipality's distributing to its area first in 2003 and Eskom starting in 2005; after which the agents did not adhere to the same shared guidelines or standards (Adam 2010; Ruiters 2009).

Finally, inadequate communication and education with regard to the technology, service options, and the numerous administrative hurdles for the qualifying populations have influenced the effectiveness of the FBE (Adam 2010; Ruiters 2009). Makonese *et al.* (2012) pointed out that households that qualified for FBE thought that choosing the service option of the self-targeting approach, which involves the electricity service provider's being able to identify households consuming a pre-determined amount of electricity, means that the electric current would be cut down and that having the

prepaid metre installed would result in high electricity costs. This behaviour, according to Makonese *et al.* (2012), shows a lack of understanding by those who qualify for FBE, both in terms of the technology and of the benefits of adopting such mechanisms.

Despite these challenges, the removal of FBE may or may not be recommended. As discussed in Chapter 4, once a subsidy is in place and people are used to low prices, its reduction or removal becomes difficult for the government. It is most likely that this would result in social and political chaos as has been experienced in other developing countries in Africa; for example, the bad results of removing the electricity subsidy in Uganda; as with the removal of the gasoline subsidy in Nigeria. The practice adopted by most governments in developing countries, when it comes to subsidy reduction or removal, is to put in place reform strategies beforehand. Should the South African government indicate an intention to revise the FBE policy, the electricity tariff structure used by the Nigerian government, as discussed in Chapter 4, has been proposed as a reform strategy.

5.6 Conclusion

In the first section, an overview of the different approaches for the measurement of energy poverty over the years in South Africa was presented: energy expenditure; thermal efficiency, and subjective approaches.

The South African energy system, which is crucial for the country's energy usage, is considered, and electricity sector was identified as being of key importance to economic growth and the well-being of all South Africans. The primary role of Eskom was emphasised because of its dominant position in the sector which factor is looked at alongside, the current challenges faced by the country's electricity system including economic challenges, ageing infrastructure, supply/demand inefficiencies, and delays in bringing in new generating capacity.

The patterns that demonstrate the differences between electrified and non-electrified houses and the wide range of energy sources employed to meet basic needs are discussed. The country's residential energy mix includes electricity, LPG, coal, paraffin, biomass, and solar energy. The national electrification programme, and, on the other

hand, policies such as the White Paper on Energy, and the policy for Free Basic Electricity (FBE) are notable programmes the results of which are also discussed in this chapter.

In addition, the impact of FBE, in terms of household benefits is set out to explore the benefits of the longer and the increased use of electricity for lighting, the transfer of expenditure from energy to other household priorities such as cooking and the time and labour saved by not having to collect fuel, as well as gains in efficiency and cleanliness. Safety and security, less spending on illnesses resulting from indoor air pollution associated with respiratory diseases, the uuse of more electrical appliance, and access to electronic media, using television, and entertainment were also mentioned as benefits of the FBE.

The chapter ended with a discussion on the challenges of the FBE policy; these included the adequacy of the size of the FBE allocation of 50kWh of free electricity. This amount was seen as insufficient to improve welfare and to have a significant effect on the energy choices of poor households. Large household sizes having concomitantly large energy demands, the need for prepaid metres by qualifying households before installation, and the limits to the electrical current being provided have also raised concerns about the effectiveness of the FBE. Other challenges discussed include the high level of inconsistency in the FBE distribution, inadequate communication, and poor education.

The next chapter explains the procedures and techniques used in carrying out the research undertaken for this thesis.

Chapter 6

PROCEDURES AND TECHNIQUES

6 Introduction

The research methods which capture the research design, data sources, variable description, the procedures and techniques used in each component of the research are set out in this chapter. The research design follows a predominantly quantitative approach because variables of energy choices are measured by quantifiable elements. The objectives of the study were [1] to investigate energy poverty in low-income households in South Africa by using a multidimensional energy poverty index; [2] to examine the extent to which the "energy ladder" or "energy stacking" models explain energy consumption patterns in South African low-income households; and [3] to examine whether the FBE policy has an impact on household energy choices and on energy poverty. The chapter describes the data sources and the processing, or the cleaning of the variables, to be used from the datasets. The specific analytical methods that were used in each component of the research conclude the chapter.

6.1 Research Design

A research design was devised that would be an appropriate research method for the attainment of the objectives of the thesis as set out in Chapter 1. Research can be conducted through various paradigms (De Vos and Strydom 2011; Neuman 2011). The roots of the qualitative and quantitative approaches extend into different philosophical research paradigms, including Positivism and Post-positivism (Creswell 2009; Lincoln *et al.* 2011; Neuman 2011). Post-positivism is characterised by two sub-paradigms, which are interpretivism and critical theory, while realism is seen as a bridge between positivism and post-positivism (Blumberg *et al.* 2011). Depending on the purpose of a research study, paradigms are used to classify research into qualitative, quantitative or a mixture of the two (Teddlie and Johnson 2009). This study employs a positivist approach because of its preference for an analytical interpretation of quantifiable data. A

quantitative research study depends on the numerical analysis of data in which the data could be gathered by primary or secondary means (Creswell 2013). Based on this positivist tradition, a quantitative method has been chosen in order to isolate, analyse and thereby understand, with the backing of secondary data the motives that determine why any particular household would make the energy choices it does.

6.2 Data Sources and Descriptions

The data employed for the analysis comes from two main sources: The National Income Dynamics Survey (NIDS) and the Income Expenditure Survey (IES). The NIDS is the first national longitudinal panel study of individuals and households established by The Presidency of South Africa (Leibbrandt *et al.* 2009; Woolard *et al.* 2014). The purpose of the panel study is to track changes over time in the livelihood of individuals and households in terms of the determinants and drivers of poverty, inequality, and labour market dynamics and to measure the impact of South Africa's social policies (Brown *et al.* 2012; Southern Africa Labour and Development Research Unit, SALDRU 2012). The target population for NIDS are private households in all nine provinces of South Africa, and residents in workers' hostels, convents, and monasteries (Leibbrandt *et al.* 2009; Woolard *et al.* 2014). The coverage excludes student hostels, old age homes, hospitals, prisons and military barracks (Leibbrandt *et al.* 2009; Woolard *et al.* 2014).

NIDS employed a stratified two-stage cluster sampling design in sampling the households included in the base wave (Brown *et al.* 2012; SALDRU 2012). The survey began in 2008 (the baseline wave), with a nationally representative sample of 28000 individuals residing in 7300 households across the country (Leibbrandt *et al.* 2009; Woolard *et al.* 2014). The survey continues to be repeated every two years with the same group of households or individuals using a combination of household, adult, child, and proxy questionnaires (Brown *et al.* 2012; Leibbrandt *et al.* 2009; NIDS 2012). Each household is tracked with a household identification number and the questionnaire is answered in a face-to-face interview with the oldest woman in the household and/or another household member knowledgeable about the living arrangements and spending patterns of the household (Brown *et al.* 2012; NIDS 2012). The household questionnaire has a set of questions on demographics (age, race, gender, marital status, location,

province, and household size), socio-economic conditions such as employment and education, energy use, and income and expenditure patterns, among other details (Leibbrandt *et al.* 2009; NIDS 2012). This study focuses on only relevant variables needed for the analysis.

A key feature of a panel study is its ability to follow the original houses, revealing the dynamic structure of households, the changes in the living conditions, and the well-being of household members (Leibbrandt *et al.* 2009; Woolard *et al.* 2014). This system, of a panel survey, provides a valuable tool for social scientists and policy-makers to explore the underlying behaviour of households and individuals (Hsiao 2014; Nicoletti *et al.* 2011). Panel surveys allow for the repeated measurement of variables over time, captures the unobserved time-invariant heterogeneity, and addresses the issue of measurement error and omitted variable bias (Hsiao 2014; Nicoletti *et al.* 2011). There is, however, a common threat to panel data which is attrition, or the failure successfully to re-interview targeted households or individuals (Gray *et al.* 2012; Kasirye and Ssewanyana 2010; Thomas *et al.* 2010).

The Income and Expenditure Survey (IES) is a nationally representative household-based survey conducted by Statistics South Africa (Statistics South Africa 2011; Vermaak *et al.* 2009). Its primary objective is to provide relevant statistical information on income and expenditure patterns of a representative sample of households (Vermaak *et al.* 2009; Statistics South Africa 2011; Woolard and Leibbrandt 2011). In addition, the IES survey updates and reweights the basket of goods and services required for the compilation of the Consumer Price Index (CPI) (Rose and Charlton 2002; Statistics South Africa 2011). The target population for the survey is the same as for the NIDS. The IES covers all households living in private dwelling units and workers living in workers' quarters in South Africa (Statistics South Africa 2011; Vermaak *et al.* 2009).

Statistics South Africa monitors South African income and expenditure patterns at five-yearly intervals using the IES (Armstrong *et al.* 2008; Statistics South Africa 2011). The 1995 version of the IES began to cover all areas of the country including metropolitan, urban, and rural areas and is thus not comparable with earlier surveys, for example, the 1985 and 1990 IES, which only covered a limited sub-set of households in the

metropolitan areas of the country (Rose and Charlton 2002; Yu 2011). The 2005/2006 IES is also different from previous IESes in other respects such as sampling design, questionnaire structure, categorisation of income, and expenditure items, etc. (Armstrong *et al.* 2008; Statistics South Africa 2011). There are four modules (IES 2010/2011) in the household questionnaire with 18 sub-sections (Statistics South Africa 2011; Yu 2011). The first module includes general household data and data on household members (Statistics South Africa 2011; Vermaak *et al.* 2009). The rest of the modules, modules 2 to 4, collected data on consumption expenditure, household finances, and income (Statistics South Africa 2011; Yu 2011). In terms of the energy data, the survey records spending by the household on the following energy types: electricity, gas, paraffin, candles, coal, solar, batteries, diesel and petrol for household generator use but not transport and firewood both bought and fetched (Statistics South Africa 2011; Vermaak *et al.* 2014). The dataset also contains an indicator for whether the household receives free basic electricity (Statistics South Africa 2011; Vermaak *et al.* 2014).

The data collection methodology of the IES has adopted the diary and recall methods (Statistics South Africa 2011; Yu 2011). The IES conducted in 1995 and 2000 used the recall method only while the IES of 2005/2006 and 2010/2011 used both diary and recall methods (Statistics South Africa 2011; Yu 2011). The recall method asks the household respondent to recall income and expenditure either during the month prior to the survey or for 12 months prior to the survey (Armstrong *et al.* 2008; Yu 2011). The diary method, on the other hand, entails the household respondent recording the household's daily acquisitions, which requires a description of the item, value, source, purpose, place of purchase, and type of retailer that are made on a daily basis (Armstrong *et al.* 2008; Yu 2011). Each household interview made use of a detailed questionnaire, and was required to keep a diary for a month during which the acquisition of all goods was recorded (Statistics South Africa 2011; Vermaak *et al.* 2009).

The IES, being a cross-sectional study, captures a specific point in time which means that there is no loss to follow-up since participants are interviewed only once (Hsiao 2014; Yee and Niemeier 1996). There is the difficulty, however, of inferring a temporal association between a risk factor and an outcome in a cross-sectional study because

data on each participant are recorded only once (Hsiao 2014; Sedgwick 2014). The design weights were constructed by applying three adjustments to the base weights, bearing in mind that the base weight for each sampled household is equal to the reciprocal of the probability of selection. The first adjustment was applied to account for segmentation in informal primary sampling units and for growth primary sampling units. The second adjustment was applied to account for the enumeration areas while the third was the non-response adjustmentsThe result is that the sampled households in the survey are assumed to represent the entire civilian population of South Africa.

6.3 Data Processing and Definition of the Descriptive Variables

The NIDS panel data collected in 2008 (wave 1), 2010 (wave 2), 2012 (wave 3), and 2014 (wave 4) was used. The data was processed using the quantitative software package, STATA version 12. The processing started with the identification of low-income households in which low-income groups are classified as earning R0 – R18 000 per annum or households with an income below R1 500 per month which follows the South African Bureau of Market Research, BMR (2011) and Statistics South Africa (2011). Once the low-income households were identified, which resulted in 10 804 observations, a descriptive statistic was carried out to assess the socio-economic and demographic characteristics of low-income households in South Africa and these were afterwards screened for attrition. The reasons for attrition in the four waves according to NIDS (2012) include refusal to participate, by an individual or household, a respondent not being contacted because not tracked or located or who moved outside South Africa, and respondents who died. Those households or individuals that were not successfully re-interviewed in any of the waves are not included. A total sample of 10 316 low-income households were appended to be used for the estimation of the MEPI. Finally, some of the variables that were not in numeric format were assigned values. For example, gender is assigned as 0 = male and 1 = female; for the energy sources, 1 = modern energy sources, 2 = transitional energy sources and 3 = traditional energy sources. Dwelling type was represented as 1 = modern dwelling, 2 = traditional dwelling and 3 = informal dwelling. Binary answers of ‘yes’ or ‘no’ were assigned, 0 = no, 1 = yes. Missing data appears as ‘dot’ (.) as STATA allows for missing or multiple missing value codes.

The age variable is in numeric form and thus coded categorically. For example, 14 – 19years = 1, and 70 years and above = 7.

Analysis was done on weighted data so that the results obtained are representative of the entire population. The first part of the analysis presents the descriptive statistics. The descriptive analysis of data highlights summary statistics about the characteristics of the sample population. The demographic and socio-economic characteristics of the sample population helps one have a good understanding of how representative is the sample of the whole research population. Accessibility to electricity, energy choices for cooking, heating and lighting, population group, gender, education, age of the household head, and type of dwelling were examined. The description of these variables is presented in Table 6.1.

Table 6:1 Description of Explanatory Variables used in the Model

Variable	Definition/Description	Type of Variable
Accessibility to electricity	If household has electricity or not	Binary: 1 = Has electricity; 0 = No electricity
Energy choices for cooking and heating	The main source of energy for cooking or heating by households	Categorical: 1 = Modern energy carriers (electricity from mains or generator, gas and solar); 2 = Transitional energy carriers (paraffin and coal); 3 = Traditional energy carriers (animal dung, wood)
Energy choices for lighting	The main source of energy for lighting by households	Categorical: 1 = Modern energy carriers (electricity from mains or generator, gas and solar); 2 = Transitional energy carriers (paraffin and coal); 3 = Traditional energy carriers (animal dung, wood); 4 = Candles
Population group	The racial group of the household head/respondent	Categorical: 1 = Black African; 2 = Coloured; 3 = Asian/Indian; 4 = White
Gender	The gender of the household head/respondent	Binary: 1 = Female; 0 = Male
Household Size	The number of people residing in the household	Categorical: 1 = 1 -4 people; 4 = 16 people and above
Age	The age of the household head/respondent	Categorical: 1 = 14 -19 years; 7 = 70 years and above
Rurality	The area defined by certain similar characteristics	Binary: 1 = Urban; 0 = Rural
Type of Dwelling	The dwelling categories of the household	Categorical: 1 = Modern dwelling; 2 = Traditional dwelling; 3 = informal dwelling

6.4 Model Specification: Multidimensional Energy Poverty Index

Following the work of Nussbaumer *et al.* (2011, 2012, 2013), MEPI was constructed for low-income households in South Africa. Measuring energy poverty on a multidimensional basis requires a comprehensive representation of the various energy needs for a society to develop (Nussbaumer *et al.* 2011, 2012; Sher *et al.* 2014). The common energy needs essential to households include cooking, heating, lighting, entertainment/education, services provided by means of household appliances, telecommunications, and mechanical power (Nussbaumer *et al.* 2011, 2012). While this study acknowledges the importance of mechanical power, the lack of information in the

data on this energy source did not allow for direct measurement of this variable. In addition, since energy poverty is measured on a multidimensional basis, it allows for flexibility in the use of different dimensions, indicators, weights, and cut-offs specific to different societies and situations (Alkire and Foster 2011; Nussbaumer *et al.* 2011). Thus, six dimensions made up of nine major indicators of energy deprivation, similar to those used in Nussbaumer *et al.* (2011), were considered. These dimensions include: use of modern cooking fuel, use of modern heating fuel, electricity access/lighting, household appliance ownership, entertainment/education appliance ownership, and telecommunication service (Nussbaumer *et al.* 2011). It is worth mentioning that some of the indicators have been used in previous research to construct the MEPI (Bekele *et al.* 2015; Edoumiekumo *et al.* 2013; Nussbaumer *et al.* 2011; Sher *et al.* 2014) and these choice indicators also reconciled with what was actually possible in terms of data availability.

The effective weighting of each indicator was determined by using the statistical approach, in which weights are assigned based on multivariate statistical methods – Multiple Correspondence Analysis (MCA) (Decancq and Lugo 2013; Krishnakumar and Nadar 2008; Maggino and Zumbo 2012). The six dimensions representing basic energy services and the corresponding six indicators and deprivation cut-offs is presented in Table 6.2.

Table 6:2 Energy Dimensions and their Respective Indicators with Cut-offs

Dimension	Indicator	Variable	Cut-off (Situation of deprivation)
Cooking	Modern cooking fuel	Type of cooking fuel	A household considered poor/deprived if using any fuel beside electricity (or generator), LPG or solar for cooking purposes
Heating	Modern heating fuel	Type of heating fuel	A household considered poor/deprived if using any fuel beside electricity (or generator), LPG or solar for heating purposes
Electricity access/Lighting	Lighting	Type of energy source for lighting	A household considered poor/deprived if using any energy source beside electricity (or generator), LPG, or solar for lighting purposes
Services provided by means of household appliances	Basic appliance ownership	Has a fridge	A household considered poor/deprived if the household has no fridge
	Luxury appliance ownership	Has a washing machine	A household considered poor/deprived if the household has no washing machine
Entertainment/Education	Entertainment/Education appliance ownership	Has a radio or television or computer	A household considered poor/deprived if the household has no radio or television or computer
Communication	Telecommunication means	Has a cell phone or landline	A household considered poor/deprived if the household has no cell phone or landline

For modern cooking fuel, a household is considered deprived if its main cooking fuel is not electricity or a generator, LPG or solar, and it is assigned the value 1, otherwise 0. For modern heating fuel, a household is considered deprived if its main heating fuel is not electricity or a generator, LPG, or solar, and it is assigned the value 1, otherwise 0. For lighting, a household is considered deprived if its main lighting energy source is not electricity or a generator, LPG, or solar and the household is assigned the value 1, otherwise 0. For household appliance ownership, a household that does not have a refrigerator or washing machine is considered deprived and it is assigned 1, otherwise 0.

For entertainment or education appliance ownership, a household is deprived if it does not have a radio, television, or computer, for which a value of 1 is assigned or otherwise 0. Lastly, for telecommunication means, a household is considered deprived if the household has no cell phone or landline, and it is assigned the value of 1 and 0 if otherwise. After computing the deprivation indexes for all households, the energy poverty score for each household, C_i is then computed as the sum of household weighted deprivation.

A second cut-off or threshold line is required to identify the multidimensionally energy poor households which is suggested by Nussbaumer *et al.* (2011), and is called the multidimensional energy poverty line, *k*. This line separates the energy poor from energy non-poor. In other words, a household is considered poor if the deprivation score is equal or greater than the energy poverty cut-off line. In this study the multidimensional energy poverty cut-off selected is intermediate, such that households identified as poor must be deprived in the equivalent of an entire dimension, for example cooking, and one other indicator. In addition, the value of *k* chosen is to ensure that no households deprived in just one dimension could be identified as multidimensionally energy poor, thus reducing the chances of inclusion error (Alkire and Santos 2014). To fit the South African context, the poverty line was estimated by using the allowance of a household for non-food necessities and the average household size so that a household is considered energy poor if it is deprived of more than a certain percentage of the indicators which is the estimated multidimensional energy poverty line. A household whose sum of weighted deprivation is greater than or equal to this percentage is classified as energy poor, and households whose sum of weighted deprivation is less than the percentage is energy non-poor. Households whose deprivation score might be below the energy poverty line, even if it is non-zero, will be replaced by a 'zero'.

6.4.1 Computing the Multidimensional Energy Poverty Index

The MEPI measures energy poverty in *d* variables across a population of *n* individuals. The $n*d$ matrix of achievements for *i* persons across *j* variables is represented by *Y* =

$[y_{ij}]$. Therefore, $y_{ij} > 0$ represents the individual i achievement in the variable j. Thus, each row vector $y_i = (y_{i1}, y_{i2}, \ldots, y_{id})$ represents the individual i achievements in the different variables, and each column vector $y_i = (y_{1j}, y_{2j}, \ldots, y_{nj})$ gives the distribution of achievements in the variable j across individuals. This method allows weighting the indicators unevenly. A weighting vector w is composed of the elements w_j corresponding to the weight that is applied to the variable j. Thus, $\sum_{J=1}^{d} w_J = 1$.

Alkire and Foster (2007) suggested that it is useful to express the data in terms of deprivations rather than achievements. Let z_j represent the deprivation cut-off in variable j and then represent all individuals deprived in any variables. Let $g = [g_{ij}]$ be the deprivation matrix, where $g_{ij} = w_j$ when $y_{ij} < z_j$ and $g_{ij} = 0$ and when $y_{ij} \geq z_j$. The entry i_j of the matrix is equivalent to the variable weight w_j when a person i is deprived in variable j, and zero when the person is not deprived. Following this, a column vector C of deprivation counts is constructed, where the ith entry $C_i = \Sigma_{J=1}^{d} g_{ij}$ represents the sum of weighted deprivations suffered by person i. The persons multidimensionally energy poor, defined by a cut-off $k > 0$ is applied across the column vector, and considers a person as energy poor if the weighted deprivation count C_i exceeds k. Therefore, $C_i (k)$ is set to zero when $C_i \leq k$ and equals C_i when $C_i > k$. Thus, $C (k)$ represent the censored vector of deprivation count and it is different from C in that it counts zero deprivation for those not identified as multidimensional energy poor. On the basis of this identification, Alkire and Foster (2007) define the following poverty measures: the headcount ratio of energy poverty; and the intensity of energy poverty. The headcount ratio of energy poverty is measured through the following equation:

$$HCR = (NEP/(NEP + NNEP))\ W_i \qquad \text{(Equation 1)}$$

Where, HCR is the headcount ratio from total households (incidence of energy poverty);

NEP is the number of energy poor;

NEP + NNEP is the number of energy poor and energy non-poor; and

W_i is the estimated weight

The energy poverty intensity was estimated using the following equation:

$$A = \sum_{i=1}^{n} Ci(k)/q \qquad \text{(Equation 2)}$$

Where, A is the intensity of energy poverty;

$\sum_{i=1}^{n} Ci(k)$ is the average of censored weighted deprivation;

Σci is the sum of weighted deprivation of person who suffers from energy poverty;

k is the multi-dimensional energy poverty line; and

q_i is the average un-weighted deprivation of energy poverty headcount.

MEPI is therefore calculated as:

$$MEPI = HCR * A \qquad \text{(Equation 3)}$$

Where, HCR is the incidence of energy poverty and A is the intensity of energy poverty.

The estimation of energy poverty depends on household energy choices, in particular, the extent of modern energy consumption. For this, it is necessary to analyse the patterns of energy used by the households.

6.5 Procedures for Data Analysis of Patterns of Household Energy Consumption

The four waves of the NIDS panel data was used to determined by the 'energy ladder' or 'energy stacking' models is a better description of energy consumption patterns of low-income households in South Africa. In order to track the energy transition of the low-income households, a balanced panel dataset was used for the analysis. According to Hsiao (2003), a panel is said to be balanced if it has the same time or periods, t = 1 … T, for each cross section observation. In this instance, a balanced panel dataset will contain all elements observed in all periods allowing an observation of the same household across the years of survey.

6.5.1 Technique of Analysis to Confirm Energy Ladder and Energy Stacking Models

The ordered logit model, also known as the proportional odds model, is a statistical technique that does take ordering into account and the odds ratio of the event is

independent of the category *j,* where *j* is the energy choice for cooking, heating, and lighting (Greene 2008). In addition, an ordinal logit regression considers the probability of that event and all others above it in the ordinal ranking. In other words, an ordinal logit regression is concerned with cumulative probabilities rather than probabilities for discrete categories (Agresti 2010). Previous studies that have used ordered logistic regression on examining household energy choice are not many as most studies preferred unordered multinomial logit regression. However, some examples of ordered logistic regression include Arthur *et al.* 2010 and Lee *et al.* 2015.

Households face choices between traditional, transitional and modern energy carriers for cooking, heating and lighting purposes and are assumed to maximise their utility by choosing one of the energy carriers as their main energy for the specific end-use. Following the approach of O'Connell (2005), there are (Y_i, $X_{1i} \dots X_{ki}$) for observations $i = 1, \dots, n$, where Y is a response variable with C ordered categories: $j = 1, \dots, C$, with probabilities, $P(Y = j) = \pi^{(j)}$ and $X_1 \dots X_k$ are k explanatory variables and observations Y_i are statistically independent of each other. The C – 1 cumulative probabilities:

$$\gamma^{(j)} = P(Y \leq j) = \pi^1 + \dots + \pi^{(j)} \text{ for } j = 1, \dots, C-1 \quad \text{(Equation 4)}$$

$$\gamma^{(j)} = P(Y \leq j) = \pi^2 + \dots + \pi^{(j)} \text{ for } j = 2, \dots, C-1 \quad \text{(Equation 5)}$$

$$\gamma^{(j)} = P(Y \leq j) = \pi^3 + \dots + \pi^{(j)} \text{ for } j = 3, \dots, C-1 \quad \text{(Equation 6)}$$

The following holds for $\gamma_i^{(j)} = P(Y_i \leq j)$ for each unit i and each category $j = 1, \dots, C-1$:

$$\text{Log } [\gamma_i^{(j)} / 1 - \gamma_i^{(j)}] = \log [P(Y_i \leq j) / P(Y_i > j] = \alpha^j - (\beta_1 X_{1i} + \dots + \beta_k X_{ki}) \quad \text{(Equation 7)}$$

Assume that the observed ordinal variable is Y_i is related to the latent variable according to the following scheme:

$$Y_i = k \text{ if } \mu_{k-1} \leq Y_i^* \leq \mu_k \text{ for } k = 1, \dots, K \quad \text{(Equation 8)}$$

The model for the cumulative probabilities is:

$$\Upsilon^{(j)} = P(Y \leq j) = \frac{\exp[\alpha j - (\beta 1 X 1 i + \ldots + \beta k X k i)]}{1 + \exp[\alpha j - (\beta 1 X 1 i + \ldots + \beta k X k i)]} \quad \text{(Equation 9)}$$

The intercept terms must be $\alpha^{(1)} < \alpha^{(2)} < \ldots < \alpha^{(C-1)}$, to guarantee that $\Upsilon^{(1)} < \Upsilon^{(2)} < \ldots < \Upsilon^{(C-1)}$. The parameters α, called thresholds are in increasing order ($\alpha^{(1)} < \alpha^{(2)} < \ldots < \alpha^{(C-1)}$), $\beta_1, \ldots, \beta_k$ are the same for each value of *j*. This is good for the parsimony of the model because it means that the effect of an explanatory variable on the ordinal response is described by one parameter (Agresti 2010; Grilli and Rampichini 2014).

In the case of three ordered categories, the equation simplifies to:

$$P(Y=1) = \frac{1}{1+\exp(\beta 1 X 1 i - k1)} \quad \text{(Equation 10)}$$

$$P(Y=2) = \frac{1}{1+\exp(\beta 1 X 1 i - k2)} - \frac{1}{1+\exp(\beta 1 X 1 i - k1)} \quad \text{(Equation 11)}$$

$$P(Y=3) = 1 - \frac{1}{1+\exp(\beta 1 X 1 i - k2)} \quad \text{(Equation 12)}$$

By maximum likelihood, estimates for α and β can be obtained. The likelihood function for each ith observation can be expressed as:

$$\ell_i(\alpha, \beta) = 1[Y_i = 0]\log[\Lambda(\alpha_1 - X_1\beta)] + [Y_i = 1]\log[\Lambda(\alpha_2 - X_1\beta) - \Lambda(\alpha_1 - X_1\beta)] + [Y_i = 1]\log[1 - \Lambda(\alpha_3 - X_1\beta)] \quad \text{(Equation 13)}$$

According to Greene (2008), the parameters for an ordered logit model can be hard to interpret. Therefore, reporting marginal effects after an ordered logistic regression is appropriate (Greene 2008; Long and Freese 2014). For this study, the marginal effects are calculated at the mean values in a covariate model showing how P(Y=1) changes as the variables changes from 0 to 1, holding all other variables at their means. The marginal effect approximates how much the dependent variable is expected to increase or decrease for a unit change in an explanatory variable: that is, the effect is presented on an additive scale (Buis 2010). The marginal effects are obtained by taking the partial derivatives of Equation 12, which is written as:

$\partial Pr(Y=0|X) / \partial X_k = -\beta_k \lambda(\alpha_1 - X\beta)$;

$\partial Pr(Y=j/X) / \partial X_k = \beta_k [\lambda(\alpha_{j-1} - X\beta) - \lambda(\alpha_3 - X\beta)]$, for $0<j<3$; and

$\partial Pr(Y=3/X) / \partial X_k = \beta_k \lambda(\alpha_3 - X\beta)$ (Equation 14)

The predicted probabilities are estimated as:

P (Y_ordinal = 'less preferred') = P (S+ u ≤ _cut1)

P (Y_ordinal = 'moderately preferred') = P (_cut1< S+ u ≤ _cut2)

P (Y_ordinal = 'most preferred') = P (_cut2< S+ u) (Equation 15)

In which the basic formula is written as:

$Pr(Y = j|X) = F(\hat{\boldsymbol{T}}_j - X_1\hat{\boldsymbol{\beta}}) - F(\hat{\boldsymbol{T}}_{j-1} - X_1\hat{\boldsymbol{\beta}})$ (Equation 16)

6.6 Procedures for Data Analysis of the Impact of FBE on Energy Consumption Patterns and Energy Poverty

The IES 2010/2011 data was used to analyse the impact of the FBE on household energy consumption patterns and energy poverty. Statistics South Africa monitors South African income and expenditure patterns at five-yearly intervals. The dataset for this analysis spans a large area, across gender, settlement (rurality), household size, population group, dwelling type, types of appliances used in the household and income deciles. Data analysis was done using the quantitative software package, STATA version 12. The analysis is restricted to low-income households who are assumed to qualify for receiving the FBE subsidy. It is important that low-income households are classified as households earning R0 – R18 000 per annum (IES 2011). Sample representative of low-income households, extracted from the IES 2010/2011 for the analysis, is 15 284. Households that are not in the low-income category but are receiving the FBE are excluded from the analysis. Analysis is done on weighted data so that the results obtained are representative of the entire population.

The analysis is presented in two parts with the first part consisting of an estimation of low-income households residing either in the urban or the rural areas and are with or without the FBE. The second part focusses on regression analysis which aims to determine the extent access to FBE increases the probability of low-income households owning an entertainment appliance and a food preservation appliance, when controlling for other variables in the model. A binary logistic regression analysis is an appropriate method of analysis because the dependent variable being investigated is a binary response option – either 'Yes' or 'No'. McCulloch and Rossi (1994) suggest that binary logistic regression is adopted when one aims to investigate a binary choice decision on a set of explanatory variables.

6.6.1 Model Specification: The Binary Logistic Regression Model

The binary logistic regression model was used to estimate the probability of a binary response based on one or more independent variables (Greene 2003; Long and Freese 2006). The dependent variable in a binary logistic regression is a dummy variable, coded 0 or 1. The form of the likelihood with a binary response is:

$Y_i = 1$ with probability π_i;

$Y_i = 0$ with probability $1- \pi_i$ (Equation 17)

Provided observed responses are independent, the likelihood is a product of π_i's and $1-\pi_i$'s. For each $Y_i=1$, the probability π_i appears in the product. Similarly, for each $Y_i = 0$, the probability $1- \pi_i$ appears in the product. In this study, the dependent variables, ownership of entertainment and food preserving appliances is a binary or dichotomous variable. An interpretation of the logit coefficient, especially for dummy independent variables, is the odds ratio (Cameron and Pravin 2009; Greene 2003). Odds ratio are in terms of the association between two variables and is estimated as the probability of the event divided by the probability of the non-event (Hosmer and Lemeshow 2000; Long and Freese 2006). Odds ratios that are greater than 1 indicate that the event is more likely to occur as the predictor increases while odds ratios that are less than 1 indicate that the event is less likely to occur as the predictor increases (Hosmer and Lemeshow 2000; Long and Freese 2006).

The binary logistic model can be expressed as:

$$E\,(Y_i|X_i) = \pi_i = e^{(\beta_0 + \beta_1 X_i)}/1 + e^{(\beta_0 + \beta_1 X_i)} \qquad \text{(Equation 18)}$$

Some peculiarities about this function, according to Long and Freese (2006), is that it is bounded between zero and one and as such eliminates the possibility of getting illogical predictions or proportions or probabilities. In addition, the sign associated with the coefficient, β_1 indicates the direction of the curve such as that a positive value indicates an increasing function while a negative value indicates a decreasing function.

6.7 Conclusion

In this chapter, a brief description of the research design, which is based on a positivist tradition, implying a quantitative research is discussed. The datasets used for the analysis are the National Income Dynamic Survey (NIDS) and Income Expenditure Survey (IES). The four waves of the NIDS was applied for the analysis of the multidimensional energy poverty and for the testing of the energy models. The quantitative software package, STATA version 12, was used for the processing of the data. The processing started with the identification of low-income households, which gave a total sample of 10 804 low-income households, which were then used for the descriptive statistics. The sorted low-income households were further screened for attrition before carrying out the econometric analysis. About 10 316 low-income households were then put forward for the econometric analysis. The demographic and socio-economic characteristics of the low-income households include racial group, gender, household size, rurality, age of the household head, and type of dwelling. Accessibility to electricity, energy choices for cooking, heating, and lighting are also examined.

The procedures and technique used for the investigation of energy poverty are explored. Following the work of Nussbaumer *et al.* (2011, 2012 and 2013), the MEPI was constructed for South African low-income households. The multidimensional energy poverty approach measures the proportion of the population that is multi-dimensionally energy poor (incidence) and the average intensity of their deprivation of energy (intensity). The first step was to check the correlation structure of the energy poverty indicators. The energy poverty indicators include electricity access, energy for cooking,

heating and lighting, ownerships of landline telephone, cell phone, radio, television, computer, fridge, and washing machine. Motivated by the concern with strong correlation by some of the energy poverty indicators and to avoid double counting, Multiple Correspondence Analysis (MCA) is employed. Based on the MCA statistical approach, the MEPI is constructed using six dimensions made up of six major indicators of energy deprivation. For a household to be identified as energy poor, the combination of those deprivation counts has to exceed a pre-defined threshold line called the energy poverty line. MEPI is therefore calculated by multiplying the incidence of energy poverty with the intensity of energy poverty.

For the testing of the energy models, the ordered logit model was chosen and the marginal effects, after an ordered logit regression, was considered. Household energy choice for three end-uses: cooking, heating, and lighting, were ranked into three ordered categories as most preferred, moderately preferred, and less preferred. Modern energy carriers are the 'most preferred', transitional energy carriers are the 'moderately preferred', while the traditional energy carriers are the 'less preferred'.

Finally, for the evaluation of the impact of FBE on low-income households in South Africa, the latest edition of the IES, which is the 2010/2011 version, was adopted for the analysis. The first part of the analysis shows the estimate of low-income households, residing in the urban or the rural areas with or without the FBE. A binary logistic regression model enables an examination of whether households accessing FBE find it of benefit or not.

The next chapter reveals the descriptive statistics of low-income households in South Africa and the multidimensional energy poverty index results.

Chapter 7

DESCRIPTIVE STATISTICS AND THE MULTIDIMENSIONAL ENERGY POVERTY RESULTS

7 Introduction

This Chapter presents the results of the analyses. The first section deals with the descriptive statistics which include the socio-economic and demographic characteristics of low-income households. The energy choices made by low-income households for cooking, heating, and lighting and in relation to rurality and dwelling types are described and are followed by the results of the correlation matrix and multiple correspondence analysis for selecting energy poverty indicators and the relevant allocation of weights. The result of the estimation of the multidimensional energy poverty line is highlighted and next is the multidimensional energy poverty index for low-income households in South Africa; this includes the relative contribution of the dimensions in measuring energy poverty. Sensitivity analysis to test the multidimensional energy poverty weights and the energy poverty line end the chapter.

7.1 Descriptive Statistics of Low-income Households in South Africa

Following the definition by the South African Bureau of Market Research (2011) and Statistics South Africa (2011), low-income households in South Africa are classified as those earning R0 – R18 000 per annum or households with an income below R1 500 per month. As a developing country, the effectiveness of electrification programmes, especially in the residential sector, should be assessed by improvement in the quality of life among those that were excluded during the apartheid era, mainly the low-income groups and/or Black African households. The NIDS panel data (waves 1 to 4), with a total sample of 10 804 low-income households was used for the descriptive statistics; these include the socio-economic and demographic characteristics of low-income households, which comprises the household head population group, gender and age.

Household size, dwelling type, geographical location, electricity access, energy choices for cooking, heating, and lighting of the low-income households were also examined.

7.1.1 Socio-economic and Demographic Characteristics of the Low-income Households

The socio-economic and demographic descriptive statistics provide a description of low-income households while energy variables highlight their energy choices. Descriptive statistics show the percentages in each group over the four waves. Table 7.1 presents the characteristics of South African low-income households with respect to their socio-economic and demographic variables between 2008 - 2014.

The table shows that most low-income households are Black African (89%). This is a not unexpected result because the incidence of poverty or energy poverty among Black African individuals was found to be the highest compared to other racial groups by Franks in 2014 and Ismail and Khembo in 2015. The Asian/Indian population group was found to have the smallest proportion of low-income households, at 0.35%.

The gender variable shows that nearly three-quarters of respondents (73%) were female, also not surprising as one of the strategies for collecting data in the NIDS is a face-to-face interview with the oldest woman in the household who may well head most households.

As indicated in Table 7.1, the age variable was grouped into seven categories. The age category suggests that the largest group of respondents are in the range of 40 – 49 years old (22%), an indication of the extent of low-income in the middle-age group. Households headed by those aged between 20 – 29 years, is 21%, which figure also shows a large representation of low-incomes in this age group. Households headed by youths of 14 – 19 years made up only 3%.

Table 7:1 Socio-economic and demographic characteristics of low-income households' in South Africa, 2008 - 2014

	Percentage of Low-income Households
Population Group (Respondent)	
Black African	89.29
Coloured	9.55
Asian/Indian	0.35
White	0.82
Gender (Respondent)	
Female	73.37
Male	26.63
Age (Respondent)	
14 – 19 years	3.02
20 – 29 years	20.73
30 – 39 years	19.93
40 – 49 years	21.71
50 – 59 years	19.90
60 – 69 years	10.71
70 years and above	4.00
Dwelling Type (Household)	
Modern dwelling	67.82
Traditional dwelling	19.24
Informal dwelling	12.93
Rurality	
Urban	43.83
Rural	56.17
Household Size (Number of persons)	
1 - 4	72.91
5 - 10	25.95
11 - 15	1.05
16 and above	0.05

The characteristics of the dwellings in which households live could provide an indication of the well-being of household members (Statistics South Africa 2013). A modern dwelling, defined by Statistics South Africa (2013), is a structure built according to approved plans with concrete blocks and consists of a house on a separate stand, a flat or apartment, a townhouse, a flatlet or a room in a backyard. Traditional dwellings are usually huts or rondavels etc. made of clay, mud, reeds or other locally available

materials (Statistics South Africa 2013). An informal dwelling is typically built with found materials, such as corrugated iron, cardboard, plastic, etc. and not approved by a local authority as a permanent dwelling (SEA 2014). The dwelling type shows that 68% of low-income households have modern dwellings while informal dwellings are the smallest category (13%). A modern type of dwelling could influence households' energy choices, especially a preference for modern energy sources.

The term rurality indicates that low-income households can be either rural or urban dwellers but as indicated in Table 7.1, low-income households are more likely to be rural dwellers (56%) rather than urban dwellers (44%). This agrees with other studies that have found that low-income households are often rural (Hills 2012; Mainali and Silveira 2013).

Five and more persons tend to live in larger households, according to Barnes *et al.* (2005) and Guta (2012). In 73% of low-income households live 1 – 4 persons. This is contrary to expectations as Rao and Reddy (2007), for example, mention that in developing countries larger households are often related to lower incomes. Only 27% of low-income households have large households of five and above.

7.1.2 Electricity Access in Low-income Households

One dimension of energy poverty in South Africa can be described in terms of households' access to electricity (Ismail 2015; Kohler *et al.* 2009). The number of households connected to the national electricity grid determine access to electricity. Low-income household access to electricity from 2008 to 2014 is presented in Table 7.2.

Table 7:2 Percentage of Low-income Households with Electricity Access, 2008 – 2014

	Year			
	2008	**2010**	**2012**	**2014**
Household with Electricity (%)	67.80	68.36	76.25	82.29
Household without Electricity (%)	32.20	31.64	23.75	17.71
Total (%)	100.00	100.00	100.00	100.00

The percentage of low-income households with electricity in South Africa has been increasing over the years, rising from 68% in 2008 to 82% in 2014. The proportion of low-income households with electricity increase the most from 2010 to 2012 (8%) and the smallest increase occurs between 2008 to 2010 which is less than 1%. The slow increase in the number of households with electricity in 2008 to 2010 could be the result of the electricity crisis that began in 2008 which lead to load shedding throughout the country and issues of affordability because of increases in the cost of electricity.

7.1.3 Residential Electricity Price in South Africa

Energy price is one of the factors that influence household behaviour in terms of energy choice(s) (Arthur *et al.* 2012; Van der Kroon *et al.* 2013). When the price of electricity increases, households, especially low-income households, may have to turn to cheaper and typically less efficient fuels.

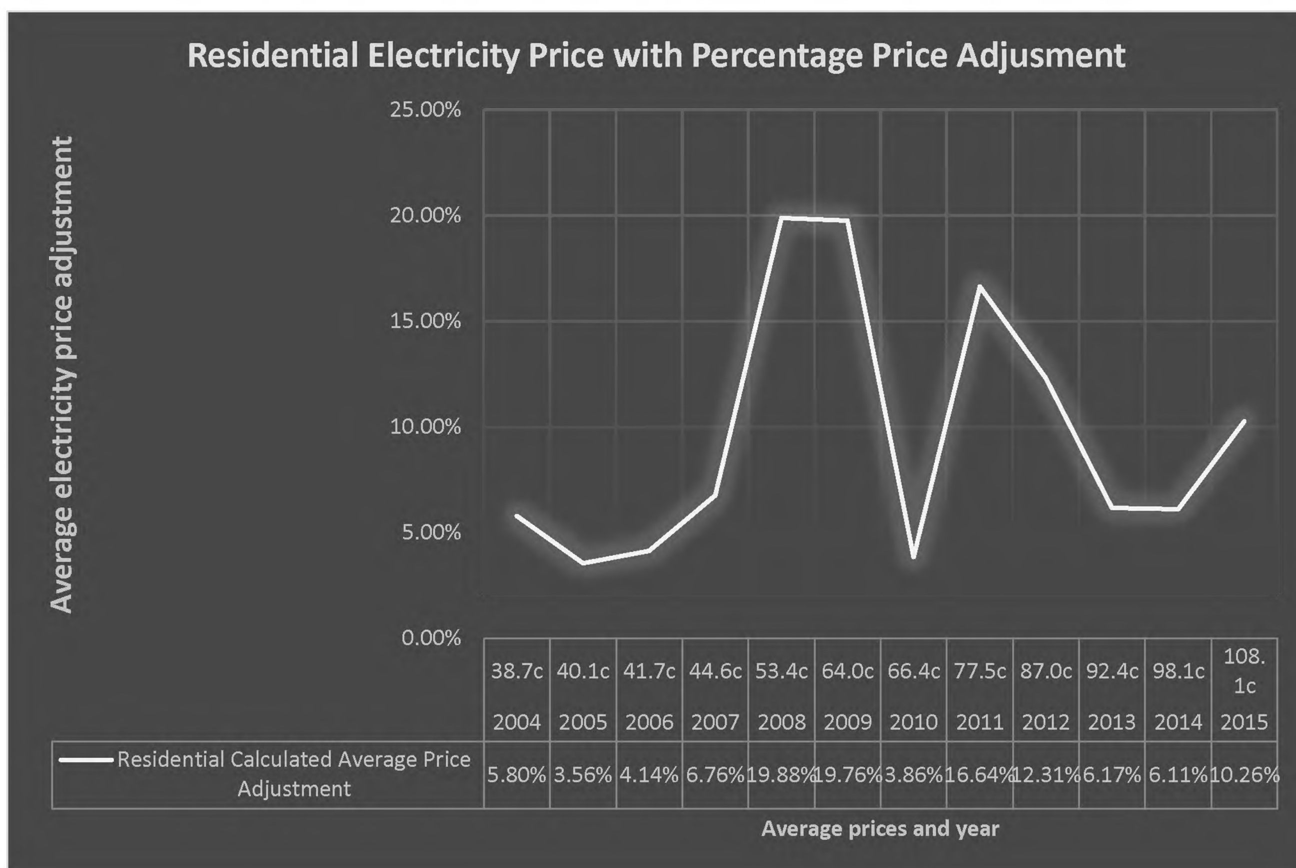


Figure 7:1 Residential Electricity Price

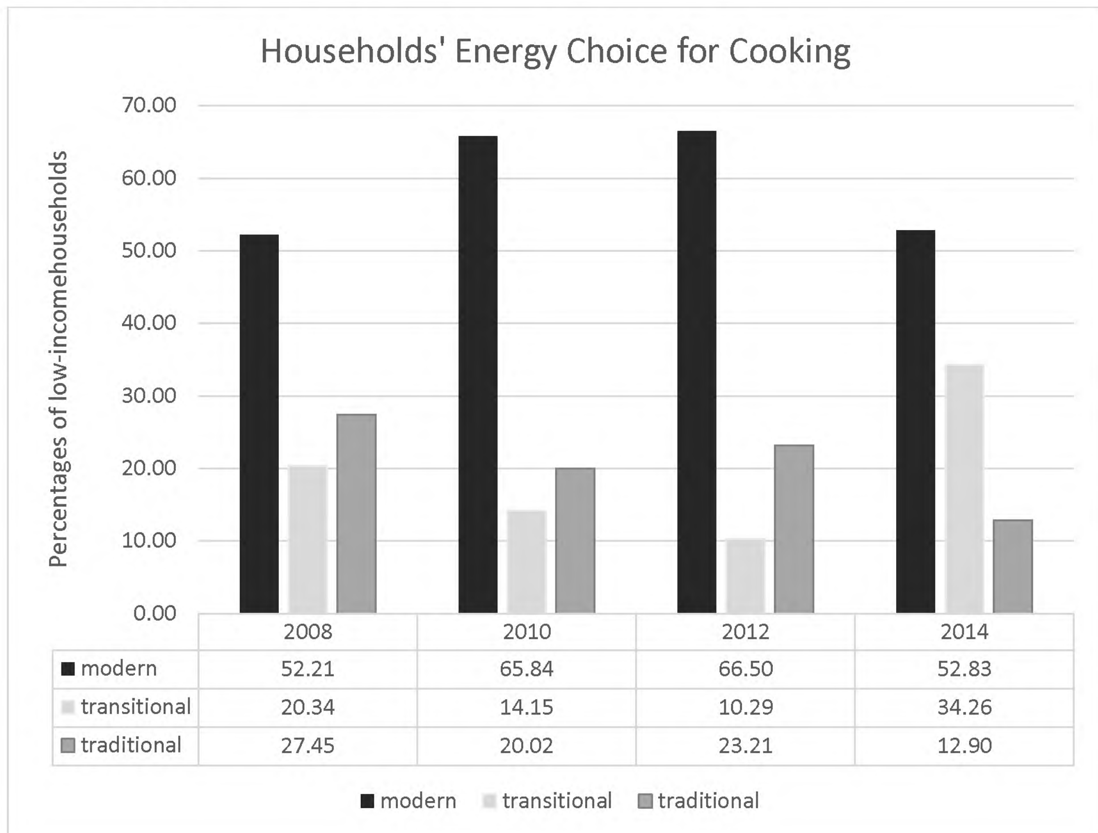
Source: Eskom 2014:3

The residential electricity price in South Africa from 2004 – 2015 is presented in Figure 7.1 showing that residential electricity price increases every year, with the first sharp rise coming in 2007/2008. The 2008 rise in price could have been due in part emergencies supply declared in that year (Trollip *et al.* 2014). Heltberg (2003) points out that low-income households are vulnerable to energy price fluctuations so the high cost of modern energy sources, such as electricity, are likely to constrain use among low-income households (Kwakwa *et al.* 2013).

7.1.4 Low-income Households' Energy Choice for Cooking

The energy sources that low-income households use in order to meet their basic needs are important. Cooking is among the most basic needs; indeed, it is the primary energy need and represents one of the most energy-intensive applications for households.

Energy choices for cooking by low-income households in South Africa from 2008 -2014 is presented in Figure 7.2.



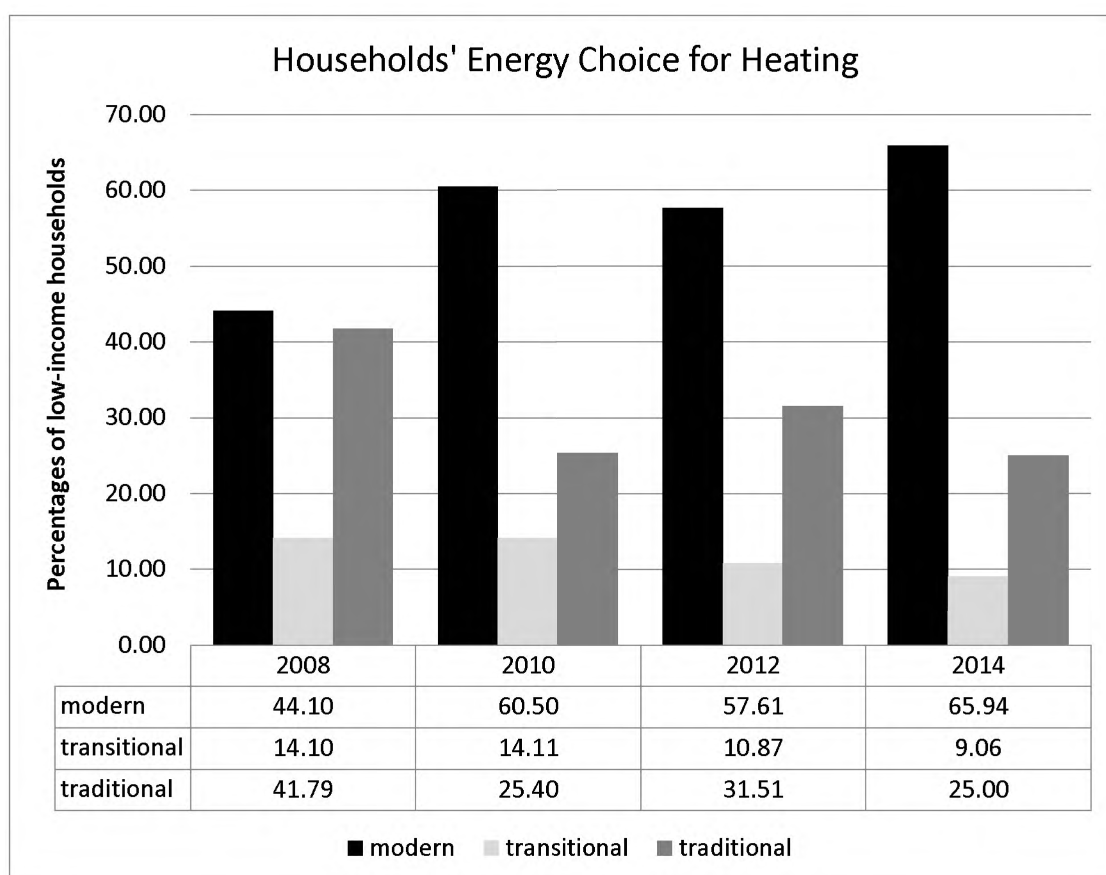
	2008	2010	2012	2014
modern	52.21	65.84	66.50	52.83
transitional	20.34	14.15	10.29	34.26
traditional	27.45	20.02	23.21	12.90

Figure 7:2 Households' Energy Choice for Cooking

With respect to this study, modern energy carriers include electricity from mains, LPG, electricity from generators and solar energy. Transitional energy carriers are comprised of paraffin and coal while traditional energy carriers include animal dung and wood. As illustrated in Figure 7.2, the use of modern energy for cooking has been predominant across the years. Wave 3, year 2012, has the highest percentage (67%) of low-income households using modern energy carriers. There is, however, a sharp increase in the use of transitional energy carrier, from 10% in 2012 to 34% in 2014. This could mean there is a substitution of modern energy for transitional energy because of an increase in the price of modern energy carriers forcing a change in energy choice. The use of transitional energy carriers for cooking in 2014 is the highest, at 34%, compared to the other waves. In 2014, traditional energy carriers are used in a small percentage of households (13%) as the main energy source to meet their cooking needs.

7.1.5 Low-income Households' Energy Choice for Heating

Apart from cooking, space heating is another household energy-intensive domestic need. The choices of energy for heating by low-income households is presented in Figure 7.3.



	2008	2010	2012	2014
modern	44.10	60.50	57.61	65.94
transitional	14.10	14.11	10.87	9.06
traditional	41.79	25.40	31.51	25.00

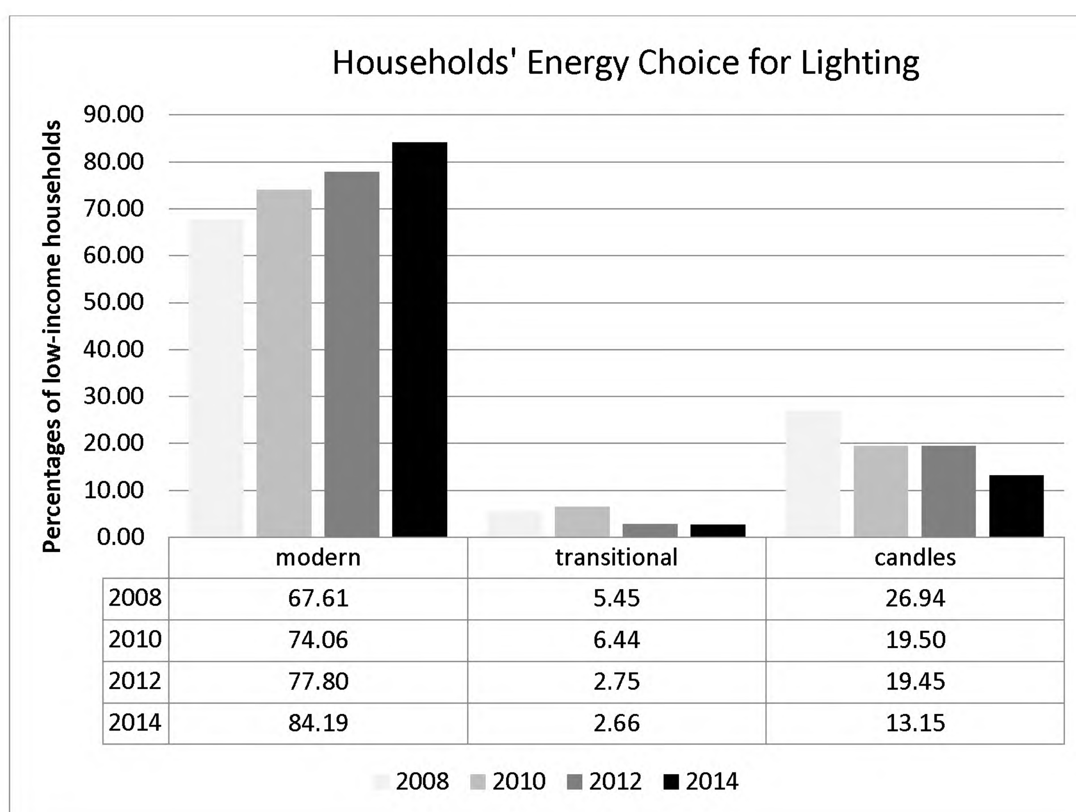
Figure 7:3 Households' Energy Choice for Heating

Modern energy carriers for space heating are the most common across the waves, with 2014 recording the highest proportion (66%) for low-income households. Also in 2014, households use fewer of the transitional energy carriers for space heating, in 9% of cases, compared to other waves. These trends suggest energy substitution strategies in which modern energy carriers become increasingly used for space heating. In 2008, more households (42%) used traditional energy carriers for space heating compared to in other years but the use of modern energy carriers for space heating in the same year is low (44%) compared to other years. The electricity crisis experienced in 2008 may

have encouraged low-income households to rely more on traditional energy carriers and less on modern energy carriers, even so, the use of transitional energy carriers for space heating appears to being phased out.

7.1.6 Low-income Households' Energy Choice for Lighting

Lighting is a fundamental human need irrespective of class, income, or gender; it provides great flexibility in time allocation through the day and evening and is powered by different energy sources (Bacon *et al.* 2010; Legros *et al.* 2009; Practical Action 2010). The findings regarding energy choices for lighting by low-income households in South Africa from 2008 – 2014 is presented in Figure 7.4.



	modern	transitional	candles
2008	67.61	5.45	26.94
2010	74.06	6.44	19.50
2012	77.80	2.75	19.45
2014	84.19	2.66	13.15

Figure 7:4 Households' Energy Choice for Lighting

The use of traditional energy carriers for lighting hardly features. The use of modern energy carriers for lighting being predominant across the four waves and increasingly so; by 2014 the largest percentage (84%) ever of households using this source. Possible explanations are that lighting uses relatively little electricity compared to those other

uses of electricity that consume more such as cooking or space heating; electric lamps and bulbs for lighting are relatively affordable for purchase and use (Rantlo and Fraser 2015).

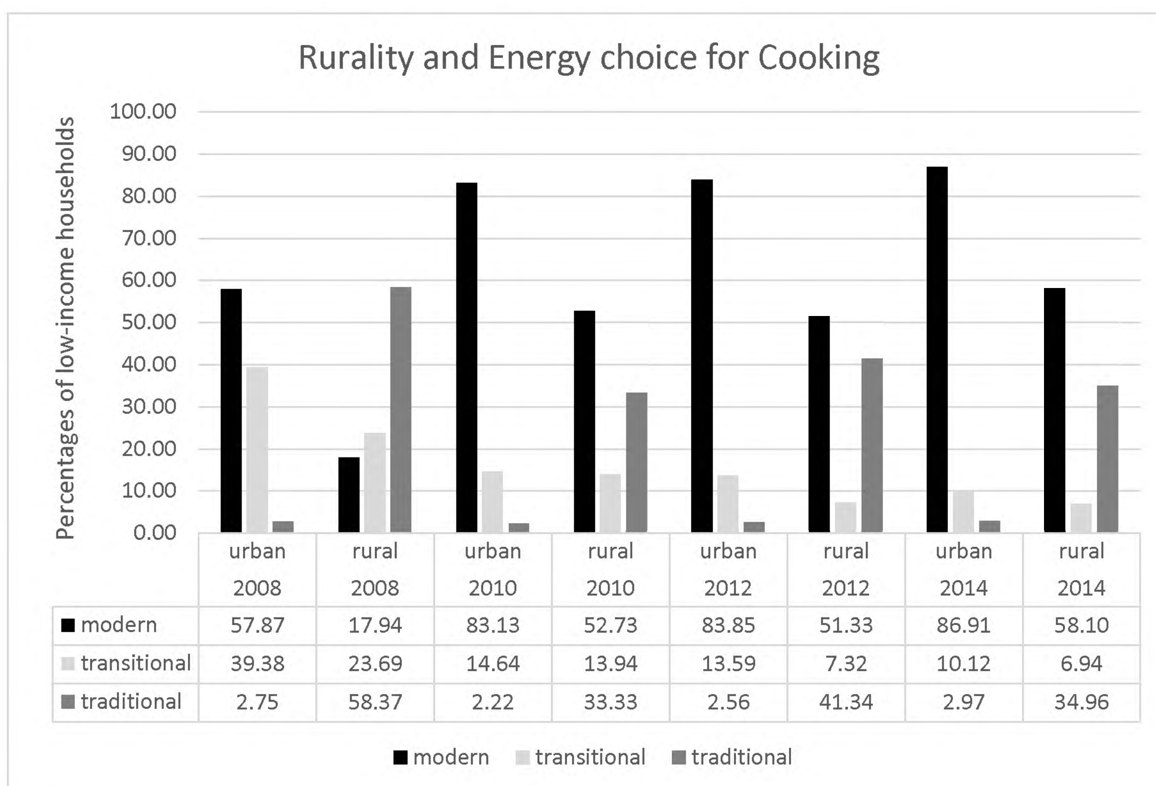
In previous studies, candles have been classified as a traditional energy carrier (e.g. Kemmler and Spreng 2007; Vermaak *et al.* 2014) or a transitional energy carrier (e.g. O'Keefe and Kirby 2014) and candles remain an important energy source for lighting other than electricity (the modern energy carrier) or kerosene (the transitional energy carrier) (Naidoo *et al.* 2013) among low-income households. As illustrated in Figure 7.4, the use of candles for lighting seems to being phased out as the number of households using candles for lighting declines. Transitional energy carriers for lighting are no longer often used by households.

7.2 Rurality and Energy Choice(s) Linkages

In addition to examining the energy choices of low-income households in South Africa, especially in domestic settings, an understanding of the differences in energy choice between rural and urban low-income households is necessary. The first basic domestic activity to be considered with respect to rurality is cooking.

7.2.1 Rurality and Energy Choice for Cooking

The choice of energy use for cooking by South African low-income households in both rural and urban areas from 2008 – 2014 is shown in Figure 7.5. Earlier literature has noted that households located in urban areas, and irrespective of their income status, are much more likely to adopt modern energy carrier than are households in rural areas with similar financial means (Lewis and Pattanayak 2012).



	urban 2008	rural 2008	urban 2010	rural 2010	urban 2012	rural 2012	urban 2014	rural 2014
modern	57.87	17.94	83.13	52.73	83.85	51.33	86.91	58.10
transitional	39.38	23.69	14.64	13.94	13.59	7.32	10.12	6.94
traditional	2.75	58.37	2.22	33.33	2.56	41.34	2.97	34.96

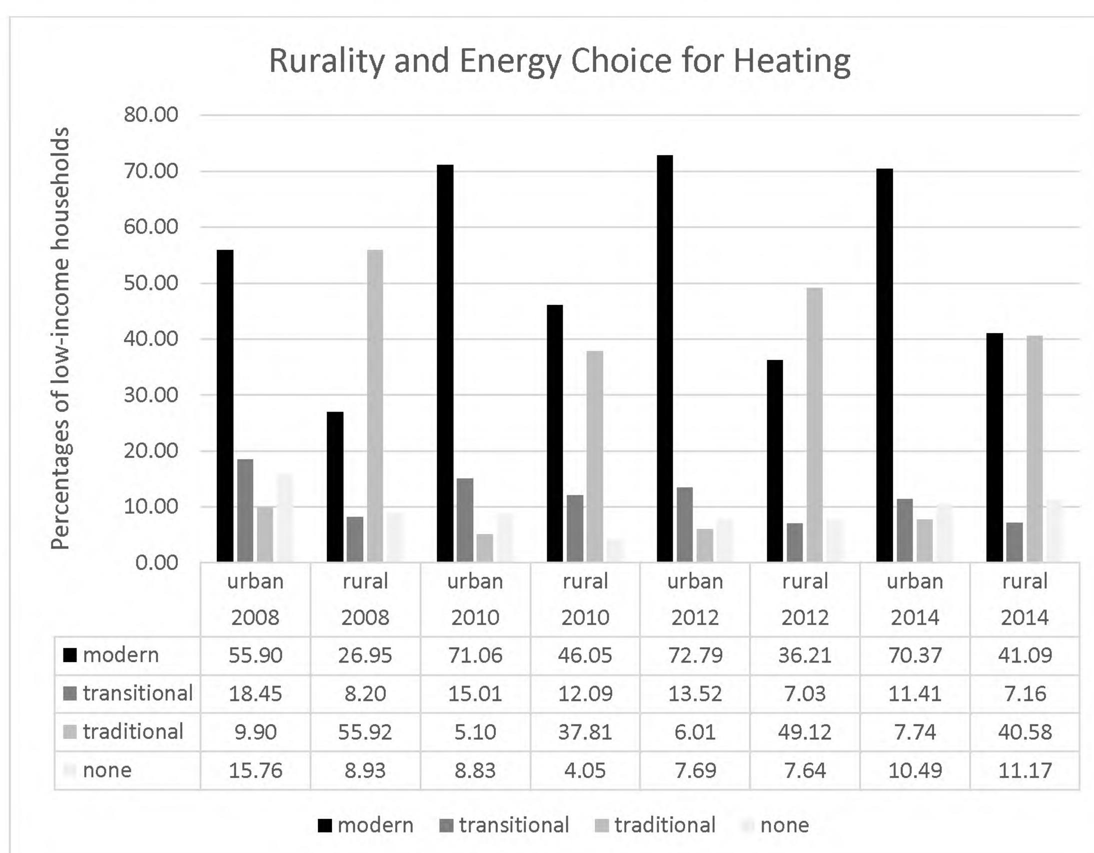
Figure 7:5 Rurality and Energy Choice for Cooking

The use of modern energy carriers for cooking by low-income households in both urban and rural areas is increasing across the years. It was expected that low-income rural dwellers would use more of the traditional or transitional energy sources due to their relatively low standard of living (Kwakwa *et al.* 2013; Matsika *et al.* 2012). But on the contrary, rural households used more modern energy carriers for cooking across the years. There was a sharp increase, from 18% to 53%, in the use of modern energy carriers by rural households from 2008 to 2010 eventhough rural households measure in 2008 used more traditional energy carriers (58%) for cooking. In rural low-income households, the use of modern energy carriers for cooking is gradually taking over from transitional or traditional energy carriers. The percentages of low-income rural households using traditional energy carriers across the years are higher when compared to low-income households in urban areas. Rural and urban households seldom use transitional energy carriers except for in 2008, when urban households used more transition energy carriers (39%). In 2014, both rural and urban households have the highest usage of modern energy carriers for cooking compared to other years, with

86.91% and 58.10% respectively. There is increasing use of modern energy carriers between the years 2008 – 2014.

7.2.2 Rurality and Energy Choice for Heating

Most households (about 60%) in South Africa, irrespective of geographic location, utilise an energy source for heating while the remaining 40% prefer to keep warm by using blankets and warm clothing (SEA 2014). The energy choice for space heating by rural and urban low-income households from 2008 – 2014 is presented in Figure 7.6.



	urban 2008	rural 2008	urban 2010	rural 2010	urban 2012	rural 2012	urban 2014	rural 2014
modern	55.90	26.95	71.06	46.05	72.79	36.21	70.37	41.09
transitional	18.45	8.20	15.01	12.09	13.52	7.03	11.41	7.16
traditional	9.90	55.92	5.10	37.81	6.01	49.12	7.74	40.58
none	15.76	8.93	8.83	4.05	7.69	7.64	10.49	11.17

Figure 7:6 Rurality and Energy Choice for Heating

Low-income households, both in urban and rural areas used more traditional energy carriers for heating in 2008 compared to other types of energy carriers. In 2014, however, rural low-income households were more inclined to use traditional and modern energy carriers. About 41%, and another 41%, used traditional and modern energy carriers respectively. In 2012, about of 73% urban low-income households used

more of modern energy carriers for their space heating. Furthermore, in 2010, low-income urban households (about 5%) rarely use traditional energy carriers for heating. The percentage of low-income urban households that use no energy source for their space heating is higher than their low-income household counterparts in rural areas except for in 2014. The use of transitional energy carriers by both rural and urban low-income households varies from 7% to 19%.

7.2.3 Rurality and Energy Choice for Lighting

It is common among South Africa households, either in the urban or rural areas, to use modern energy sources, specifically electricity, for lighting (Department of Energy 2012). The major reason is its comparative cheapness (Rantlo and Fraser 2015). Energy choices for lighting by rural and urban low-income households between 2008 and 2014 is presented in Figure 7.7.

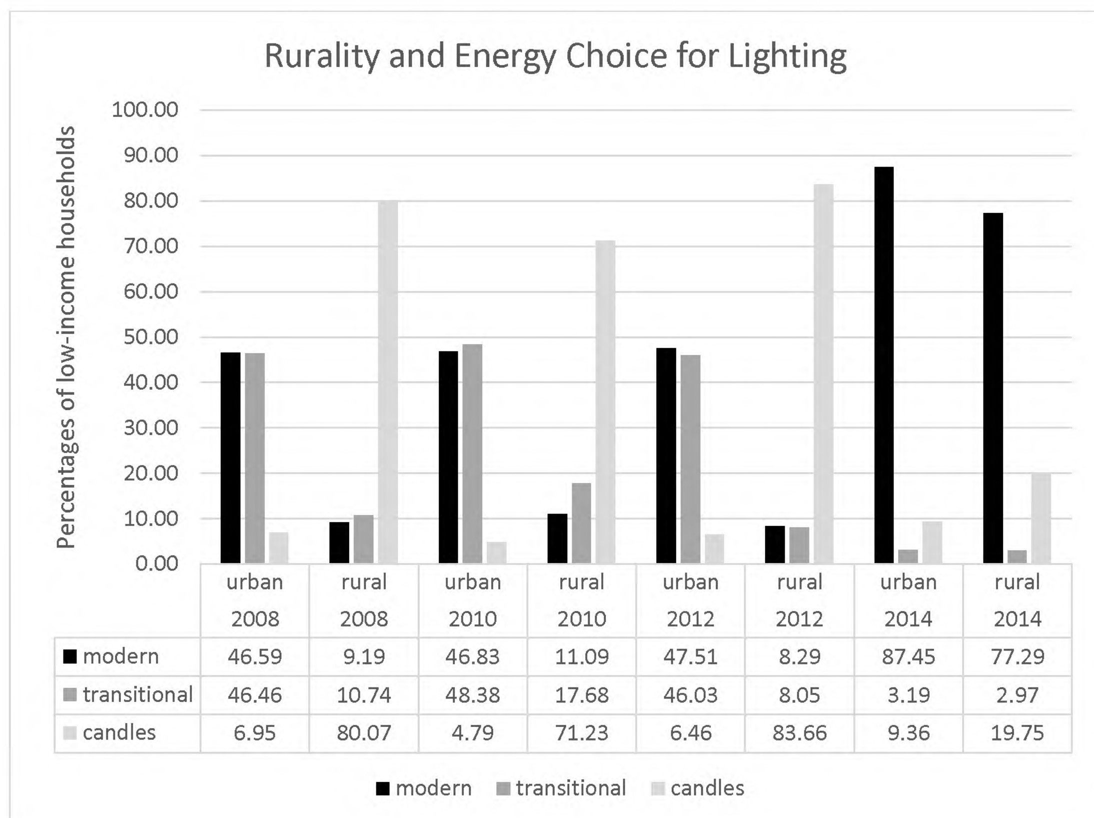


Figure 7:7 Rurality and Energy Choice for Lighting

Low-income households in urban areas mostly used modern and transitional energy carriers for their lighting from 2008 to 2012. In rural areas, low-income households used candles as the main source of lighting in 2008 – 2012. In 2014, the majority of low-income households in both rural areas (77%) and urban areas (88%) chose modern energy carriers for lighting. There is a large decrease in the use of candles in 2014 in rural areas. The proportion of low-income households using transitional energy carriers for lighting in 2008 – 2012 is substantially high in urban areas, which seems not to agree with previous studies claiming that urban households consume a smaller share of transitional energy sources than do rural households (Palit *et al.* 2014).

7.3 Dwelling Type and Energy Choice(s) Linkages

Energy choices are assumed to vary among different dwelling categories – modern, traditional, or informal dwelling types (Miah *et al.* 2011). As mentioned earlier, in South Africa modern dwelling is usually built with concrete blocks, traditional dwelling is made of clay, mud, reeds, or other locally available materials, and informal dwelling is typically built with found materials such as corrugated iron, cardboard and plastic, etc.

7.3.1 Dwelling Types and Energy Choice for Cooking

The type of dwelling, according to Suliman (2013), makes a difference to cooking energy adoption strategies. The energy choice for cooking based on the type of dwelling from 2008 to 2014 is presented in Figure 7.8.

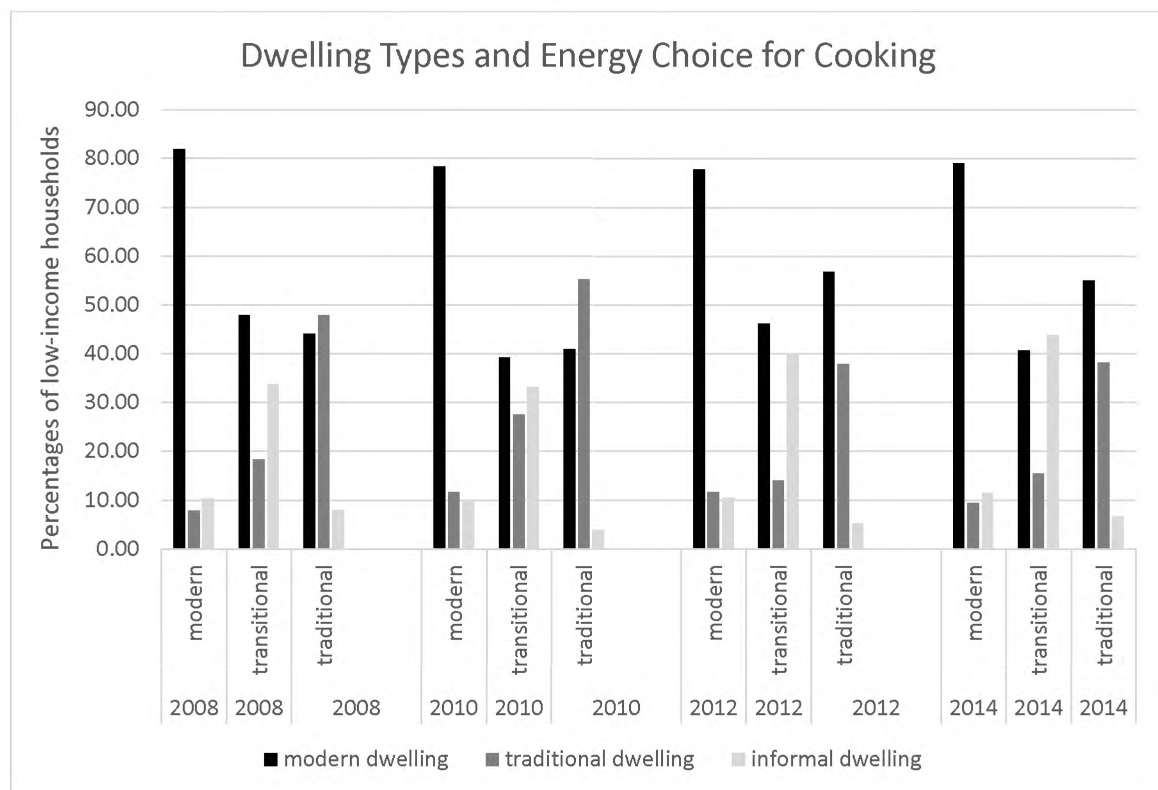


Figure 7:8 Dwelling Types and Energy Choice for Cooking

Low-income households living in a modern type of dwelling adopt modern energy carriers for their cooking: 2008 has the highest proportion (82%) of the low-income households; and traditional or informal dwellers seldom use modern energy carriers for cooking. This agrees with previous studies that modern dwelling encourages the use of modern energy sources (Baiyegunhi and Hassan 2014; Suliman 2013). It is clear that over the years, more traditional dwellers use traditional energy carriers for their cooking than do those in informal dwellings. Cooking indoors by informal dwellers might be problematic for them compared with traditional dwellers because of the nature of their building materials. The increase in the use of traditional energy carriers for cooking by modern dwellers is unexpected though it is difficult to explain why considering that modern houses usually have their kitchens indoors. Cultural preferences and habits for cooking could make some people and/or households continue to use traditional energy carriers with which to cook. Transitional energy carriers for cooking seem to maintain a consistent pattern in all the dwelling types across the years. The tendency is for modern dwellers to use it more compared with traditional or informal dwellers. The percentage

of informal dwellers using transitional energy carriers seems to be increasing across the years, with 2014 having the highest usage, of 44%.

7.3.2 Dwelling Types and Energy Choice for Heating

Comparison of dwelling types and heating is assumed to depend upon the nature of construction materials and the extents of their insulation (Maruejols *et al.* 2011). The energy choice for heating by low-income households between 2008 - 2014 with respect to the type of dwelling is presented in Figure 7.9.

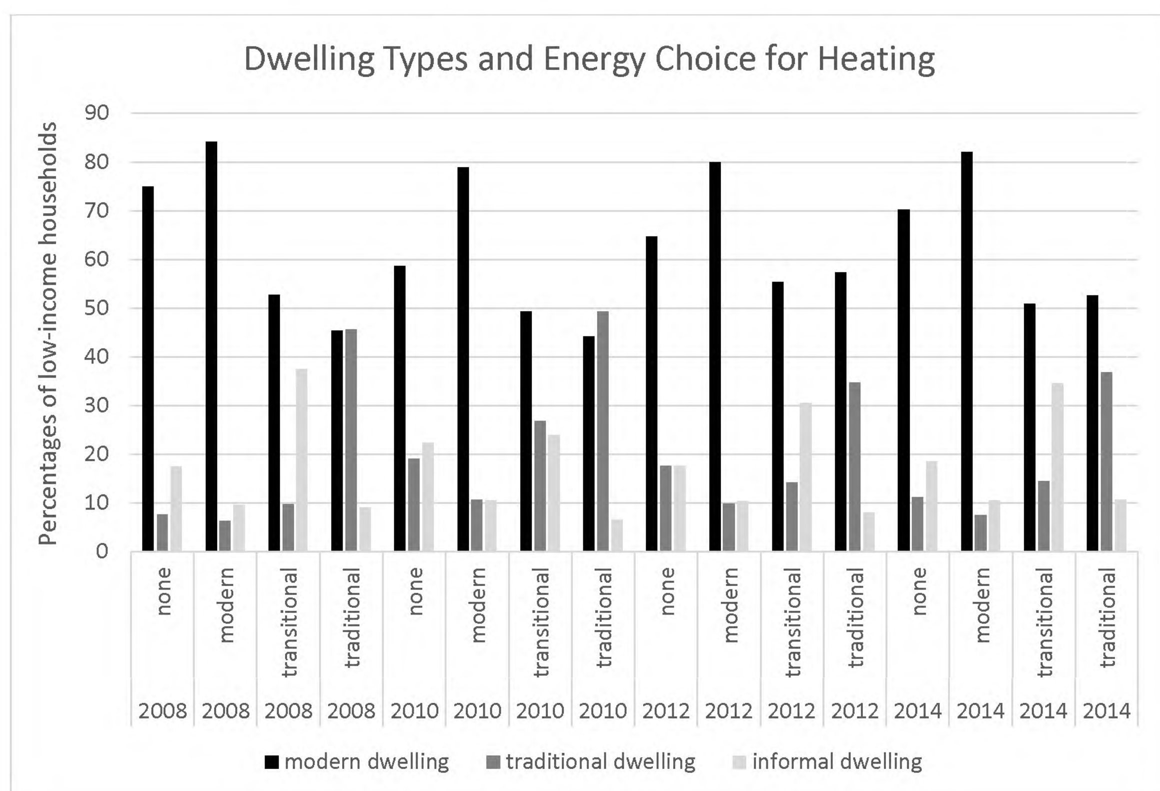


Figure 7:9 Dwelling Types and Energy Choice for Heating

Low-income households residing in a modern dwelling used modern energy carriers for their space heating across the years. This result is similar to energy choice for cooking by modern house-type dwellers. However, most modern dwellers do not use any energy carriers for their space heating and 2008 has the highest proportion (75%) of low-income households who do not heat their dwellings. This may imply that urban low-income households are not able to afford to use modern energy carriers for this

service is energy intensive. Traditional energy carriers are used by modern and traditional dwellers across the years, with 2012 having the highest modern dwellers (57%) and 2010 for traditional dwellers (49%). The use of transitional energy carriers for heating by modern dwellers is higher than in traditional or informal dwellers and informal dwellers seldom use traditional energy carriers for heating across the years.

7.3.3 Dwelling Types and Energy Choice for Lighting

The trend of modern dwellers using modern energy carriers for cooking or heating has been demonstrated. As in Figure 7.10, the trend in the energy choice for lighting by low-income households prevails.

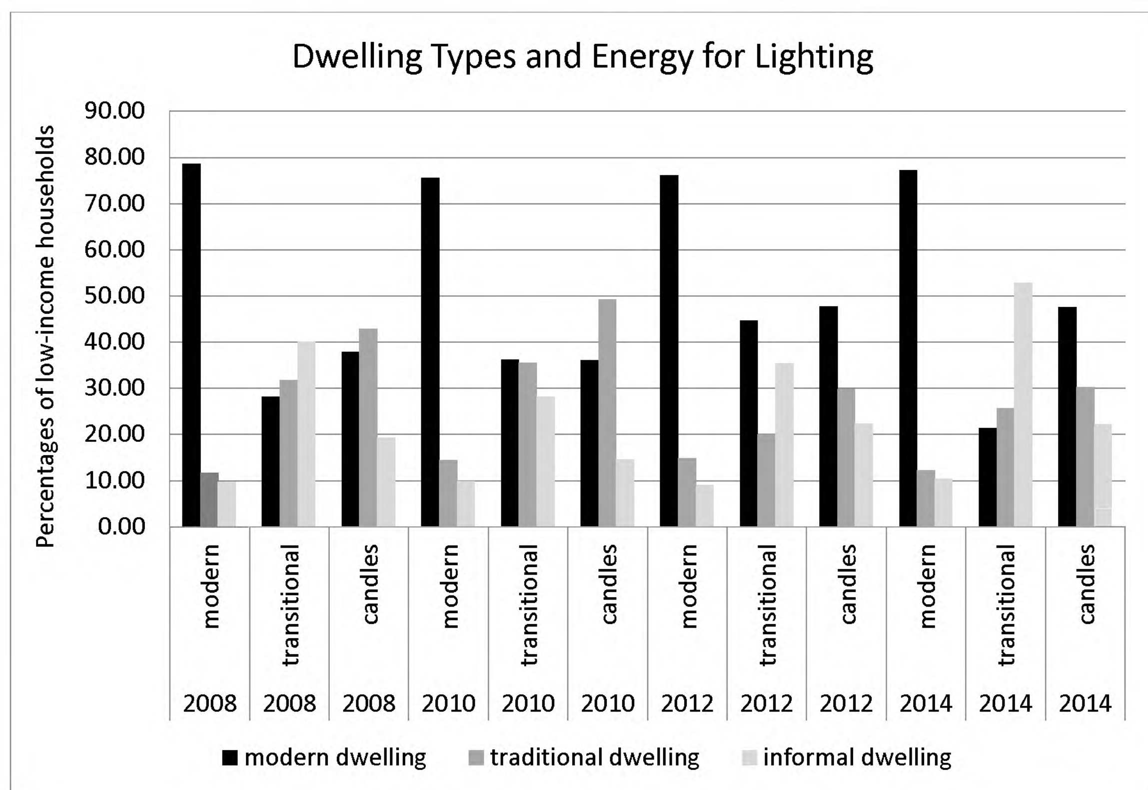


Figure 7:10 Dwelling Types and Energy Choice for Lighting

Low-income households living in a modern type of dwelling used modern energy carriers for their household lighting across the years. Transitional energy carriers are used the most by informal dwellers in both 2008 (40%) and 2014 (53%). In 2010 and 2012, however, the use of transitional energy carriers by informal dwellers was low. The use

of candles for lighting by traditional dwellers is higher in both 2008 (43%) and 2010 (49%) compared to 2012 (30%) and 2014 (30%). Modern dwellers, on the other hand, extend the use of candles for lighting in 2012 (48%) and 2014 (48%) compared to previous years. These changes could be attributed to frequent load shedding as electricity prices rose more steeply in and after 2008 and 2012. As expected, informal dwellers use less modern energy carriers for their lighting than do modern or traditional dwellers. Since the local authority does not approve informal dwellings as permanent dwellings, the use of a modern energy carrier, specifically electricity, in such dwellings could be difficult and expensive.

7.4 Conclusion

Knowing the socio-economic and demographic characteristics of low-income households in South Africa is central to this study. There is a higher representation of low-income households in the Black African community than other racial groups and most respondents are female because many households are run by women. A greater percentage of the household representatives are in the age range of 40 – 49 years, indicating the frequency of low-incomes in this group. Most low-income households reside in modern dwellings and live in the rural areas. Many low -income households consist of a small household size of one to four persons.

The section also highlights the energy provision pertaining to electricity access for low-income households. The number of households connected to the national electricity grid determines the extent of their access to electricity. Results demonstrated that 82% of low-income households in South Africa had been connected to the national electricity grid by 2014. The picture of electricity pricing shows that residential electricity price have been increasing every year since 2008.

The use of modern energy carriers for cooking by low-income households is increasingly predominant over the years for. The use of transitional energy carriers, as the main energy source for cooking needs in 2014, is the highest, while the use of traditional energy carriers is the lowest in the same year. Space heating is another energy-intensive domestic activity by households and modern energy carriers for space heating have been the largest across the years. Transitional energy carriers for space heating by low-

income households appears to be being phased out. A considerable percentage of households use traditional energy carriers for space heating. Lighting is also another activity that can be powered by different energy sources so that the use of traditional energy carriers for lighting hardly occurs. Modern energy carriers for lighting have predominanted over the years so that the use of Candles has gradually declined. Transitional energy carriers for lighting are not often used.

The section also reveals differences in energy choices between rural and urban low-income households. The use of modern energy carriers for cooking by low-income households in both urban and rural areas is increasing. Both rural and urban households seldom use transitional energy carriers for cooking. With respect to heating, low-income rural households used more traditional energy carriers for heating compared to other types of energy carriers. Low-income urban households, on the other hand, used more modern energy carriers and rarely use traditional energy carriers for space heating. The percentage of low-income urban households that use no energy source for space heating is higher compared to rural households. As for lighting, low-income households in urban areas use modern energy carriers for lighting, while those in the rural areas have used modern energy carriers only since 2014 before when low-income households in rural areas used candles as their main source of lighting for the years 2008-2012. Contrary to expectation, the proportion of low-income urban households using transitional energy carriers for lighting is higher than those in rural areas.

Energy choices are assumed to vary for the different dwelling categories of modern, traditional, or informal dwelling types. As expected, low-income households living in a modern type of dwelling adopt modern energy carriers for their cooking while traditional or informal dwellers rarely use modern energy carriers for cooking. The use of transitional energy carriers seems to be phasing out gradually in all dwelling types. Over the years, using traditional energy carriers for cooking by low-income households residing in traditional houses is higher compared to those residing in informal dwellings. When comparing dwelling types and their heating, it is assumed this depends on the nature of construction materials and the extent of insulation. Low-income households residing in a modern dwelling use modern energy carriers for their space heating but most modern dwellers do not have space heating. Traditional energy carriers are being

used more and more by modern and traditional dwellers and the use of transitional energy carriers for heating by modern dwellers is higher than traditional or informal dwellers. The trend of modern dwellers to use modern energy carriers for cooking or heating also applies to their lighting. Transitional energy carriers in all the dwelling types are seldom used for lighting in all the dwelling types. The use of candles for lighting by traditional dwellers is high in both 2008 and 2010 and high too for modern dwellers in 2012 and 2014. Informal dwellers use modern energy carriers for lighting more than they use transitional energy carriers or candles.

7.5 Multidimensional Energy Poverty Dimensions, Indicators, and Weights

Measuring energy poverty through the choice of energy poverty dimensions, indicators, and setting weights to different indicators of the dimensions may lead to different poverty levels across a population (Nussbaumer *et al.* 2012, 2013). The first step was to check the correlation structure of the energy poverty indicators which include electricity access, energy for cooking, heating, and lighting, ownerships of landline telephone, cell phone, radio, television, computer, fridge, and washing machine. The correlation coefficients for each pair of the indicators is given in Table 7.3. (see Appendix A for the full correlation results).

Table 7:3 Correlation Matrix of the Energy Poverty Indicators

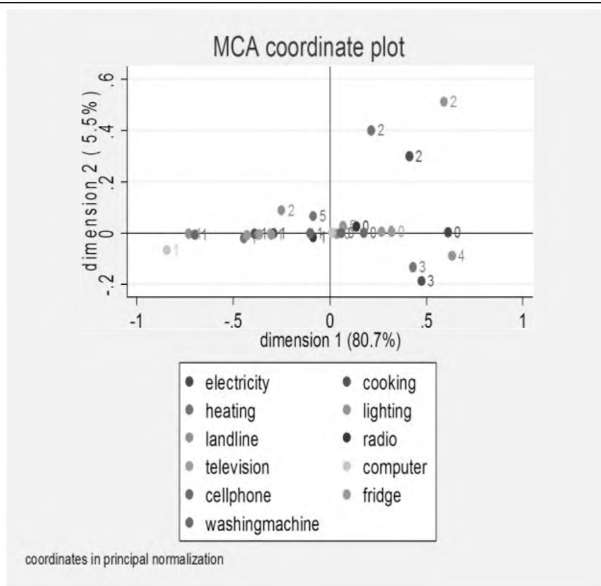
Energy Poverty Indicators	Year			
	2008	2010	2012	2014
Electricity access	cooking (-0.624) heating (-0.321) lighting (-0.866) television (0.450) fridge (0.423)	cooking (-0.553) heating (-0.354) lighting (-0.735) television (0.424) fridge (0.409)	cooking (-0.528) heating (-0.344) lighting (-0.854) television (0.452) fridge (0.418)	cooking (-0.501) lighting (-0.764) television (0.367) fridge (0.376)
Cooking	heating (0.414) lighting (0.639) television (-0.395) fridge (-0.381)	heating (0.555) lighting (0.666) television (-0.419) fridge (-0.376)	heating (0.510) lighting (0.590) television (-0.366) fridge (-0.350)	heating (0.429) lighting (0.537) television (-0.318)
Heating	lighting (0.346)	lighting (0.447)	lighting (0.393)	lighting (0.326)
Lighting	television (-0.439) fridge (-0.419)	television (-0.496) fridge (-0.439)	television (-0.485) fridge (-0.456)	television (0.385) fridge (-0.377)
Television	fridge (0.519)	cell phone (0.310) fridge (0.520)	fridge (0.524)	fridge (0.500)

Note: The figures in parentheses are the correlation coefficients and the minus sign indicates a negative or an inverse relationship.

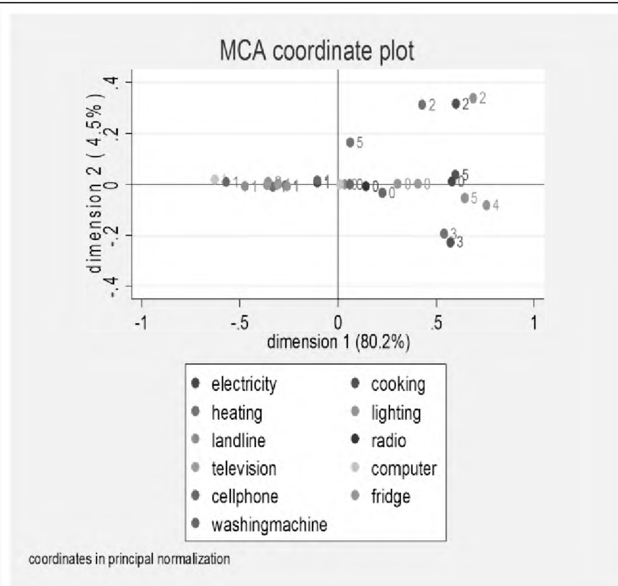
Following the rule of thumb by Spearman (1910) or Pearson (1920), a correlation coefficient between +/- .00 to .30 is considered a negligible correlation. Thus, a correlation coefficient above 0.30 indicates a weak/low to moderate correlation while a coefficient value above 0.50 indicates high/strong to very high/very strong correlation (Garcia 2011; Piovani 2008). For example, Table 7.3 shows that between 2008 and 2014, electricity access has a high correlation with cooking and lighting, a moderate correlation with television and fridge and a low correlation with heating. High correlations, according to Mukaka (2012) and Piovani (2008), denote that the two energy poverty indicators moved in a very similar manner over these years (2008 – 2014), implying that the two indicators are highly correlated with each other over time. According to (Mukaka) 2012 and Zou *et al.* (2003), on the other hand, if the correlation between the energy poverty indicators is low, then it is unlikely that they share common factors.

Motivated by the concern of a strong correlation by some of the energy poverty indicators and to avoid double counting, a statistical technique was employed to choose the energy poverty indicators and their corresponding weights. The variables

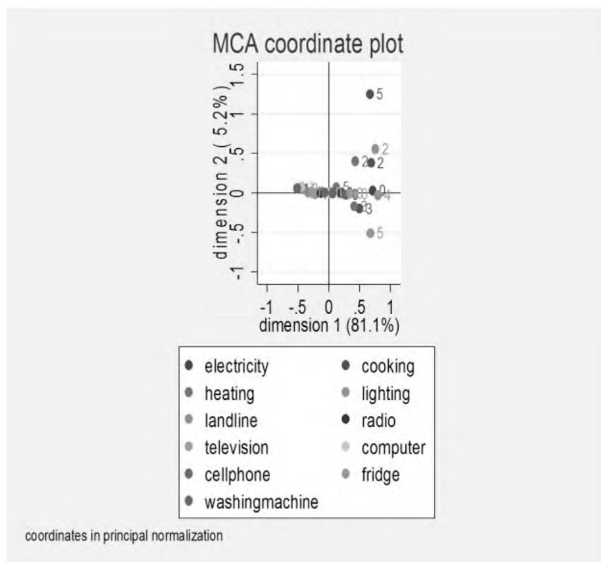
representing the multidimensional energy poverty indicators in the dataset used for this research are in ordinal/categorical forms whose modalities are coded as 0 or 1, for which Principal Component Analysis (PCA) is not *a priori* an optimal approach (Hoffman and Leeuw 1992; Njong and Ningaye 2008; Wardhana 2010). Multiple Correspondence Analysis (MCA) is more suited to discrete or categorical variables and therefore employed in choosing the energy poverty indicators and to assign weights in constructing the multidimensional energy poverty index. Based on the MCA statistical approach, weighting is in order to correct for the overlapping of information if two or more correlated indicators, and it is not a measure of importance of the associated indicator (Alkire and Foster 2011; Pinar *et al.* 2014). The MCA results are presented in Figure 7.11. (see Appendix B for the full MCA results).



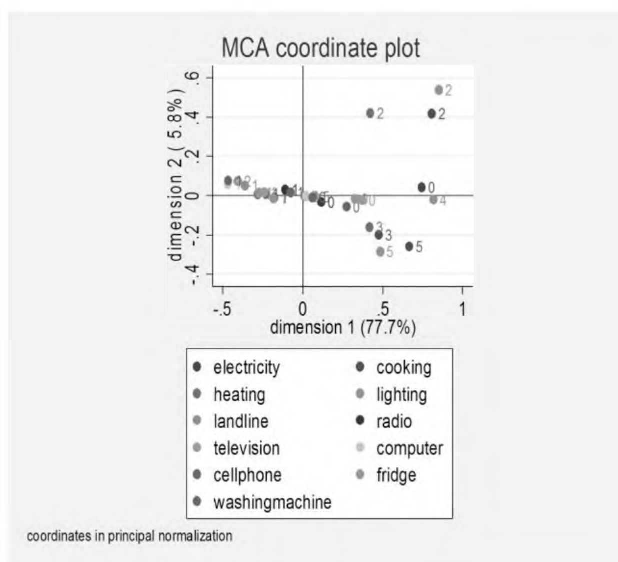
MCA coordinate plot 2008



MCA coordinate plot 2010



MCA coordinate plot 2012



MCA coordinate plot 2014

Figure 7:11 MCA coordinate plots for 2008-2014

A similar pattern is seen in all the plots with regard to the clustering of some variables. The variables that clustered together in the four waves include electricity (electricity access), landline, television, lighting, and computer. Some variables clustered together

in only two or three waves which include heating, radio, and fridge. The remaining variables (cooking, cell phone, and washing machine) either clustered together only in one wave or did not form a cluster at all. According to Greenacre (2006) and Le Roux and Rouanet (2010), the implication of the clustering together of variables in MCA coordinate plots is compatibility with others. In other words, the variables are related. Thus, grouping the variables into their dimensions, electricity and lighting are energy poverty indicators and belong to the dimension electricity access. Landline and computer belong to the dimension communication while television and radio are in the entertainment dimension. At this juncture, it is natural to consider the importance of each clustered indicator. In order to address this, the energy poverty indicators are reduced based on the correlation system from the MCA coordinate plots and the weights are also implicitly determined by considering the energy poverty indicators which have more effect in determining energy poverty. The final selection of the energy poverty indicators and their assigned weights is presented in Table 7.4.

Table 7:4 Selected Energy Poverty Indicators, Assigned Weights, and Deprivation Cut-off

Dimension	Indicator	Variable (weights in brackets)	Deprivation cut-off (poor if ...)
Lighting	Modern energy lighting	Type of energy source used for lighting (0.35)	Use transitional energy carriers or candles for lighting
Cooking	Modern cooking fuel	Type of cooking fuel (0.30)	Use transitional or traditional energy carriers for cooking
Services provided by means of household appliances	Basic appliance ownership	Has a fridge or washing machine (0.10)	A household is deprived if it does not have a fridge or washing machine
Entertainment/Education	Entertainment/Education appliance ownership	Has a radio (0.10)	A household is deprived if it does not have a radio
Communication	Telecommunication means	Has a cell phone (0.10)	A household is deprived if it does not have a cell phone
Space Heating	Modern heating fuel	Type of heating fuel (0.05)	Use transitional or traditional energy carriers for heating

The highest relative weights are given to those indicators that are deemed to be more important. In this study, the choice of allocation of a higher weight is skewed in favour of lighting (0.35). Lighting is a fundamental human need irrespective of class, income, or gender (Legros *et al.* 2009; Practical Action 2010). Previous studies (Bekele *et al.* 2015; Edoumiekumo *et al.* 2013; Nussbaumer *et al.* 2013) assigned a higher weight to the cooking dimension based on the evidence that cooking is a dominant energy service (Pachauri *et al.* 2004). However, cultural preferences and habits for cooking could force people/households to continue to cook with traditional or transitional energy sources even when they can afford to use modern energy sources. Lighting, on the other hand, takes only a small share of energy consumption and so serves to illustrate the joint relationship between income and energy. The dimension of cooking therefore takes the next highest weight of 0.30. Basic appliance ownership (having a fridge or washing machine, 0.10), entertainment/education appliance ownership (having a radio, 0.10) and telecommunication means (having a cell phone, 0.10) have the next highest weights. According to Bekele *et al*. (2015) and Cecelski (2003), the ability to own and use a fridge, radio, or cell phone is a basic need for the acquisition of a sense of belonging to the mainstream of development. The same may be said of several other household appliances of convenience such as a washing machine as it reduces labour intensity for household chores and allows people to redirect the time saved towards other activities for self-improvement or economic advancement. Space heating takes the least weight (0.05), being an energy service; people/households could decide not to heat their dwellings as they prefer to keep warm by using blankets and warm clothing.

It is important that the energy indicators that clustered together (from the MCA coordinate plots) in the four waves were not considered; these include electricity (electricity access), landline, television, and computer. Nevertheless, each of these indicators has a valid proxy. For example, electricity access being a proxy for lighting, radio being a proxy for television in the entertainment/education dimension, cell phone being a proxy for landline and computer in the telecommunication dimension. Consequently, all these energy services are contingent on electricity access so that not considering electricity access avoids double counting.

Since the multidimensional nature of energy poverty should be reflected in the essential household energy services, the choice of the six indicators of energy deprivation is assumed to capture this motive.

7.6 Empirical Specification of the Energy Poverty Line

The choice of the energy poverty line, k, is crucial to the extent that it determines the conclusions for energy poverty comparisons (Barnes *et al.* 2010; Statistics South Africa 2015; Wardhana 2010). There is no apparent non-arbitrary level to set the energy poverty line. In a money-metric case, poverty lines are often derived from the food price required to meet caloric intake or from the costs of basic goods (Statistics South Africa 2015; Vermaak *et al.* 2014). Statistics South Africa (2015) employed the cost-of-basic-needs-approach, to produce three poverty lines. These poverty lines include the food poverty line (FPL), the lower bound poverty line (LBPL), and the upper bound poverty line (UBPL). The FBL is the food component while the LBPL and UBPL include a non-food component (Bhorat *et al.* 2012; Statistics South Africa 2015). The FBL is anchored on a computation of the food basket that enables households to meet the food-energy intake requirement of 2 100 kilocalories per person per day (Bhorat *et al.* 2012; Statistics South Africa 2015). The computation of allowance for consumption of non-food basic necessities determine the LBPL and UBPL (Bhorat *et al.* 2012; Statistics South Africa 2015).

According to the South African Department of Energy, a household is deemed energy-poor if it spends 10% of its income on domestic energy needs (Department of Energy, DoE 2009, 2010). There is, however, no official energy poverty line for South Africa (Bhorat *et al.* 2012; Oosthuizen 2008), which means that policy makers, researchers, and institutions utilise a range of unofficial poverty lines to measure the incidence and severity of energy poverty in South Africa. Therefore, in this study, the energy poverty line is estimated by own calculations by multiplying the LBPL and UBPL (being a non-food component) values for 2014 by the average household size (3.8 people), as recorded in the 2010/2011 Income and Expenditure Survey (Bhorat *et al.* 2012; Statistic South Africa 2012). The resulting values are added together and estimated as a percentage of total number of households. This approach is similar to the method used

in the estimation of poverty line (not energy) by Bhorat *et al.* (2012) and Statistic South Africa (2015). The estimation of the energy poverty line is presented in Table 7.5.

Table 7:5 Estimation of Energy Poverty Line for South Africa

	Per Capita Poverty Line 2013 Rand Value	**Household Poverty Line Based on Average Household Size of 3.8**	
Lower Bound Poverty Line, LBPL (2014)	R544	R2 067.2	
Upper Bound Poverty Line, UBPL 2014)	R753	R2 861.4	
Total	R1 297	R4 928.6	
Total Number of Households (2013)			15,107
Share of Household Poverty Line			32.62%

Source: Own calculations; Statistics South Africa 2014, 2015.

As illustrated in Table 7.5, the multidimensional energy poverty line, k, is therefore 32.67% approximately 33 percent (k = 0.33).

A household is therefore energy poor if it is deprived of more than 33 percent of the indicators mentioned earlier. Hence, a household whose sum of weighted deprivation is greater than or equal to 0.33 is categorised as energy poor and a household whose sum of weighted deprivation is less than 0.33 is energy non-poor. Both the weights and multidimensional cut-off are somewhat arbitrary. The robustness of these parameters is tested in the sensitivity analysis presented in the latter part of this chapter.

7.7 Results of Multidimensional Energy Poverty for South African Low-income Households

The multidimensional energy poverty index (MEPI) measures the incidence of energy poverty, which is the proportion of the population that is multidimensionally energy poor and the average intensity of their deprivation of energy (Bekele *et al.* 2015; Nussbaumer *et al.* 2011). According to Nussbaumer *et al.* (2013), an experience of acute degree of energy poverty is when MEPI exceeds 0.7 and a low degree when the MEPI is less than 0.3. An MEPI greater than 0.3 but less than 0.7 indicates moderate energy

poverty (Nussbaumer *et al.* 2013). For a comparison, the MEPI results are outlined and are based on the rurality (urban or rural) of low-income households across the four waves. The inferences at any particular point in time (cross-sectional results) of multidimensional energy poverty is presented in Table 7.6.

Table 7:6 Cross-sectional Analysis of MEPI (2008-2014): Urban Low-income vs Rural Low-income

	2008		2010		2012		2014	
	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural
Intensity of energy poverty, A	0.381	0.619	0.374	0.620	0.409	0.591	0.408	0.592
Adjusted multidimensional headcount, M0	0.996	0.993	0.977	0.991	0.999	1.000	0.999	1.000
MEPI (HCR *A)	0.379	0.615	0.365	0.614	0.409	0.591	0.408	0.592

Alkire and Foster (2007) MDP Indices
Group Variable: Rurality
Note: Adjusted Multidimensional Headcount M0 = HCR = incidence of energy poverty

The low-income rural households are energy deprived with respect to energy services compared to those in urban areas as their average intensity value ranges from 0.59 to 0.62. In this instance, low-income households living in rural areas have a higher percentage of energy deprivation than the percentage among those living in urban areas for each year of analysis. While, however, the percentages of low-income households in rural areas that are energy deprived started reducing after 2010, the percentages for urban areas increased after 2010. This is contrary to expectations because urban populations have access to higher quality energy services than do rural populations (Khandker *et al.* 2012; Miah *et al.* 2011). Notwithstanding, this could imply that low-income rural households are benefitting more from energy programme interventions such as subsidies for electricity and LPG than are low-income households in the urban areas are. This result is a confirmation of there being continued progress in the reduction of energy poverty for rural populations. The results also confirms that there is increasing energy poverty in urban areas.

Taken over the years, the MEPI results for low-income urban and rural households varies between 0.37 and 0.62 indicating that low-income households in both urban and rural areas are in a state of moderate energy poverty but at different levels. The moderate state of energy poverty could imply that energy poverty among low-income populations is not as was anticipated if considering the energy programmes and policies targeted towards low-income households in South Africa.

A panel analysis of MEPI for urban and rural low-income households is presented below.

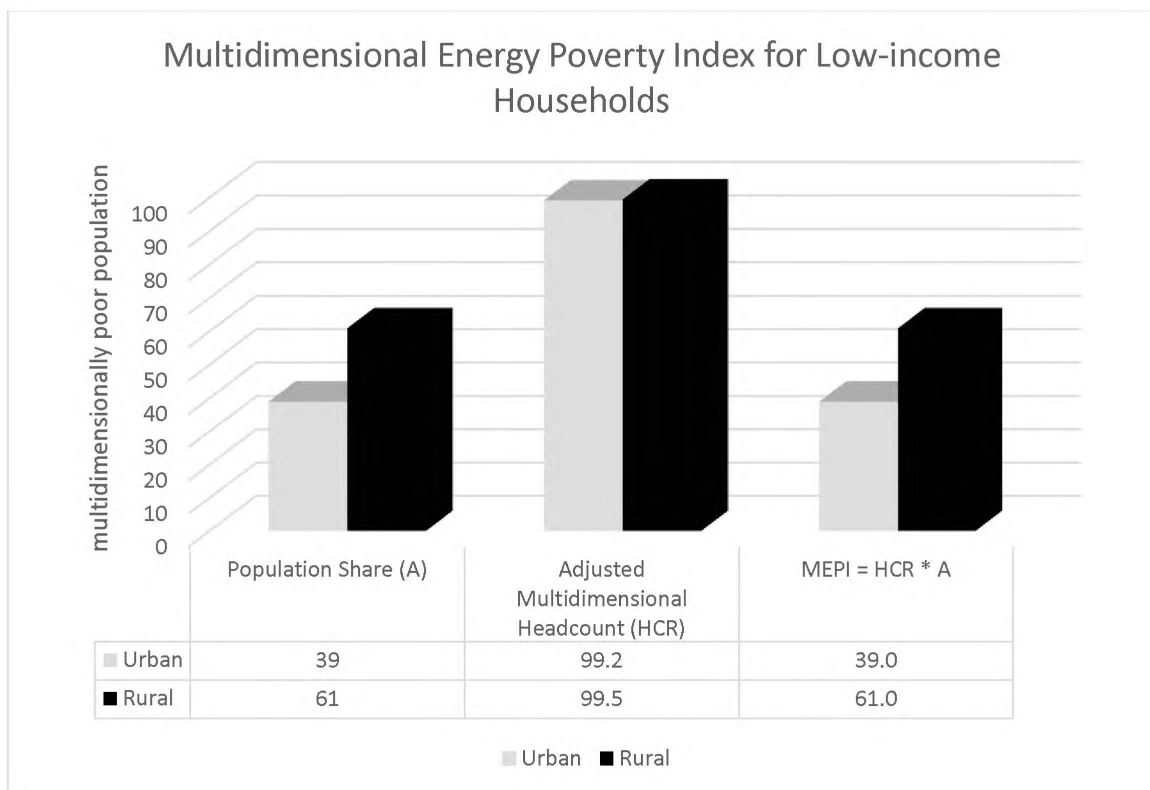


Figure 7:12 MEPI for low-income households

Figure 7.12 shows that among low-income households in urban and rural areas, 39% and 61% respectively are multidimensional energy poor. The result validates the cross-sectional analysis of MEPI.

A study of energy poverty at the level of energy services or dimensions shows the extent to which how households are energy poor and also could determine where policy interventions should be directed. This information can be used for targeting each

dimension if one wants to reduce energy poverty for low-income households in South Africa. The dimensional deprivation reveals that any attempts to solve the problem of energy poverty for low-income households should target each dimension with varying degrees of emphasis. The cross-sectional results of dimension-wise breakdown of energy poverty for 2008-2014 is presented in Table 7.7.

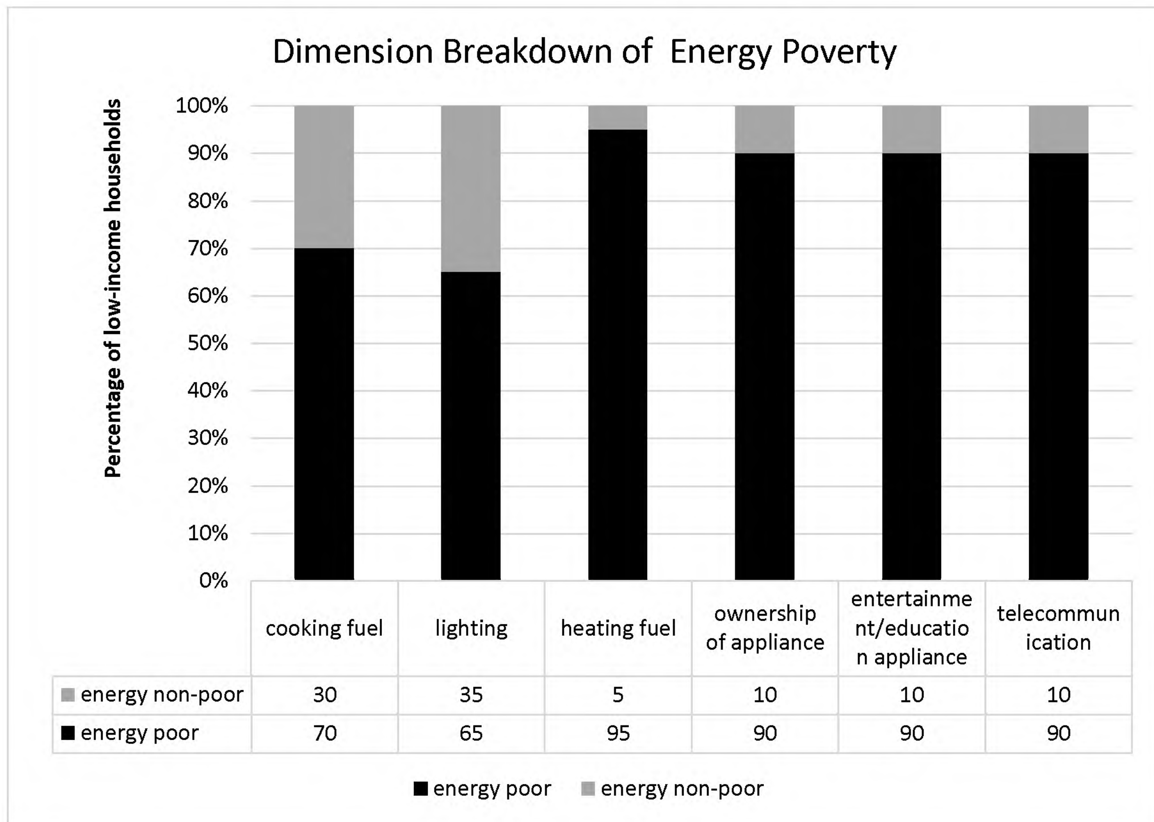
Table 7:7 The Relative Contribution of Dimensions to the Alkire and Foster (2007)

	Year			
Dimensions	2008	2010	2012	2014
Cooking	30.00	30.29	30.00	30.00
Heating	4.94	5.05	5.00	4.99
Lighting	35.00	35.36	35.00	34.99
Ownership of Appliance	10.02	9.77	10.00	10.01
Entertainment/Education Appliance	10.02	9.77	10.00	10.00
Communication	10.01	9.77	10.00	10.01

Note: The figures are in percentage

Low-income households residing either in urban or rural areas are energy non-poor mostly in heating fuel, across the years (4 – 5%). Households are least energy non-poor in lighting dimension across the years (35%) while the cooking dimension follows next (30%). For the rest of the dimensions, households maintain a consistent pattern across the years although 2010 has the least percentage of energy non-poor for each of these dimensions (10%).

The panel result of the contribution of the dimensions in multidimensional energy poverty is presented in Figure 7.13. The panel result shows the percentage of energy poor and energy non-poor.



	cooking fuel	lighting	heating fuel	ownership of appliance	entertainment/education appliance	telecommunication
energy non-poor	30	35	5	10	10	10
energy poor	70	65	95	90	90	90

Figure 7:13 Dimension-wise Breakdown of MEPI Headcount for Overall Low-income

Low-income households living either in the urban or rural areas are mostly deprived in the heating fuel dimension (95%) and least deprived in lighting (65%). Further results show that 90% of the low-income households in both urban and rural areas are deprived in terms of home appliances, entertainment/education appliance, and telecommunication. These results therefore depict that low-income households in either urban or rural areas are energy poor mostly in terms of heating fuel, ownership of appliance, entertainment/education appliance, and telecommunication.

7.8 Sensitivity Analysis

7.8.1 Testing the Multidimensional Energy Poverty Line, k

This sensitivity analysis tests the multidimensional energy poverty cut-off. The initial cut-off is 0.33 as mentioned above. This cut-off is now changed to 0.2, 0.3, 0.4, and 0.5. The new cut-offs represent the other possible weighted sum of deprivations that the household can achieve. The weights take the original value that was assigned to

construct the MEPI, that is the dimension of lighting having the highest weight of 0.35 and the dimension of cooking has 0.30. The dimensions of ownership of home appliance, entertainment/education, and telecommunication takes equal weight at 0.10. Lastly, the heating dimension takes the value of 0.05. Table 7.10 shows the changes of each state when changing the multidimensional energy poverty cut-off line.

Table 7:8 A Panel Result of Energy Poverty Intensity, Incidence, and MEPI for Different Values of k, Urban, and Rural Areas

	K= 0.2		K= 0.3		K= 0.4		K= 0.5	
	Urban	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
Intensity of energy poverty, A	0.390	0.608	0.390	0.608	0.390	0.608	0.390	0.608
Adjusted multidimensional headcount, M0	0.992	0.996	0.992	0.996	0.992	0.995	0.992	0.995
MEPI (HCR* A)	0.387	0.606	0.387	0.606	0.387	0.605	0.387	0.605

Alkire and Foster (2007) MDP Indices
Group Variable: Rurality
Note: Adjusted Multidimensional Headcount M0 = HCR = incidence of energy poverty

7.9 Conclusion

In the estimation of the MEPI, the correlation structure of the energy poverty indicators are necessary. Following the rule of thumb by Spearman (1910) and Pearson (1920), electricity access has a very high correlation with cooking and lighting while cooking is highly correlated with lighting. A statistical technique (Multiple Correspondence Analysis – MCA) was employed to choose the energy poverty indicators. From the results of the MCA, a final selection of the energy poverty indicators was made which include cooking, heating, lighting, basic appliance ownership (has a fridge or washing machine), entertainment/education appliance ownership (has a radio), and telecommunication means (has a cell phone).

Weights were assigned to these selected energy poverty indicators so that the choice of allocation of higher weight is skewed in favour of lighting while heating has the lowest weight. Lighting is assumed to take only a small share of energy consumption and

serves as an illustration of the joint relationship between income and energy. On the other hand, heating is an energy service for which individual people or a household could decide not to use any electrical appliance, as they can keep warm by using blankets.

With respect to specification of the energy poverty line, own calculation was employed as there is no official energy poverty line for South Africa. The study uses the lower bound poverty line (LBPL) and upper bound poverty line (UBPL) values for 2014 and the average household size (3.8 people), as recorded in the 2010/2011 Income and Expenditure Survey. The computation of allowance for consumption of non-food basic necessities determine the LBPL and UBPL so that the multidimensional energy poverty line, k, is estimated as 33 percent (k = 0.33).

Finally, the MEPI results shows that both rural and urban low-income households are in a state of moderate energy poverty, but at different levels as based on the scale of measurement proposed by Nussbaumer *et al.* (2013). The conclusion is that low-income households living in rural areas have a higher percentage of energy deprivation than among those living in urban areas for each year of analysis as their MEPI value ranges between 0.59 – 0.62. Interestingly, while the percentage of energy poverty is decreasing for low-income households in rural areas in subsequent time periods, it is increasing for those in urban areas. In total, among low-income households in urban and rural areas, 39% and 61% respectively are multidimensionally energy poor.

The results also show energy poverty at the level of energy services or dimensions. This is to examine how households are energy poor and it could also determine where policy interventions should be directed. Low-income households in both rural and urban areas are mostly deprived in the heating fuel dimension (95%) and least deprived in lighting (65%). Results also show that 90% of the low-income households in both urban and rural areas are deprived in terms of home appliances, entertainment/education appliance, and telecommunication. This dimensional deprivation reveals that any attempts to solve the problem of energy poverty for low-income households in South Africa should target each dimension with varying degrees of emphasis.

Sensitivity analysis to check the robustness of the dimensional weights and the energy poverty line ends the chapter. The sensitivity analysis shows that the results are sensitive to changes in the dimensional weights and also that if the energy poverty cut-off line is increased or decreased, the MEPI score for low-income households will still be in a moderate state.

The next chapter deals with the results of the energy models and the FBE policy.

Chapter 8

INVESTIGATING THE APPLICABLE ENERGY MODEL AND THE IMPACT OF THE FBE POLICY ON LOW-INCOME HOUSEHOLDS

8 Introduction

Chapter 3 demonstrated that patterns of energy use are closely related to degrees of energy poverty for households. This highlights the importance of understanding household energy choice and energy switching behaviour in order to find appropriate policies which would support the transition towards higher living standards. For a number of developing countries, particularly those in Africa, the issue of understanding these patterns is necessary from a policy standpoint. Policy choice is between either the 'energy ladder' or the 'energy stacking' model of household decision-making. The results of the pattern of energy choice by low-income households through these two energy models are presented in this chapter. Firstly, a review of the principal energy models on household energy use and decision-making was undertaken followed by the specifications of the estimation model and its variables and the results of the estimation of the energy consumption pattern for low-income households ends the section.

8.1 Energy Ladder versus Energy Stacking Models?

The energy transition theory suggests there is a ladder of energy preferences, the 'energy ladder', according to this theory, as a household's income increases, it will rise up the energy ladder by moving away from traditional energy carriers, for example animal dung or wood, towards transitional energy carriers of paraffin or coal, and will finally adopt a modern energy carrier (electricity, LPG, or solar) (Lee *et al.* 2015; Van der Kroon *et al.* 2013). This study investigates whether low-income households in rural and urban areas do indeed move up the energy ladder as their income increases. This would be determined if income is statistically significant in relation to a household's decision concerning energy choices for cooking, heating, and lighting. The 'energy ladder' will be

accepted for low-income households if the sign of the income variable is positive and statistically significant. This is because the 'energy ladder' model assumes that a household's energy choice to move up the energy ladder in a unidirectional manner depends crucially on the household's income level.

It has been suggested that households prefer 'energy stacking', which means that traditional or transitional energy carriers are discarded when there is an increase in income, but are retained and used in combination with modern energy carriers (Kowsari and Zerriffi 2011; Lee *et al.* 2015). The 'energy stacking' model, or multiple fuel use, would be accepted for low-income households if income is not statistically significant in relation to household decisions concerning energy choices for cooking, heating, and lighting because this model assumes that with increasing income, households diversify their energy choices.

8.2 Estimation Model and Variable Specification

The dataset used for examining whether the energy transition pattern of low-income households follow the 'energy ladder' or the 'energy stacking' model arises from the four waves of the NIDS. The first wave was collected in 2008 and the survey was repeated with the same set of households at two-year intervals. In order to track mobility of households with respect to their main energy choice for the three main energy services, and to identify the determinants of the energy transition process, a balanced panel data is used. A balanced date panel, rather than an unbalanced one, has been given preference because it enables an observation of the same household over the years of the survey. On average, an observation of 760 low-income households was used for the analysis.

The method of estimation, as discussed in Chapter 6, was the ordinal logit model chosen because of the nature of the dependent variable which is ordered and in categories. In the literature on household energy choice discussed in Chapter 3, it was argued that as income increases, households move from using traditional energy carriers first to transitional energy carriers, and then to modern energy carriers. As a result, modern energy carriers are perceived to be superior both to transitional and traditional energy carriers. Traditional energy carriers are less sophisticated and of a lower quality than

are transitional energy carriers. Within this household energy choice theory, often based on the 'energy ladder' model, the dependent variable is ordered with three choices: less preferred, moderately preferred, and most preferred. The 'less preferred' energy choice is traditional energy carriers coded as 1, 'moderately preferred' is transitional energy carriers coded as 2, and 'most preferred' is modern energy carriers coded as 3. The ordered logit equation for three ordered categories is written as:

$$P(Y=1) = \frac{1}{1+\exp(\beta 1 X 1 i - k 1)}$$

$$P(Y=2) = \frac{1}{1+\exp(\beta 1 X 1 i - k 2)} - \frac{1}{1+\exp(\beta 1 X 1 i - k 1)}$$

$$P(Y=3) = 1 - \frac{1}{1+\exp(\beta 1 X 1 i - k 2)}$$

The equations are for each unit *i* and each category *j*. As required, the households' choices are mutually exclusive, as only one choice of main energy source can be made for each end-use. The specific question asked in the questionnaire was, '*what is the main source of energy/fuel for this household for cooking'*? (NIDS 2012). This question was also asked for heating and lighting. The likelihood of choosing any specific energy type will be dependent upon the characteristics of each household and decisions about energy choice are discrete. The marginal effects are obtained by taking the partial derivatives of the ordered logit equation:

$$\partial \Pr(Y=0|X) / \partial X_k = - \beta_k \lambda (\alpha_1 - X\beta);$$

$$\partial \Pr(Y=j/X) / \partial X_k = \beta_k [\lambda (\alpha_{j-1} - X\beta) - \lambda (\alpha_3 - X\beta)], \text{ for } 0<j<3; \text{ and}$$

$$\partial \Pr(Y=3/X) / \partial X_k = \beta_k \lambda (\alpha_3 - X\beta)$$

The predicted probabilities are estimated as:

P (y_ordinal = 'less preferred') = P (S+ u ≤ _cut1)

P (y_ordinal = 'moderately preferred') = P (_cut1< S+ u ≤ _cut2)

P (y_ordinal = 'most preferred') = P (_cut2< S+ u)

Data analysis was done with the software package STATA version 12. The dependent variables are the main energy carrier chosen by households for cooking, heating, and lighting from modern, transitional, or traditional energy carriers. The low-income household chooses the main energy source for each energy service. For cooking and heating, a modern, transitional, or traditional energy carrier is used; for lighting, it is modern or transitional or candles. Traditional energy carriers were not used for lighting as discussed in Chapter 7.

Furthermore, the study highlights some endogenous characteristics as being key to determining choice(s), as discussed in Chapter 3. Independent variables were first tested for multi-collinearity and include age, gender of the household respondent, income, rurality, household size, and dwelling type. The variable 'Year' is part of the independent variables. The variance inflation factor (VIF) and tolerance value detect if multi-collinearity exists among the variables. As a rule of thumb, a variable whose VIF value is greater than 10 or the tolerance value is lower than 0.1 means that there is a linear combination of other independent variables which may merit further investigation (Gujarati and Porter 2009). The test result shows that the VIF for each independent variable is less than 1.5 and the tolerance value ranges between 0.7 to 0.9 (See Appendix C for full result). Multi-collinearity is not a problem to the regression analysis. The explanatory variables, their measurement and expected signs are presented in Table 8.1.

Table 8:1 Variable description, measurement and expected signs

Variable names	Variable description and measurement	Expected sign		
Dependent variables				
Energy choice for cooking	Outcome1= traditional energy carrier (less preferred) Outcome2= transitional energy carrier (moderately preferred) Outcome3= modern energy carrier (most preferred)			
Energy choice for heating	Outcome1= traditional energy carrier (less preferred) Outcome2= transitional energy carrier (moderately preferred) Outcome3= modern energy carrier (most preferred)			
Energy choice for lighting	Outcome1= candles (less preferred) Outcome2= transitional energy carrier (moderately preferred) Outcome3= modern energy carrier (most preferred)			
Independent variables		**outcome1**	**outcome2**	**outcome3**
Household income	A continuous variable indicating the monthly household income in South African Rand			
Age	A continuous variable indicating the age of household respondent in years	+/-	+/-	+/-
Gender	A binary variable indicating the gender of household respondent 1=female; 0=male	-	-	+
Rurality	A binary variable indicating the location where household lives 1=urban; 0=rural	-	-	+
Household size	A binary variable indicating the number of people living in a household 1= small household size (1-4persons); 0=large household size (5persons and above)	-	-	+
Dwelling type	A binary variable indicating the type of household dwelling 1=modern dwelling; 0=non-modern dwelling	-	-	+
Year	A nominal variable representing the year of survey, base=2008			
	Year 2010	-	-	+
	Year 2012	-	-	+
	Year 2014	-	-	+

The dependent variables represent the energy choices made by low-income households for cooking, heating, and lighting. Categories of energy choice are ordered, and taken

from the energy ladder concept. Modern energy carriers should be preferred (being the most effective and efficient) by the low-income households for their cooking, heating, and lighting. Transitional energy carriers are assumed to be moderately preferred being middling in efficiency while the traditional energy carrier will be least preferred because it is the least efficient.

With the independent variables, gender is a binary variable with female respondent as the base. Rurality is also a binary variable, with urban low-income households used as the base. Household size is a binary variable and small household size is used as the base. Dwelling type is a binary variable and low-income households residing in modern houses are the base. The 'year' variable is a categorical variable and 2008 is the base year. Results are interpreted relative to each base dummy. Finally, household income and age are continuous variables. Household income is the total amount of after-tax household income. Household income has been adjusted for inflation; so the real income of the household is used. The age variable represent the age of the respondent household head.

The *a priori* expectations of each independent variable are to show their expected direction of influence on the dependent variable. The reference points for the binary variables are at base dummy=1, while household income and age are set at their means, which are R776.56 and 50.82 years respectively. For the 'year' variable, STATA sets a mean for 2010, 2012, and 2014. Each of the following independent variables are expected to have negative signs for traditional and transitional energy carriers holding other independent variables constant at the reference points. For gender, rurality, household size, and dwelling type, it is expected that the marginal effect will be that low-income households with a female household respondent, in an urban settlement, having a small household size and living in a modern dwelling will use less traditional and transitional energy carriers for cooking and heating holding other independent variable constant at their reference points. For lighting, it is expected that the marginal effect will be that low-income households with a female household respondent, in an urban settlement, having a small household size and living in a modern dwelling are expected to use few candles plus transitional energy carriers holding other independent variable constants at their reference points. The expected signs are presumed to be

negative knowing that health and safety risks are associated with traditional or transitional energy carriers and also candles compared to modern energy carriers (Kowsari and Zerriffi 2011; Swart and Bredenkamp 2012).

Age is an ambiguous variable hypothesised to positively or negatively influence household energy choice for cooking and heating. The expectation is that the marginal is that a household respondent with a mean age of 51 may use less or more traditional and transitional energy carriers for cooking and heating holding other independent variable constant at their reference points. For lighting, the marginal effect is expected to be that low-income households with the household respondent with a mean age of 51 may use more or fewer candles and transitional energy carriers holding other independent variables constant at their reference points.

For household income, the *a priori* expectation with respect to the sign is ambiguous. As the sample involves low-income households, some households could be earning close to the margin, between R1 400 – R1 500 per month, while some could be far from the margin; the marginal effect is expected to show that low-income households earning a monthly average of R776.56 are likely to use less or more modern energy carriers for cooking, heating, and lighting, holding other variables in the model constant at their reference points, depending on the energy choice model.

For the 'year' variables, it is expected that low-income households in 2010, 2012, and 2014 will use less than they did in the base year 2008 of traditional or transitional energy carriers for their cooking and heating holding other independent variables constant at their reference points. For lighting, it is expected that low-income households in 2010, 2012, and 2014 will use fewer candles with transitional energy carriers holding other independent variable constant at their reference points.

Further, the *a priori* expectations of each independent variable for a modern energy carrier is different from traditional and transitional energy carriers. Thus, for gender, rurality, household size, and dwelling type, a positive sign is expected. Therefore, the marginal effect is expected to be that low-income households with a female household respondent, in an urban settlement, having a small household size, and in a modern

dwelling are more likely to use modern energy carriers for their cooking, heating, and lighting holding other independent variables constant at their reference points. Positive signs are expected for modern energy carrier usage because it impacts on human well-being by reducing the health and safety risks associated with traditional or transitional energy carriers (Kowsari and Zerriffi 2011; Swart and Bredenkamp 2012). In addition, the use of modern energy carriers could decrease time budget constraints on household members particularly women and children, increase labour productivity, and improve gender inequality and literacy (Howells *et al.* 2003; Swart and Bredenkamp 2012).

Household income and age may be either positive or negative, as with the *a priori* expectations for traditional and transitional energy carriers. The marginal effect is expected to be that low-income households earning an average of R776.56 monthly, with the household respondent having a mean age of 50.82 years, may use less or more modern energy carrier for cooking, heating and lighting holding other independent variable constant at their reference points.

Finally, for the 'year' variable, low-income households in 2010, 2012, and 2014 are hypothesised to have positive signs for modern energy carriers. The marginal effect is expected to be that low-income households are more likely to use modern energy carrier for their cooking, heating, and lighting in 2010, 2012, and 2014 than was the case in the base year 2008 holding other independent variables constant at their reference points.

8.3 Result of the Marginal Effects for the Different Energy Choices

The result of the marginal effects of the ordered logistic regression with respect to cooking energy service is presented in Table 8.2. For the ordered logistic regression, see Appendix D.

Table 8:2 Marginal Effects - Energy Choice for Cooking

	Marginal effects for traditional energy carrier	Marginal effects for transitional energy carrier	Marginal effects for modern energy carrier
Household income	-5.44e-05*	-2.97e-05	8.42e-05*
Dwelling type (modern dwelling)	-0.1807***	-0.0735***	0.2542***
Age	8.09e-05	4.42e-04	-0.0012
Gender (female)	-0.0107	-0.0057	0.0164
Rurality (urban)	-0.2043***	-0.1055***	0.3099***
Household size (small household size)	-0.1086**	-0.0440**	0.1526***
Year (2010)	-0.0685**	-0.0413**	0.1101**
Year (2012)	-0.0959***	-0.0599***	0.1559***
Year (2014)	-0.0947***	-0.0598***	0.1546***

T-statistics: * significant at 10% ** significant at 5%; *** significant at 1%

Household income is an important variable, as it determines the energy consumption for low-income households. The energy consumption pattern for the three main energy end-usage will be discussed, and, in the interpretation of the results, the marginal effects of the ordered logistic regression are reported.

Household income is statistically significant for both traditional and modern energy carriers at a 10% level of significance. This result has partly confirmed an 'energy ladder' behaviour with respect to cooking energy service. The implication is that as real income rises, there is transition up the energy ladder for the choice of energy for cooking. The result finds support from other studies (Hosier and Dowd 1987, Lay *et al.* 2013 and Lee 2013), as was discussed in Chapter 3. For example, Lee (2013) presented evidence that Ugandan households' transition away from wood, a traditional energy source, and kerosene, a transitional energy source, when there is an increase in income.

For low-income households in South Africa, income was found to be a statistically significant determinant of energy choice for cooking, reflecting a direct relationship with the energy ladder theory. In addition, the energy ladder behaviour of low-income

households reflects the importance of modern energy carriers for cooking as their economic status changes for the better.

Results revealed, as expected, that modern dwelling type, rurality (urban), and small household size have negative indications and are statistically significant at 1%, 1%, and 5% level of significance respectively for traditional and transitional energy carriers. For dwelling type, for example, low-income households living in modern dwellings are 18% less likely to use traditional energy carriers and 7% less likely to use transitional energy carriers for cooking than their counterparts living in a non-modern dwelling. For modern energy carriers, the sign for modern dwelling type is positive as hypothesised. Therefore, low-income households living in modern dwellings are 25% more likely to use modern energy carriers for their cooking than are low-income households living in traditional or informal dwellings non-modern dwellings. Thus, the inference is that modern dwelling increases the probability of modern energy carrier being chosen for cooking. Suliman (2013) identified that a modern roof significantly increases the probability of households adopting modern energy carriers as modern dwellers tend to avoid roof stain in the course of using traditional energy carriers.

Urban low-income households are 20% less likely to use a traditional energy carrier and 11% less likely to use a transitional energy carrier for cooking than are rural low-income households. For a modern energy carrier, the sign for urban is positive. Urban low-income households are 31% more likely to adopt a modern energy carrier for cooking compared to rural low-income households. Baiyegunhi and Hassan (2014) confirm a similar result in a study conducted in Kaduna State, Nigeria which showed that urban households use modern energy carriers for cooking because the kitchen is indoors, not outside.

Low-income households with a small household size of less than 5 people are 5% less likely to use traditional energy carriers and 5% less likely to use transitional energy carriers for cooking than are their counterparts of a larger household size. For modern energy carriers, the sign for small household size is positive as expected; with small household size are 15% more likely to use modern energy carriers for cooking than are their counterparts with larger households. Barnes *et al.* (2005), Guta (2012) and Van der

Kroon *et al.* (2013) also found increasing family sizes limiting the need to use modern energy carriers for cooking since there is abundant labour available for fuel collection, for example of wood.

For the 'year' variables, 2010, 2012, and 2014 have negative signs as hypothesised for traditional and transitional energy carriers. The implication is that, in 2010, 2012, and 2014, low-income households are 7%, 10%, and 10% respectively less likely to use traditional energy carriers for cooking than they were in 2008. Furthermore, low-income households are 4% less likely to use transitional energy carriers for cooking in 2010, and 6% less likely in 2012 and 2014 than in 2008. For modern energy carriers, the sign for 2010, 2012, and 2014 is positive as hypothesised. This implies that low-income households are 11% more likely to use modern energy carriers for cooking in 2010 than in 2008 and 16% more likely in 2012 and 2014 than in 2008. The result conforms with the descriptive statistics of those low-income households who have the choice of energy for cooking as discussed in Chapter 7; this shows an increase in the use of modern energy carriers for cooking by low-income households from 2010 to 2012 to 2014 compared to 2008. One could say that South Africa is making progress in terms of improving access to modern energy sources. This could be because of accessibility and affordability issues have been addressed through, for example, the expansion of the national electricity grid or because of policies such as FBE.

Finally, the variables, age, at mean 51 years, and the female gender of the household head are not statistically significant because irrelevant in influencing the choice of energy carriers (traditional, transitional, or modern) for cooking by low-income households, holding all other variables in the model constant.

The study further analysed the predicted probabilities of the low-income households for the choice of energy for cooking in order to see their highest probability of preference and to examine whether the result of the logistic regression confirms the probability.

	95% confidence interval
Pr (y=1= less preferred | x: 0.1826	[0.1531, 0.2120]
Pr (y=2=moderately preferred | x: 0.1803	[0.1504, 0.2102]
Pr (y=3=most preferred |x: 0.6371	[0.5987, 0.6755]

The interpretation of the result is that there is a 64% probability of the choice of modern energy carriers being most preferred for cooking by low-income households, holding other variables constant at their reference points. Furthermore, there is an 18% probability that low-income households will choose transitional or traditional energy carriers for their cooking, holding other variables in the model constant at their reference points.

The result of the marginal effects of the ordered logistic regression with respect to heating energy service is presented in Table 8.3. For the ordered logistic regression, see Appendix E.

Table 8:3 Marginal Effects - Energy Choice for Heating

	Marginal effects for traditional energy carrier	Marginal effects for transitional energy carrier	Marginal effects for modern energy carrier
Household income	-7.12e-05	-1.74e-05	8.86e-05
Dwelling type (modern dwelling)	-0.2701***	-0.0351***	0.3053***
Age	0.0016	4.03e-04	-0.0204
Gender (female)	0.0195	0.0050	-0.0245
Rurality (urban)	-0.2613***	-0.0634***	0.3247***
Household size (small household size)	-0.1331**	-0.0185**	0.1516***
Year (2010)	-0.1824***	-0.0619***	0.2444***
Year (2012)	-0.1418***	-0.0461***	0.1879***
Year (2014)	-0.1457***	-0.0484***	0.1941***

T-statistics: * significant at 10% ** significant at 5%; *** significant at 1%

The variable, household income is not statistically significant for the energy choice for heating for low-income households. This result implies likely evidence of there being

'energy stacking' behaviour by low-income households for space heating. Thus, should income increase, it is most likely that the households will not completely abandon the use of traditional or transitional energy carriers for space heating and that low-income households continue to use them in combination with modern energy carriers. There are some low-income households that do not use any heating as shown in the descriptive statistics earlier.

Modern dwellings, urban and small household size are statistically significant at the 1%, 1%, and 5% level of significance respectively and have negative signs as expected for traditional and transitional energy carriers.

Low-income households living in modern dwellings are 27% less likely to use traditional energy carriers and 4% less likely to use transitional energy carriers for heating than do their counterparts living in non-modern dwellings, holding other variables in the model constant at their reference points. For modern energy carriers, the sign for modern dwelling is positive as hypothesised, implying that low-income households living in modern dwellings are 31% more likely to use modern energy carriers for their space heating than do low-income households living in non-modern dwellings, holding other variables in the model constant at their reference points.

Urban low-income households are 26% less likely to use traditional energy carriers for heating and 6% less likely to use transitional energy carriers compared to their counterparts in rural areas. For a modern energy carrier, the sign for rurality (urban) is positive as expected indicating that urban low-income households are 33% more likely to use a modern energy carrier for heating compared to low-income household in rural areas, holding other variables in the model constant at their reference points.

Low-income households with a small household size are 13% less likely to use traditional energy carriers for heating and 2% less likely to use transitional energy carriers compared to low-income households with a larger household size. For modern energy carriers, the sign for small household size is positive as expected, with small households being 15% more likely to use modern energy carriers for heating than low-income households with larger household size. As is the case with energy choice for cooking, a

small household size implies less energy demand and low-income households prefer to use a modern energy carrier for space heating.

Lastly, as hypothesised, 2010, 2012, and 2014 have negative signs for traditional and transitional energy carriers and are statistically significant at a 1% level of significance for each year. The inference is that low-income households are 18% less likely to use traditional energy carriers in 2010 than in 2008, 14% less likely in 2012, and 15% less likely in 2014. For transitional energy carriers, low-income households are 6% less likely to use it for heating in 2010 and 5% less likely in 2012 and 2014. For a modern energy carrier, the signs for 2010, 2012, and 2014 are positive as expected, indicating that low-income households are 24% more likely to use modern energy carriers for heating in 2010, 19% more likely in 2012 and in 2014 compared to 2008. The result conforms to the descriptive statistics of low-income households with the choice of energy for heating with respect to modern energy carriers, as discussed in Chapter 7. The descriptive statistics show that, compared to 2008, low-income households used 61% more modern energy carriers in 2010 which then reduces in 2012 to 58% and increases to 66% in 2014.

The predicted probabilities for the energy choice for heating by low-income households is:

	95% confidence interval	
Pr (y=1= less preferred | x: 0.2755	[0.2380,	0.3129]
Pr (y=2=moderately preferred | x: 0.1886	[0.1549,	0.2223]
Pr (y=3=most preferred |x: 0.5359	[0.4934,	0.5784]

The outcome suggests that there is a 54% probability that the choice of a modern energy carrier will be made for heating among low-income households. There is a 19% probability that low-income households will choose a transitional energy carrier and a 28% probability for the option of a traditional energy carrier for space heating, holding other variables constant at their means. These probabilities are in accordance with the descriptive statistics of low-income households discussed in Chapter 7 with respect to energy choice for heating.

The result of the marginal effects of the ordered logistic regression with respect to lighting energy service is presented in Table 8.4. For the ordered logistic regression, see Appendix F.

Table 8:4 Marginal Effects - Energy Choice for Lighting

	Marginal effects for candles	Marginal effects for transitional energy carrier	Marginal effects for modern energy carrier
Income	-5.29e-05	-9.49e-06	6.24e-05
Dwelling type (modern dwelling)	-0.2237***	-0.0312***	0.2549***
Age	2.12e-04	3.82e-05	-0.0002
Gender (female)	- 0.0515	-0.0086	0.0601
Rurality (urban)	-0.0818***	-0.0146***	0.0965***
Household size (small household size)	-0.0304	-0.0052	0.0356
Year (2010)	-0.0277	-0.0051	0.0328
Year (2012)	-0.0544*	-0.0102	0.0646*
Year (2014)	-0.0905***	-0.0175**	0.1081***

T-statistics: * significant at 10% ** significant at 5%; *** significant at 1%

Unexpectedly, household income variable was found to be insignificant, confirming an energy stacking for lighting as presented in Table 8.4.

The results reveal that modern dwelling and urban are statistically significant at 1% level of significance and have negative signs as hypothesised for candles and transitional energy carriers.

Low-income households living in modern dwellings are 22% less likely to use candles and 3% less likely to use transitional energy carriers for lighting than are their counterparts living in non-modern dwellings. For modern energy carriers, the sign for modern dwelling is positive as hypothesised, indicating that low-income households living in modern dwellings are 26% more likely to use modern energy carriers for lighting than do those living in non-modern dwellings.

The marginal effect shows that urban low-income households are 8% less likely to use candles for lighting and 2% less likely to use transitional energy carriers compared to rural households. For modern energy carriers, the sign for urban households is positive as hypothesised, signifying that urban low-income households are 10% more likely to use modern energy carriers for lighting than are rural low-income households. What this marginal effect shows is that there is a wider difference in the probability of using modern energy carriers for lighting between urban/rural than there was for heating (33%).

Table 8.4 shows that 2012 is statistically significant at a 10% level of significance for candles with a negative sign while 2014 is statistically significant at a 1% level of significance for candles and a 5% level of significance for transitional energy carriers but having negative signs as expected. Thus in 2012, low-income households are 6% less likely to use candles; and in 2014, low-income households are 9% less likely to use candles and 2% less likely to use transitional energy carriers for lighting. The marginal effect shows that low-income households were 7% and 11% more likely to use modern energy carriers for lighting in 2012 and 2014 respectively. Unexpectedly, 2010 is not as statistically significant for the three energy choice options as it was for cooking and heating.

The predicted probabilities for energy choice for lighting by low-income households is thus shown:

	95% confidence interval
Pr (y=1= less preferred | x: 0.1871	[0.0316, 0.0629]
Pr (y=2=moderately preferred | x: 0.047	[0.1572, 0.2168]
Pr (y=3=most preferred |x: 0.7657	[0.7329, 0.7986]

For energy choice for lighting, candles are ‘less preferred’ refers, ‘moderately preferred’ refers to transitional energy carriers and ‘most preferred’ is for a modern energy carrier; and the result is a 77% probability that a modern energy carrier will be chosen for lighting and a less than 1% probability that low-income households are likely to opt for transitional energy carriers; and lastly, there is a 19% probability that low-income

households will choose candles for lighting. These outcomes are not surprising as they corroborate with the choice of energy for lighting as discussed in Chapter 7 that low-income households mostly use modern energy carriers for lighting and use candles less often. A transitional energy carrier, on the other hand, is seldom used for lighting

An observation regarding the percentage probabilities of a modern energy carrier's being preferred for the three-energy end use shifts. For energy choice for cooking, the predicted probability is 64%; 54% for heating; while lighting is 77%. These percentages reflect the energy intensity needed for each service if electricity is considered to be the source of energy. Though heating consumes a lot of electricity, lighting uses much less. Cooking is in the middle and reflects an average energy consumption. Also, and as discussed in Chapter 2, lighting is the major user of electricity by both rural and urban households; though this usage extends beyond lighting for urban households (Barnes *et al.* 2011; Khandker *et al.* 2012).

8.4 Estimating the Impact of the FBE Policy on Low-income Households using the Income Expenditure Survey

8.4.1 Introduction

The section discusses the impact of the FBE policy on household energy use by low-income households in South Africa. Subsidies, including energy subsidies, are an important tool for socio-economic policy for many governments. In developing countries, subsidies in the energy sector are targeted towards consumers, as is discussed in Chapter 4, with the primary objective of reducing the cost of living for low-income households. South Africa, like other developing countries, seeks options through which relief can be brought to poor households. For this reason, the South African government introduced the FBE policy in 2003, which allocates 50kWh of free electricity monthly to grid-connected low-income households in order to address affordability issues. As discussed in Chapter 5, an access to grid connection aside, the FBE policy stipulates that the homes of low-income households applying for free basic electricity must have a prepaid electricity metre.

The description of low-income households for the allocation of FBE differs from descriptions of low-income households by the South African Bureau of Market Research (2011) and Statistics South Africa (2011). As discussed in Chapters 5 and 6, the South African Bureau of Market Research (2011) and Statistics South Africa (2011) defined low-income households as earning R0 – R18 000 per annum or households with an income below R1 500 per month. Then, in 2003, the Department of Mineral and Energy, DME (2003), defined low-income households qualifying for FBE as those whose gross monthly income of the total number of members of the household does not exceed two old age pensions. In 2010/2011, the old age pension was R1 080 per month (South Africa Social Development 2010/2011). This amount changes every year, however, so, the current amount for 2016/2017 is between R1 500 – R1 530 per month (South African Social Security Agency 2016/2017). Thus, any household collecting R2 160 or less per month in 2010/2011 is categorised as low-income and therefore qualifies for FBE.

The section sets out to examine the proportion of low-income households receiving, or not receiving FBE and the level of significance is the FBE received by low-income households in determining energy poverty. As discussed in Chapters 4 and 5, it is possible to have a scheme in which subsidies are well targeted but the incidence of benefit is low because only a few low-income households actually receive the subsidy. Significantly, a subsidy might reach most low-income households but still be ineffectual if it does not help pull low-income households out of energy poverty or improve their energy consumption patterns. The starting point in this section, therefore, is a brief reminder of the dataset used for the analysis. This is followed by the summary statistics of low-income households by using the Income and Expenditure Survey (IES). An overview of the econometric model for the analysis and the specification of the variables for the analysis is discussed. The results of the estimation of low-income households receiving the FBE and also the impact of FBE are considered in the latter part of the section.

8.5 Overview of the Dataset- Income and Expenditure Survey

As discussed in Chapter 6, the Income and Expenditure Survey (IES) is a nationally representative household-based survey conducted by Statistics South Africa with the

primary objective of providing relevant statistical information on income and expenditure patterns of a representative sample of households. Statistics South Africa monitors South African income and expenditure patterns at five-yearly intervals using the IES. The IES, being a cross-sectional study, captures a specific point in time meaning that there will be no loss to follow-up since participants are interviewed only once. There is the difficulty of inferring a temporal association between a risk factor and an outcome in a cross-sectional study because data on each participant are recorded only once. The design weights were constructed by applying three adjustments to the base weights (the base weight for each sampled household is equal to the reciprocal of the probability of selection). The sampled households in the survey are assumed to represent the entire civilian population of South Africa.

The latest edition of IES 2010/2011 has been used for the estimation of the impact of the FBE. As mentioned in Chapter 6, IES 2005/2006 is different from IES 2010/2011 as the former does not contain an indicator of whether the household receives free basic electricity or not. For the summary/descriptive statistics, the definition of the low-income households, which was based on the allocation of FBE, was used. The IES 2010/2011 dataset has a total observation of 9 046 low-income households. This is about 59% of the whole population of households in the IES 2010/2011.

In preparation of the dataset for analysis, some of the variables that were not in numeric format were assigned values. For example, for gender, 1= male and 0 = female; and for the population group, 1= Black African, 2= Coloured, 3= Asian/Indian and 4= White. Dwelling type was represented as 1= modern dwelling, 2= traditional dwelling, 3= informal dwelling. Household size is in numeric form and thus coded categorically. For example, 1-4 persons =1, representing small household size while 5 and above =0 implying large household size. Binary answers of 'yes' or 'no' as in the case of having electricity connection or ownership of appliances, for example, were assigned, 1= yes, 0= no.

The summary statistics include the socio-economic and demographic characteristics, which comprises of population group and the gender of the household head, type of dwelling, rurality, household size, and income. Electricity connection and ownership of

household electrical appliances such as fridge/freezer, radio/television, microwave/washing machine, and computer/cell phone/landline/internet were also examined. According to Awan *et al.* (2013) and Kaygusuz (2011), ownership of household electrical appliances depends on electricity access, income aside. Bearing that in mind, the occurrence of energy poor has been found to be higher for households without access to electricity (IEA 2010; Sher *et al*. 2014). More importantly, according to Nussbaumer *et al.* (2011), the measure of energy poverty should be multidimensional as it sheds light on the issue of energy services, which is important to people and makes a difference in their lives. For low-income households, their being in a position to own electrical appliances was found to produce a sense of belonging to the mainstream of development (Jones *et al*. 2015; Mzini and Lukamba-Muhiya 2014).

8.6 Summary Statistics of Low-Income Households using IES 2010/2011

The socio-economic and demographic characteristics provide a description of low-income households that qualify for FBE in South Africa. The summary statistics show the percentages of low-income households in each group. The characteristics of low-income households using the IES dataset 2010/2011 is presented in Table 8.5.

Table 8:5 Socio-Economic and Demographic Characteristics of Low-Income Households' in South Africa, 2010/2011

	Percentage of Low-income Households
Population Group (Household respondent)	
Black African	92.75
Coloured	5.93
Asian/Indian	0.31
White	1.02
Gender (Household respondent)	
Female	54.88
Male	45.12
Type of dwelling	
Modern dwelling	72.29
Traditional dwelling	15.59
Informal dwelling	12.12
Rurality	
Urban	48.33
Rural	51.67
Household size	
1– 4 persons (small household size)	75.24
5 persons and above (large household size)	24.76

From the analysis represented in Table 8.5, about 93% of low-income households are Black African. The Asian/Indian population group has the smallest proportion of low-income households. About 55% of the low-income household respondents are female. Types of dwelling are in three categories: modern, traditional, and informal. There are three dwelling categories. About 72% of the low-income households are in a modern house compared to 12% living in informal buildings. A high proportion of low-income households are rural dwellers while about 75% of the low-income households in South Africa have a small household size comprising 1 – 4 persons.

8.6.1 Electricity Access of the Low-income Households

The number of households that have a connection to the main electricity supply on the national electricity grid determines electricity access. Low-income households' access to electricity in 2010/2011 is presented in Table 8.6.

Table 8:6 Proportion of Low-income Households with Connection to the National Electricity Grid, 2010/2011

	2010/2011
Low-income households connected to the national grid (%)	80.18
Low-income households without connection to the national grid (%)	19.57
No response (%)	0.25

The proportion of low-income households connected to the grid in 2010/2011 is about 80%. Having connection to the electricity grid increases the chances of low-income households being able to access the FBE.

8.6.2 Income Comparisons within Low-income Households

As mentioned earlier, in 2010/2011, low-income households are categorised as earning R2 160 or less on a monthly basis. An examination of income variations among low-income households will contribute to knowledge about modes of distribution in them. Low-income household income groupings is presented in Figure 8.1.

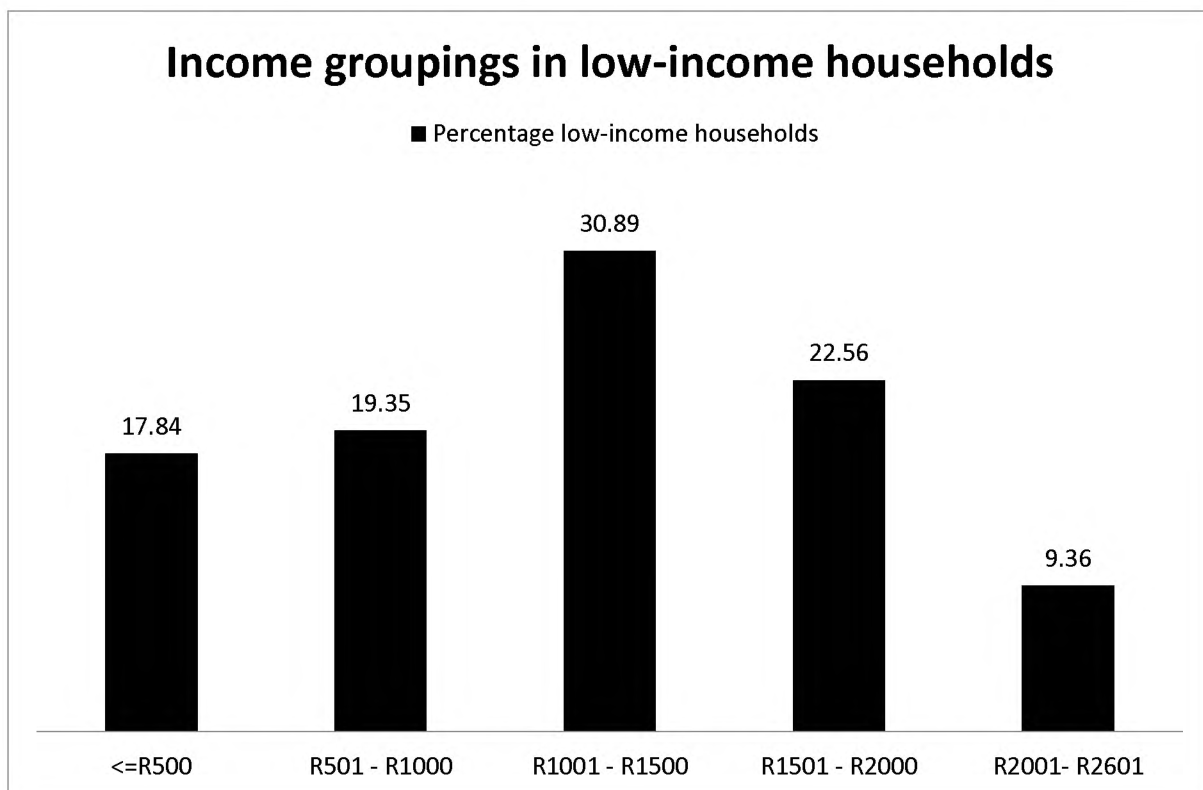


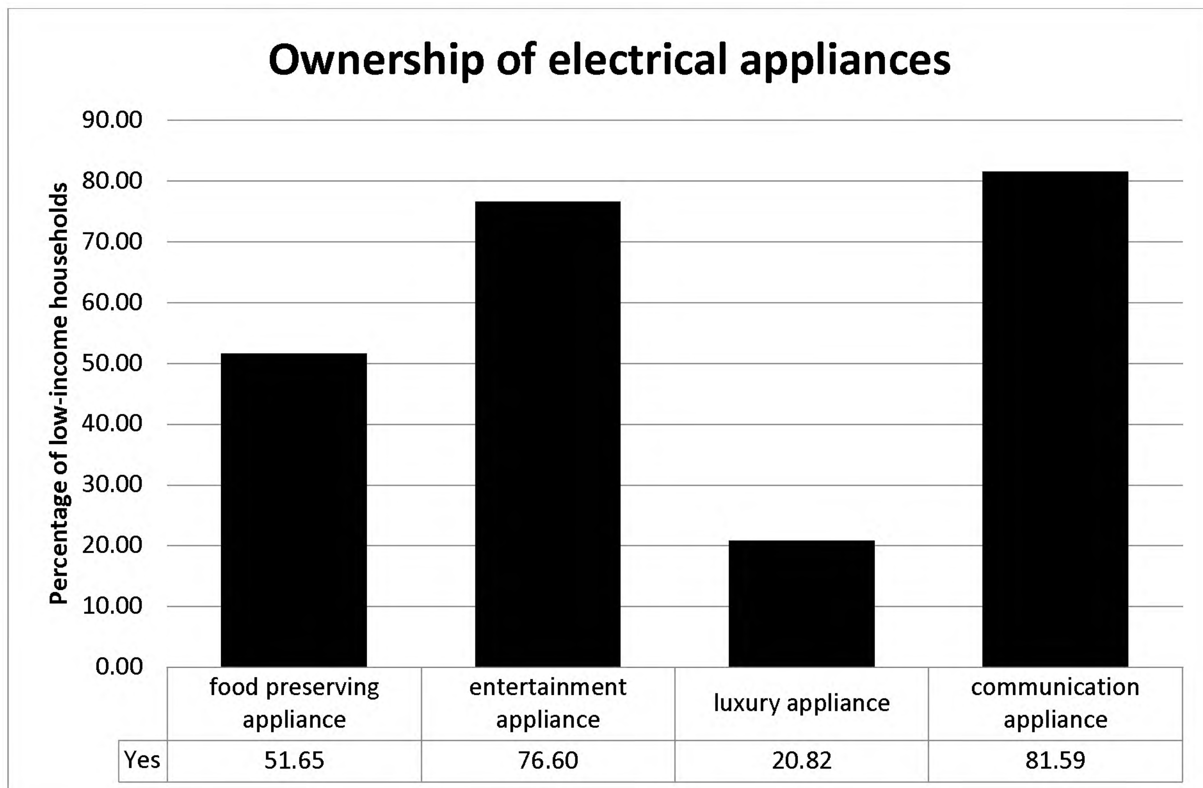
Figure 8:1 Income Groupings in Low-income Households

About 31% of low-income households in South Africa earned between R1 000 – R1 500 monthly in 2010/2011. About 23% of low-income households earned between R1 501 – R2 000 while about 9% earned between R2 001 – R2 601 a month. It seems that most low-income households in 2010/2011 are earning less than two old peoples' pension; one person's pension in South Africa in 2010/2011 was R1 080.

8.6.3 Ownership of Electrical Appliances by Low-income Households

Residential electricity consumption can be divided into five categories cooking, heating, lighting, use of electrical appliances, and other social and economic needs (Mzini and Lukamba-Muhiya 2014). Focus in this section is on the use by low-income households of electrical appliances such as fridge, freezer, radio, television, microwave and washing machine, cell phone, computer, and landline. The aim is to have an overview of electricity usage by examining the extent to which low-income households own electrical appliances. For ease of interpretation, the household electrical appliances are grouped according to their functions. Following Sparknet (2010), fridge/freezer are

grouped as food preserving appliances, radio/television are classified as entertainment appliances and microwave/washing machines are grouped as luxury appliance, and, lastly, ownership of a cell phone, computer, and/or landline are classified as communication appliances. The possession of the different types of electrical appliances by low-income households is presented in Figure 8.2.



	food preserving appliance	entertainment appliance	luxury appliance	communication appliance
Yes	51.65	76.60	20.82	81.59

Figure 8:2 Ownership of Electrical Appliances by Low-income Households

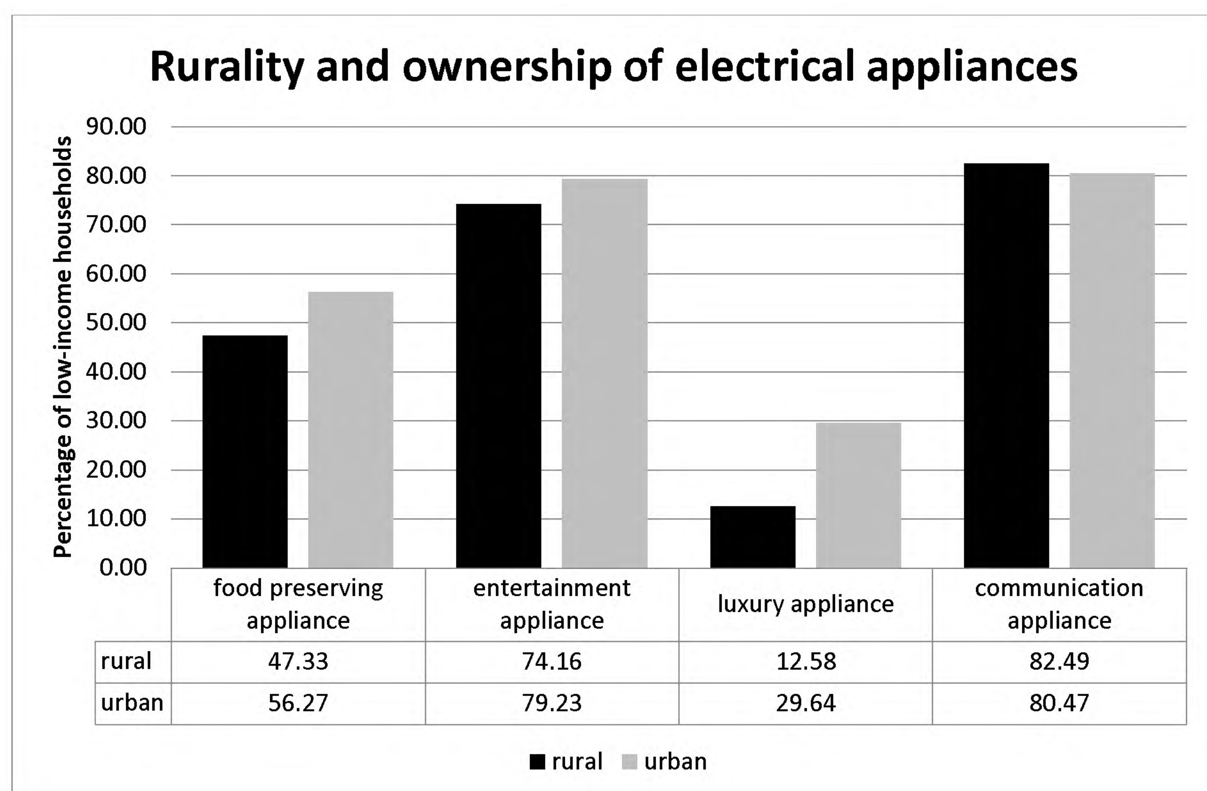
About 82% of low-income households use communication appliances which is an indication of the relative importance to them of cell phone, computer, or landline. As shown in Chapter 2 the use of a landline or cell phone plays a crucial role in socio-economic development (Nussbaumer *et al.* 2011, 2012; Practical Action 2010).

Entertainment appliances are useful for keeping abreast of world events, and for entertainment (Jones *et al.* 2015; Marker *et al.* 2002). Ownership of entertainment appliances is one of the dimensions of multidimensional energy poverty (Nussbaumer *et al.* 2011), serving as a measurement of energy poverty. The proportion of low-income households owning a radio or television is about 77% in 2010/2011.

There is, in fact, a low level of ownership of luxury appliances among low-income households about 21% of whom own a microwave or a washing machine. Washing machines*, which provide relief from cumbersome washing methods (Sparknet 2010),* are seldom found in low-income households (Jones *et al.* 2015; Matsumoto 2015 and Mzini and Lukamba-Muhiya 2014). Also only, about 52% of low-income households have access to refrigerator which allow the purchase of perishable products in bulk, thereby saving money and time.

8.7 Rurality and Ownership of Electrical Appliances

An understanding of the differences in ownership of electrical appliances between rural and urban low-income households is important. The linkage between rurality and ownership of electrical appliances is presented in Figure 8.3.



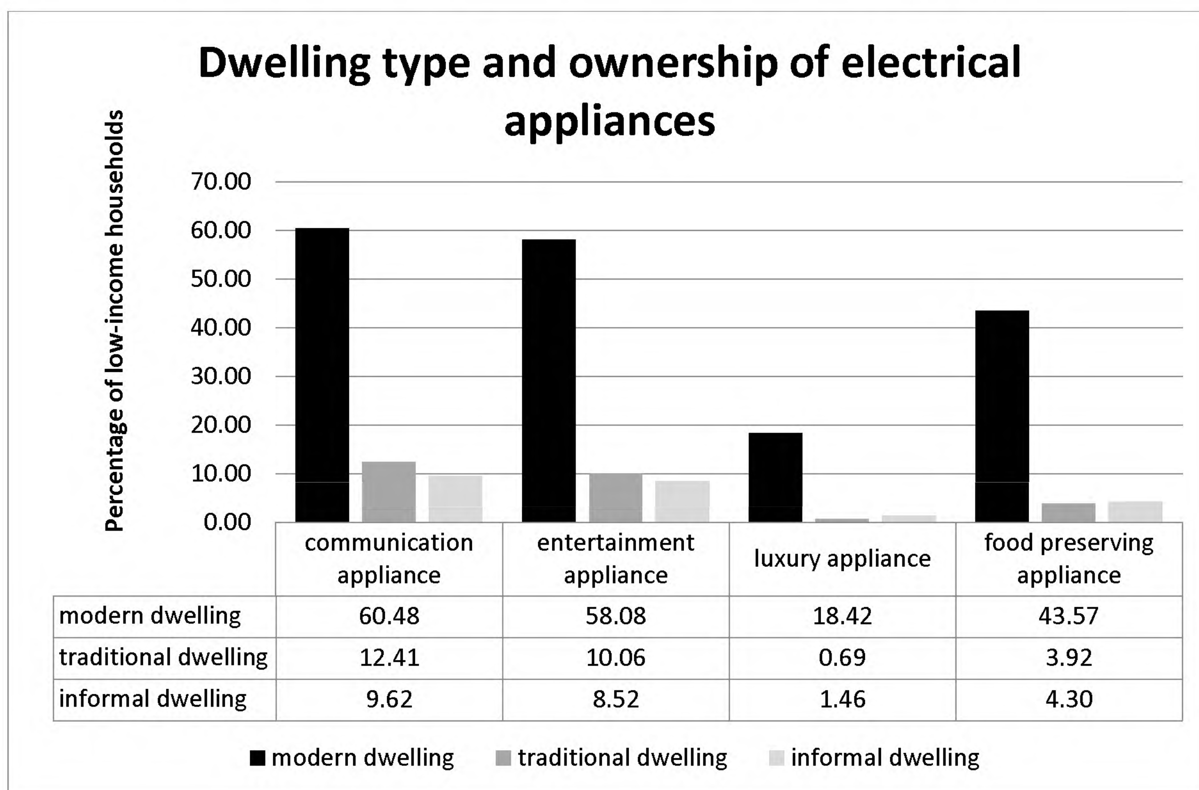
	food preserving appliance	entertainment appliance	luxury appliance	communication appliance
rural	47.33	74.16	12.58	82.49
urban	56.27	79.23	29.64	80.47

Figure 8:3 Rurality and Ownership of Electrical Appliances

About 81% of low-income households in both urban and rural areas have communication appliances. Surprisingly, more rural low-income households are in possession of communication appliances than their counterparts in urban areas. A probable reason for this is that rural households need to communicate with people in urban areas to get assistance for infrastructures and services without having to travel to the cities. This is of less concern to urban low-income households who have these essential infrastructures and services close at hand (Food and Agriculture Organisation 2016). Luxury appliances are barely possessed by either urban or rural low-income households. There are about 30% and 13% of low-income households with luxury appliances in the urban and rural areas respectively. Furthermore, low-income households in both urban and rural areas are more likely to own entertainment appliances than food preserving appliances. About 74% of rural low-income household own a radio and/or television compared with the 47% that own a fridge and/or freezer. Likewise, about 79% of urban low-income households claim ownership of an entertainment appliance while 56% own a food-preserving appliance. This deduction corresponds with the study by Rathi *et al.* (2012), who found that entertainment appliances are more sought after by low-income households in China than are food preserving appliances.

8.8 Dwelling Type and Ownership of Electrical Appliances

Dwelling types and ownership of electrical appliances are assumed to be linked (Jones *et al.* 2015). The type of dwelling, modern, traditional or informal, could justify a possible reason for the acquisition of electrical appliances (Jones *et al.* 2015). It is notable that while informal settlements are the fastest growing household sector in South Africa, the vast majority of these informal households are not linked to the national electricity grid (Gaunt *et al.* 2012). The relationship between dwelling types and ownership of electrical appliances by low-income households in 2010/2011 is presented in Figure 8.4.



	communication appliance	entertainment appliance	luxury appliance	food preserving appliance
modern dwelling	60.48	58.08	18.42	43.57
traditional dwelling	12.41	10.06	0.69	3.92
informal dwelling	9.62	8.52	1.46	4.30

Figure 8:4 Dwelling Type and Ownership of Electrical Appliances

Low-income households living in a modern type of dwelling are mostly in possession of electrical appliances compared to their counterparts living in either a traditional or informal house type. Low-income households living in modern, traditional, or informal dwelling are more frequently in possession of communication appliances than of entertainment, luxury, and food preserving appliances. The ownership of entertainment appliances is more predominant than of food preserving appliances by low-income households in all three main dwelling types. Luxury appliances are seldom owned by modern (18%), traditional (1%), and informal dwellers (2%). It is, however, surprising to find that there are more low-income households in informal dwellings that are in possession of luxury and food-preserving appliances than there are among their counterparts residing in traditional dwellings. Most low-income households living in an informal dwelling are in urban areas and consequently are likely to have connections that are in fact illegal connections (SEA 2014).

8.9 Correlation Analysis, Overview of the Econometric Model and Variable Description

A correlation analysis was first conducted among the most likely variables to be used in the regression analysis; these include ownership of a communication appliance, a luxury appliance, an entertainment appliance, a food-preserving appliance, dwelling type, rurality, household size, household income, gender, and access to FBE. If the household owns a communication appliance, such as cell phone, landline, or computer, the variable was coded as 1, and 0 otherwise. For ownership of a luxury appliance, the variable was coded as 1 if the household owned a microwave or washing machine, and 0 otherwise. If the household owned an entertainment appliance such as a radio or television, the variable was coded as 1, and 0 otherwise. Lastly, with electrical appliances, for ownership of a food-preserving appliance, the variable was coded as 1 if households owned a fridge or freezer, and 0 otherwise. Dwelling type is a binary variable and low-income households living in a modern dwelling were coded as 1, and 0 otherwise or living in a non-modern dwelling. Rurality is also a binary variable and urban low-income households were coded as 1, and 0 otherwise for a rural low-income household. Household size was coded as 1 if the household size is small with 1 – 4 persons and 0 if the household size is large at 5 persons and more. Household income is a continuous variable indicating the actual household income per month. Gender is a binary variable and a male household head was coded as 1, and 0 if household head is a woman. Finally, access to FBE was coded as 1 if the low-income household has access to FBE, and 0 otherwise.

The correlation coefficients for these variables is given in Table 8.7. A high correlation or multicollinearity in cross sectional models violates the assumptions of the model and can produce biased estimates (Maddala 2001; Mukaka 2012; Tu *et al.* 2005). If the coefficient value lies between ± 0.50 and ±1, then it is said to be a strong correlation (Garcia 2011; Piovani 2008). A correlation coefficient between ±0.30 and ±0.49 suggests a moderate correlation while a value below ± 0.29 is said to be a low or weak correlation (Garcia 2011; Piovani 2008).

The correlation matrix suggest that household income is strongly correlated with the rest of the variables as illustrated in Table 8.7. This suggests that household income shares common factors with the other variables and that to include it in the same model, as correlated variables would produce biased estimates. As discussed in Chapter 6, a binary logistic model (reporting odds ratio) was used to examine whether FBE is significant for the low-income households. The purpose of the FBE is to ensure that low-income households spend less on electricity thereby being able to transfer expenditure on energy to other household priorities such as food (Wentzel 2005).

Table 8:7 Correlation Analysis of Variables Considered for Regression Analysis

Variables	rurality	hhsize	gender	dwelling	FBE	hhincome	food-preserving	entertainment	luxury	communication
Rurality		- 0.001	-0.013	0.207	0.000	0.612	0.030	0.113	0.108	0.089
HHsize	-0.011		0.026	0.000	-0.004	-0.483	-0.023	-0.009	-0.002	-0.013
Gender	-0.013	0.026		0.009	-0.006	-0.513	-0.031	-0.006	0.005	-0.009
Dwelling	0.207	0.003	0.009		-0.007	-0.596	-0.080	0.093	0.244	0.074
FBE	0.000	-0.004	-0.006	-0.007		0.871	0.019	0.004	-0.003	0.006
HH income	0.612	-0.488	-0.513	-0.596	0.871		0.469	0.439	-0.931	0.668
Food-preserving	0.030	-0.023	-0.031	-0.080	0.019	0.469		0.050	-0.031	0.064
Entertainment	0.113 0.141	-0.009	-0.006	0.093	0.004	0.439	0.249			0.049
Luxury	0.108	-0.002	0.005	0.244	-0.003	-0.931	-0.031	0.049		0.038

Other benefits include extended electricity use as well as electrical appliance acquisition and health and safety improvements (Mapako and Prasad 2005). In such instances, the allocation of the free 50kWh of electricity was intended to enable low-income households to meet their energy needs for lighting, ironing, cooking, boiling water in an electric kettle, a small fridge, a black and white television and a small radio. From these lists, data for ownership of fridge, television, and radio is available in the IES 2010/2011. The impact of FBE is narrowed down to the ownership of electrical appliances because the dataset did not allow the investigation of the FBE on a full range of household energy needs. According to Wentzel (2005), the ownership of electrical appliances by low-income households is an important indicator that some social equality has been achieved and it is also linked to an improved quality of life. Furthermore, Leahy *et al.* (2012) report that ownership of electrical appliances could determine residential electricity consumption.

The dependent variables are ownership of entertainment appliance and ownership of food-preserving appliance. Each electrical appliance type is an indicator of whether the low-income households receiving FBE acquire electrical appliances. The independent variables considered include rurality, household size, dwelling type, and access to FBE. The gender of the household head is also included as part of the independent variables. The reason for including gender is to understand the differences ownership of electrical appliances and gender, perhaps a female household head might potentially own electrical appliances or *vice versa*. The objective is to determine to what extent access to FBE increases the probability of low-income households owning an entertainment appliance and a food preservation appliance when controlling for other variables in the model.

As the choice of the model is based on the dependent variable, which has a binary response of either yes or no, the binary logit model to be fitted for each dependent variable is written as:

E(ownership of entertainment appliance) = $e^{(\beta 0 + \beta 1X1 + \beta 2X2 + \ldots\ldots + \beta kXk)} / 1 + e^{(\beta 0 + \beta 1X1 + \beta 2X2 + \ldots\ldots + \beta kXk)}$ and;

E(ownership of food-preserving appliance) = $e^{(\beta 0 + \beta 1X1 + \beta 2X2 + \ldots\ldots + \beta kXk)} / 1 + e^{(\beta 0 + \beta 1X1 + \beta 2X2 + \ldots\ldots + \beta kXk)}$

The binary logit model estimates a set of regression coefficients that predict the probability of the outcome of interest (Hosmer and Lemeshow 2000; Long and Freese 2006). The odd that access to FBE increases the ownership of entertainment/food-preserving appliances implies the ratio of the number of low-income households who possess the appliance to the number of low-income households who do not. The coefficients in the logistic regression model shows the extent to which the logit changes are based on the values of the independent variables (Hosmer and Lemeshow 2000; Long and Freese 2006).

The considered independent variables, with the exception of household income, were tested for multi-collinearity. The variance inflation factor (VIF) and tolerance value were used to detect if multi-collinearity exists among the variables. The test result showed that the VIF for each independent variable is less than 1.2 and the tolerance value ranges between 0.986 and 0.996 (See Appendix G for full result). Multi-collinearity is not a problem in the regression analysis. The description and measurement of the variables with their hypothesised signs is presented in Table 8.8.

Table 8:8 Variable Description, Measurement, and Hypothesised Signs

Variable names	Variable description and measurement	Hypothesised sign
Dependent variables		
Entertainment appliance	A binary variable indicating ownership of radio or television 1= has radio/television; 0= no radio/television	
Food preserving appliance	A binary variable indicating ownership of fridge or freezer 1= has fridge/freezer; 0= no fridge/freezer	
Independent variables		
Household size (small household size is the reference category)	A binary variable indicating the number of people living in a household 1=small household size (1-4 persons); 0=large household size (5persons and above)	+
Dwelling type (modern dwelling is the reference category)	A binary variable indicating the type of household dwelling 1=modern dwelling; 0=non-modern dwelling	+
FBE (access to FBE is the reference category)	A binary variable indicating whether the household receives the free basic electricity or vice versa 1= access to FBE; 0= no access to FBE	+
Rurality (urban is the reference category)	A binary variable indicating the location where household lives 1=urban; 0=rural	+
Gender (female is the reference category)	A binary variable indicating the gender of household head 1=male; 0=female	+/-

All the predictors, other than the gender, are hypothesised, *a priori*, to have a positive influence on ownership of entertainment/food-preserving appliances. The odds ratio suggest that ownership of food-preserving/entertainment appliances will be positively affected by small household size, modern dwelling type, receiving FBE, and living in an urban area. As discussed in Chapter 5, these assumptions are based on the notion that 50kWh is suitable for small household size which are likely to have limited energy demands (Eberhard 2004, and are more likely to be in possession of entertainment/food-preserving appliances than would be a large household size.

Low-income households living in a modern dwelling are more likely to own entertainment/food-preserving appliances than are their counterparts. Informal dwellings, which are under the sub-group of non-modern dwelling, are on unauthorised land which is not zoned for residential development so unlikely to be connected to the national electricity grid (SEA 2014). There is a relationship between a modern type of dwelling and ownership of entertainment/food-preserving appliances with respect to low-income households.

Low-income households with access to FBE are more likely to own entertainment/food-preserving appliances than those without FBE. There is a relationship between FBE access and ownership of entertainment/food-preserving appliances.

Low-income households living in urban areas are more likely to own entertainment/food-preserving appliances than are those in rural areas because, as discussed in Chapter 5, urban settlements are likely to have access to the national electricity grid whereas those in rural are not (SEA 2014).

Lastly, gender is ambiguous and so is hypothesised as having either a positive or a negative influence on ownership of entertainment/food-preserving appliances. As the guidelines of the FBE determine, the electricity allocation is intended to enhance the well-being of the poor, and especially the women and children, because they probably spend most of their time in the house (Chapter 5) (DoE 2013).

8.10 The Proportion of Low-income Households Accessing FBE

As mentioned earlier, the Department of Minerals and Energy defined qualified low-income households for FBE as households whose total and gross monthly income does not exceed two old age pensions which is R2160 (DME 2003). Following this definition, the total number of low-income households in the IES 2010/2011 is 9 046. The assumption is that these households are eligible for FBE but not all are connected to the electricity grid. The number of low-income households eligible for the FBE policy compared to the proportion actually receiving FBE provides an insight into the beneficiary incidence (the ratio of low-income households that qualify for FBE to those actually receiving FBE). The result of low-income urban and rural households with and without the FBE is presented in Table 8.9.

Table 8:9 Share of Low-income Households Receiving FBE

	Urban		Rural	
	Number	Percentage	Number	Percentage
Total representative sample of low-income households	4372	48.33	4674	51.67
Low-income households receiving FBE	1294	29.60	720	15.40
Low-income households not receiving FBE	2372	54.25	2845	60.87
No response	706	16.15	1109	23.73

Table 8.9 shows that about 30% of urban low-income households who responded receive FBE while only 15% of their counterparts receive FBE in the rural areas. This shows that less than half (45%) of low-income households received the FBE in 2010/2011. There are various figures about access to FBE reported from different government bodies: according to DoE (2013), about 59% of poor households are benefiting from the FBE policy while the National Treasury reported that about 30%

benefitted in the same year. Statistics South Africa (2013), on the other hand, reported the figure as 51%. Eberhard and PDG (2010) reported that only one-third of eligible households receive FBE which is in agreement with the findings of the National Treasury. Nevertheless, the reality remains, from this study, that more than half of the eligible households are not receiving the FBE. Both those low-income households receiving FBE and those not receiving, but who qualify to receive it were used in the regression analysis.

Furthermore, urban and rural low-income households not receiving FBE is about 54% and 61% respectively. These percentages show that there are more rural low-income households not receiving the FBE than there are in urban areas.

8.11 Binary Logit Regression showing the Significance of FBE through Ownership of Entertainment and Food-preserving Appliances

The results of the binary logit regression for ownership of an entertainment appliance is presented in Table 8.10. The purpose of the binary logit regression is to demonstrate the significance of the FBE policy through the ownership of entertainment and food-preserving appliances. In interpreting the results, the exact levels of significance were used to interpret statistical significance of estimates; the signs of the coefficients indicate the direction of influence of the independent variables on the dependent variable, which is the ownership of entertainment/food-preserving appliances. According to Long (1997), an odds ratio greater than 1 indicates that success is more likely than failure and an odds ratio less than 1 indicates that failure is more likely than success. The likelihood ratio chi-square of 139.49 with a p-value of 0.0000 means that the model fits statistically better than does a model with no predictors.

Table 8:10 Binary Logit Regression for Ownership of Entertainment Appliance

Variables	Odds ratio	Standard error
Rurality (urban)	1.334***	0.086
Household size (small)	0.512***	0.042
Gender (male)	1.042	0.066
Dwelling type (modern dwelling)	1.524***	0.111
Access to FBE	1.284***	0.096

Number of observations: 7169 low-income households
Pseudo R^2: 0.0209
LR chi2 (7): 139.49
Prob > chi2: 0.0000
T-statistics: * significant at 10%; ** significant at 5%; *** significant at 1%

Rurality (urban), household size (small household size), dwelling type (modern dwelling) and access to FBE are statistically significant at 1% level of significance and with positive signs.

The results show that, holding all the other control variables constant, the probability of low-income households owning an entertainment appliance is positively and significantly influenced by access to FBE. The odds ratio of access to FBE is 1.284, implying that access to FBE could increase the probability of low-income household owning an entertainment appliance by about 1.3, holding other variables in the model constant. It was argued that the free 50kWh per month is adequate for a poor/low-income household to meet their needs for lighting, media access, limited water heating, and basic ironing and cooking (Makonese *et al.* 2012). Mapako and Prasad (2005) contend that the FBE policy intervention does indeed have significant social benefits as demonstrated by their study, which showed that low-income households have more electricity days in a month which has enabled them to have access to media by means of television and radio, among many others. Their findings are supported by the results of this study.

Furthermore, the odds ratio of living in an urban area is 1.334. The implication is that living in an urban area could increase the probability of low-income households owning

an entertainment appliance by about 1.3. This is because a larger percentage of urban low-income households, about 30%, access FBE than do their rural counterparts (15%).

The odds ratio for low-income households with small household size is 0.512, implying that small household size could increase the probability of low-income households owning an entertainment appliance by about 0.5, than could those of large household size. Cowan and Mohlakoana (2004) and Dugard (2009) have shown that larger household size, of five persons and above, do not benefit from the free electricity because the FBE allocation has to be shared between more people that can reasonably take advantage of it. The odds ratio for small household size, less than 1, indicates that failure is more likely than success. One criticism discussed in Chapter 5 was that the FBE does not benefit large size households as much as it does households of smaller sizes. This is because the amount decided upon for the FBE was based on the argument that low-income households usually have a low demand for electricity but this thesis disregarded household size. The present study concludes that low-income households of small household size benefit from FBE more than do those of large household size.

The result also shows that the type of dwelling which a low-income household lives influences the likelihood of owning an entertainment appliance. The odds ratio of a modern dwelling is 1.524 implying that living in a modern dwelling could increase the probability of low-income households owning an entertainment appliance by about 1.5 holding other variables in the model constant. Rao and Ummel (2017), in their study with respect to South African households, discovered that better quality homes (an indicator of wealth) are more likely to have electrical appliances than are simpler ones.

Lastly, the odds ratio of a male-headed household does not influence the probability of owning an entertainment appliance.

Table 8.11 shows the binary logit regression for ownership of food-preserving appliance.

Table 8:11 Binary Logit Regression for Ownership of Food-preserving Appliance

Variables	Odds ratio	Standard error
Rurality (urban)	1.252^{***}	0.065
Household size (small)	0.512^{***}	0.032
Gender (male)	1.740^{***}	0.088
Dwelling type (modern dwelling)	2.345^{***}	0.145
Access to FBE	1.414^{***}	0.083

Number of observations: 7161 low-income households
Pseudo R^2: 0.0209
LR chi2 (7): 510.20
Prob > chi2: 0.0000
T-statistics: * significant at 10%; ** significant at 5%; *** significant at 1%

All the variables are statistically significant at a 1% level of significance and with positive signs.

The results show that, holding all the other control variables constant, the probability of low-income households owning a food-preserving appliance is positively and significantly influenced by access to FBE. The odds ratio of access to FBE is 1.414, implying that access to FBE could increase the probability of low-income households owning a food-preserving appliance by about 1.4, holding all other variables in the model constant. Ruiters (2009) argues thus, that, the 50kWh is in fact insufficient to cover refrigeration as most low-income households still depend on old appliances that are energy inefficient. The inference from this result is that it is most probably that a modern fridge/freezer is owned by the low-income households as they are designed with energy saving initiatives and as such consume 75% less energy compared to the old models of refrigeration, which consume more energy (Makonese *et al*. 2012).

The odds ratio for low-income households living in an urban settlement is 1.252 meaning that the probability of low-income households owning a food-preserving appliance is increased by about 1.25 more than are the odds for rural low-income

households owning such an appliance. Rathi *et al.* (2012) found among Indian low-income households that the ownership of refrigerators is low in urban areas and very low in rural areas as a refrigerator is classified as an electrical appliance for higher income earners.

As found with ownership of entertainment appliances, the odds ratio of small households is 0.512, implying that small household size could increase the probability of low-income households owning a food-preserving appliance by about 0.51.

Gender is statistically significant, implying that a household headed by a male is likely to own a food-preserving appliance. The odds ratio is 1.74, meaning male-headed households are 1.74 times more likely to own food-preserving appliance than the odds for a female household head.

Lastly, a modern type of dwelling influences the probability of owning a food-preserving appliance. The odds ratio of living in a modern dwelling is 2.345, which means that a modern dwelling could increase the probability of low-income households owing a food-preserving appliance by about 2.4. As discussed earlier, about 44% of low-income households living in a modern dwelling own a food-preserving appliance compared to those living in non-modern dwellings (traditional dwelling- 4% and informal dwelling- 4%).

An observation from these results is that the FBE is an effective subsidy for those low-income households who have access to it. In addition, low-income households of 1 to 4 persons benefit more than those of 5 and more persons.

8.12 Conclusion

Evidence of the transition pattern of low-income households is the topic of this chapter. The outcome of the ordered logit regression shows that income is statistically significant for energy choice for cooking, which is an energy ladder behaviour and statistically insignificant for energy choices for heating and lighting suggesting an energy stacking behaviour. The marginal effect also highlights the key roles of some non-economic characteristics in determining the energy choice/s of households. Modern energy carriers are most preferred by low-income households for cooking, heating, and lighting.

Living in a modern dwelling, living in an urban area and having a small household size are statistically significant variables influencing the preferred use of a modern energy carrier for cooking and heating over transitional or traditional energy carriers. Low-income households used more modern energy carriers for cooking/heating in 2010, 2012, and 2014 than they did in 2008. The predicted probabilities show a high preference for modern energy carriers for cooking and heating.

Living in a modern dwelling and living in an urban area are statistically significant variables influencing the preferred use of a modern energy carriers for lighting. A large number of low-income households preferred to use a modern energy carrier for lighting in 2014. The predicted probability shows a higher preference for modern energy carriers for lighting than for candles or transitional energy carriers.

The chapter also considers the results of the FBE policy by using the IES 2010/2011. Most low-income households are connected to the national electricity grid and are earning less than two old people's pension and for them the ownership of a communication appliance is common while ownership of a luxury appliance is least common. Rural low-income households own more communication appliances than do their urban counterparts. Living in a modern dwelling is very likely to influence the possession of electrical appliances. More urban low-income households receive FBE than do their rural counterparts.

The binary logistic regression showed that for small household sizes, living in a modern dwelling, with access to the FBE program and living in an urban area are statistically significant factors influencing the ownership of an entertainment appliance for low-income households. On the other hand, living with a male household head in an urban area, in a modern dwelling with a small household size, and access to the FBE program are significant factors that will influence the ownership of food-preserving appliances for low-income households. Household size, especially a larger household size, is most likely to benefit less from the FBE subsidy while those with a small household size are likely to benefit more. On a final note, the FBE is an effective subsidy-obviuosly-only to those low-income households that have access to it.

Chapter 9

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

9 Introduction

Energy poverty, at the micro-economic level, is a growing concern among low-income populations in developing countries (Pachauri and Spreng 2011). The importance of accessibility to electricity in defining energy poverty for developing countries has been identified as crucial in alleviating energy poverty (Nussbaumer *et al.* 2012; Sovacool *et al.* 2012). Most countries in Africa face substantial challenges in widening and improving access to modern energy services, particularly electricity (Sokona *et al.* 2012). A large proportion of Africa's population relies on traditional and/or transitional energy carriers. Only 28% of Africa's population, excluding that of South Africa, have access to electricity through the grid (Hailu 2012).

South Africa is a country in energy transition and is one of a few African countries that has made significant progress towards addressing the provision of modern energy services (Ismail and Khembo 2015). The government has introduced a number of national programmes in order to extend access to electricity (DoE 2013). These include, the Integrated National Electrification Programme (INEP) and the Free Basic Electricity (FBE) Policy. The INEP provides the socio-economic support that ensures that previously unconnected houses have access to electricity while the FBE policy aims to address affordability problems related to electricity.

This study set out to contribute to knowledge in the field of energy economics and environmental and natural resource economics by investigating the energy use patterns and trends amongst low-income South African households. The intention was to determine whether the FBE policy have achieved their objectives of alleviating energy poverty for low-income households. The overall goal of the study was to evaluate energy use patterns and trends in low-income South African households through the following objectives; to investigate the extent of energy poverty in low-income

households; to examine the extent to which the 'energy ladder' or 'energy stacking' models explain energy transition patterns; and to examine whether the FBE policy has had an impact on household energy choices and on energy poverty. The research utilised the National Income Dynamics Survey and Income and Expenditure Survey datasets to address its objectives. The study investigated energy poverty using the multidimensional energy poverty index (MEPI) which is designed to capture energy deprivations experienced by a person or a household by using a basket of energy dimensions. The study also looks at the energy transition models that govern the energy consumption patterns of low-income households in South Africa. Understanding the energy choice of low-income households is vitally important in designing suitable policies for the support of the transition process. In addition, the results from the study suggest a spectrum of determinants that go beyond income in influencing energy choice/s. The extent to which low-income households which are eligible for the receipt of FBE was undertaken to assess the impact of the FBE policy by using a binary logistic regression analysis to record and understand the characteristics of the low-income households that take advantage of the FBE allocation. During the study, some questions arose that are related to energy poverty, energy patterns and trends, and energy policies. In order to accommodate these questions, areas for future further research have been proposed towards the end of the chapter.

9.1 Summary of Research Findings

9.1.1 Multidimensional Energy Poverty among Low-income Households in South Africa

The discussion of the MEPI measure focused on investigating the extent of energy poverty among low-income households in terms of basic energy services which are defined as dimensions. The six dimensions used in the MEPI measure, as discussed in Chapter 7, include, cooking, heating, lighting, basic household appliances, entertainment/education appliances, and telecommunication appliances. The MEPI allows for decomposability, for example, urban versus rural, which is indicated in the results.

Following Nussbaumer *et al.* (2013), a MEPI score greater than 0.3 but less than 0.7 indicates moderate energy poverty and in this study, the MEPI from both the cross-sectional and panel analyses are within this range of 0.37 – 0.62 implying that low-income households either in urban or rural areas are in a moderate state of energy poverty but at different levels. Chapter 5 demonstrates how different approaches have been used in South Africa to measure energy poverty. The use of energy expenditure approach revealed that 47% of all South African households were found to be energy poor in 2012. The thermal efficiency approach showed that 49% of South African households were energy poor in 2012. Lastly, the subjective approach identified 66% of South African households as being energy poor in 2012. The advantage of the MEPI, however, is that it can be disaggregated into sub-groups such as rural and/or urban, and also that energy poverty in different dimensions can be explored in such a way as to identify the group that is in a state of energy poverty. Using the MEPI approach, energy poverty was endemic in rural low-income households, more so than in urban low-income households.

Having a disaggregated look at the MEPI score across the years, 2008 to 2014, it becomes clear that there is a gradual change in energy poverty for both rural and urban low-income households. From the 2008 findings, 62% of rural-low income households were multidimensionally energy poor whereas in 2014, 59% were energy poor. The percentage of low-income households that were energy poor consistently decreased marginally over time for rural low-income households between 2008 and 2014. This demonstrated some marginal progress with regard to alleviating energy poverty in rural areas. Among urban low-income households, 38% were multidimensionally energy poor in 2008 whille 41% were multidimensionally energy poor in 2014. The trend indicated an increase in energy poverty. This result was based on the use of a panel data (NIDS) in which the same houses are being interviewed at two-yearly intervals. Rising energy poverty in urban areas could be the result of an increased migration of rural low-income households to urban settlements which makes it difficult for the government to keep pace with increasing demand from the the fast growing urban population. Another reason is that low-income households in urban areas could be using more electricity but that increase in electricity prices have resulted in greater energy poverty. These

conclusions may be correct but cannot be deduced from this data. It is not surprising that more urban low-income households have become energy poor over time between 2008 and 2014 as demand for electricity increases. Although policies addressing accessibility and affordability of electricity in urban settlements could be in place, the expansion of access may be falling below population growth rates. The census data of 2011 revealed that South Africa's metros and secondary cities are rapidly growing in population size (Statistics South Africa 2012) and that approximately 64% of the country's population reside in urban areas (2011 national census data) (Ruhiiga 2014; SEA 2014).

Urbanisation, according to Ruhiiga (2014), requires an understanding of the demographic changes taking place in the city itself as well as in the context of rural-urban migration. One of the challenges posed by urbanisation is government service provision in which energy supply in the form of electricity is part of the bundle (Gaunt *et al.* 2012). Gaunt *et al.* (2012) also found that most urbanisation growth occurs in informal settlements and among low-income groups with the result that basic service delivery challenges escalate in informal settlements, especially among low-income group. The majority of informal settlements are situated on the boundary of cities, where there is no formal access to Eskom or to electricity distributed by Municipalities (SEA 2014; Swart and Bredenkamp 2012). Many households in informal settlements that do have access to electricity are likely to be receiving it through illegal connections (SEA 2014; Swart and Bredenkamp 2012). One of the objectives of the National Development Plan is to build modern houses for the poor which are considered to have the potential to resolve some of the challenges of energy poverty. Although informal settlements have been included in electrification programs in order to address accessibility, their access to the FBE, which would address affordability is not yet in place. Clearly, the government has to pay close attention to the social welfare of low-income households in informal settlements.

As already mentioned, the measure of multidimensional energy poverty takes into account the extent of energy poverty among individuals or households (Nussbaumer *et al.* 2011). According to Alkire *et al.* (2011) and Nussbaumer *et al.* (2012), the capacity of low-income households to have access to electricity and to afford to use the electricity is

one important intervention that could address energy poverty. That people can benefit from the services with effective use of electrical equipment such as electric stoves, refrigerators, washing machines, and television and communication technology is an indicator of being energy non-poor.

Descriptive statistics showed that most low-income households could acquire basic electrical appliances, such as fridges or washing machines, educational/entertainment appliances such as radios, telecommunication devices such as cell phones, and are able to use modern fuels for cooking and lighting. Low-income households, however, in either urban or rural areas, were mostly deprived in the heating fuel dimension. Since low-income households demonstrate a severe deprivation, of 95% energy poor, regarding access to modern energy fuel for heating purposes, indicates that this is perhaps the dimension that should be prioritised by policy makers. Although South Africa does not have extreme cold conditions, it is one of the few countries on the African continent that does have cold winters. In South Africa, the incidence of influenza or flu is seasonal and during winter there are death rates of between 6 000 – 11 000 every year (Health Department 2014; Wright *et al.* 2014). Households must employ a range of strategies to keep warm but the Department of Energy (2013) reported that 39% of electrified households, not specifically low-income households, use no energy source for heating, but use blankets and warm clothing.

Space heating is an energy-intensive thermal application and consumes a high electricity current so that some low-income households cannot afford to use a modern energy carrier such as electricity for their space heating. In terms of indoor air pollution, modern energy carriers are clean and more efficient than traditional or transitional energy carriers (Bhide and Monroy 2011; Van der Kroon *et al*. 2013). The descriptive statistics in Chapter 7, with respect to the link between rurality and energy choice for heating, shows that most rural low-income households use traditional energy carriers for heating rather than modern energy carriers. According to Practical Action (2010), space heating is a matter of energy balance. Promoting and supporting the use of modern energy carriers for this energy service leads to less wood fuel being collected for heating (Practical Action 2010). .

Amartya Sen's capability approach rejects monetary income as its indicator of well-being and focuses on indicators of the freedom to live a valued life or the ability to satisfy certain crucially important activities or functionings up to certain minimal levels (Sen and Nussbaum 1993). One could associate multidimensional energy poverty measures with Sen's capability approach. Amartya Sen's capability approach (Sen and Nussbaum 1993). The implication of this is that affordable access to electricity and how it affects quality of life for low-income households is a measure of the freedom to live fulfilled lives. In this way, low-income households should be in a position to decide freely the level of consumption of electricity that is necessary to meet their basic needs and the capability approach should enable this access to the fulfilment of basic needs thereby achieving energy non-poverty.

9.1.2 Energy Transition Patterns of Low-income Households in South Africa

The study also set out to examine the energy transition patterns for low-income households in the light of three major energy services: cooking, heating, and lighting needs. Energy transition has been conceptualised in the form of the 'energy ladder' or 'energy stacking' models (Kowsari and Zerriffi 2011; Lee *et al.* 2015; Van der Kroon *et al.* 2013). The 'energy ladder' model assumes that households will move to modern energy carriers, which are at the top of the energy ladder, as their income increases. The 'energy stacking' model, on the other hand, implies that with an increase in income, households tend to use a combination of energy carriers as insurance against supply failure, or to risk minimisation, or because of cultural preferences. The use of panel data enables control for unobserved effects and explains energy choice over time. An 'energy ladder' or 'energy stacking' behaviour was analysed using an ordered logit model by examining households under three categories of their energy choice/s for cooking, heating, and lighting. The marginal effects of the different determinants on the probability of choosing a specific energy carrier were computed for low-income households.

The results confirmed an 'energy ladder' theory for cooking by low-income households. An insight on energy ladder behaviour for cooking is one key finding in this study in that low-income households that originally used traditional or transitional energy carriers

would shift up to transitional or modern energy carriers for cooking as their income increases. Modern energy carriers for cooking by low-income households reduces problems associated with traditional or transitional energy carriers, such as indoor air pollution. Chapter 3 provides examples of low-income households in some developing countries, specifically in Africa, who follow the transition pattern of an energy ladder behaviour, even though they are in urban areas.

This study also confirmed the 'energy stacking' theory for heating but suggests that energy stacking for lighting may not be true because low-income households use electricity for lighting as it does not consume much electricity. In the matter of heating, it is most likely that low-income households in either rural or urban settlements do not fully embrace the 'energy ladder' as income increases. Rather, traditional or transitional energy carriers are used as complements alongside with modern energy carriers. The result is consistent with previous studies that households do not move up the energy ladder as income increases, but rather engage in multiple fuel use (Guta 2012; Kowsari and Zerriffi 2011; Masera *et al*. 2000; Mekonnen and Kohlin 2008; Takama *et al.* 2011; Yonemitsu *et al.* 2014). One would expect that the energy policy, for example the FBE policy, would enable low-income households to switch completely to modern energy carriers. This suggests that one needs to look at factors that influence household energy choice and transition other than household income or energy price, as is widely assumed by the 'energy ladder' model.

With respect to country case studies of energy transition patterns, also explored in Chapter 3, the South African case is similar to other low-income households in Africa, for example, Ethiopia. Low-income households in Ethiopia exhibit an energy stacking behaviour which implies that households prefer to increase the number of fuels they use as their income improves. According to Guta (2012) and Mekonnen and Kohlin (2009), in their studies of Ethiopian low-income households, preference of food taste, dependability of energy supply, and availability of technology are highlighted as reasons for energy stacking behaviour. Although the electrification rate, or access to electricity, in Ethiopia is much lower, (27.2%) compared to that in South Africa (86%), there are problems for South African low-income households in affording electricity as the main source of power for space heating.

The results that emerge for the energy choice for cooking and heating is that living in an urban settlement, in a modern dwelling, and having a small household size (1– 4 persons) encourages the adoption of modern energy carriers. For urban low-income households who meet these criteria, there is a higher probability of using modern energy carriers for cooking and heating than for traditional or transitional energy carriers, and, even, when income increases there is not a complete switch to modern energy carriers at the top of the energy ladder. Rather, the complete switch to the top of the energy ladder is taken if the dwelling type is modern, the household size is small and it is in an urban settlement. The switch to modern energy carriers is not instantaneous holding these factors constant. Nevertheless, the use of energy efficient appliances for heating could assist in the switch to modern energy carriers. The importance of adopting an energy ladder behaviour by low-income households is the reduction of the use of traditional or transitional energy carriers; this would in turn have positive external results for society which include less deforestation and no emissions into the atmosphere.

The marginal effects corroborate findings from other studies. Suliman (2013) established that the effect of a modern roof significantly increases the probability of of the choice of the modern energy carrier, LPG and Baiyegunhi and Hassan (2014) show that households living in traditional houses are less likely to choose natural gas and electricity over wood. Van der Kroon *et al.* (2013) found that increasing family sizes suggest that the abundant labour available for fuel collection limits the need to use modern energy purchased in the markets. Khandker *et al.* (2012), in an energy poverty survey in India, found that 90% of the people who are without electricity live in rural areas where traditional fuels are the main source of energy. According to Mwaura *et al.* (2014), living in urban settlements is generally associated with access to more modern energy carriers and improved income.

Regarding energy choice for lighting, the facts are that living in a modern dwelling and in an urban area encourages the adoption of modern energy carriers so urban low-income households living in a modern dwelling are more likely to use a modern energy carrier for lighting than candles or transitional energy carriers. In addition, it does make sense that small household size does not influence an energy ladder behaviour for lighting as it

does for the energy choice for cooking and heating. Because lighting uses less electricity than does cooking and heating (Rantlo and Fraser 2015) as the numbers consuming electricity for lighting has no effect on the amount of electricity used.

Finally, findings show that the probabilities of modern energy carriers that are most preferred by low-income households for cooking is 64%, heating is 54%, and lighting is 77%. These percentages reflect an association between energy intensity and energy service. As already mentioned that lighting uses little electricity justifies most low-income households opting for modern energy carriers for their lighting. Regarding electricity current, cooking has less energy-intensive thermal application compared to heating. Putting aside energy intensity, these probabilities show the scale of preference by low-income households once accessibility and affordability of electricity is in place. The implication is that low-income households will first address lighting when there is affordable access to electricity so lighting is the major use of electricity (Barnes *et al.* 2011; Khandker *et al.* 2012). Other studies, for example, Swart and Bredenkamp (2012) and Vermaak *et al.* (2014) discovered that electrified houses use electricity differently from non-electrified houses: those with electricity use it mainly for lighting, then cooking, then space heating. A link to Sen's capability approach is that access to a good lighting source increase the quality of life for low-income households in terms of extended study time for students, extension of business hours for traders, and a perception of improved safety and security (Adam 2010; Ismail 2015; Mapako and Prasad 2005).

9.1.3 The Impact of the FBE Policy on South African Low-income Households

In summing up the research findings, the impact of the FBE policy on low-income households was examined. In 2003, the South African government introduced the policy of free basic electricity, a basic services support tariff, which allocates 50kWh of free electricity each month to low-income households (DME 2003; Inglesi 2010; Ruiters 2011). Due to apartheid's legacy of unequal municipal services provision, South Africa has had to provide infrastructure and subsidies one of which is the National Electrification Programme designed to alleviate the negative impact of energy poverty

by providing electrified low-income households with optimal socio-economic benefits (Bhorat *et al.* 2012; DME 2003; Eskom 2011).

The study, using the IES 2010/2011 dataset, found that 45% which is less than half of the surveyed low-income households who qualify either in the urban or rural areas receive FBE; the question is why. Previous studies, for example, Eberhard and PDG (2010) and Marquand *et al.* (2007) reported similar results. The descriptive statistics shows that 80% of low-income households were connected to the national electricity grid in 2010/2011, but the low percentage of access to FBE by eligible households is not only due to lack of connection to the grid but that challenges for the FBE policy include poor targeting, non-acquisition of prepaid metre, and tedious administrative processes.

According to Rawls's difference principle, 'an inequality in the distribution of wealth or income is unjust whenever it doesn't benefit the poorest members of society' (Altham 1973:75). This principle probably underpins the implementation of the FBE policy. Applying this principle to the roll out of the FBE policy requires that the government's dissemination of the policy be in the best interests of low-income households. Previous studies, for example Makonese *et al.* (2012) and Ruiters (2011), reported that there are some households not qualified as beneficiaries, who, nevertheless, are receiving FBE. If the government is sincere enough in its intention of addressing the affordability of electricity through the FBE policy, the implementation has to be well considered if the long standing expectations of low-income groups are to be maximised.

The study examined the effectiveness of the FBE policy, and based on the results of the study, it became apparent that the FBE policy is effective for low-income households who have access to it. The allocation was designed to meet the energy needs for lighting, ironing, cooking, boiling water with an electric kettle, small fridge, a black and white television and a small radio (DME 2004; Makonese *et al.* 2012). Also, food preserving and entertainment/education appliances link to the effectiveness of the FBE policy because it can influence the probability of low-income households owning a television, radio, and refrigeration electrical appliance.

The basic energy services that the FBE policy addresses align with the multidimensional measure of energy poverty both of which capture the essential energy services which can be used to communicate energy issues to policy makers and the public. The implication is that both the MEPI and the FBE results have shown the specific and defining factors of the way energy poverty is experienced among low-income households in South Africa. The use of modern energy carriers, especially electricity, to power the household basic energy services of cooking, heating, lighting, and ownership of electrical appliances are key issues and concerns in the eradication of energy poverty. This does not imply that the idea of energy poverty is asset-driven in nature in terms of electrical appliances. According to Nussbaumer *et al.* (2011), a range of energy services needs to be captured in order to reflect the complexity of the nexus between access to modern energy services and human development.

The findings have increased an understanding of the influence upon low-income households in South Africa of modern dwelling types when living in an urban area regarding the likelihood of being able to own a food preserving appliance and an education/ entertainment appliances. This information is important for providing support for the design and implementation of effective energy policies for the residential sector.

The research analysis has shown further that household size influences the effectiveness of the FBE for low-income households. Failure of the FBE is more likely than success considering the household size because 50kWh monthly must be shared by the whole household for their basic energy needs, so a large household would receive less benefit than would a small one; in this way, the policy is, in a sense, unfair. Previous criticisms of the FBE policy that also raised this point include Cowan and Mohlakoana (2004), Eberhard (2004), and Ruiters (2009). It will be necessary to suggest the use of energy saving appliances to increase the utility level of this subsidy.

The overall objective of this research was to evaluate energy use patterns and trends in low-income South African households and to gain an understanding of energy poverty from different perspectives for low-income household. The thesis undertook multidimensional perspective, an energy transition patterns perspective, and a policy

impact perspective. Following a level of consistency from the results (MEPI, energy transition patterns and impact of FBE policy), it became evident that low-income households in South Africa are indeed in a moderate state of energy poverty but that they do move up the energy ladder as income increases. Thus, income is very important in alleviating energy poverty. In addition, the FBE policy, which the government initiated towards the alleviation of energy poverty, had a considerable and positive impact on those that had access to it. That positive impact is likely to diminish if the household size increases to five persons and above and they will remain energy poor despite the 50kWh free allocation per month.

In summing up the discussion, a general assumption, with respect to energy poverty issues is that electricity contributes to fighting energy poverty. Accessibility and affordability of electricity is an indicator of human well-being as it informs all aspects of life and supports the fulfilment of important needs. While the FBE policy has undoubtedly contributed to decreasing levels of energy poverty, it is also clear that the FBE is not accessible to all qualified low-income households.

9.2 Implications of the Findings

The findings of the study indicate the necessity for different sectors to play active and supporting roles in order to decrease levels of energy poverty among low-income households. This section gives a series of options that can be deliberated.

9.2.1 Implications for South Africa

Low-income households are the focus for addressing energy poverty. The MEPI provides information on the extent of energy poverty, the group that has the greatest energy poverty and the energy dimension that measures the energy poverty of a household. MEPI could be useful in tracking improvements over time, for the low-income households. In addition, the energy dimension which can be used to address energy poverty, could be tracked for the welfare of the household because some are more important than others.

The MEPI analysis reveals that the most extensive energy poverty is to be found among rural low-income households. For urban low-income households, the MEPI analysis shows that energy poverty is increasing. These different levels of energy poverty suggest a need for different strategies to be implemented for each group.

The implications of the findings of the energy ladder versus energy stacking analysis is that in South Africa with a majority of the population having electricity access, some households are still energy poor. Policies to reduce energy poverty need a multi-pronged approach and not only a focus on electricity access, and this suggests that provision of a subsidy on transitional energy carriers, such as paraffin, could be an advantage.

The FBE results show that low-income households who have access to FBE are likely to own modern electrical appliances which points to the effectiveness of the policy despite criticisms that the 50kWh free monthly allocation is insufficient. A problem persists that 45% or less than half the surveyed low-income households, do access FBE. Further research could be undertaken to explore factors preventing qualified low-income households from gaining access to the FBE. Furthermore, the targeting technique for low-income households could be revised.

Should the South African government indicate an intention to revise the FBE policy, the electricity tariff structure used by the Nigerian government, as discussed in Chapter 4, is proposed as a reform strategy.

Improving housing for urban low-income households, especially those living on the boundary of the cities, might be a good policy and for increasing the use of modern energy carriers and reducing energy poverty. It is therefore suggested that urban planners and the Department of Energy work closely together to achieve success for these overlapping objectives.

A possible option to promote and support the use of modern energy carriers for heating would be an upgrade of heating methods to efficient appliances, which can save the consumer money and energy.

For a more accurate estimation of energy poverty than is possible as present, most especially in the evaluation of the impact of energy policy (FBE) and/or programme, it would be useful if the NIDS could incorporate information on FBE. This would facilitate a tracking over time of the effect of the FBE policy on low-income households resulting in precise information being obtained in the future.

9.2.2 Suggestions for Future Research

The study raised some questions, which deserve further investigation:

Like other developing countries, carrying out a multidimensional estimation of energy poverty at the national level is vital. Having an energy poverty index for the country enables comparison with other countries and the effective valuation of energy policy.

Considering the huge government investment in addressing the social welfare of low-income households, a comparative systematic research program is urged in order to examine the effect of using, or not using, energy saving appliances on the 50kWh free monthly allocation is suggested. This would enable one to determine whether the amount is sufficient or not and a new allocation could then be proposed.

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Appendix A: Correlation Result for MEPI

Variables	Electricity	Cooking	Heating	Lighting	Landline	Radio	Television	Computer	Cell phone	Fridge	Washingmachine
Electricity	1										
Cooking	-0.626	1									
Heating	-0.321	0.414	1								
Lighting	-0.866	0.639	0.346	1							
Landline	0.096	-0.122	-0.103	-0.107	1						
Radio	0.107	-0.058	-0.091	-0.100	0.032	1					
Television	0.450	-0.395	-0.251	-0.439	0.131	0.175	1				
Computer	0.066	-0.075	-0.083	-0.066	0.099	0.080	0.108	1			
Cell phone	0.117	-0.144	-0.109	-0.115	0.010	0.136	0.240	0.070	1		
Fridge	0.423	-0.381	-0.248	-0.419	0.145	0.142	0.519	0.115	0.240	1	
Washingmachine	0.192	-0.222	-0.139	-0.190	0.170	0.059	0.267	0.243	0.068	0.286	1

Appendix B: Multiple Correspondence Analysis (MCA) Result: Wave1

Multiple/Joint correspondence analysis — Number of obs = 2889; Total inertia = .1167513

Method: Burt/adjusted inertias — Number of axes = 5

Dimension	principal inertia	percent	cumul percent
dim 1	.0941642	80.65	80.65
dim 2	.0063966	5.48	86.13
dim 3	.0017118	1.47	87.60
dim 4	.0003079	0.26	87.86
dim 5	7.73e-06	0.01	87.87
Total	.1167513	100.00	

Statistics for column categories in principal normalization

Categories		overall		dimension_1			dimension_2			dimension_3		
	mass	quality	%inert	coord	sqcorr	contrib	coord	sqcorr	contrib	coord	sqcorr	contrib
electricity												
0	0.029	0.861	0.110	0.612	0.856	0.117	0.002	0.000	0.000	0.048	0.005	0.040
1	0.061	0.861	0.053	-0.293	0.856	0.056	-0.001	0.000	0.000	-0.023	0.005	0.019
cooking												
1	0.049	0.886	0.072	-0.391	0.883	0.079	-0.002	0.000	0.000	-0.022	0.003	0.014
2	0.017	0.806	0.046	0.412	0.526	0.030	0.299	0.278	0.231	0.024	0.002	0.006
3	0.026	0.836	0.069	0.474	0.721	0.061	-0.187	0.112	0.141	0.026	0.002	0.010
heating												
1	0.036	0.915	0.067	-0.445	0.913	0.075	-0.019	0.002	0.002	-0.012	0.001	0.003
2	0.011	0.725	0.027	0.214	0.159	0.005	0.401	0.556	0.278	0.046	0.007	0.014
3	0.034	0.862	0.068	0.430	0.786	0.066	-0.132	0.074	0.092	0.020	0.002	0.008
5	0.010	0.632	0.003	-0.087	0.265	0.001	0.065	0.149	0.007	-0.072	0.182	0.032
lighting												
1	0.061	0.854	0.057	-0.305	0.849	0.060	-0.006	0.000	0.000	-0.022	0.005	0.018
2	0.005	0.832	0.032	0.591	0.473	0.019	0.512	0.355	0.206	0.056	0.004	0.009
4	0.025	0.856	0.101	0.632	0.835	0.105	-0.089	0.017	0.031	0.045	0.004	0.029
5	0.000	0.577	0.000	0.067	0.027	0.000	0.027	0.004	0.000	-0.206	0.250	0.005
landline												
0	0.084	0.931	0.001	0.039	0.823	0.001	-0.003	0.005	0.000	-0.013	0.099	0.009
1	0.003	0.886	0.022	-0.730	0.720	0.020	-0.003	0.000	0.000	0.335	0.152	0.227
2	0.003	1.005	0.002	-0.251	0.872	0.002	0.087	0.106	0.004	-0.009	0.001	0.000
radio												
0	0.035	0.991	0.007	0.138	0.868	0.007	0.026	0.032	0.004	-0.029	0.039	0.018
1	0.056	0.991	0.004	-0.086	0.868	0.004	-0.017	0.032	0.002	0.018	0.039	0.011
television												
0	0.048	0.947	0.045	0.320	0.944	0.053	0.004	0.000	0.000	-0.013	0.002	0.005
1	0.042	0.947	0.051	-0.365	0.944	0.060	-0.005	0.000	0.000	0.015	0.002	0.006
computer												
0	0.090	0.893	0.000	0.012	0.606	0.000	0.001	0.004	0.000	-0.009	0.282	0.004
1	0.001	0.893	0.013	-0.846	0.606	0.010	-0.068	0.004	0.001	0.577	0.282	0.257
cellphone												
0	0.033	0.896	0.011	0.176	0.825	0.011	0.001	0.000	0.000	-0.012	0.004	0.003
1	0.058	0.896	0.006	-0.101	0.825	0.006	-0.001	0.000	0.000	0.007	0.004	0.002
fridge												
0	0.056	0.949	0.036	0.268	0.945	0.043	0.005	0.000	0.000	-0.014	0.003	0.007
1	0.035	0.949	0.059	-0.430	0.945	0.069	-0.009	0.000	0.000	0.023	0.003	0.011
washingmac~e												
0	0.084	0.928	0.003	0.060	0.837	0.003	0.001	0.000	0.000	-0.019	0.089	0.019
1	0.007	0.928	0.036	-0.699	0.837	0.037	-0.007	0.000	0.000	0.228	0.089	0.217

Categories	dimension_4			dimension_5		
	coord	sqcorr	contrib	coord	sqcorr	contrib
electricity						
0	0.009	0.000	0.007	0.001	0.000	0.004
1	-0.004	0.000	0.004	-0.000	0.000	0.002
cooking						
1	-0.008	0.000	0.009	-0.000	0.000	0.001
2	0.011	0.000	0.007	0.002	0.000	0.012
3	0.007	0.000	0.004	-0.001	0.000	0.003
heating						
1	-0.004	0.000	0.002	-0.003	0.000	0.043
2	0.021	0.001	0.015	-0.002	0.000	0.009
3	0.006	0.000	0.004	-0.001	0.000	0.008
5	-0.027	0.025	0.025	0.017	0.010	0.404
lighting						
1	-0.004	0.000	0.003	-0.001	0.000	0.003
2	-0.001	0.000	0.000	-0.006	0.000	0.024
4	0.011	0.000	0.009	0.002	0.000	0.012
5	-0.190	0.213	0.022	0.118	0.082	0.340
landline						
0	0.003	0.004	0.002	0.000	0.000	0.002
1	-0.102	0.014	0.118	-0.002	0.000	0.003
2	0.042	0.024	0.017	-0.010	0.001	0.041
radio						
0	-0.034	0.052	0.129	-0.001	0.000	0.002
1	0.021	0.052	0.081	0.000	0.000	0.001
television						
0	-0.012	0.001	0.023	-0.000	0.000	0.001
1	0.014	0.001	0.026	0.000	0.000	0.001
computer						
0	0.001	0.002	0.000	-0.000	0.000	0.000
1	-0.043	0.002	0.008	0.012	0.000	0.025
cellphone						
0	-0.050	0.066	0.268	-0.003	0.000	0.033
1	0.029	0.066	0.154	0.002	0.000	0.019
fridge						
0	-0.008	0.001	0.013	-0.000	0.000	0.001
1	0.014	0.001	0.021	0.001	0.000	0.002
washingmac~e						
0	0.003	0.002	0.002	-0.000	0.000	0.000
1	-0.035	0.002	0.028	0.002	0.000	0.004

Multiple Correspondence Analysis (MCA) Result: Wave 2

```
Multiple/Joint correspondence analysis        Number of obs      =       2474
                                              Total inertia      =   .1149982
    Method: Burt/adjusted inertias            Number of axes     =          6
```

Dimension	principal inertia	percent	cumul percent
dim 1	.0921809	80.16	80.16
dim 2	.0051857	4.51	84.67
dim 3	.0017299	1.50	86.17
dim 4	.0006943	0.60	86.78
dim 5	.0003069	0.27	87.04
dim 6	.0000281	0.02	87.07
Total	.1149982	100.00	

Statistics for column categories in principal normalization

Categories	mass	overall quality	%inert	dimension_1 coord	dimension_1 sqcorr	dimension_1 contrib	dimension_2 coord	dimension_2 sqcorr	dimension_2 contrib	dimension_3 coord	dimension_3 sqcorr	dimension_3 contrib
electricity												
0	0.029	0.901	0.093	0.580	0.899	0.104	0.011	0.000	0.001	0.002	0.000	0.000
1	0.062	0.901	0.043	-0.266	0.899	0.048	-0.005	0.000	0.000	-0.001	0.000	0.000
cooking												
1	0.060	0.873	0.056	-0.306	0.871	0.060	0.001	0.000	0.000	-0.004	0.000	0.001
2	0.013	0.808	0.064	0.601	0.634	0.050	0.314	0.173	0.244	0.015	0.000	0.002
3	0.018	0.815	0.074	0.572	0.702	0.065	-0.226	0.110	0.180	0.024	0.001	0.006
5	0.000	0.566	0.014	0.599	0.042	0.001	0.038	0.000	0.000	-2.092	0.513	0.465
heating												
1	0.052	0.891	0.056	-0.332	0.888	0.062	-0.009	0.001	0.001	-0.005	0.000	0.001
2	0.012	0.803	0.037	0.429	0.525	0.024	0.310	0.275	0.226	0.026	0.002	0.005
3	0.022	0.828	0.075	0.541	0.732	0.068	-0.193	0.093	0.154	0.017	0.001	0.004
5	0.005	0.581	0.003	0.062	0.053	0.000	0.164	0.369	0.028	-0.084	0.097	0.022
lighting												
1	0.067	0.863	0.046	-0.261	0.860	0.050	-0.009	0.001	0.001	-0.000	0.000	0.000
2	0.006	0.854	0.036	0.689	0.686	0.031	0.338	0.165	0.132	0.032	0.001	0.004
4	0.018	0.869	0.102	0.757	0.857	0.109	-0.082	0.010	0.022	0.013	0.000	0.002
5	0.000	0.575	0.014	0.646	0.049	0.001	-0.053	0.000	0.000	-2.107	0.522	0.471
landline												
0	0.084	0.910	0.001	0.036	0.815	0.001	0.000	0.000	0.000	-0.001	0.001	0.000
1	0.005	0.910	0.012	-0.475	0.822	0.012	-0.008	0.000	0.000	0.010	0.000	0.000
2	0.002	0.852	0.003	-0.356	0.686	0.002	0.010	0.000	0.000	0.026	0.004	0.001
radio												
0	0.038	0.979	0.007	0.143	0.922	0.009	-0.009	0.003	0.001	0.001	0.000	0.000
1	0.053	0.979	0.005	-0.105	0.922	0.006	0.006	0.003	0.000	-0.000	0.000	0.000
television												
0	0.039	0.935	0.060	0.406	0.932	0.070	0.002	0.000	0.000	-0.005	0.000	0.001
1	0.052	0.935	0.045	-0.305	0.932	0.052	-0.001	0.000	0.000	0.004	0.000	0.000
computer												
0	0.089	0.949	0.000	0.011	0.753	0.000	-0.000	0.001	0.000	-0.001	0.005	0.000
1	0.002	0.949	0.007	-0.630	0.753	0.007	0.019	0.001	0.000	0.051	0.005	0.002
cellphone												
0	0.029	0.918	0.015	0.227	0.841	0.016	-0.033	0.018	0.006	-0.022	0.008	0.008
1	0.062	0.918	0.007	-0.105	0.841	0.007	0.015	0.018	0.003	0.010	0.008	0.004
fridge												
0	0.049	0.943	0.043	0.305	0.939	0.050	0.001	0.000	0.000	-0.005	0.000	0.001
1	0.042	0.943	0.051	-0.363	0.939	0.059	-0.002	0.000	0.000	0.006	0.000	0.001
washingmac~e												
0	0.082	0.921	0.003	0.061	0.864	0.003	-0.001	0.000	0.000	-0.002	0.001	0.000
1	0.009	0.921	0.029	-0.570	0.864	0.031	0.008	0.000	0.000	0.019	0.001	0.002

Categories	dimension_4 coord	dimension_4 sqcorr	dimension_4 contrib	dimension_5 coord	dimension_5 sqcorr	dimension_5 contrib	dimension_6 coord	dimension_6 sqcorr	dimension_6 contrib
electricity									
0	0.028	0.002	0.032	0.006	0.000	0.003	0.002	0.000	0.003
1	-0.013	0.002	0.014	-0.003	0.000	0.002	-0.001	0.000	0.001
cooking									
1	-0.013	0.002	0.015	-0.005	0.000	0.006	0.001	0.000	0.001
2	0.019	0.001	0.007	0.003	0.000	0.000	-0.002	0.000	0.002
3	0.027	0.002	0.019	0.015	0.000	0.013	-0.001	0.000	0.000
5	0.278	0.009	0.020	0.124	0.002	0.009	0.009	0.000	0.001
heating									
1	-0.011	0.001	0.010	-0.008	0.000	0.010	0.004	0.000	0.026
2	0.025	0.002	0.011	0.004	0.000	0.001	0.006	0.000	0.016
3	0.024	0.001	0.019	0.015	0.001	0.015	-0.000	0.000	0.000
5	-0.045	0.028	0.016	0.008	0.001	0.001	-0.050	0.034	0.465
lighting									
1	-0.012	0.002	0.014	-0.002	0.000	0.001	-0.000	0.000	0.000
2	0.021	0.001	0.004	0.006	0.000	0.001	0.012	0.000	0.029
4	0.037	0.002	0.035	0.004	0.000	0.001	-0.004	0.000	0.008
5	0.179	0.004	0.008	0.001	0.000	0.000	0.034	0.000	0.007
landline									
0	-0.009	0.052	0.010	0.008	0.042	0.018	-0.000	0.000	0.000
1	0.097	0.034	0.068	-0.120	0.052	0.236	0.020	0.001	0.074
2	0.160	0.138	0.061	-0.045	0.011	0.011	-0.049	0.013	0.143
radio									
0	-0.020	0.018	0.023	-0.027	0.032	0.089	-0.009	0.003	0.102
1	0.015	0.018	0.017	0.020	0.032	0.065	0.006	0.003	0.075
television									
0	-0.012	0.001	0.007	-0.018	0.002	0.042	0.001	0.000	0.000
1	0.009	0.001	0.006	0.014	0.002	0.032	-0.000	0.000	0.000
computer									
0	-0.006	0.186	0.004	0.001	0.004	0.000	0.000	0.001	0.000
1	0.313	0.186	0.228	-0.048	0.004	0.012	-0.017	0.001	0.016
cellphone									
0	-0.030	0.015	0.037	-0.048	0.037	0.213	0.003	0.000	0.008
1	0.014	0.015	0.017	0.022	0.037	0.098	-0.001	0.000	0.003
fridge									
0	-0.017	0.003	0.020	-0.010	0.001	0.016	0.002	0.000	0.004
1	0.020	0.003	0.024	0.012	0.001	0.019	-0.002	0.000	0.005
washingmac~e									
0	-0.014	0.049	0.025	0.006	0.007	0.008	0.001	0.000	0.001
1	0.135	0.049	0.232	-0.052	0.007	0.077	-0.005	0.000	0.008

Multiple Correspondence Analysis (MCA) Result: Wave 3

```
. mca cooking heating lighting landline radio television computer cellphone fridge washingmachine, normalize(principal) dimensions(6
> )

Multiple/Joint correspondence analysis          Number of obs     =      2426
                                                Total inertia     =  .0868184
    Method: Burt/adjusted inertias              Number of axes    =         6
```

Dimension	principal inertia	percent	cumul percent
dim 1	.0667128	76.84	76.84
dim 2	.0066629	7.67	84.52
dim 3	.0003785	0.44	84.95
dim 4	.0001946	0.22	85.18
dim 5	.0000374	0.04	85.22
dim 6	.00003	0.03	85.25
Total	.0868184	100.00	

Statistics for column categories in principal normalization

Categories	overall			dimension_1			dimension_2			dimension_3		
	mass	quality	%inert	coord	sqcorr	contrib	coord	sqcorr	contrib	coord	sqcorr	contrib
cooking												
1	0.067	0.834	0.060	0.255	0.830	0.065	0.010	0.001	0.001	0.015	0.003	0.038
2	0.010	0.760	0.081	-0.597	0.520	0.055	0.405	0.239	0.251	-0.019	0.001	0.010
3	0.023	0.777	0.090	-0.467	0.645	0.076	-0.208	0.128	0.151	-0.033	0.003	0.068
5	0.000	0.623	0.003	-0.854	0.134	0.000	1.392	0.357	0.012	-0.259	0.012	0.007
heating												
1	0.053	0.865	0.067	0.306	0.863	0.075	0.004	0.000	0.000	0.014	0.002	0.027
2	0.010	0.730	0.052	-0.381	0.321	0.022	0.428	0.405	0.274	-0.040	0.004	0.042
3	0.029	0.785	0.081	-0.396	0.652	0.069	-0.176	0.128	0.135	-0.032	0.004	0.079
5	0.008	0.728	0.004	-0.128	0.383	0.002	0.084	0.165	0.008	0.078	0.142	0.122
lighting												
1	0.078	0.857	0.039	0.193	0.852	0.043	-0.013	0.004	0.002	0.007	0.001	0.010
2	0.003	0.828	0.030	-0.646	0.444	0.017	0.595	0.377	0.147	-0.059	0.004	0.025
4	0.019	0.865	0.119	-0.677	0.862	0.133	-0.029	0.002	0.002	-0.018	0.001	0.017
5	0.000	0.940	0.001	-0.612	0.492	0.001	-0.537	0.379	0.007	-0.198	0.052	0.017
landline												
0	0.096	0.925	0.000	-0.019	0.871	0.001	-0.001	0.005	0.000	-0.001	0.001	0.000
1	0.003	0.899	0.009	0.456	0.820	0.009	0.028	0.003	0.000	0.022	0.002	0.004
2	0.001	0.891	0.003	0.391	0.821	0.003	0.046	0.012	0.000	0.004	0.000	0.000
radio												
0	0.041	0.976	0.018	-0.192	0.948	0.023	0.005	0.001	0.000	0.031	0.025	0.104
1	0.059	0.976	0.013	0.134	0.948	0.016	-0.004	0.001	0.000	-0.022	0.025	0.073
television												
0	0.039	0.907	0.079	-0.402	0.906	0.094	-0.003	0.000	0.000	0.014	0.001	0.020
1	0.061	0.907	0.050	0.253	0.906	0.059	0.002	0.000	0.000	-0.009	0.001	0.013
computer												
0	0.096	0.908	0.000	-0.017	0.824	0.000	-0.003	0.018	0.000	0.003	0.020	0.002
1	0.004	0.908	0.011	0.465	0.824	0.012	0.069	0.018	0.003	-0.073	0.020	0.051
cellphone												
0	0.019	0.976	0.018	-0.278	0.931	0.022	-0.017	0.003	0.001	0.053	0.034	0.141
1	0.081	0.976	0.004	0.066	0.931	0.005	0.004	0.003	0.000	-0.012	0.034	0.033
fridge												
0	0.048	0.915	0.066	-0.330	0.913	0.078	0.002	0.000	0.000	0.014	0.002	0.026
1	0.052	0.915	0.060	0.301	0.913	0.071	-0.002	0.000	0.000	-0.013	0.002	0.024
washingmac~e												
0	0.089	0.939	0.005	-0.064	0.912	0.005	-0.006	0.007	0.000	0.005	0.005	0.005
1	0.011	0.939	0.038	0.530	0.912	0.045	0.046	0.007	0.003	-0.038	0.005	0.040

Categories	dimension_4			dimension_5			dimension_6		
	coord	sqcorr	contrib	coord	sqcorr	contrib	coord	sqcorr	contrib
cooking									
1	0.002	0.000	0.001	0.001	0.000	0.003	0.000	0.000	0.000
2	-0.011	0.000	0.006	-0.008	0.000	0.020	0.009	0.000	0.027
3	-0.001	0.000	0.000	-0.001	0.000	0.000	-0.004	0.000	0.012
5	0.406	0.030	0.035	0.478	0.042	0.252	-0.500	0.046	0.343
heating									
1	-0.001	0.000	0.000	0.004	0.000	0.028	0.002	0.000	0.006
2	0.003	0.000	0.000	0.001	0.000	0.000	0.009	0.000	0.026
3	0.000	0.000	0.000	0.001	0.000	0.000	-0.001	0.000	0.002
5	0.001	0.000	0.000	-0.035	0.028	0.244	-0.020	0.009	0.102
lighting									
1	0.004	0.000	0.005	0.001	0.000	0.001	0.000	0.000	0.000
2	0.042	0.002	0.025	0.022	0.001	0.036	-0.029	0.001	0.075
4	-0.021	0.001	0.044	-0.006	0.000	0.019	0.004	0.000	0.013
5	0.056	0.004	0.003	0.067	0.006	0.020	-0.078	0.008	0.033
landline									
0	0.004	0.046	0.009	-0.000	0.000	0.000	0.001	0.001	0.002
1	-0.131	0.067	0.261	0.041	0.007	0.135	0.004	0.000	0.002
2	-0.024	0.003	0.004	-0.070	0.027	0.158	-0.073	0.028	0.210
radio									
0	-0.005	0.001	0.006	0.000	0.000	0.000	-0.005	0.001	0.041
1	0.004	0.001	0.004	-0.000	0.000	0.000	0.004	0.001	0.029
television									
0	-0.008	0.000	0.012	0.003	0.000	0.009	-0.001	0.000	0.002
1	0.005	0.000	0.008	-0.002	0.000	0.006	0.001	0.000	0.001
computer									
0	0.004	0.044	0.008	0.000	0.001	0.001	0.001	0.001	0.001
1	-0.107	0.044	0.214	-0.012	0.001	0.014	-0.016	0.001	0.029
cellphone									
0	-0.023	0.007	0.054	0.009	0.001	0.037	0.004	0.000	0.009
1	0.006	0.007	0.013	-0.002	0.001	0.009	-0.001	0.000	0.002
fridge									
0	-0.002	0.000	0.001	0.002	0.000	0.004	0.000	0.000	0.000
1	0.002	0.000	0.001	-0.002	0.000	0.004	-0.000	0.000	0.000
washingmac~e									
0	0.008	0.015	0.031	0.000	0.000	0.000	0.001	0.000	0.003
1	-0.068	0.015	0.254	-0.002	0.000	0.001	-0.009	0.000	0.029

Multiple Correspondence Analysis (MCA) Result: Wave 4

```
. mca electricity cooking heating lighting landline radio television computer cellphone fridge washingmachine, normalize(principal)
> dimensions(6)

Multiple/Joint correspondence analysis          Number of obs     =      2135
                                                Total inertia     =  .0909292
    Method: Burt/adjusted inertias              Number of axes    =         6
```

Dimension	principal inertia	percent	cumul percent
dim 1	.070673	77.72	77.72
dim 2	.0053051	5.83	83.56
dim 3	.0015409	1.69	85.25
dim 4	.0004649	0.51	85.76
dim 5	.0002411	0.27	86.03
dim 6	.0000106	0.01	86.04
Total	.0909292	100.00	

Statistics for column categories in principal normalization

	overall			dimension_1			dimension_2			dimension_3		
Categories	mass	quality	%inert	coord	sqcorr	contrib	coord	sqcorr	contrib	coord	sqcorr	contrib
electricity												
0	0.017	0.861	0.124	0.744	0.855	0.137	0.043	0.003	0.006	0.022	0.001	0.006
1	0.073	0.861	0.030	-0.177	0.855	0.032	-0.010	0.003	0.001	-0.005	0.001	0.001
cooking												
1	0.065	0.868	0.044	-0.231	0.862	0.049	0.010	0.002	0.001	-0.012	0.002	0.006
2	0.007	0.804	0.084	0.806	0.634	0.069	0.417	0.170	0.245	0.003	0.000	0.000
3	0.018	0.810	0.068	0.475	0.675	0.059	-0.200	0.120	0.139	0.065	0.013	0.050
5	0.000	0.655	0.013	0.665	0.132	0.002	-0.260	0.020	0.004	-1.253	0.466	0.347
heating												
1	0.050	0.906	0.048	-0.282	0.902	0.056	0.006	0.000	0.000	-0.001	0.000	0.000
2	0.008	0.777	0.042	0.424	0.392	0.021	0.419	0.384	0.274	0.015	0.000	0.001
3	0.023	0.832	0.062	0.417	0.713	0.057	-0.160	0.104	0.112	0.058	0.014	0.051
5	0.010	0.782	0.004	0.084	0.178	0.001	-0.006	0.001	0.000	-0.145	0.538	0.133
lighting												
1	0.074	0.842	0.032	-0.181	0.835	0.035	-0.015	0.006	0.003	-0.003	0.000	0.000
2	0.003	0.839	0.036	0.849	0.596	0.028	0.539	0.240	0.149	-0.032	0.001	0.002
4	0.014	0.846	0.118	0.817	0.840	0.128	-0.022	0.001	0.001	0.047	0.003	0.019
5	0.000	0.638	0.009	0.483	0.069	0.001	-0.287	0.024	0.004	-1.278	0.484	0.271
landline												
0	0.088	0.864	0.000	0.012	0.678	0.000	-0.002	0.016	0.000	0.000	0.000	0.000
1	0.002	0.821	0.005	-0.361	0.592	0.004	0.052	0.012	0.001	-0.014	0.001	0.000
2	0.001	0.855	0.002	-0.406	0.670	0.002	0.073	0.022	0.001	0.032	0.004	0.000
radio												
0	0.044	0.948	0.008	0.116	0.825	0.008	-0.032	0.062	0.009	-0.023	0.031	0.015
1	0.047	0.948	0.007	-0.109	0.825	0.008	0.030	0.062	0.008	0.021	0.031	0.014
television												
0	0.036	0.918	0.060	0.371	0.906	0.070	-0.025	0.004	0.004	-0.021	0.003	0.010
1	0.055	0.918	0.039	-0.241	0.906	0.045	0.016	0.004	0.003	0.013	0.003	0.006
computer												
0	0.087	0.986	0.000	0.021	0.919	0.001	-0.003	0.015	0.000	-0.002	0.007	0.000
1	0.004	0.986	0.010	-0.468	0.919	0.012	0.059	0.015	0.003	0.041	0.007	0.004
cellphone												
0	0.019	0.914	0.020	0.274	0.807	0.021	-0.057	0.035	0.012	-0.050	0.027	0.032
1	0.071	0.914	0.005	-0.075	0.807	0.006	0.016	0.035	0.003	0.014	0.027	0.009
fridge												
0	0.041	0.925	0.053	0.325	0.915	0.062	-0.016	0.002	0.002	-0.016	0.002	0.007
1	0.050	0.925	0.044	-0.272	0.915	0.052	0.014	0.002	0.002	0.013	0.002	0.006
washingmac~e												
0	0.080	0.961	0.004	0.061	0.910	0.004	-0.010	0.024	0.001	-0.005	0.005	0.001
1	0.011	0.961	0.028	-0.465	0.910	0.032	0.075	0.024	0.011	0.035	0.005	0.008

	dimension_4			dimension_5			dimension_6		
Categories	coord	sqcorr	contrib	coord	sqcorr	contrib	coord	sqcorr	contrib
electricity									
0	0.036	0.002	0.049	0.014	0.000	0.015	0.001	0.000	0.001
1	-0.009	0.002	0.012	-0.003	0.000	0.003	-0.000	0.000	0.000
cooking									
1	-0.011	0.002	0.018	0.000	0.000	0.000	-0.000	0.000	0.001
2	0.008	0.000	0.001	-0.002	0.000	0.000	-0.000	0.000	0.000
3	0.030	0.003	0.035	-0.001	0.000	0.000	0.001	0.000	0.002
5	0.342	0.035	0.086	0.080	0.002	0.009	0.017	0.000	0.009
heating									
1	-0.014	0.002	0.022	0.010	0.001	0.020	0.000	0.000	0.001
2	0.005	0.000	0.000	-0.006	0.000	0.001	0.003	0.000	0.006
3	0.019	0.001	0.017	-0.001	0.000	0.000	0.001	0.000	0.005
5	0.024	0.015	0.012	-0.043	0.048	0.076	-0.008	0.001	0.053
lighting									
1	-0.008	0.002	0.010	-0.003	0.000	0.002	0.000	0.000	0.000
2	-0.048	0.002	0.014	-0.020	0.000	0.005	-0.002	0.000	0.001
4	0.045	0.003	0.060	0.016	0.000	0.015	-0.000	0.000	0.000
5	0.440	0.057	0.106	0.092	0.003	0.009	0.040	0.000	0.039
landline									
0	0.001	0.007	0.000	-0.006	0.162	0.012	0.000	0.000	0.000
1	-0.088	0.035	0.036	0.198	0.178	0.346	0.020	0.002	0.082
2	0.124	0.063	0.023	0.132	0.071	0.050	-0.079	0.025	0.402
radio									
0	-0.019	0.022	0.034	-0.010	0.006	0.019	-0.005	0.002	0.112
1	0.018	0.022	0.031	0.010	0.006	0.018	0.005	0.002	0.105
television									
0	-0.027	0.005	0.054	0.007	0.000	0.006	-0.002	0.000	0.016
1	0.017	0.005	0.035	-0.004	0.000	0.004	0.001	0.000	0.010
computer									
0	-0.003	0.014	0.001	-0.004	0.030	0.005	0.001	0.001	0.004
1	0.058	0.014	0.028	0.085	0.030	0.114	-0.016	0.001	0.093
cellphone									
0	-0.050	0.027	0.106	0.040	0.018	0.131	-0.000	0.000	0.000
1	0.014	0.027	0.029	-0.011	0.018	0.036	0.000	0.000	0.000
fridge									
0	-0.024	0.005	0.053	0.003	0.000	0.002	-0.000	0.000	0.001
1	0.020	0.005	0.044	-0.003	0.000	0.002	0.000	0.000	0.001
washingmac~e									
0	-0.008	0.014	0.010	-0.006	0.008	0.012	0.001	0.000	0.007
1	0.057	0.014	0.075	0.045	0.008	0.088	-0.007	0.000	0.053

Appendix C: Multicollinearity Test of the Energy Transition Pattern Variables

```
. regress dwellingtype age gender location hhsize

      Source |       SS       df       MS              Number of obs =     742
-------------+------------------------------           F(  4,   737) =    1.26
       Model |  1.08823745     4  .272059362           Prob > F      =  0.2854
    Residual |  159.484539   737  .216396932           R-squared     =  0.0068
-------------+------------------------------           Adj R-squared =  0.0014
       Total |  160.572776   741  .216697404           Root MSE      =  .46518

------------------------------------------------------------------------------
dwellingtype |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         age |  -.0016376   .0011531    -1.42   0.156    -.0039014    .0006261
      gender |   .0578225   .0450927     1.28   0.200    -.0307028    .1463479
    location |   .0405928   .0347292     1.17   0.243    -.0275871    .1087728
      hhsize |   -.002899   .0119158    -0.24   0.808     -.026292     .020494
       _cons |   1.299902   .0869792    14.94   0.000     1.129146    1.470659
------------------------------------------------------------------------------

. vif

    Variable |       VIF       1/VIF
-------------+----------------------
      hhsize |      1.26    0.791866
      gender |      1.20    0.836714
         age |      1.07    0.934185
    location |      1.03    0.973568
-------------+----------------------
    Mean VIF |      1.14
```

```
. regress year dwellingtype age gender location hhsize

      Source |       SS       df       MS              Number of obs =     742
-------------+------------------------------           F(  5,   736) =    3.98
       Model |  96.6811396     5  19.3362279           Prob > F      =  0.0014
    Residual |  3579.16253   736  4.86299256           R-squared     =  0.0263
-------------+------------------------------           Adj R-squared =  0.0197
       Total |  3675.84367   741  4.96065272           Root MSE      =  2.2052

------------------------------------------------------------------------------
        year |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
dwellingtype |  -.1072429   .1746194    -0.61   0.539    -.4500544    .2355686
         age |   .0226632   .0054737     4.14   0.000     .0119172    .0334091
      gender |  -.1860807   .2140011    -0.87   0.385     -.606206    .2340446
    location |   .0181869   .1647871     0.11   0.912     -.305322    .3416958
      hhsize |   -.010645   .0564895    -0.19   0.851    -.1215447    .1002548
       _cons |   2010.077   .4706773  4270.61   0.000     2009.153    2011.001
------------------------------------------------------------------------------

. vif

    Variable |       VIF       1/VIF
-------------+----------------------
      hhsize |      1.26    0.791803
      gender |      1.20    0.834852
         age |      1.07    0.931636
    location |      1.03    0.971767
dwellingtype |      1.01    0.993223
-------------+----------------------
    Mean VIF |      1.11
```

Appendix D: Ordered Logistic Regression for Cooking

```
. ologit energychoiceforcooking year2010 year2012 year2014 moderndwelling realincome age female urban hhsize

Iteration 0:   log likelihood = -683.64524
Iteration 1:   log likelihood = -611.50662
Iteration 2:   log likelihood = -609.82075
Iteration 3:   log likelihood = -609.81595
Iteration 4:   log likelihood = -609.81595

Ordered logistic regression                     Number of obs     =        739
                                                LR chi2(9)        =     147.66
                                                Prob > chi2       =     0.0000
Log likelihood = -609.81595                     Pseudo R2         =     0.1080

------------------------------------------------------------------------------
energyc~king |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    year2010 |   .4959104   .2130452     2.33   0.020     .0783495    .9134714
    year2012 |   .7158848   .2216682     3.23   0.001     .2814232    1.150346
    year2014 |   .7127674   .2380433     2.99   0.003      .246211    1.179324
moderndwel~g |   1.073498   .1634241     6.57   0.000     .7531927    1.393803
  realincome |   .0003636    .000226     1.61   0.108    -.0000794    .0008065
         age |  -.0054086   .0054734    -0.99   0.323    -.0161363     .005319
      female |   .0707139   .1968255     0.36   0.719    -.3150571    .4564848
       urban |   1.400514    .165383     8.47   0.000     1.076369    1.724659
      hhsize |   .6318035   .2321019     2.72   0.006     .1768921    1.086715
-------------+----------------------------------------------------------------
       /cut1 |   .9747662   .4085752                      .1739735    1.775559
       /cut2 |   1.910737   .4132789                      1.100725    2.720748
------------------------------------------------------------------------------
```

Appendix E: Ordered Logistic Regression for Heating

```
. ologit energychoiceforheating year2010 year2012 year2014 moderndwelling realincome age female urban hhsize

Iteration 0:   log likelihood = -640.82129
Iteration 1:   log likelihood = -563.37647
Iteration 2:   log likelihood = -562.22569
Iteration 3:   log likelihood = -562.22279

Ordered logistic regression                     Number of obs     =        650
                                                LR chi2(9)        =     157.20
                                                Prob > chi2       =     0.0000
Log likelihood = -562.22279                     Pseudo R2         =     0.1227
```

energy~ating	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
year2010	1.035062	.2282693	4.53	0.000	.5876622	1.482461
year2012	.7823723	.2307733	3.39	0.001	.330065	1.23468
year2014	.8112588	.2439035	3.33	0.001	.3332168	1.289301
moderndwel~g	1.263323	.1721187	7.34	0.000	.925977	1.60067
realincome	.0003563	.0002326	1.53	0.126	-.0000996	.0008123
age	-.0082348	.0057219	-1.44	0.150	-.0194495	.0029799
female	-.0989266	.2090795	-0.47	0.636	-.5087148	.3108617
urban	1.360756	.1696581	8.02	0.000	1.028233	1.69328
hhsize	.6125	.2349089	2.61	0.009	.152087	1.072913
/cut1	1.480158	.4181061			.6606853	2.299631
/cut2	2.30322	.4241981			1.471807	3.134633

Appendix F: Ordered Logistic Regression for Lighting

```
. ologit energychoiceforlighting year2010 year2012 year2014 moderndwelling realincome age female urban hhsize

Iteration 0:   log likelihood = -511.74946
Iteration 1:   log likelihood = -473.67342
Iteration 2:   log likelihood = -472.38556
Iteration 3:   log likelihood = -472.38375

Ordered logistic regression                     Number of obs   =        739
                                                LR chi2(9)      =      78.73
                                                Prob > chi2     =     0.0000
Log likelihood = -472.38375                     Pseudo R2       =     0.0769

------------------------------------------------------------------------------
energy~hting |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    year2010 |   .1876457   .2353012     0.80   0.425    -.2735361    .6488276
    year2012 |   .3783301   .2445454     1.55   0.122      -.10097    .8576302
    year2014 |   .6623029   .2724353     2.43   0.015     .1283396    1.196266
moderndwel~g |   1.284526   .1775048     7.24   0.000     .9366225    1.632429
  realincome |   .0003471   .0002499     1.39   0.165    -.0001426    .0008369
         age |  -.0013959   .0061133    -0.23   0.819    -.0133777    .0105859
      female |   .3199115    .214178     1.49   0.135    -.0998697    .7396926
       urban |   .5435288   .1798244     3.02   0.003     .1910794    .8959782
      hhsize |   .1910936   .2589594     0.74   0.461    -.3164575    .6986447
-------------+----------------------------------------------------------------
       /cut1 |   .5777254   .4416709                     -.2879337    1.443384
       /cut2 |   .8628973   .4420839                     -.0035712    1.729366
------------------------------------------------------------------------------
```

Appendix G: Multicollinearity Test of the FBE Variables

```
. regress rurality hhsize gender dwelling fbe hhincome

      Source |       SS       df       MS              Number of obs =    7176
-------------+------------------------------           F(  5,  7170) =  101.70
       Model |  118.775996     5  23.7551993           Prob > F      =  0.0000
    Residual |  1674.81765  7170  .233586841           R-squared     =  0.0662
-------------+------------------------------           Adj R-squared =  0.0656
       Total |  1793.59365  7175  .249978208           Root MSE      =  .48331

------------------------------------------------------------------------------
    rurality |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      hhsize |   .1628717   .0135154    12.05   0.000     .1363776    .1893658
      gender |  -.0615566   .0115795    -5.32   0.000    -.0842558   -.0388574
    dwelling |   .1285302   .0143664     8.95   0.000     .1003678    .1566926
         fbe |   .1914505   .0127521    15.01   0.000     .1664527    .2164483
    hhincome |   6.93e-06   9.79e-06     0.71   0.479    -.0000123    .0000261
       _cons |   .2549168   .0216347    11.78   0.000     .2125064    .2973272
------------------------------------------------------------------------------

. vif

    Variable |       VIF       1/VIF
-------------+----------------------
      hhsize |      1.05    0.955037
    hhincome |      1.04    0.956979
      gender |      1.02    0.984103
    dwelling |      1.01    0.989958
         fbe |      1.00    0.996045
-------------+----------------------
    Mean VIF |      1.02
```