

AN ECONOMETRIC ANALYSIS OF ENERGY POVERTY AND SUSTAINABLE DEVELOPMENT IN BLANTYRE (MALAWI)

BY

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“As sorrowful, yet always rejoicing; as poor, yet making many rich; as having nothing, and yet possessing many things” – (Holy Bible, 1611 - King James Version).

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You all went on to be with the Lord while I was buried in this project.

DECLARATION

I declare that this thesis entitled

**AN ECONOMETRIC ANALYSIS OF ENERGY POVERTY AND SUSTAINABLE
DEVELOPMENT IN BLANTYRE, MALAWI,**

is my own original work and that all resources that were used or quoted as background or otherwise were duly acknowledged by way of in-text citations and complete references at the end, and that it has not been submitted to this or another university or institution of higher learning for an award of a Degree or Diploma

Betchani Henry Mbuyampugatete Tchereni

ABSTRACT

Key Words: Energy Poverty, Sustainable Development, Logit, Engel Function, Renewable Energy, South Lunzu, Biomass.

Energy is the driver of activity in every economy and, therefore, its importance cannot be overemphasised. However, Sub-Saharan Africa (SSA) faces general problems of access to modern energy. Most households and industry in SSA use traditional and unclean energy resources for activities such as cooking, lighting and drying of farm produce. Many households in less developed countries have very limited choices with regard to alternatives to traditional energy supplies. Energy poverty is overt in many poor countries, particularly in the Sub-Saharan region where 700 million people are deprived of access to modern energy facilities.

In Malawi, less than 6 percent of the population have access to electricity. There are, therefore, many questions regarding the state of energy poverty still to be answered, not only in Malawi, but also the entirety of the SSA region. Questions such as what is the level of energy poverty in these regions? What determines this level of poverty? Why are people not adopting renewable energy facilities for their household needs? Are some energy facilities inferior to others? Such questions were the centre of the present study. These questions are important because, with energy poverty, nearly all the Millennium Development Goals are unachievable and sustainable development could not be a success story where the dominant source of energy for both households and industry is biomass.

This study was based on a survey conducted in South Lunzu Township (SLT), which is a low income area to the east of Ndirande Mountain in the city of Blantyre, Malawi. The survey administered a standard questionnaire through face-to-face interviews with heads of households. Data was collected from 319 respondents who were selected through random sampling techniques. The descriptive statistics suggest that the average household size for South Lunzu Township is 5 people. The average age of the sampled respondents was about 38.

The findings of the thesis suggest that over 90 percent of the households sampled were energy poor with energy expenditure exceeding 10 percent of total household expenditure. In terms of energy resources used in SLT, 2.9 percent used electricity for cooking meals. Only 2 households, representing 0.63 percent, use liquefied petroleum Gas (LPG) and just 1 household, representing 0.31 percent, depended mostly on solar power. On the other hand, energy facilities that are considered dirty, inefficient and a danger to the health of people seem to be popular. For instance charcoal and firewood were used by 25 percent and 4.7 percent of the total sample respectively. Most households use a combination of energy facilities; however, those that are considered inferior are preferred. Of the sample, 42 percent use both charcoal and firewood to cook their meals.

Further, the results of the Engel functions suggest that charcoal and wood were not regarded as inferior products for the cooking needs of households despite improvements in income. Electricity, which was also regarded as a normal energy resource, had positive income elasticity. To improve access to modern energy facilities at the household level, the thesis recommends that a flexible trade and tax regime, one that will improve the availability and affordability of renewable energy to the majority, should be adopted.

The Logit model of energy poverty reveals that household expenditure on transport, income level, age, and education level of the head of household; household size; and home size, are important factors in explaining the level of energy poverty in South Lunzu Township. Further, the results revealed that expenditure on housing and marital status could not be relied upon as important predictors of the probability of energy poverty in South Lunzu.

Expenditure on education was associated with lower levels of energy poverty. Households who spent more on schooling also spent more on food items and their expenditure on energy resources was less than 10 percent of the total expenditure per month. In addition, those households that spent more on food were also likely to be energy well-off.

Results of the multinomial logit (MNL) model suggest that most socioeconomic variables under study were inelastic in influencing the probability for the outcomes, at the household level, to be used for the purposes of cooking. Statistically, age, income and education level of the head of household, together with household size, were important factors that influenced the choice of most of the outcomes for cooking purposes, including electricity, charcoal, firewood and LP gas.

The major recommendation of this study is that campaigns emphasising the abilities of renewable energy be developed and disseminated. That renewable energy is relegated to poor and uncivilised societies is a notion that must be rooted out of the mindset of the average, civilised urban dweller. Also, the use of LP gas for cooking purposes must be encouraged. Import tax regimes that discourage international trade of renewable energy resources must be removed to encourage lower prices on such facilities. These policies would ensure sustainable development by reducing reliance on biomass, which is depleting at a faster rate than it is regenerating.

OPSOMMING

Sleutelwoorde: Energie-armoede, Volhoubare ontwikkeling, Logit, Engel-funksie, Hernubare energie, Suid-Lunzu, Biomassa.

Energie is die dryfveer van aktiwiteit in elke ekonomie en die belang daarvan kan nie genoeg beklemtoon word nie. Afrika suid van die Sahara (ASS) staan egter algemene probleme van toegang tot moderne energie in die gesig. Die meeste huishoudings en nywerhede in ASS gebruik tradisionele en onsuier energiebronne vir aktiwiteite soos kosmaak, beligting en die droging van landbouprodukte. In minder ontwikkelde lande het baie huishoudings beperkte keuses ten opsigte van alternatiewe tot tradisionele energievoorrade. Energie-armoede is in verskeie arm lande duidelik waarneembaar, veral in die streek suid van die Sahara, waar 700 miljoen mense sonder toegang tot moderne energiefasiliteite leef.

In Malawi het minder as 6 persent van die bevolking toegang tot elektrisiteit. Daar is dus baie onbeantwoorde vrae oor die toestand van energie-armoede – nie slegs in Malawi nie, maar ook in die hele ASS-streek. Hierdie vrae sluit onder meer die volgende in: Wat is die vlak van energie-armoede in hierdie streke? Wat bepaal hierdie vlak van armoede? Waarom wend mense nie hernubare energiefasiliteite vir hulle huishoudelike behoeftes aan nie? Is sommige energiefasiliteite minderwaardig teenoor ander?

Sodanige vrae vorm die kern van die huidige studie. Hierdie vrae is belangrik, omdat feitlik al die Millenniumontwikkelingsdoelwitte betreffende energie-armoede onbereikbaar is. Volhoubare ontwikkeling kan ook nie suksesvol wees indien biomassa die oorheersende energiebron vir huishoudings sowel as nywerhede is nie.

Hierdie studie is gebaseer op 'n opname wat gemaak is in Suid-Lunzu-township (SLT), 'n lae-inkomstegebied oos van Ndirande-berg in Blantyre, Malawi. Die opname bestaan uit 'n gestandaardiseerde vraelys wat deur middel van aangesig-tot-aangesig-onderhoude met hoofde van huishoudings afgeneem is. Data is versamel van 319 respondente wat deur ewekansige steekproefnemingstegnieke gekies is. Die beskrywende statistiek suggereer dat die gemiddelde huishouding in SLT uit vyf mense

bestaan. Die gemiddelde ouderdom van die respondente in die steekproef is ongeveer 38 jaar oud.

In hierdie tesis is bevind dat meer as 90 persent van die huishoudings in die steekproef energie-arm is, en dat energiebesteding meer as 10 persent van die totale huishouding se uitgawe uitmaak. Wat die gebruik van energiebronne in SLT betref, gebruik 2,9 persent elektrisiteit om kos gaar te maak. Slegs twee huishoudings, wat 0,63 persent verteenwoordig, gebruik vloeibare petroleumgas (VPG) en slegs een huishouding, wat 0,31 persent verteenwoordig, is feitlik heeltemal van sonkrag afhanklik. Aan die ander kant blyk dit dat energiefasiliteite wat as vuil of ondoeltreffend beskou word en wat 'n gesondheidsrisiko vir mense inhou, meer as enige van die ander fasiliteite deur die bewoners van Suid-Lunzu township gebruik word. Houtskool en vuurmaakhout word byvoorbeeld deur onderskeidelik 25 persent en 4,7 persent van die totale steekproef gebruik. Die meeste huishoudings gebruik 'n kombinasie van energiefasiliteite. Dié wat oor die algemeen as minderwaardig beskou word, is egter die voorkeurfasiliteite. Van die steekproef gebruik 42 persent houtskool sowel as vuurmaakhout om kos gaar te maak.

Die resultate van die Engel-funksies, wat die verhouding tussen inkomste en die aanvraag na die hoeveelheid van enige goedere toets, toon verder dat houtskool en hout nie as minderwaardige produkte vir huishoudings se kosmaakbehoeftes van huishoudings in die informele nedersetting beskou word nie, ten spyte van verhoogde inkomste. Elektrisiteit, wat ook as 'n normale energiebron beskou word, het positiewe inkomste-elasticiteit. Om toegang tot moderne energiefasiliteite op huishoudingsvlak te verbeter, word die aanbeveling in die tesis gemaak dat 'n buigbare handels- en belastingbeleid aangeneem word wat die beskikbaarheid en bekostigbaarheid van hernubare energie aan die meerderheid sal verhoog.

Volgens die Logit-model van energie-armoede is besteding aan vervoer, asook op inkomstevlak, en die ouderdom, opvoedingspeil van die hoof van die huishouding, huishoudingsgrootte, en die grootte van die woning belangrike faktore wat die vlak van energie-armoede in SLT verduidelik. Die resultate onthul verder dat besteding op

behuising en huwelikstatus nie betroubaar is as belangrike voorspellers van die waarskynlikheid van energie-armoede in SLT nie.

Besteding aan opvoeding word met laer vlakke van energie-armoede vereenselwig. Huishoudings wat meer op skoolopvoeding bestee, bestee ook meer aan voedselitems en hulle besteding aan energiebronne is minder as 10 persent van die totale uitgawe per maand. Boonop is dié huishoudings wat meer aan voedsel bestee ook geneig om welgesteld te wees ten opsigte van energie.

Volgens die resultate van die multinomiale Logit-model het die meeste sosio-ekonomiese veranderlikes in hierdie studie onelastisiteit getoon in hulle invloed op die waarskynlikheid vir die uitkomste om op huishoudingsvlak vir kosmaakdoeleindes gebruik te word. Wat die statistiek betref, is die hoof van die huishouding se ouderdom, inkomste- en opvoedingspeil, tesame met huishoudingsgrootte, belangrike faktore wat die keuse van die meeste van die uitkomste vir kosmaakdoeleindes, insluitend elektrisiteit, houtskool, vuurmaakhout en VPG, beïnvloed het.

Die vernaamste aanbeveling van hierdie studie is dat veldtogte, wat die vermoë van hernubare energie beklemtoon, ontwikkel en versprei word. Die afskuif van hernubare energie na arm mense, veral dié in landelike gebiede, is 'n nosie wat uitgeroei moet word uit die ingesteldheid van die gemiddelde stadsbewoner. Verder moet die gebruik van VLP vir kosmaakdoeleindes aangemoedig word. Invoerbelastingsbeleid wat die internasionale handel van hernubare energiebronne ontmoedig, moet verander word om laer pryse op hierdie fasiliteite aan te moedig. Afhanklikheid van biomassa, wat teen 'n vinniger tempo uitgeput raak as wat dit hernu, sal ook deur só 'n beleid ontmoedig word, wat op sy beurt volhoubare ontwikkeling sal bewerkstellig.

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LIST OF ABBREVIATIONS

AIDS	Almost Ideal Demand System
DFID	United Kingdom's Department for International Development
ESCOM	Electricity Supply Commission of Malawi
ESMAP	Sector Management Assistance Programme
FAO	Food and Agriculture Organisation
FDI	Foreign Direct Investment
GDP	Gross Domestic Product
GHG	Green House Gases
GOM	Government of Malawi
HDI	Human Development Index
HH	Household
HL	Hosmer-Lemeshow Statistic
IEA	International Energy Agency
IH	Induction Heating
IHS	Integrated Household Survey
LDC	Less Developed Country
LPG	Liquefied Petroleum Gas
LRR	Liquidity Reserve Ratio
MDGs	Millennium Development Goals

MERA	Malawi Energy Regulatory Authority
MK	Malawi Kwacha
MNL	Multinomial Logit
MW	Mega Watt
NEPAD	New Partnership for African's Development
NSO	National Statistical Office
OLS	Ordinary Least Squares Method
OECD	Organisation for Economic Co-operation and Development
OMO	Open Market Operations
PV	Photovoltaic
QUAIDS	Quadratic Almost Ideal Demand System
RE	Renewable Energy
REP	Rural Electrification Programme
RET	Renewable Energy Technology
RPL	Random Parameters Logit Model
RSA	Republic of South Africa
SADC	Southern African Development Community
SAPs	Structural Adjustment Programmes
SD	Sustainable Development
SLT	South Lunzu Township

SOE	State Owned Enterprise
SSA	Sub-Saharan Africa
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UNMP	United Nations Millennium Project
UNIDO	United Nations Industrial Organisation
UNDP	United Nations Development Programme
USA	United States of America
WB	World Bank
WHO	World Health Organisation
WSSD	World Summit for Sustainable Development
WTP	Willingness-to-Pay
ZAR	South African Rand

CHAPTER 1 INTRODUCTION AND PROBLEM STATEMENT

1.1 BACKGROUND AND INTRODUCTION

Energy is a basic commodity in the same class as food, water and health. However, the majority of the population in Africa still cannot access it in its modern form (Birol, 2007:3, Barnes & Floor, 1996:509). All economic agents require enough energy to maximise their objective functions. Households require energy to light their homes when it is dark. They also need energy to cook, warm their meals and provide warmth during winter periods. Industries require energy to run their machines. Hospitals and schools need energy to provide better services to patients and learners respectively. The Malawian Government has indicated that energy is amongst the key priority areas after food security and health. It is committed to generate and distribute sufficient amounts of energy to meet national socio-economic demands (Malawi Growth and Development Strategy II, 2012:78).

However, the global energy industry is facing three major problems. Firstly, there is the growing risk of disruptions to energy supply leading to high levels of energy insecurity. Secondly, there is the threat of environmental damage caused by energy production and use. The production and use of unclean energy releases greenhouse gases, which are blamed for climate change world over. Lastly, there is persistent energy poverty, particularly in less developed countries (LDCs), causing many economic agents to rely on unsustainable energy resources (Birol, 2007:2; Pegels, 2010:4945). Further, many households in LDCs have very limited choice with regard to alternative energy supplies. Typically, fuel wood remains the primary source of energy to a majority of the population in Africa (Gebreegziabher *et al.*, 2010:3; Abebaw, 2007:1).

Two main events, the United Nations Conference on Environment and Development (UNCED) in 1992 and the World Summit for Sustainable Development (WSSD) in 2002, integrated energy into the poverty alleviation programmes of multilateral financial and development institutions. These organisations theorise that modern energy improves

LDCs' livelihoods through facilitated water access; health and education services in rural areas; the enhancement of primary agriculture and agro-processing industries; and preservation of biodiversity (Karekezi & Kithyoma, 2003:6).

As modern energy facilities can change the lives of poor people, it has become a necessity for leaders of developing countries to seriously consider the provision of reliable and sustainable energy sources for economic growth and development. The basis for this position emanates from what many authors in the late 80s and early 90s ably showed: that the growth of LDCs cannot be possible without industrialisation. Adopting more advanced production technologies that would provide finished products to the world market is one of the major contributors to higher economic growth (Kaluwa, 2011; Pack, 2003). However, as countries realise the importance of industry, the demand for energy increases (Mataya, 2010; Pegels, 2010). Unfortunately, the high demand for energy in LDCs has not been associated with improvements of energy systems (Government of Malawi (GOM, 2003)).

The United Nations' (UN) Millennium Development Goal (MDG) number seven (7) addresses environmental sustainability. Malawi has underperformed in this aspect. By way of illustration, the total land area under forest cover declined from 46 percent to 36 percent between 1999 and 2009 (Kambewa & Chiwaula, 2010:9). This decline is attributed to cutting down trees for firewood, burning of trees for charcoal, and farming, housing projects. In other words, energy systems have contributed to the largest part of the environmental burden in Malawi in particular and the world in general (GOM, 2003; Apergis *et al.*, 2010:2255). It follows, therefore, that sustainable development and energy systems that are less expensive and cleaner are needed for reliable and dependable economic growth.

With 37 percent of Malawians living below the poverty line, defined by \$1 a day, access to and use of modern forms of energy remains low. Biomass, which comprises all organic and traditional energy resources such as firewood, charcoal, animal dung and crop residues, account for 97 percent of Malawi's total primary energy supply of which 59 percent is used in its primary form, firewood (52 percent), and residues (7 percent),

while the remaining 38 percent are converted into charcoal. In 2008, 43.4 percent of all households (h/hs) in urban areas used charcoal, 41.8 percent firewood, and only 13.6 percent used electricity for cooking (Kambewa & Chiwaula, 2010:10).

At the household level, energy is demanded mainly for cooking meals and lighting. In many cases, cooking requires higher amounts of energy when compared to lighting. However, the health risks associated with the use of inefficient resources for lighting of rooms or cooking of meals do not differ. In the decade 2000 – 2010, there has been an emphasis on understanding the demand for energy facilities in rural areas of many parts of the world such as Pakistan, India, Cameroon and South Africa (Mirza *et al.*, 2010:928, ESMAP, 2003:10, Njong & Johannes, 2011:336; Rajmohan & Weerahewa, 2007:61). What has been neglected in many of these studies is the cooking energy mix of relatively poor urban communities. This thesis covers this research gap.

1.2 PROBLEM STATEMENT

In production theory, energy drives the economy of any country through industrial processes by powering manufacturing plants. At the household level, the lack of access to modern energy resources is a state of deprivation leading to a high demand for unhealthy and expensive energy resources which, inevitably, takes the already poor households to a condition of pitiable livelihoods in LDCs (Foster *et al.*, 2000:4; Birol, 2007:3 and IEA *et al.*, 2010:12). The current global agenda of cutting greenhouse gas (GHG) emissions while pursuing economic growth and development is not achievable in underdeveloped countries where many households are still energy poor (Agba, 2011:50, Pegels, 2010:4946). Several researchers (Chineke & Ezike, 2010:680; Agba 2011:49) suggest that there is lack of political will to discourage the use of traditional energy resources, which are not environmentally friendly. Biomass is creating the risk of political unpopularity for whosoever tries to stop its entrepreneurial and household consumption, especially in Malawi. Therefore, strategies that can be influential in enabling people to demand RE sources would be important to energy poverty reduction (OECD & IEA 2010: 6).

Situations that affect the supply of fossil fuels negatively, such as political instability in the Middle East, are a cause of concern to energy-unsecure nations which do not have their own facilities. In Malawi, all fossil fuels are imported and this is a heavy cost for the nation. Less than 5 percent of all the households have electricity and 25,000 apply for new connections every month with just about 1,000 getting connected because the generation capacity of the Electricity Supply Commission of Malawi (ESCOM) is so low that it is failing to meet demand (GOM, 2011). In addition, the problem is also affecting Industry, which due to the lack of a reliable power supply, is facing problems in sustaining continuous production and business. Sometimes power cuts are so frequent and long that machines and man-power remain idle, which might lead to huge losses at the firm level and slow growth at the macro level.

ESCOM has implemented a load shedding programme as a way of rationing electricity. Foreign exchange, which should have been used for other productive uses such as purchase of raw materials in industry, is channelled to fund fuel imports. There is, therefore, an eminent energy crisis in Africa and Malawi in particular (Deichmann *et al.*, 2010:7, World Bank 2009:8, IEA 2010:20).

The main question this study addresses is how energy poverty can be eradicated in Malawi to promote sustainable development by identifying the determinants of energy resource choices at the household level in urban areas. The study aims to determine the forces behind the choice of energy resources by using econometric methods based on survey data modelling.

Studies of energy access, choice and efficiency have received attention lately due to the ever-growing concerns of climate change. While in the past, particularly the industrial revolution era, economic growth was propelled by coal fired plants, the current agenda has recognised the risk of climate change problems emanating from greenhouse gas emission due to, among other things, consumption of inefficient energy facilities. A green economic growth path is now sought as a way of balancing the development agenda sustainably. However, most of the studies at the microeconomic level have placed emphasis on the demand for energy facilities by rural households, thereby

neglecting urban households (Leach & Mearns, 1988:20; Barnes & Floor, 1996:515; Njong & Johannes, 2011:337; Mekonnen & Kohlin, 2008). This study is, therefore, important for four main reasons. Firstly, there is no empirical literature suggesting that the introduction of RE to the economy will be profitable for the providing firms and agencies (Kambewa & Chiwaula, 2010:19; GOM, 2006:14). There is no experimental data in support of the existence of demand for renewable energy in poor-urban areas. This study is the first to estimate Microeconometric energy demand models in Malawi.

Secondly, the adoption of RE in LDCs has not received resistance (Matriot, 2001:690; Chineke & Ezike, 2010:683; Karekezi & Kithyoma, 2003:8). It is of great interest that several years after the discovery of alternative energy resources, African people are yet to adopt RE fully (Matriot, 2001:691). This thesis assessed knowledge of other alternative sources of energy in urban-poor areas to determine socio-economic factors that may be causing the “snail’s pace” of taking up. In the energy set of Malawians, the researcher observes that there are no RE elements, yet world leaders and the multilateral institutions have established a platform for renewable energy and there is no return.

Thirdly, it is an overstatement that is both sweeping and misleading for any practitioner to overly suggest that income and earning power are the two most important determinants of energy demand at the household level. In Malawi and many SSA countries, as already pointed out, there is a short supply of modern energy, thereby, creating a shrunken set from which households can choose for their needs. Further, the conditions necessary for people to decide that they will opt for modern energy facilities, particularly for cooking, might depend on a thorough and clear understanding of the abilities such a facility can possess. Other energy facilities are deemed as inferior because they have not been proved to provide enough energy for relatively heavy uses such as cooking of beans, water heating and ironing.

Lastly, some studies have shown that a direct relationship between poverty and demand for traditional energy sources, such as fuel wood and biomass, exist (Agba 2011:50). Biomass is affordable and readily available to both rural and urban poor

citizens (Kambewa & Chiwaula, 2010:28). Previous studies attempted to find this link but nearly all of them highlight the shortage of experience and published articles that analyse welfare improvements from the provision of RE in developing countries. As Toman and Jemelkova (2003) and Cabraal *et al.* (2005), point out, there exists a general agreement on the need for better data, a clearer picture of the needs among beneficiaries of alternative energy intervention projects, and the modern energy services that can meet those needs.

In a generation that is facing the challenge of balancing economic growth through industrialisation, which requires huge amounts of energy on the one hand and abating the effects of the ever increasing climate change due to the increase in energy consumption on the other, there is a need to research the factors that are impeding the adoption of renewable energy facilities. This study is justified because at the household level, especially in the poor urban societies, there is an acceptable level of awareness of the presence and variety of renewable energy yet very few households have ever tried them. The rationale is that, having established such factors, relevant programmes aimed at energy use behavioural change can be designed and implemented to create a wayer for sustainable development and green economic growth.

The main question this thesis addresses is how energy poverty can be eradicated in Malawi to promote sustainable development through the identification of the determinants of energy resource choices at the household level in the urban areas. The thesis aims at determining the forces behind choice of energy resources by using econometric methods based on survey data modelling.

These problems, therefore, lead to the following questions, which the study aims at answering:

- What are the determinants of energy choice in urban poor societies?
- Why are renewable energy resources demanded in lower quantities in urban areas in Malawi?
- How is energy demand linked to sustainable development in Blantyre?

- What is the level of energy poverty in South Lunzu Township?
- What is the willingness-to-pay for renewable energy, if any?
- What are some of the socioeconomic factors that affect energy poverty levels?
- What strategies can be adopted to increase uptake of renewable energy for sustainable development?

1.3 OBJECTIVES OF THE PROJECT

The overall objective of this study is to measure energy poverty of households in Malawi in general and Blantyre in particular, and to econometrically estimate demand for energy facilities. Specifically, the study aims to:

- Establish the knowledge levels of the existence, benefits and costs of renewable energy resources among households in South Lunzu Township of Blantyre City, Malawi;
- Review the history of energy and economic policy in Malawi;
- Investigate household responsiveness of energy demand to changes in income in Blantyre;
- Determine and analyse the dynamics of willingness-to-pay for renewable energy;
- Determine and compute energy poverty measurement;
- Econometrically estimate energy demand models;
- Examine the impact of household social and economic characteristics on energy choices; and
- Consider energy policy options and recommendations for Malawi in general.

1.4 JUSTIFICATION OF THE STUDY

Sustainable development is essential for future generations to benefit from the resource base without making them worse-off. The state of energy deprivation in Malawi is appalling and the rate at which fuel wood is depended upon for household energy needs is a cause for alarm. There is need for strategies to be identified where sustainable energy resources can be made available to people. In this way, green

growth together with many other Millennium Development Goals will be achievable.

With this in mind, it is imperative that research to inform policy be carried out. Hypotheses generally regarded by government institutions must be investigated as such hypotheses inform current energy policy. For instance, renewable energy technologies are believed to be specifically designed for rural energy electrification programmes, yet the ability to pay for the resources is lower among rural poor compared to urban poor communities. This research is important in that it will identify strategies that, if followed, will encourage the use of sustainable energy resources in urban societies, which will lead to a reduction in greenhouse gas emissions.

1.5 RESEARCH METHODOLOGY AND DATA USED

The study employed both qualitative and quantitative strategies to answer the questions raised. These strategies included an in-depth literature study, field surveys through questionnaires administered through face-to-face interviews, descriptive analysis of the data collected, and econometric methods.

1.5.1 Literature Study

In this study, a detailed literature review, which included government documents, policy briefs, parliamentary proceedings, books, regional and multilateral forum reports, and referred journal articles were reviewed. Books were reviewed to provide a theoretical premise for energy poverty and sustainable development. Journals, conference papers, working papers, discussion papers, and professional reports provided the state of current research in the area of energy poverty and sustainable development. Methodological aspects and results of other empirical studies addressing similar problems and questions were reviewed. Government documents which included policy briefs, laws, ministerial papers, and parliamentary proceedings assisted in determining the direction of debate and policy government of Malawi was taking regarding the state of energy use.

1.5.2 Empirical Study

Random sampling was used to collect survey data in Blantyre City's high density area of South Lunzu (SLT), which lies to the east of Ndirande Mountain. SLT has twelve sectors each with about 500 households. Among the 12 sectors, data was collected in areas Five, Six, Seven, Eight and Ten. Households were chosen at random and, in total, the survey collected data through questionnaires administered to 318 heads of household and their spouses. The cross section data was subjected to a four stage analysis. First, descriptive statistics of continuous data and frequency distribution for discrete data were computed and interpreted. A pictorial examination of the data was also employed using pie charts, bar graphs, histograms and box plots.

South Lunzu and Nkolokoti are high density townships to the east of Blantyre City in Malawi. These two townships are relatively new compared to other areas such as Ndirande, Bangwe, Zingwangwa and Chilomoni. They emerged mainly due to their closeness to the two main industrial areas of Chirimba and Limbe. They are, therefore, preferred by such people who work in the nearby industrial areas. Recently, however, South Lunzu has seen an increase in relatively middle income settlers building and renting homes in the area. This is due to the availability of utility supplies such as water, electricity, and relatively good feeder streets. The population of Nkolokoti Township continues to increase as a new industrial area in Maoni Park develops, thereby, bringing more people working or seeking employment and demanding accommodation close to the site.

Of the two townships, South Lunzu is more organised and well planned with formal and city council recognised settlements. There are 12 sectors in South Lunzu stretching from north to east and south east of Ndirande Mountain. In each sector there are well designed plots (stands), each one facing a gravel feeder street, thereby making each household accessible as compared to most parts of Nkolokoti Township. The city council organised the area and made water and electricity connections available within a reasonably affordable connection distance from a main supplying line.

On the other hand, Nkolokoti Township is more of an informal settlement area where distribution of plots (stands) is strictly under customary means through local chiefs (community leaders). As such, the land market in this area is highly informal and based solely on trust and approvals of the community leaders. There are very few houses which face or share their boundary with any feeder road. Furthermore, most of the dwelling units are built from mud. They are substandard and clearly without proper utility supplies such as water and electricity. However, the two townships are within the same geographical area and, to a greater extent, their boundaries are blurred.

In addition, the inhabitants of these two areas have many things in common. For example, secondary school pupils from these two areas go to the same institutions, namely, South Lunzu Community Day Secondary School, Chichiri Secondary School, and Nanjiriri Community Day Secondary School. South Lunzu Health Centre is the main clinic for both areas, together with South Lunzu Police Station.

They use the same public transport routes, entertainment and sport grounds, as well as churches. Furthermore, the main market places are the same. In addition, the political boundary for Blantyre City Constituency and Blantyre Kabula constituency is situated in South Lunzu Township, meaning that some households in South Lunzu Township vote for a member of parliament who largely represents the people of Nkolokoti Township. People in these two areas face almost the same economic and social conditions, such that pooling samples from both areas might not be entirely unreasonable.

Stratified random sampling was used to choose households from where respondents were drawn. Each enumerator was assigned a block from where every 5th household was visited. If a head of household was not available, the spouse or partner was requested to respond to the questions. Where neither of them was available, the immediate household was visited instead and the counting resumed. A semi-structured questionnaire was designed (see Appendix B) and given to the enumerators to be used for information collection. The questionnaire contained questions regarding demographics (age, sex, and household size), socioeconomic aspects (employment, education, knowledge) and energy use.

Second, was econometric analysis using Engel function framework to identify energy commodities which are inferior and those superior to others. Other demand systems were also reviewed and their strengths and weaknesses were presented. The Quadratic Almost Ideal Demand System (QUAIDS) was extensively discussed. However, the simpler Engel curve was adopted and used to model the effect of income on each one of the energy facilities under scrutiny due to data limitations.

Lastly, discrete choice analysis using both logistic and Multinomial Logit models for binary and polynomial dependent variables, respectively, was conducted.

1.6 ETHICAL CONSIDERATIONS

Since the study questioned people on their economic and social behaviours, all efforts were made to fully inform them about the objectives of the research and its impacts. Their willingness to participate in the study was requested through a Statement of Consent, which accompanied the questionnaire. Respondents were not forced to answer any questions if they did not want to. Furthermore, respondents were not forced to provide their identities and were assured that the information and data was only for academic purposes. Confidentiality was also assured to all respondents. Plot numbers were recorded only for operational purposes in case there was a need for a tracer to confirm information.

1.7 CHAPTER OUTLINE OF THE STUDY

In this paper, **Chapter one** is the introduction where the background, motivation and rationale of the research is provided. The research questions and problem statement are also presented.

Chapter 2 reviews the theoretical literature on energy poverty and classification of energy. The measurement approaches to energy poverty are also discussed in this chapter. The chapter reviews the history of energy and consider the state of energy poverty in Africa.

Chapter 3 links the importance of an energy poverty free community to the attainment of sustainable development through the achievement of the Millennium Development Goals. In this chapter, sustainable development measurement approaches are presented.

Chapter 4 presents the theoretical methodology used in the study. Particularly, the derivation of energy demand models and consumer choice analysis of utility maximisation are presented.

A review of literature on the economic policy of Malawi with a detailed examination of the energy sector is provided in **Chapter 5**.

In **Chapter 6**, a statistical profile of South Lunzu Township, based on the survey data collected by providing descriptive statistics and charts, is presented

Chapter 7 is a discussion of results of the analysis based on methodologies specified in chapter four including econometric models founded on discrete choice models and a system of demand equations. Engel functions, energy poverty determination and a logistic model of energy poverty are discussed.

Chapter 8 is a presentation and discussion of the Multinomial Logit model of energy resources normally used for cooking.

Chapter 9 summarises and concludes with policy recommendations and study limitations.

CHAPTER 2 THE STATE AND APPROACHES OF ENERGY POVERTY

2.1 INTRODUCTION

Energy poverty is defined as the poor access of quality energy resources to power household activities and run machineries for production in industries (Pachauri & Spreng, 2003:1). International development agencies such as the World Bank, Millennium Challenge, and United Nations Development Program stress that access to affordable and sustainable energy resources is a prerequisite for economic growth and development. However, as the International Energy Agency Energy Outlook (2007:4) reported, there is an overt poor access to energy resources especially in sub-Saharan Africa (SSA) where over 580 million people representing 80 percent of the total population still relies on biomass for daily energy requirements (International Energy Agency, 2009:10).

Further, the global growth and development agenda has changed tremendously over the last four decades, from an emphasis on economic growth through industrialisation to more sophisticated future-oriented goals. As a result, the use and production of energy has also been impacted by the green revolution, which is advancing green growth. Green growth is defined as the pursuance of economic growth and development by following a balance that demands the use of clean energy (Wilkins, 2002:22). The use of fuels that produce greenhouse gases is discouraged at the household and industry level, creating the need for nations to adopt agreements such as the Kyoto Protocol, which spells out the amount of allowable emission levels of greenhouse gases.

Prior to the industrial revolution, there was no need to classify energy as renewable or non-renewable. The global agenda at that time was concerned with wealth creation by accelerating industrialisation. Coal was the main driver of economic growth, whose heat energy was used to propel machinery and trains, and warm homes. In the 19th century, the discovery of oil excited many entrepreneurs to consider petroleum as the main

source of energy to power manufacturing plants. This was boosted by the discovery of the automobile and later, the aeroplane. Ships were now run on oil, relatively cleaner petroleum types, such as paraffin were brought to homes to provide light in darkness. As new discoveries were made, even oil became classified as a dirty fuel whose supply was not sustainable. It was discovered that oil was a depletable resource that could be exhausted by continuous use, despite being dirty (Ibid:23).

The need for sustainable energy resources soon took over policy platforms, more so with the rise of the middle class, which increased pressure on the demand for privately owned automobiles and more and more factories being built. Soon, energy supply became a global concern. With the classification of energy as being cleaner or not, many households faced the threat of deprivation of cleaner facilities. Although biomass and coal are generally considered as renewable energy resources, the rate at which they were consumed meant that their supply could be exhausted faster than their regeneration, such that they soon got classified as non-renewables. The rate at which they formed was considerably slower for a renewable energy resource (Seifried & Witzel, 2010:78). It is imperative, at this stage, to understand the classification of energy.

Having provided the background and problem statement of the study in Chapter 1, this chapter describes the trajectory of energy classification over the past three centuries. The chapter starts by putting forward definitions of concepts that have been used frequently and are at the hub of the study. First, energy is defined and then classified in two ways as either primary or secondary energy. Next, the classification turns to the modern criteria of renewable versus non-renewable energy to reflect the global agenda of advancing green growth. The study further presents a review of economics of energy and its history. In the final analysis, a review of energy poverty is provided and related to the general poverty analysis.

2.2 CLASSIFICATION OF ENERGY

This section is an exposition of definitions for some terms and concepts that have been used frequently in this study. Energy is the keyword of the project hence it becomes the beginning. In this study, the term energy was used interchangeably with fuel and/or power.

2.2.1 The Definition of Energy

Energy, in simple terms is the ability for physical beings to do work (Foley & Nassim, 1981:17; Mills & Toke, 1985:3). Energy makes machines such as computers, printers and cell phones to function. Where there is no energy, life is impossible. When in its stored form, sometimes called potential energy, then it is the trait of matter that has the potential to make things happen. By "happen", according to Watson (2005:1), it means to make things move or change condition. For example, objects can change in volume, position, shape, mass and chemical composition. There are also changes in pressure, temperature, and density, which are called changes of state in thermodynamics (Ibid:1). Phase changes, such as changing from solid to liquid, or liquid to vapour, or back the other way, are also examples of condition changes. In all these examples, something happened and that is because there was energy.

One important nature of energy, according to the first law of thermodynamics (energy conservation), is that the total amount of energy of the universe remains constant but only transforms from one form to another (Bhattacharyya, 2011:9). Energy is neither gained nor lost; it only changes its form. Physical and chemical reactions are needed to transform energy from a dormant form to a usable state, depending on the form it was in. For example, batteries rely on chemical reactions to release electrical current, which can be used to operate appliances such as radios, cars and computers. Moving energy in water and/or wind drives turbines that transform the energy to electrical current, which is used for cooking, lighting, heating in households and driving electrically operated machines in industries. Solar power is used to operate space ships and stations by transforming sunlight energy to electricity.

Energy resources can be classified into primary and secondary and/or renewable or non-renewable depending on certain characteristics to which the study now turns its attention.

2.2.2 Primary and Secondary Approach of Classifying Energy

The term primary energy is used to refer to an energy source that is extracted from a stock or flow of natural resources that have not undergone any transformation or conversion other than separation and cleaning (Bhattacharyya, 2011:10). Examples include coal, crude oil, natural gas, solar power, and nuclear power. Secondary energy, on the other hand, refers to any energy that is obtained from a primary energy source employing a transformation or conversion process. Thus, oil products or electricity are secondary energies as these require refining or electric generators to produce them. In the SSA region, primary energy is more common than secondary energy. In many cases, primary energy requires transformation processes to make it efficient.

2.2.3 Commercial and Non-Commercial Energies

As shown by Bhattacharyya (2011:10), energy can also be classified as either commercial or non-commercial resources. Commercial energies are those that are traded wholly or almost entirely in the market place and, therefore, would command a market price. Examples include coal, oil, gas and electricity. On the other hand, non-commercial energies are those which do not pass through the market place and accordingly, do not have a market price. Common examples include energies collected by people for their own use.

When a non-commercial energy enters the market, by the above definition, the fuel becomes a commercial form of energy. The boundary could change over time and will depend on the location. For example, earlier fuel wood was just collected and not sold in the market. It was hence a non-commercial form of energy. Now, in many urban (and even in rural) areas, fuel wood is sold in the market and, hence, it has become a commercial energy. At other places, it is still collected and hence a non-commercial form of energy. This creates overlaps in coverage. In many rural areas of the SSA in

general and Malawi in particular, energy resources for household and farm use are not obtained from the market place. Energy is mainly a non-commercial commodity (Government of Malawi Department of Energy, 2009:16).

Another term which is commonly used is modern and traditional energies. Modern energies are those which are obtained from some extraction and/or transformation processes and require modern technologies to use them. On the other hand, traditional energies are those which are obtained using traditional simple methods and can be used without modern gadgets. Often, modern fuels are commercial energies and traditional energies are non-commercial. This description does not prevent traditional energies to be commercial either (Bhattacharyya, 2011:12).

Table 2.1 Classification of energy resources

Conventionality	Renewability	
	Renewable	Non-renewable
Commercial	Large Scale Hydro	Fossil fuels
	Geothermal	other nuclear
	Nuclear	
Traditional/Non-commercial	Animal residues	Unsustainable fuel-wood
	crop residues	
	windmills and water mills	
	fuel-wood (sustainable)	
New and Novel	Solar	Oil from oil sands
	Mini and Micro-hydro	Oil from coal or gas
	Tidal and wave	
	Ocean thermal	

Source: Bhattacharyya (2011:12)

2.2.4 Conventional and Non-Conventional Energies

This classification is based on the technologies used to capture or harness energy sources. Conventional energies are those which are obtained through commonly used technologies. Non-conventional energies are those obtained using new and novel technologies or sources. Once again, the definition is quite ambiguous as conventions are subject to change over time, allowing non-conventional forms of energies to become quite conventional at a different point in time. Based on the above discussion, it is possible to group all forms of energy in two basic dimensions: renewability as one dimension and conventionality as the other (Ibid: 12).

2.2.5 Renewable Energy and Non-Renewable Approach of Classifying Energy

A non-renewable source of energy is one where the primary energy comes from a finite stock of resources. In this case, drawing down one unit of the stock leaves lesser units for future consumption (Bhattacharyya, 2011:10). For example, coal or crude oil comes from a finite physical stock that was formed under the earth's crust in the geological past and hence these are non-renewable energy resources.

Non-renewable energy resources deplete at a faster rate than their regeneration and most of them do not even regenerate. For example, most fossil fuels such as paraffin, diesel and petrol are non-renewable. Others, such as coal, regenerate at slower rate than their use. Biomass, defined as all animal and plant products with potential to provide energy (Seifried & Witzel, 2010:72), is a form of renewable energy if its harvest is slower than the rate at which it is used. Plants regenerate and animal dung is produced for as long as there are live animals. Coal forms on the earth's crust as an accumulation of organic sediments, which takes longer to form than the process of mining and use. Consequently, many authors have classified biomass as a non-renewable energy resource (Barnes & Floor, 1996: 502; IEA, 2007:5; Bugaje, 2004:609; Chineke & Ezike, 2010:683; Wilkins, 2002:17; Bhattacharyya, 2011:10).

Renewable energy (RE) can be defined as energy that is derived from a source that is rapidly replaceable, or renewed, by a natural process (Wilkins, 2002:17; Bhattacharyya,

2011:10; Siegel *et al.*, 2008:27). When looking at sources of energy the world can offer, renewable energy resources include the following:

2.2.5.1 Solar Power

This energy is sourced from the sun whose warmth and light produce solar energy. This energy can be transformed into electricity by using photovoltaic cells and hot water systems. Solar energy is probably the most common and popular renewable energy resource for two main reasons (Krohn, 2002:8).

Firstly, sunlight is available for at least 7 hours a day in most parts of the world where energy poverty is prevalent. Of all the energy sources available, the Sun is the largest source by far, dropping 970 trillion kWh worth of free energy every day. Enough solar energy strikes the United States each day to supply its needs for one and a half years (Siegel *et al.*, 2008:27). Further, Krohn (2002:8) shows that the sun is the most important and inefficiently used energy resource with a capacity of radiating 174 423 000 000 000 kilowatt hours of energy to the earth per hour. There is, therefore, more energy produced by the sun than what the earth needs.

Secondly, the complications of setting up solar panels on roof tops, bare ground and any other open space are less compared to the needs of other technologies such as wind mills, geothermal and mini hydro power stations. There are many households in Africa which rely on solar energy generated from small panels fixed to the ground, on roof tops and, in many cases, loosely attached to electrical appliances such as television screens. A household is able to produce solar power for home use through increasingly easier and cheaper methods related to this natural energy source (Clean Energy Ideas, 2009).

One of the main advantages of a solar power system for any home is the lack of pollution given off by solar panels when generating electricity. The only pollution that can be associated with a solar power cell would be the production of the cell, and transportation of the cell until it reaches the consumer (Siegel *et al.*, 2008:20; Clean Energy Ideas, 2009).

Apart from being completely renewable, unlike other forms of energy, another major advantage of solar energy is that it has the ability to bring power to the most remote locations. All that is required is the equipment, labour and the sun. This is probably one of the greatest contributions solar power has had to poverty reduction and wellness improvement (Krohn, 2002:10).

Solar panels are particularly important in areas where the terrain is a constraint to travel. In disaster affected areas such as those affected by floods, tornados and earthquakes, solar energy becomes handy as it is easy to assemble. The other captivating aspect, is that newer technologies have enabled storage of solar electricity through the use of solar power battery chargers (Clean Energy Ideas, 2009).

Despite all the advantages, solar energy is not without disadvantages. However, as will be observed in the few paragraphs to follow, the disadvantages are trivial and insignificant. The advantages are far much important and outnumber the disadvantages.

The first major disadvantage of solar power is that it has limited capacity to free people from the need for cooking fuel. Most solar panels are small generating enough power for smaller appliances such as radios, televisions and, to some extent, refrigerators. However, it is cooking and heating needs which need a replacement of biomass. The needs for the aforementioned appliances are not environmental and health related. They solve problems to do with education time, lighting and information sourcing from the electronic media. To use solar power for needs such as heating and cooking, the investments required are also huge (Krohn, 2002).

Secondly, the initial cost of the equipment used to harness the energy from the sun is considerably high for a poor to average household in Africa in general and Malawi in particular (Siegel *et al.*, 2008:22; Krohn, 2002:9; GOM, 2006). Solar energy technologies still remain a costly alternative to the use of readily available fossil fuel technologies such as firewood, charcoal and animal dung for many energy poor households in the sub-Saharan region. However, as the process of fitting a solar power

generation system becomes less complicated the price also is decreasing and the expectation is that the use of solar cells is likely to increase to generate electricity.

To illustrate the downward trend in the price for solar energy, Wilkins (2002:132) shows that in 1970s when solar PV started to take off, the price of a watt of capacity was around US \$20; in 2004 that had dropped to US \$2.70 Siegel *et al.* (2008:34). Compared to coal generated power with costs around 2 to 4 cents per kWh, clean energy is clearly rapidly closing the gap on dirty energy (Siegel *et al.*, 2008:36).

Costs of producing a unit of solar cell have been coming down due to increasing economies of scale arising from more output is realised from a plant. Some more facts should help prove that solar power is the future of energy the world should look up to especially in LDCs. The production costs of PV solar cells are dropping by 8 percent per year in Japan, and 5 percent per year in California (Siegel *et al.*, 2008:36).

Thirdly, a solar energy installation requires a large area for the system to be efficient in providing a source of electricity. This may be a disadvantage in areas where space is in short supply, or expensive (such as inner cities). For more energy to be generated there is a need for more and bigger cells to be planted. This might require large open spaces to accommodate even bigger cells. However, the amount of space required cannot be compared to that needed for wind turbines.

Lastly, pollution can be a disadvantage to solar panels, as pollution can degrade the efficiency of photovoltaic cells. Clouds also provide the same effect, as they can reduce the energy of the sun's rays. This disadvantage is more of an issue with older solar components, as newer designs integrate technologies to overcome the worst of these effects (Siegel *et al.*, 2008:40). Solar energy is only useful when the sun is shining. At night, the expensive solar equipment becomes almost useless; however the use of solar battery chargers has helped to reduce effects of this disadvantage. The solar waves are converted into electricity after charging batteries which themselves release chemical energy. Converters transform the power to electrons which are needed for household

exploit (Siegel *et al.*, 2008:40). In this way, therefore, the energy is stored for future use and in times of short supply of sunlight such as rainy season.

2.2.5.2 *Hydro and Wind energy*

Scientifically, this energy is a result of the heating of our oceans, earth, and atmosphere by the sun. Wind waves are a result of this heating which causes different air pressure levels leading to the movement of air away from the high pressure zones. Deeper science reveals that wind energy is a form of solar since the weather forces that cause wind to blow are influenced by the operations of the sun (Krohn, 2002:8; Pecan *et al.*, 2000:4). There are wind turbines in many parts of the world that are used to generate electricity for both households and industry. The most contentious debate around the generation of electricity from wind is that it needs more land on which food crops can be grown to feed the poor.

Hydropower is also a form of renewable energy that is generated from force of flowing water, tides and waves. One typically need water falls to run turbines to generate the electricity. Countries without natural waterfalls have built dams in rivers just to create falls. For example, the Kariba Dam in Zimbabwe was formed by blocking the Zambezi River to create falls that supply electricity to Zambia and Zimbabwe. Hydropower is probably the most demanded energy resource in households around the world. However, initial costs of establishing power generation stations are high and not within the abilities of most poor communities.

The scarcity of waterfalls also work as a negative factor in bringing the electricity closer to the people as transmission costs have to be factored in. The advantage of hydroelectricity is that it is smart, pollution free electricity, which can be used for many needs such as cooking, lighting, and heating. Also, the power generated can be used to drive heavy machines in factories for industrial production (Krohn, 2002).

2.2.5.3 Bio-energy

This is energy from plants and animal waste. This energy is used as a fuel to run machines and household heating. Examples include sugarcane, maize, Jatropha, which are used to produce bio-fuels such as ethanol. The trade-off between food production and biofuel need is the major issue hampering the large scale take-off of the biofuels industry. The same crops, that if allowed to mature would be food for the masses that are going without proper diet, cannot be used for fuels to run machines at the expense of life. Most biomass varieties have the potential to produce forms of energy.

2.2.5.4 Geothermal

Geothermal energy is power that is tapped from natural steam produced from heating of the earth and water bodies. These processes also are a main source of renewable energy. Unfortunately though, very little energy in the world is sourced from this resource which has the potential of solving all our energy needs. Unimaginable amounts of energy are stored within the Earth's crust and the space we live in. Consequently, more than 95 percent of our planet is hotter than 1000°C (Seifried & Witzel, 2010:122). Heat is constantly flowing to the relatively thin crust of the Earth from its core, untapped, while the majority of people in the world are facing deprivation of efficient energy.

Scientists have proved that the amount of heat that reaches the surface worldwide is roughly equivalent to 250 percent of our global energy consumption (Ibid: 122). It is imaginable that, to this date, most of it has escaped into space untapped. It is obviously observable that this geothermal heat can be an important part of our sustainable energy supply. After all, it is available around the clock in all seasons, unlike intermittent solar and wind energy.

Alternative energy resources discussed above have become politically viable issues due to the ever increasing risk of energy insecurity which is the next concept to be defined.

2.3 MEASUREMENT OF ENERGY SECURITY

Energy security is defined as the reliable and adequate supply of energy at reasonable prices (Bhattacharyya, 2011:463). Brown *et al.* (2003:7) broadly define energy security as a resilient energy system which must withstand threats through a combination of active and direct security measures. It must be a system that enables less reliance on vulnerable energy infrastructure. This definition goes beyond just the logistical aspect of supply and demand but also the whole range of energy protection services and important infrastructure needed in the entire energy supply chain system that will curb possible disruptions of supply.

Poor and landlocked countries, particularly those that rely on imports of energy resources such as oil, are more energy insecure. This insecurity arises due to a number of factors. Firstly, developing countries have very unreliable energy supply systems, creating a limited choice for the citizen's use. Where choices have to be made, it is basically from dirty and inefficient and, therefore, expensive resources such as biomass (Pegels, 2010:4946; Gebreegziabher *et al.*, 2010:12).

Secondly, homeland security services in developing countries have many challenges from finances to equipment and intelligence services. As a result, alternative and smaller localised power generation activities are important if a possible disruption of the entire energy supply system is to be avoided (Siegel *et al.*, 2008:35).

Energy security is an important aspect of energy markets. An energy insecure economy is as good as one that does not exist at all (Bhattacharyya, 2011:463; Brown *et al.*, 2003:10). Energy disruption affects and costs the economy a lot. For example, some computers might lose data, employees being paid for idle hours, women losing their lives in delivery rooms, and many other channels that rely heavily on energy supply. In other words, there is a need for developing countries to find strategies that provide solutions to the energy security problem. It turns out that alternative energy resources are not only cleaner but also better ways through which citizens can have full control and security of the supply chain.

Some authors have linked energy insecurity to income and energy poverty (Nussbaumer *et al.*, 2011:15; Foster *et al.*, 2000:2; Manlove 2009:2). Unsecured energy systems might drift already deprived communities further down the energy ladder, thereby increasing health, growth and development risks associated with poor access to improved energy facilities. Energy security is an important element that can transform the lives of poor people. It must, therefore, be provided for this reason. The next section discusses the concept of poverty in general.

2.4 APPROACHES OF MEASURING POVERTY

As already indicated in Chapter 1, the main thrust of this study is to measure energy poverty for households in Malawi in general and Blantyre in particular and econometrically estimate demand for energy commodities. It is imperative, at this stage therefore, that an understanding of what poverty is, be examined. Probably one of the areas of greater concern for international financial institutions, non-governmental organisations and governments all over the world, poverty has been the centre of many policy interventions over the years. However, the term has not been defined universally creating problems of identification and methods of intervention programmes. Others have defined poverty as simply a condition of deprivation of basic needs (Rio Group, 2006:16; DFID, 2002:9; World Bank 2005:9).

Poverty is defined as a pronounced deprivation in wellbeing (Word Bank 2005:9). The bone of contention in the modern debate centres on what constitutes wellbeing. Conventionally, economic agents are deemed to be well off if they amass control and command over resources such as land, food, property and health.

The analysis of poverty as a phenomenon and its solutions has been one of the major preoccupations of welfare and development experts for a long time. In Europe, efforts to deal with poverty can be traced to as far back as the 16th century where laws aimed at regulating and sustain the poor were ratified before the time of Queen Elizabeth I which established, among other institutions, the first “Commissioners for the Poor” (Lambarde, 1579 as quoted by Townsend, 2006:15). The purpose of the Commission

was to assess people's living conditions throughout England and to trace corresponding conditions across Europe. By and by, the obligation of defining what constituted a needs basket of the poor in relation to their income rested on governments and rulers.

Intervention programmes started to be organised by those in charge of local and small localities such as parishes and villages by developing forms of indoor and outdoor relief for the poor long before the industrial revolution (Townsend, 2006:17). Economies newly based on manufacturing industries and a wage system posed new problems of estimating and regulating the amounts to be received by the poor outside, as well as inside, Poor Law institutions. The costs of maintaining institutions and their inmates had been a cause of concern for ruling groups and figured in the formulation of a new scheme to manage the poor starting in 1834 in Britain. The principle of "less eligibility" played a crucial part in the thinking both of politicians and those undertaking scientific enquiries.

From the 1880s to the present day, three alternative conceptions of poverty have evolved as a basis for international and comparative work. They depend principally on the ideas of subsistence, basic needs and relative deprivation. In Britain, the "subsistence" standard developed in two stages, first in conjunction with the work of nutritionists by means of surveys carried out by entrepreneurs like Rowntree (1901 and 1918), and then in the war years 1939-1945, by means of a report on social security drawn up by Beveridge (1942).

Formerly, under the old Poor Laws, the needs of the poor had been measured in terms of quantities of bread or bread-flour or their cash equivalent, and in some communities such as around presbyteries and parishes allowances for the addition of other necessities had become common practice as the needs basket continued to be defined. Now, as a result of work prompted by the nutritionists, families were defined to be in poverty when their incomes were not "sufficient to obtain the minimum necessities for the maintenance of merely physical efficiency" (Rowntree, 1901: 86 as quoted by Rio Group 2006:18). A family was treated as being in poverty if its income minus rent fell short of the poverty line.

Stiglitz (2010:5) has argued for a different measure of economic wellbeing, a happiness index. The idea is that there are many things which make people happy but are ignored and not quantified as part of welfare. The major objective of any well-meaning government is to bring happiness to the people, therefore, it is of paramount importance that a happiness index that does not measure welfare based on income or economic performance using Gross Domestic Product (GDP) be constructed.

DFID (2002:11) chronicles the history of early efforts to define the term poverty by many scholars and governments. England being one of them which tried to identify all those not in employment as being poor because generally they could not afford to purchase their basic basket from food, medicine, shelter and clothing. Other terminologies qualifying poverty were developed as it emerged that poverty was indeed a state of deprivation but not just of income, but also many other assets of life such as social recognition, entertainment and recently energy.

There are two main methods that are used to measure how poor a household is. The first and most common is the “*poverty line*” approach, and second is by using ‘*deprivation indicators*’ (Todaro & Smith, 2006:196-211; Rio Group, 2006:35-90).

The focus of this research is urban energy poverty. Urbanisation might lead to more unorganised settlements in many African cities and towns. This situation has brought in challenges to municipal and city authorities especially as they try to optimise welfare to their citizens. It is important to recognise the impact of urbanisation on the distribution of poverty. Others might disagree to the urban bias thesis of poverty as the present study focuses on. However, there is evidence that there is growing urban poverty where young people are flocking to the cities to look for formal employment (Sekhampu, 2009).

As DFID (2002:9) suggests, urbanisation of poverty requires that a position that views poverty as a largely rural phenomena be abandoned. In particular, the corollary that rural development policy can somehow slow or stem the flow of migration to cities has largely been exposed as a myth. Indeed the idea that urbanisation is simply a flow of people to large cities because of economic pressures is itself questionable, as much

urbanisation consists of smaller settlements along the main lines of infrastructure or in strategic rural locations, taking on urban characteristics. Urbanisation is a fundamental and irreversible demographic process that has, everywhere, accompanied industrialisation. These rural-urban migrants need to be provided with utilities such as clean water and energy for a better welfare.

A household is assumed to be poor if its income or expenditure is below a certain acceptable minimum level. There are three different lines which can be adopted in the analysis of poverty namely (i) absolute poverty line, (ii) relative poverty line and (ii) subjective poverty line.

2.4.1 Relative Poverty Line

Relative poverty line is considered most real and close to the understanding of poverty of a particular society. In other words, the poverty line for the United States of America should not be the same to that of Malawi and in Malawi different societies must have different poverty lines (Rio group 2006:74).

As shown by Townsend (2006:17), relative poverty line is the point below which an individual is in deprivation of the generally accepted consumption level according to the society they belong to. Poverty, in this sense, represents the inability for an economic agent to participate in the normal life defined by that society. The relative poverty line is an average of resources for each society. The measure of average that is preferred is the median as opposed to the mean since the latter can be affected by less robust yet extreme variables. For instance, those with very high levels of income in a society might be few in number. However, if a mean is to be derived, the extremely high values would have a tendency to pull the average upwards. In which case the relative poverty line would be skewed to the right and mislead any development practitioner.

The relative concept recognises that people can be excluded through lack of income and cannot participate in the cultural life of their society, that their choices are restricted and that the avoidance of risk becomes paramount with a feeling of lack of control over their lives. In these countries, quality of life becomes an issue and definitions of relative

poverty start to place increasing emphasis on participation, social capital and exclusion. Problems arise in deciding what level of material possessions and monetary income constitutes the poverty level and what items of expenditure it should be expected to cover. These two approaches are often presented as opposing but are also used in a complementary way.

While income and consumption-based indicators are still the most commonly used measures of progress in poverty reduction, the fact that there are many other aspects to poverty, both rural and urban, is now widely recognised by policy-makers and development programme designers. Income poverty is increasingly embedded within a wider, multi-dimensional concept of human poverty. The latter encompasses the idea of people being constrained by many forms of deprivation and unable to meet, not only their immediate needs, but also to realise their full potential or exploit to the full their range of capabilities (Sen, 2000). It is thus tied up with notions of human development and the achievement of a multi-faceted wellbeing and quality of life.

2.4.2 Absolute Poverty Line

The idea of absolute poverty is most frequently found in countries where the average income is very low and the incidence of poverty is high. Income is the most common measure for absolute poverty (as often also for relative poverty where it is regarded as an indicator for more general deprivation) (Rio group 2006:17).

Absolute poverty is based on the idea of economic deprivation, which people need to consume a minimum level of goods to survive (Beard, 2001). While all definitions of poverty have at least some element of relativity, the use of minimum levels of daily food energy requirement (translated into a 'food poverty line' or 'bread basket poverty line') is the nearest there is to an absolute measure, sometimes used where rural subsistence is the norm. It has little relevance in the urban setting where people are unable to live without access to cash for other purposes – except in conditions of emergency and economic disruption.

The UNDP (1997) define a condition of ultra-poverty, 'when a household cannot meet 80 percent of the FAO-WHO minimum calorie requirement, even when using 80 percent of its income to buy food'. The use of caloric intake assessment was once common, but has fallen into decline, except for rural areas in very poor countries where subsistence agriculture is the norm. It is difficult to establish an appropriate minimum level of daily energy requirement and it has become more usual to define poverty by reference to some criteria of subsistence. These measures go beyond basic survival but refer to very low levels of consumption.

Absolute poverty lines are constructed to represent the cost of acquiring a basket of essential items that allows one to meet the absolute thresholds of satisfying certain basic needs. The definition of the normative basket should, therefore, entail first, deciding on absolute thresholds for each of the basic needs; second, defining the type and quantities of the goods and services that are necessary to meet each of those standards; and, third, pricing those goods and services.

Absolute poverty lines are universal in that there is a generally accepted universal threshold of recourse below which one is considered poor. For example, the United Nations and its members have generally agreed that in any country if there are people living on less than US \$1 per day then they are considered poor (World Bank, 2005:43).

2.4.3 Subjective Poverty Line

While objectivity is the backbone of both absolute and relative poverty lines, the subjective poverty line relies on the perceptions of economic agents. There is less science in the development of these lines compared to the first two. Economic agents are asked to state their perception on whether they believe to be poor or not. As the Rio Group (2006:80) suggests, the subjective approach of poverty lines is mainly used as a complementary, and not the core aspect. Through the use of surveys, where questionnaires are administered to individuals, an in-depth enquiry is conducted where a perceived minimum amount of income is expected to be determined. Through these

levels of income, a poverty line is derived for purposes of separating between those deemed to be poor from those well-off.

Most of the emphasis in the study of poverty has been on income poverty. However this study adopts the relative and subjective poverty line methodology to develop the energy poverty line for Blantyre in Malawi.

2.5 STATE OF ENERGY POVERTY IN AFRICA

Energy poverty has been defined as the state of deprivation where a household or, indeed, an economic agent is barely able to meet most of the minimum energy requirements for basic needs (IEA, 2010; Modi *et al.*, 2005:24; Foster *et al.*, 2000:2). Many authors have provided the definition in theory, but in practice, they fail to agree on what exactly is the minimum level below which a household can be classified as being energy poor (Pachauri & Spreng, 2003:7; Pachauri *et al.*, 2004:2087; Mirza & Szirmai, 2010:12). The International Energy Agency believes that there is a minimum level of energy consumption for the rural areas on the one hand and urban locations on the other. For rural areas, the minimum estimated comprises of two light bulbs, 5 hours of radio, while for the urban areas with additional appliances such as television and refrigerator, the requirements would be higher (Foster *et al.*, 2000:4). However, other important energy needs such as cooking, ironing, and washing are not included.

More and more efforts in modern times are leaning towards an investigation that should establish an energy poverty line just like there is an income poverty line. Authors such as Fahmy (2011), Foster *et al.* (2000) and Pachauri *et al.* (2004) have established an energy poverty line for specific areas based on techniques that are scientific from both engineering and economic sciences. Using subjective and relative poverty line measures based on economics as opposed to engineering, this study also estimated an energy poverty line for Blantyre in Malawi.

Using access as a method of determining whether a household is energy poor or not, many studies have shown that Africa is lagging behind in the provision of modern energy facilities to its citizens. As Table 2.2 shows, 554 million people did not have

access to electricity in Africa in 2006. Sub-Saharan Africa had the highest number of people without electricity at 547 million compared to North Africa, which had 7 million people with electricity. This suggests that, generally, sub-Saharan Africa has the lowest electrification rate compared to Northern Africa. Compared to Asia, Africa is still the lowest. This leads to a clear conclusion that energy poverty is more pronounced in the SSA than anywhere else in the world.

Table 2. 2 African electrification rates 2005

	Africa	Sub-Saharan Africa	North Africa
Population without electricity (millions)	554.0	547.0	7.0
population with electricity (millions)	337.0	191.0	146.0
Electrification rate (percent)	37.8	25.9	95.5
Urban electrification rate (percent)	67.9	58.3	98.7
Rural electrification rate (percent)	19.0	8.0	91.8

Source: International Energy Agency (2006B)

Further, Table 2.3 summarises the number of people lacking access to electricity compared to those who rely on biomass for their cooking needs. Still the table shows that Africa has a higher number of people who lack access to electricity after Asia as supplied by the main grid. A further observation shows that, in Africa, it is the sub-Saharan Africa region which has more people lacking access to modern electricity, with 653 million people out of a total of 657 million representing 24 percent of the world total number of people still relying on biomass for their cooking needs.

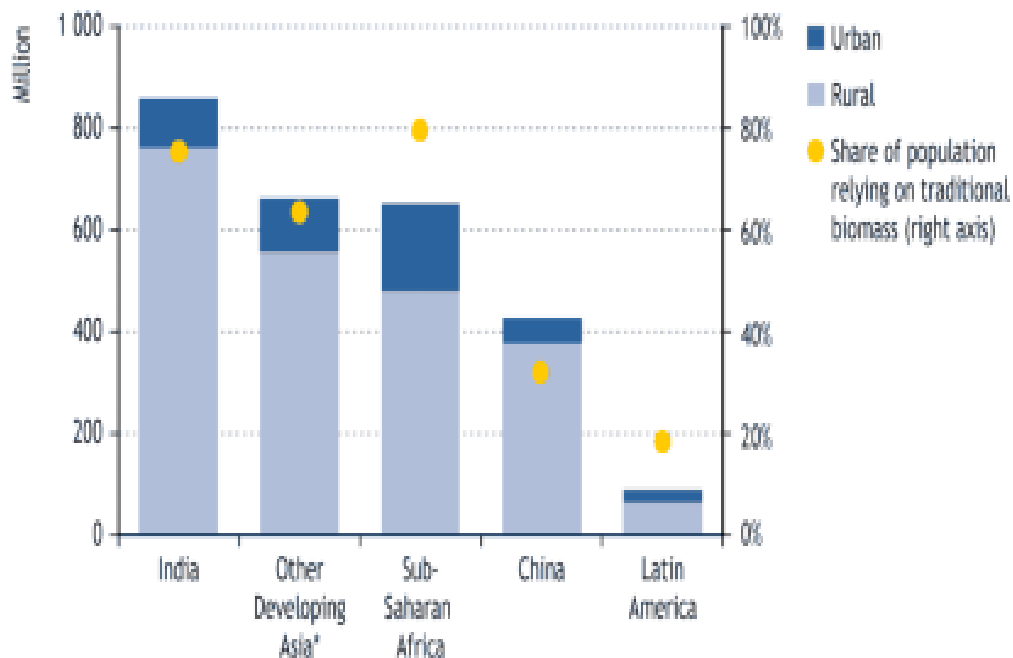
Table 2. 3 Number of People without Electricity and Relying on Biomass

	Number of people lacking access to electricity (Million)	Number of people relying on the traditional use of biomass for cooking (Million)
Africa	587	657
Sub-Saharan Africa	585	653
Developing Asia	799	1937
China	8	423
India	404	855
other Asia	387	659
Latin America	31	85
Developing countries	1438	2679
World	1441	2679

Source: International Energy Agency (2009B)

Figure 2.1 provides a further picture indicating the severity of poor access to modern energy facilities in the poorer regions of the world. In particular, the figure shows that about 80 percent of the people living in the SSA lack access to modern, clean and efficient energy facilities, such as electricity, gas and renewables, as of 2010. This shows that the situation has been deteriorating instead of improving since in 2009. As Table 2.2 shows, about 653 million people lacked better access to cleaner energy facilities, while in the year 2010, about 800 million people were energy poor, a further drifting by almost 150 million more people going below the energy poverty line.

Figure 2. 1 Share of people relying on biomass for cooking by region, 2009



*Includes developing Asian countries except India and China.

Source: IEA, UNDP and UNIDO (2010:20)

Poor countries have low energy intensity measured by the ratio of total amount of energy consumed to gross domestic product (GDP). Low energy intensity levels are an indication that a country is consuming very low amounts of energy which might imply that access is also very poor. However, care has to be taken as low energy intensity figures might also be an indication of energy efficiency per unit of output.

2.6 TECHNIQUES OF MEASURING ENERGY POVERTY

The link between energy and poverty has been considered in a number of studies (Bacon *et al.*, 2010:20; IEA, 2004:9; Manlove, 2009:2; IEA, 2010:21; ESMAP, 2006:11; World Bank, 2009:7). As previously argued, access to modern energy is a fundamental service that enables economic growth and contributes to the success of international efforts to eradicate poverty. Yet solving energy poverty entails its own risks and challenges (Manlove, 2009:2). One such challenge is to determine the definition and,

therefore, the measurement of energy poverty that can be accepted by practitioners with minimal hesitation. This study's major aim is to determine the levels of energy poverty in Blantyre and estimate a model that explains its variability. The area of energy poverty is still new that many studies are still busy to find a better approach that can be universally agreed upon as a measure of energy deprivation. That energy poverty entails deprivation of modern and cleaner energy facilities, has been agreed upon. However, the measurement of the deprivation is still a bone of contention. Basically, as advanced by Pachauri *et al.* (2004:2086), there are economic and engineering-based approaches.

Recently, there have been attempts to apply these approaches to derive an Energy Poverty Index with a similar meaning to the popular Human Development Index (HDI).

2.6.1 Economic-Based Approaches of Defining Energy Poverty Index

The most common method of identifying energy poor households involves an analysis of a share of energy expenditure in the total budget of the economic agent (Hills, 2011:90; Fahmy, 2011:1). This approach assumes that a household whose share of energy expenditure exceeds 10 percent of total expenditure is in stress and need of the resource. Energy takes up a higher share of the total budget. The approach was started by the UK government a few decades ago in the quest to identify individuals and households that were in need of social and public assistance for heating purposes. Expenditure on energy is calculated by adding together all the money-metric costs incurred to fetch energy facilities. These include:

- i. Transport cost to and from the place of fetching the energy facility;
- ii. Actual purchase cost of the facility;

The formula for this calculation is given by:

$$EEX_{ij} = ETPT_{ij} + APC_{ij} \quad (1)$$

Where EEX_{ij} total expenditure on energy facility i by household j ; $ETPT_{ij}$ is transport expenses incurred towards the acquisition of energy facility i by household j ; and APC_{ij} is the actual purchase cost of energy facility i by household j . Since the expenditure on transport as a recurrent activity mainly involves purchases of energy, ETPT includes transport expenses the household incurred per month. For those who commute, bus fares are a direct function of the price of petrol and diesel on the energy market. Those who use bicycles and walking could not be captured as energy conversion factors could not be identified to assist with the process. Particularly, walking and cycling do not involve the use of energy whose cost can be quantified in monetary terms. For those who used cars for travel, the cost of petrol and diesel was added. The result in equation number (1) when divided by total expenditure of the household gives the energy poverty ratio (BRE, DTI & DEFRA, 2006:1).

Having identified whether a household is energy poor or not, methods analogous to income poverty studies, where research has attempted to find an energy poverty line can then be adopted (Foster *et al.*, 2000:3; Pachauri *et al.*, 2004:2087). An average of energy consumption in a sample is calculated and a household's periodic consumption is compared to the line. Those below the average are considered poor and those on or above the threshold better-off. In the case of Guatemala, Foster, Tre and Wodon (2000:2) applied the first three measures of the Foster, Greer and Thorbecke, (1984) (hereafter referred to as the FGT) class of poverty measurements.

First, the headcount index of energy poverty denoted by P_0 , which is simply the percentage of the population living in households with equivalent energy consumption below the energy poverty line, is calculated. The second measure is the energy poverty gap index P_1 , which measures the depth of poverty. Just like in income poverty, this measure estimates the average distance separating the energy poor from the energy poverty line as a proportion of that line. A mean over the whole sample is taken and those that are found to be not poor are given a distance of zero (Foster *et al.*, 2000:4).

Thirdly, squaring the energy poverty gap ratio gives the severity measure which is denoted by P_2 . It takes into account not only the distance separating the energy poor

from the energy poverty line, but also the inequality among the poor. In other words, apart from measuring the poverty level of the household to be visited, the energy access inequality and its factors can be analysed. It should be pointed out that this study expects urban poor localities to be prone to more overt energy resource inequalities than suburbs and rural areas because of large income disparities.

If the energy consumption for household i is denoted by E_i , by Z the energy poverty line, by N population size, by W_i the weight for household i (equal to the household size times the expansion factor, the sum of the weights being 1), then we can specify the three measures of energy poverty as discussed above for θ equal to 0, 1, and 2 respectively in:

$$P_{\theta} = \sum_{E_i \leq Z} \frac{W_i}{N} \left(1 - \frac{E_i}{Z}\right)^{\theta} \quad (2)$$

The definition of Z is contentious but as reviewed, it is not unique to the energy sector alone. Income poverty has many other contentious issues regarding the measurement of the poverty line.

One of the methods is to use the definition of energy poverty by the United Kingdom's Centre for Sustainable Energy, which states that a household should be regarded as being energy poor if, in order to maintain a satisfactory energy needs such as heating, lighting and cooking, it would be required to spend more than 10 percent of its income on total energy expenditure per period. The definition of income itself is not so clear in many other areas. In this study, this approach is adopted assisted by the second one below.

The second method consists of computing the average energy consumption of households whose overall per capita consumption level falls within plus or minus 10 percent of the US \$1 income poverty line used in the international literature on income poverty (Mirza & Szirmai, 2010:12). In other localities, such as Guatemala in 1998/99, this gives a subsistence energy threshold of 2,125 kilowatt-hours per year (5.8 kilowatt-hours).

As can be observed from the preceding two paragraphs, the determination of the energy poverty line is so contentious that the economic measurements are almost meaningless without considering the engineering methods.

2.6.2 Engineering-Based Approaches

The major advantage of using engineering methods in determining the energy poverty line is that the basic needs for households are established in energy units of account thereby making it possible for an analyst to easily compare households.

The methods involve defining a basic set of energy needs. This requires an expert group consultation with authorities in government and energy supply institutions. Taking Guatemala as a benchmark and starting point, these types of consultations led to the suggestion that a household should be able to run two 60 watt light bulbs and one 16 watt radio for four hours each day (Foster *et al.*, 2000:3). A household should also be able to use five two-kilogram logs of fuel wood each day for cooking. This leads to a fuel poverty line of 2,154 kilowatt-hours per year (5.9 kilowatt-hours per day).

In India, a similar approach was used to estimate basic energy needs for cooking, lighting and heating, and it was assumed that for cooking needs to be met, each person required about 30 W of useful energy. Similarly, 1.5 W is required for lighting and space heating respectively for each person giving a total of 33 W per-capita of useful energy (Pachauri *et al.*, 2004:2089). Reddy (1999) found that where LPG is used for cooking and electricity for lighting, each person requires 100 W of end-use energy.

There are a number of indices that can be used to develop the energy poverty index based on problems being addressed, such as inconvenience in obtaining the energy resource through transportation, time required to burn, method of acquiring be it purchase or self-collection. Also, using a measure of access and the quantity accessed compared to the size of household.

2.6.3 Computation of the Indices

The indices are calculated based on the dimensions of energy poverty. Basically there are two dimensions as stated above. First is the energy shortfall a household faces and second is the inconvenience faced by the household to obtain the energy resources.

2.6.3.1 Household Energy Shortfall

This is a situation where households are unable to have sufficient energy to meet their basic needs such as cooking, heating and lighting. Following Mirza and Szirmai (2010:15), this can be given as:

$$HES_h = \left\{ \left(\frac{AEC_h - TER}{TER} \right) \right\} * 100 \quad (3)$$

Where HES represents the energy shortfall for household h, AEC represents the actual energy consumption per household in kilowatt hours and TER is the per capita threshold energy requirements.

The AEC per capita is calculated by converting all the energy sources into kilowatt hours on the basis of the quantities of energy sources used by a single household and, here, standard conversion factors to convert quantities of energy sources used into kilowatt hours have to be used.

The TER is a minimum level of energy requirements in kilowatt hours below which an individual has insufficient energy for basic needs such as cooking, heating and lighting and is therefore considered to be energy poor. The derivation of TER is based on previous literature. It can be calculated on the basis of the TOE (tonne of oil Equivalent) per annum per capita required to attain 0.8 levels on HDI (Human Development Index) (Pokharel, 2006). However, a threshold level of 1 TOE, derived from HDI is characteristic for advanced economies. For poor economies, such as Malawi, the energy requirement level is adjusted to 0.75 TOE.

By converting 0.75 TOE into kilowatt hours (kwh) and then dividing it by 52 for weekly requirements, one obtains a threshold value of 156.55 kwh per week per capita. Note

that the shortfall measure is also on a per capita basis, so that households of different sizes can be compared. To make the energy inconvenience index and the energy shortfall index comparable, so that same sign should indicate energy poverty, the TER was subtracted from the AEC_h instead of subtracting the AEC_h from the TER. Thus, a household energy shortfall is represented by negative values.

2.6.3.2 Energy Inconvenience

Energy poverty is manifested in a number of dimensions. The use of traditional energy sources by rural households always comes with associated inconveniences, which are not associated with modern sources such as electricity and gas.

From the collection of firewood, to the buying of LPG, households are required to make unusual efforts to meet their domestic energy needs. Households with better energy access in terms of kilowatt hours (kwh) are normally those who suffer the highest degrees of inconvenience. In this context, the energy inconveniences for a household can be defined as the degree of physical difficulties or inconveniences involved in acquiring and using a particular energy source to meet household energy needs.

To measure energy inconvenience, the following indicators relevant for energy access by poor households are proposed by Mirza and Szirmai (2010:11):

- 1) Frequency of buying or collecting a source of energy;
- 2) Distance from household travelled;
- 3) Means of transport used;
- 4) Household member's involvement in energy acquisition;
- 5) Time spent on energy collection per week;
- 6) Household health; and
- 7) Children's involvement in energy collection.

This study did not experiment on any energy inconvenience index due to data limitations. The survey collected data in a place where items were bought, thereby giving an estimate of distance, number of times per month a particular energy facility

was bought, and the means of transport that was used to bring the facility to the household. Data on health status of the household regarding pollution related illnesses was also collected.

The other point of departure for this study is that an inconvenience index, based on frequency and length of blackouts, is also computed. Whenever there is a blackout, especially those that are unannounced, people experience higher levels of frustration and stress. This deprives those with a connection from the main grid of the access of electricity in the right quantities and at pick hours such as in the morning, midday and evening.

2.7 HISTORY OF ENERGY

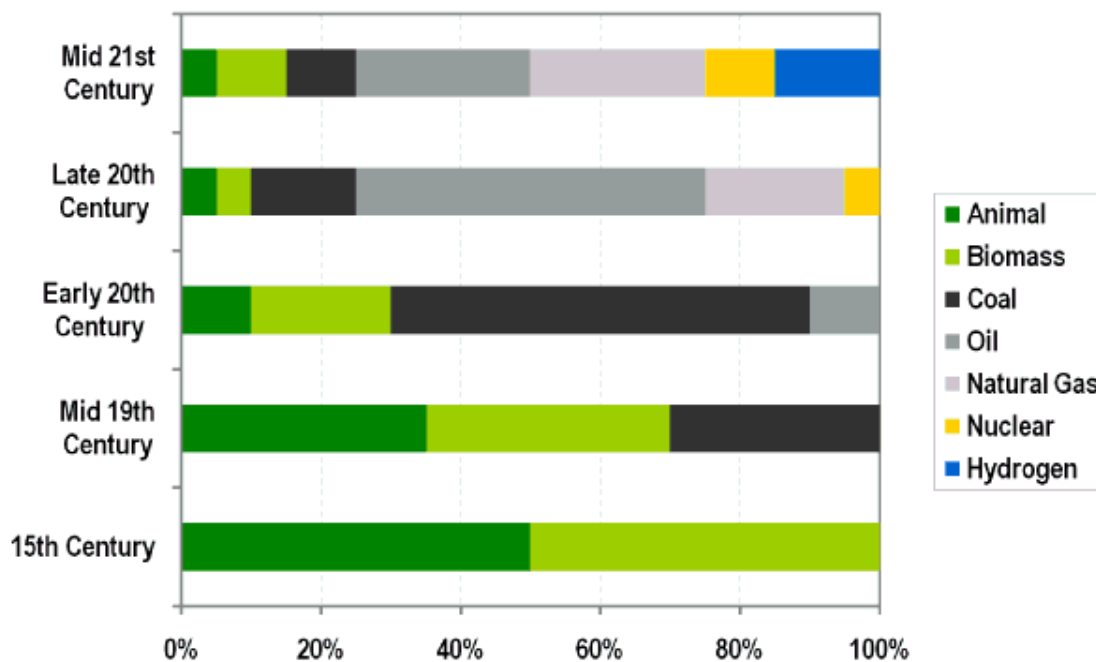
Williams (2006:1) shows that there is a historical foundation to the belief that civilisation and energy are linked. Human behaviour over the span of existence has focused on storage of energy resources and making sure that they are secure for the future. From the beginning of history up to the industrial revolution (18th century), mankind's use of energy relied only on muscular and biomass sources. Most work was provided by manual labour and animals, while biomass (mainly wood) provided for heating and cooking energy needs. Other sources of energy, such as windmills and watermills were present but their overall contribution was marginal.

The revolution of energy sector can be classified into four main transitions. The first one is the age of water power. In this era, water and wind generated power was relied upon to draw water for agricultural purpose, grazing land for commercial farming, and building of structures that made ancient cities and towns (Williams, 2006:1). In particular, moving water due to either gravity or wind, benefited the transport sector in Europe, which was used to drive ships transporting merchandise across large bodies of water. The discovery of America, Jamaica and Africa, and its subsequent colonisation was made possible because of wind and water power.

Figure 2.2 is a summary of the transition man has gone through as improvements in energy resources used. As can be observed from the figure, the period up to the 15th

century the only available energy resource was animal power and biomass. Animal power was used for transportation of cargo and passengers. Some of the animals such as horses were useful to pull war wagons and cultivation of land for agricultural purposes. For most household use such as cooking, heating and lighting, biomass was the only choice (Rodrigue *et al.*, 2009).

Figure 2. 2 History of energy resources over the years



Source: Rodrigue *et al.* (2009: Chapter 8)

The second is the age of steam that was used mainly to mine coal, itself an important source of energy by the 18th century. Steam, together with the then traditional water power, was reorganised and brought together to operate mine pumps. Steam power had the advantage of being used even in areas where enough water was not available to generate power and as a result, it became very popular with entrepreneurs of the day. Another reason entrepreneurs in industry quickly adopted steam power was its flexibility to be used in a number of factories, steam could support so many mills in the textile industry, thereby reducing the cost of production. Steam power, therefore, linked fossil energy resources to industrialisation with greater flexibility (Ibid).

Third is the electrical age, which provided even more flexibility in generation and transmission of power from source to the consumer. Power could now be generated using batteries and transmitted through wires. Electric motors were developed and planted in areas far from the generation points of electricity. More common was hydro generated electricity from massive natural waterfalls. So deep was the belief in the

abilities of hydro power that countries without natural waterfalls started to construct dams with special features to generate electricity. Zimbabwe constructed and commissioned the Kariba Dam in the 1950s whose electricity is shared with Zambia.

Fourth, towards the end of the 20th and the beginning of the 21st century, the world entered a nuclear age where power is generated through burning gases from hydrogen reactions. Notwithstanding the dangers associated with nuclear power plants and waste, it is still a popular source of energy to many countries because one plant has the ability to generate a lot of electricity both for household and industry (Williams, 2006:6). Apart from fears associated with waste, nuclear power has the potential for nations to develop nuclear weapons which are essentially banned through international agreements after the devastation caused at the Hiroshima bombing in the world war. Generally, nuclear power generation is also expensive such that developing countries can only dream about it.

Lastly, due to the ever increasing demand for energy in social and economic activities, and the need for cost efficiency in production, scientific research has turned to renewable sources of energy. Water, wind and sun waves are now the future focus of energy insecure countries. There are many disadvantages associated with the traditional energy resources which necessitate alternatives to be put to use. At this stage, it is necessary to turn the discussion to modern problems in the energy sector to appreciate why renewable (alternative) energy is the option of the current and future situation.

2.8 MODERN ENERGY PROBLEMS

As discussed in Section 2.4, the past had its own energy problems. Previous generations were more concerned with quantity of energy than quality. Resources were abundant with relatively less advanced technologies that offered little efficiency levels. Of much importance was the supply of power to industry following mercantilism, an economic school of thought that advanced economic growth, development and, therefore, political and territorial authority depended on wealth which a nation has

accumulated. As a result, the major objective of investments in generation of power was to enhance the mining of precious minerals such as gold, silver, diamond and platinum as these defined the wealth of nations.

Birol (2007:4) suggests that in the 21st century, the energy industry has now become a topical issue discussed at high profile international conferences. The importance of energy must not be for industry alone but also for households. Economic activities, such as mining have both positive and negative impacts on the environment. Questions of equity and fairness coupled with universal rights as laid out in the Universal Declaration of Human Rights call for a carefully planned supply chain of all commodities including energy. Modern energy problems are concerned with the emission of greenhouse gasses more than aspects of welfare, such as access of modern facilities by the poor.

Current problems include energy insecurity which many developing countries are facing due to political instability in the Arab region where most of the oil is coming from. Given prolonged disruptions in the supply chain of the oil, many countries might as well come to a standstill in their economic and social activities. Apart from the political instability, the volume of oil reached its peak at the beginning of the 21st century causing panic and a scramble for the little resources believed to exist in the North Pole. Exploration of new oil reserves by richer countries in places that could not be visited is intensive. For less developed countries with weaker terms of trade (TOT), internationally accepted foreign currency to be used for petroleum procurement is scarce. Others, such as Malawi, Zambia and Zimbabwe, are landlocked, which increases transportation cost, thereby making the commodity more unaffordable to the people. In addition, the little currency that is generated is used for the procurement of more essential commodities such as drugs and fertiliser.

The most neglected problem though is access of energy by the poor people in poor countries (World Bank 2009:9). Just like in the Industrial Revolution and the mercantile era, the present world order is also placing more emphasis on the supply chain of energy to the industrial sector and, with the reduction of greenhouse gasses emission at the heart of the global agenda, households have been completely neglected. Research

and Development agencies are developing technologies mainly aimed at providing cleaner energy resources to the industrial sector to cut GHG emissions than improving access by poorer households.

There is low power generation capacity especially in LDCs worsening the access problem. For instance as the World Bank (2009:1) notes, generation capacity in Africa at 39 Mega Watts (MW) per million populations is about one tenth of the levels found in other low income regions such as East Asia and Latin America. The power generation plants are old and they do not meet the current power demands. The middle class has been growing and with it the demand for power due to an increase in the use of electricity powered appliances such as stoves, televisions, geysers and heaters. As a result some 30 African countries have been experiencing frequent outages and load shedding. High-cost and unreliable energy services in Africa have become a significant drag on economic growth and competitiveness in the region (World Bank, 2009:6). Some economists have estimated that the economic value of power outages can amount to as much as 2 percent of GDP for countries affected (Mataya, 2009:20).

It has been estimated that redressing Africa's power deficit could boost economic growth by 1.9 percentage points (ESMAP, 2006; Mataya, 2009; World Bank, 2009). To cope with widespread outages, a number of countries have had to contract short term leases for emergency generation in the form of containerised mobile diesel units costing as much as U\$0.35 per kilowatt-hour, with lease payment absorbing more than 1 percent of GDP in many cases (ESMAP, 2006:10).

Therefore, strategies aimed at improving access of modern energy by the poor are long overdue. Low income levels coupled with electricity grids that are very far away from villages and peri-urban areas are a cause of concern. Efforts by non-governmental organisations (NGOs) to bring power to the most remote areas in many poor countries have failed due to a number of reasons. For example, most NGOs rely on short-term funding, which is not sustainable for projects of this nature (ESMAP, 2003:4; ESMAP, 2004:7; Girdis & Hostetke, 2005:10). It is imperative therefore that funding agencies and

global think tanks should consider long-term financing programmes to bring energy to the needy.

Probably the most overt problem facing the energy industry is the ever rising price of oil. After the 1970s oil shocks, the trend has, generally, not reversed. As the resource gets further depleted, supply is also dwindling, creating excess demand. The solution is in efficient energy resources used by efficient appliances such as smaller engine motor vehicles. Oil itself is a non-favoured source of energy since its burning is also one of the major contributors of environmental degradation.

The rising prices of energy resources are a danger to the problem of access to already poor people. Very rural areas in many poor countries rely on diesel or petrol propelled generators for their social activities such as health and education. However, with the rising prices, it means that they can no longer afford electricity unless they obtain subsidies. The rising prices are also in the face of foreign exchange challenges aggravated by weak terms of trade.

As of the year 2012, even the much desired nuclear energy has been facing more of a reverse than a forward adoption. Although nuclear energy is renewable, efficient and clean at use, it has become less favoured mainly due to the following four reasons (Seifried & Witzel, 2010:22):

- I. The danger of a reactor meltdown like the one in Chernobyl (1986) remains, as events in July 2006 at Sweden's Forsmark nuclear plant revealed. In March 2011, the Japanese Fukushima nuclear plant was heavily shaken with an earthquake and the toxic waste affected, not only human life, but also aquatic life for many months;
- II. As of 2012, there was still no final repository for highly radioactive waste. Nuclear waste is highly toxic and hazardous to human health. If it comes in contact with humans, there are usually higher chances of death than survival. It, therefore, follows that nuclear waste management requires expensive and highly specialised equipment;

- III. The 'peaceful' use of nuclear energy cannot be completely separated from military applications implying that other countries might take advantage of the systems and make nuclear weapons, and;
- IV. Again as of the year 2012 there was no perfect way to protect nuclear plants from terrorist attacks. Nuclear power was enclosed under heavy security infrastructure but the nature of the radioactive material is so volatile that terrorists might target them knowing that one attack might kill more people than suicide bombs.

These reasons confirm that nuclear energy with all its promises is also not a solution to the problem of supply breaks. The solution then lies in other sources of renewable energy which are safer to generate, supply and use compared to nuclear power (Petrie, 2007).

Lastly, the world is facing *Energy Peaks* as a major problem. As shown by Siegel (2008:1), all the depletable resources have been rising in both production and use prior to the 21st century. However, between now and the year 2025, the world will be at a peak following a bell shape resource availability and utilisation. After the peak, the rapid decline of these fuels is witnessed, leaving people vulnerable to what could amount to the biggest disruption the global economy has ever witnessed. For example, the largest oil wells were discovered prior to 1970s and three quarters of them are now mature. Oil, in the near future, will be a very scarce resource (Petrie, 2007:4). In addition, natural gas, firewood, hydropower capacity, and coal have also reached their peak production with the increase in world human population now above 6 Billion. There is only one solution which is to turn to renewable energy.

Current energy problems therefore are beyond historical problems of access to energy only. There is a need to provide sustainable energy resources that do not deplete the available quantities at a rate that make future generations worse off. In addition, the global agenda of cutting down the greenhouse gas emission to abate effects of climate

change have increased the efforts of scientists and economists alike to consider clean and efficient energy resources that are also safe to use.

Having reviewed some of the concepts that form the bedrock of this study, it is imperative to introduce and connect economic theory to energy poverty and sustainable development as a basis of the empirical analysis. There is a strong linkage between the consumption of energy and societal welfare. The next chapter, therefore, examines some of the main economic theories underlying the present study.

2.9 SUMMARY AND CONCLUSION

The concept of poverty in general has been defined by many researchers and practitioners in many ways. The definitions stem from the measurement of poverty for an economic agent, to be classified as energy poverty, is a new concept stemming from the general literature of poverty. It is defined as the deprivation of efficient energy resources in the right quantities for economic agents to meet their needs. Households need enough energy for cooking their meals, lighting in darkness and warming their rooms in winter. Industry needs energy to run their manufacturing machinery to produce goods.

The trajectory of energy use and development clearly shows that man has evolved tremendously from reliance on animal power and biomass for subsistence living to more cleaner and modern fuels over the years. While other developed countries have an abundance of sustainable energy resources, many economic agents in the SSA still suffer from deprivation of clean energy resources. As a result, foreign direct investment and other social services such as education and health are also minimally provided.

In the past, the energy sector problem was mainly around quantity where economic agents were worried with supply without considering the possible risks of pollution coming from production and consumption of energy. As a consequence dirty, inefficient, and often expensive, and heavily polluting energy resources such as coal, wood, agricultural residues, and oil, were commonly used to provide power both at the household and industry level. The current global energy challenges are, however, more

complex than in the past. Apart from worrying about access to energy, leaders of nations have to deal with the balance between quantity and quality of resources while achieving badly needed economic growth. Energy poverty is not defined just as deprivation of energy resources but also the lack of access to modern, pollution free and sustainable energy resources.

Energy resources must be secure and reliable while at the same time advancing green growth by not emitting GHGs at production and consumption. These problems are more overt in poorer and fragile economies of Asia and Africa. Energy poverty is real and it is affecting many people in sub-Saharan Africa. However, the measurement of energy poverty is itself challenging as income poverty is. Still to this day, there have been no universal agreements as to what exactly should be a measure of energy poverty. Borrowing from studies in poverty and welfare, energy poverty can be measured by considering an energy poverty line in both absolute and relative terms. However, this method becomes handy where engineering methods are employed. The problem with engineering methods is that data requirements are enormous and special conversion factors are required to standardize the amount of energy that is used. Where conversion factors have been obtained and data for quantities of each energy resource used has been acquired, then engineering methods are recommended.

Economic methods are easy to compute as they rely on expenditure on energy facilities. For example, one common method that has been employed in the literature is where any household that spends more than 10 percent of its income on energy resources is considered energy poor. The data required in this case is simply household expenditure on energy resources and income. In addition, there is no need to standardise measurements as all expenditures are in monetary terms. However, this approach compromises the fact that different energy resources provide different amounts of usable energy. The actual cost of fuel wood may be beyond any measurements in monetary terms as it might require that other costs, such as health risks, time spent on collecting the wood, and inconveniences met acquiring some energy resources, might also be unmeasured costs in money terms.

Economic measurements have also tried to borrow from the main stream poverty analysis to consider drawing an energy poverty line. Typically a relative energy poverty line is drawn by taking an average of all expenditures on energy facilities for all households in any sample. Households below that energy poverty are classified as energy poor and those above it are well-off. Again, the problems of measuring other associated costs of each energy resource arise.

The link of energy poverty to the achievement of the MDGs is crucial for sustainable development monitoring. After reviewing the approaches of measuring energy poverty in this chapter, the next chapter turns to the measurement of sustainable development and the linkages between energy poverty and the fulfilment of the MDGs. MGDs cannot be a success story without a proper and sufficient supply of affordable and quality energy to the poor people.

CHAPTER 3 MDGs AND SUSTAINABLE DEVELOPMENT NEXUS

3.1 INTRODUCTION

Energy poverty has the potential of leading to economic growth and development that is unsustainable for economies where it is overt (Pachauri *et al.*, 2004:2085). Households lacking modern energy resources resort to the use of biomass in the form of fuel-wood, crop and animal residues. If the rate of harvesting of fuel wood, oil and coal is faster than the regeneration rate, then future generations are left with very few choices to make for their own development and welfare needs. There is a strong link between energy poverty and sustainable development. Emission of greenhouse gases due to consumption and production of energy is common in areas where people depend on dirty fuel resources. Among the many indicators of sustainable development, the access to affordable and environmentally friendly energy resources comes out clearly (Bossel, 1999:11).

In poor countries, there are energy preferences which economic agents make clearly following the predictions of economic theory. Consumer welfare, however, is held back by exogenous factors such as unavailability of resources (OECD & IEA, 2010:20). Literature reviews seem to suggest that many households in poor countries cannot contribute effectively to sustainable development and green growth initiatives because although they prefer energy resources that are considered to be on higher points of the energy ladder, the available resources such as hydro power are unreliable due to frequent blackouts. The energy ladder theory, therefore, faces challenges apart from income as a determining factor, other factors also related to the economic environment seem to have an important influence as economic agents go about making important energy choice decisions.

In addition, the growth path and strategies as set out in MDGs by world leaders in the year 2000 is not possible without universal access to affordable and efficient energy. As Modi *et al.* (2006:3) shows, there is a missing MDG, which is to ensure that all people in the world have enough access to clean energy. Poverty reduction, literacy, gender

empowerment, and desired health status cannot be a success story without clean energy. Others, such as Hasan (2010:4) and Modi *et al.* (2009:17) have suggested a revision of the whole package forming the MDGs and incorporate a ninth MGD as universal access to clean, efficient and affordable energy resources by the year 2030. Sustainable development, therefore, without the MDGs being achieved, which depend much on low levels of energy poverty, is just another story.

This chapter links energy poverty to sustainable development by examining economic theories of consumer welfare through the energy choices households make. In particular, the energy ladder hypothesis was reviewed. This section will be followed by approaches and measurement of sustainable development. Finally, consumer choice and derivation of demand curves is presented.

3.2 SUSTAINABLE DEVELOPMENT DEFINED

Sustainable development (SD) is a subject that has received attention from the last three decades to the present time. It is now one of the major topics discussed at world leaders' forums because of its importance. However, there are differences as to what exactly is the meaning of SD and how can it be measured to provide a benchmark on which nations can compare themselves and determine whether they are on the right path towards SD (Bossel, 1999:1).

SD is one of the important theories in the economics of energy literature, which has strong linkages to the production, transportation, consumption and disposal, of energy facilities (UNECE/OECD/Eurostat, 2008:48). The existence of human kind has depended on the natural environment to supply needs such as food, water, shelter, medication and energy. However, the state of the world has changed. In the current period, man has to travel longer distances to fetch natural commodities, which were just at the door step. All this implies that life can no longer be sustained by the natural environment as before. It is inadequate. Towards late 1980s, more attention turned to the understanding of SD. Research and Development (R&D) is busy finding solutions to the problems of rapid environmental degradation to turn the state of affairs.

One of the most common definitions of SD considers the economic development of more than other sectors of the society; that it is “the use of the current stock of resources that meets the needs of the present generation without compromising the ability of future generations to meet their own needs” (World Commission on Environment and Development, 1987:2). Sustaining the stock of resources only is a narrow view of SD. A much broader view defines SD as:

...the kind of human activity that nourishes and perpetuates the historical fulfilment of the whole community of life on earth (Engel, 1990:10).

What is common in both definitions is that present generation’s consumption of resources should not be at the expense of future generations’. One view of SD, called the Integrated Approach, argues that SD should mean improved wellbeing of both the present and future generations (UN, 2008:21). SD advances development that is not only happening and desired to happen in future, but also needed by the community.

As pointed out in section 2.2.1 above, energy consumption is essentially a change of form of energy itself from one state to another. Sustainable development demands that the consumption of energy stock available in the current period as development activities are undertaken should not leave the future generations with resources of energy that are inadequate and in forms that cannot be used. The stock of resources in economic terms includes the natural resources and those that are social in nature. Poor people’s energy needs are satisfied through the use of biomass obtained from the natural environment. As a result, SD is more talk than reality. The rate at which deforestation is taking place compared to reforestation is disquieting. Environmental degradation induced by energy consumption is a threat for SD efforts.

Bossel (1999:4), in a report to the Balaton Group, noted that sustainable development is constrained by a set of available resources from which subjective choices are made by human kind. Current and future possibilities for both an individual and society’s development path are constrained by the amount of resources that are available in the

present day and the future itself. Sustainability, however, is a dynamic concept through societal and environmental changes. Aspirations, technologies and cultures change with time. This suggests that societies which are sustainable must adapt to rapid and continuous change without necessarily being stagnant. SD does not imply complacency with the state of affairs, future generations will define development in their own ways and when they do so, things will have to be allowed to change as long as their own future generations will not be left worse-off.

In poorer societies, change requires strong campaigns that should break cultural barriers. The energy sector takes a special case. The current generation has embraced globalisation using fast telecommunication and social networks. It is, therefore, more knowledgeable about a better energy basket that can meet their needs without leaving future generations worse-off. Through internet, satellite television systems, and education facilities, economic agents are aware that the world is not short of technologies and technical solutions to SD and energy poverty in particular. For example, modern diesel engines in Europe are much cleaner today than the higher emission older technologies still used in many developing countries that do not have environmental regulations. Natural gas is a much cleaner fuel than oil and can replace liquid fuels for power generation and even transportation (World Bank, 2009:29).

Just like any desirable state of affairs, SD has indicators to tell a story of the status quo. Indicators of sustainable development are needed to guide policies and decisions at all levels of society, be it a village, town, city, county, state, region, nation, continent and world. To develop better indicators, sustainable development has been simplified into a question of whether a country's total capital base (total national wealth) is managed in a way that secures its maintenance over time (UN 2008:41). National wealth can either be financial, real output, natural, human or social stocks (Bossel, 1999:8).

From the definitions of SD above, it is clear that SD can be deciphered using the wealth (capital) approach. At this stage, the study turns to a discussion of the approaches of SD focusing on national capital approach which classifies national capital into five types that together form the national wealth.

3.3 THE CAPITAL APPROACH TO SUSTAINABLE DEVELOPMENT

From a capital perspective, sustainable development can be defined as non-declining per capita wealth over time (United Nations *et al.*, 2003 as cited in Joint UNECE/OECD/Eurostat Working Group on Statistics for Sustainable Development (UNECE/OECD/Eurostat), 2008:6)). As stated, this definition directly emphasises the need to maintain wealth as the basis of any socioeconomic growth trajectory hoping to lead to sustainable development. In addition, the definition also recognises that wealth per capita is important, not just the total wealth of a society. This reflects the fact that populations increase over time and that the rate of increase of wealth must be at least equal to population growth if sustainable development is to be achieved (ibid:6).

Further, UNECE/OECD/Eurostat (2008:6) observes that this definition views all goods and services as being produced through the use of some form of capital, normally in conjunction with human labour. Since the concept of sustainable development demands a very broad view of consumption, it is necessary to take an equally broad view of capital. Any nation starts from a point of a natural resource base, which when proper scientific extraction processes are employed, growth takes place. The natural resources, together with all the other resources that exist as a result of some conversion processes, form the national wealth. The national wealth can be modelled as having five main segments namely, natural, produced, financial, human and social capital; to which the study turns to provide a thorough description for a proper linkage to the energy poverty subject.

3.3.1 Natural Capital

Natural capital according to the UN (2008:49) refers to the earth's natural resources, land and the ecological systems that provide goods and services necessary for the economy, society and all living things. It can be embraced as comprising three principal categories: natural resource stocks, land and ecosystems. All are considered essential to the long-term sustainability of development for their provision of 'functions' to the economy, as well as to mankind outside the economy and other living beings (ibid:49).

Natural resources can be renewable, such as trees, water bodies and animals, which reproduce or non-renewable resources such as land, oil, gas and gold. The renewable resources differ by the rate at which they renew. For instance, coal renews very slowly compared to trees and sunlight.

3.3.2 Produced or Real capital

Produced or real capital comprise of assets or resources which exist after a production process. In other words, these are resources that have been made by man through manufacturing processes using machines. They can be tangible, such as machinery, buildings, roads, harbours and airports, or intangible, such as computer software, music, skill and goodwill. Products from production lines are also part of real capital.

Accountants and book-keepers record the value of produced capital in the balance sheet accounts of the national accounts. It is a common assumption that observed market prices for produced and financial capital are fair reflections of their wellbeing effects. In other words, market prices come close to the theoretical ideal of accounting prices for produced and financial capital. In practice, however, the reported numbers are not always certain (UN, 2008:54).

3.3.3 Financial capital

Financial capital is defined formally to include any asset for which a counterpart liability exists somewhere on the part of another institutional unit. These include currency and other forms of bank deposits, stocks and bonds, derivatives, accounts receivable, pension funds and insurance reserves. The value of financial capital is recorded in the balance sheet accounts of the national accounts (Bodie *et al.*, 2004:7). Finances are important especially when they are used as (a) a store of value and (b) medium of exchange for goods and services. The transfer of value from one owner to another is well documented given proper pricing through a money metric channel. Availability of money is crucial for people to exchange with modern energy facilities.

3.3.4 Human capital

Human capital can be used as the state of health, education and capacity that have the potential to raise personal productivity if increased (Todaro & Smith, 2006:369). This perspective places more weight on the production side of the economy and an individual. Others define it as the knowledge, skills, competencies and attributes embodied in individuals that facilitate the creation of personal, social and economic wellbeing (OECD, 2001:18), thus placing more weight on the wellbeing aspect. What is common in both definitions is that human capital is about capacity and capability of the person to perform a particular task. Investments in education and health programmes are crucial to the development of human capital (Dunga, 2012:56). Education equips people with the necessary technical and managerial skills. Health programmes enhance the developed skills and affords people to work more effectively and for longer.

The economic importance of knowledge and skills is widely recognised, both within labour economics, growth theory and business economics. At the same time, many see the personal and social wellbeing effects of learning as being as important as the economic ones. Human capital development does not accord wellbeing to the community alone, but also the individual. This is why on-the-job training, advanced academic training and R&D are encouraged in the workplace. Todaro and Smith (2006:369) clearly show that individuals can estimate returns to education as an investment based on future expected pay-offs. Using net present value, the decision on whether to invest in a particular skill development and gap filling programme is made by an economic agent.

It is a well-supported thesis that better-educated people are more likely to be at work, and if economically active, are less likely to be unemployed. The UN (2008:60) indicate that an additional year of schooling is associated with, on average, between 5 and 15 per cent higher earnings, though the variations among countries may be quite high. Similarly, data from the International Adult Literacy Survey (OECD, 2000:61) show that education, literacy, experience, parent's education and the use of mother tongue account for between 20 to 50 percent of the total variations in the labour market

earnings. However, the author is not aware of a study that links the level of education and human capital to the adoption of modern energy resources. Further, sustainable development efforts are a waste of resources if it runs out that modern energy is linked to the level of human capital in the community.

3.3.5 Social Capital

Social capital comprises of the norms, morals and cultural values which a community upholds as important (UN 2008:7-11). This capital is important for sustainable development efforts as it is the channel through which the dos and don'ts of any society are internalised from one generation to the next. The values of the society are established and safeguarded via institutions that exist to regulate behaviour. The consumption of particular energy resources might be a cultural phenomenon, which sometimes works against sustainable development interventions. The mindset of people might have to be changed if SD is to be an achievable goal.

Observation suggests that the use of LPG in other cultures such as Malawi is considered dangerous and the society sends such messages through the process of social internalisation. Other resources of energy, such as solar, wind and electricity are considered for the rich and, therefore, those who have the perception that they are poor are less likely to use.

In conclusion, changes of financial, produced, natural, human, and social capital stocks and resultant products determine whether the capital base of a country is increasing or declining over time. Development, therefore, is seen as the trade-off between or among the types of capital stocks and sustainability would imply availability of the wealth not only in a different form but also usable without running down the total.

The substitutability of the various capital stocks has wellbeing effects in that some of the stocks might not be usable as desired. For example, cutting down a tree for timber to be used on building a house might be challengeable as to whether future generations will be left better off even if the value of the capital stock is the same or even higher. Property is valuable but trees are also good in providing a cleaner environment.

Substitutability of usefulness determines the wellbeing of future generations and it is an important element of the links between energy resources available and sustainable development.

Access to modern energy, therefore, is an important element in sustainable development. It is the consumption and use of some of the capital stocks for energy purposes that might change the value of wealth thereby creating sustainability challenges. As Dincer (2000:171) argues, a secure supply of energy resources is important for economic growth and development. However, the energy resources so supplied need be renewable and accessed at a lower cost with abilities to achieve most of the common purposes at both household and industry level for the achievement of sustainable development.

From the forementioned, it is clear that energy is an integral part of national wealth. Achieving the MDGs is a function of harnessing the national wealth in a manner that utilises the best energy facilities following means that sustain the path of economic growth no matter how defined. Further, there is a need for sustainable energy resources to be supplied to all economic agents in order to hope for a meaningful development that trickles down to the masses. The next section provides the important linkage between sustainable development paths especially as it relates to the supply of affordable clean energy resources.

By taking the perspective of capital, the challenge of sustainable development is simplified into a question of whether a country's total capital base, or total national wealth, is managed in a way that secures its maintenance over time. Thus, simplified, the focus of the sustainable development challenge is sharpened and put into concrete terms. The question whether financial, produced, natural, human and social capital stocks per capita are increasing or declining over time is one that lends itself to a precise answer. Furthermore, this focus helps make sense of the inevitable trade-offs that must be weighed as development proceeds. For example, if one capital stock, such as petroleum wealth, declines, the framework allows us to ask whether it is being offset by growth of another stock, such as human capital.

3.4 LIMITATIONS ON THE THEORETICAL CAPITAL APPROACH

To reach its full potential, the capital approach requires measurement of all capital stocks using a common unit. The only obvious choice of unit, money, is problematic for two reasons (UN, 2008).

Firstly, it is difficult to uniquely determine all of the ways in which capital contributes to well-being. Those that cannot be identified obviously cannot be valued. Secondly, even for those contributions we can identify, it is sometimes difficult to translate their value into dollars. This is partly because functioning markets rarely achieve the ideal conditions economists impose upon them in their valuation methods and partly because the methods themselves remain underdeveloped in some cases.

There is in addition to the debate over the economics of valuation a debate over its ethical underpinnings. Certain observers place a question mark after the right of humans to exploit nature in a destructive manner, even if this, at least in the short run, may increase total national wealth. Clearly, aggregating nature along with other forms of wealth as though humans are indifferent to its existence so long as their wellbeing is assured is at ethical odds with this view.

A third limitation on valuation is the degree of substitutability among capital types. It is generally accepted that the various components of national wealth cannot always and without difficulty be replaced with each other. It is not so, for instance, that ecosystem services, which may be considered as one of the dividends of natural capital, can easily and always be replaced by increased income, the dividend of financial, produced or human capital. Capital services, for which no substitute can be found, are said to flow from critical capital stocks. To the extent that some capital stocks are indeed critical, the possibility of using a single monetary aggregate to measure sustainable development disappears. It would be wrong to aggregate values for non-critical capital with those for critical capital into a single measure. In doing so, essential information for sustainable development would be lost.

3.5 THE SYSTEMS APPROACH TO SUSTAINABLE DEVELOPMENT

The limitations of the theoretical approach to SD suggest that a practical implementation of the capital framework cannot rest on monetary indicators alone. Certainly, monetary indicators are desirable and should form part of any set of sustainable development indicators based on capital. Additionally, the approach requires separate indicators of critical capital stocks measured in physical units.

The systems approach of national wealth/capital to SD is essentially a way of looking at SD as a combination of improvements or indeed as the definition suggests maintained capital of the economy as a whole. Another approach considers the society or community as a set of systems which must coexist in a symbiotic way. Suggested by Bossel (1999:39), the systems approach to sustainable development envisages an economy as composed of the social, financial, environmental and productive subsystems which depend on each other for survival in an ecological fashion.

The main departure of this approach from the capital methodology is that here there are more indicators ranging from coexistence, freedom of choice, freedom of action, sustained security level, psychological needs and adaptability of the system to new environments among many units. Questions regarding the state of each one of the subsystems are asked and the answers provide policy and decision makers to gauge whether sustainable development is being achieved in a particular economy. Further, this approach does not simplify SD by reducing it to only five subsystems of wealth, which largely depends on composite measures such as GDP or the Human Development Index. These indices tend to overlook certain important aspects of life deemed of lesser value yet important in their own right. For example, the value of sports, insecurity and adaptability of the new system are not captured by the capital approach (Ibid: 39).

Nonetheless, the efforts of both approaches are similar with differences in depth only. One of the major criticisms of the capital approach, for example, is that it is very difficult for all the types of capital to be valued for a standardised comparison between periods.

Valuation of social capital for instance can be both subjective and meaningless in many ways. But the same valuation problems are also likely to be faced by the systems approach. However, the fragmentation of the systems approach implies that certain aspects can still be used to proxy for sustainable development indicators.

In this thesis, the adoption of renewable, cleaner and efficient energy at the household will be used as a measure of sustainable development. If more than 50 percent of the households will be found to be using cleaner and greener energy resources such as solar, wind, and electricity, in South Lunzu Township, then it will be concluded that there are strides towards sustainability. However, if less than 50 percent are found to be using cleaner energy resources then sustainability would not be achieved.

3.6 MDGS-ENERGY POVERTY-SUSTAINABLE DEVELOPMENT NEXUS

At the United Nations Millennium Summit in September 2000, world leaders of 189 nations placed development at the heart of the global agenda by adopting the Millennium Declaration from which the eight Millennium Development Goals (MDGs) were later extracted (UNDP, 2000:10; Modi *et al.*, 2006:7). The MDGs are eight targeted development aims designed to free humanity from extreme poverty, hunger, illiteracy and disease by the year 2015. The following is the list of the goals:

- 1) Eradicate extreme poverty and hunger;
- 2) Achieve universal primary education;
- 3) Promote gender equality and empower women;
- 4) Reduce child mortality;
- 5) Improve maternal health;
- 6) Combat HIV and AIDS, malaria and other diseases;
- 7) Ensure environmental sustainability; and

8) Develop a global partnership for development.

Each one of the goals has specific targets which spell out indicators for change towards the attainment of the MDGs. For example, goal number 7, which aims to ensure environmental sustainability, has three targeted areas, namely:

- Integrate the principles of sustainable development into country policies and programmes and reverse the loss of environmental resources;
- By 2015, reduce by half the proportion of people without access to safe drinking water; and
- By 2020 achieve significant improvement in the lives of at least 100 million slum dwellers (UNDP, 2000:10).

However, as can be observed from the list above, energy poverty is not addressed as a separate problem needing urgent and specific solutions. The targets of goal number seven contain some elements of energy consumption. However, the main goal is to provide for consumption of the present stock of natural resources without making future generations worse off, thus emphasising holistic sustainable development but not specifically addressing problems of access. There is no mention of energy access as an important goal for improvement of welfare. Excluding universal access to modern energy which is both clean and efficient renders all efforts of striving for sustainable development itself desecrate. Most of the environmental damage in the world is caused by burning of fuels, prevalently inefficient and dirty ones as energy resources are used up (Matriot, 2001:690; Chineke & Ezike, 2010:683; Karekezi & Kithyoma, 2003:8).

Recently, the Millennium Project has realised the importance of accessible modern energy to the achievement of all the MDGs. Most of the countries which signed the Millennium Declaration in the year 2000 are poor and energy poverty is more pronounced in such areas. There are linkages through which adequacy, in both quality and quantity of energy services, can lead to a quicker and satisfying attainment of the targets of the MDGs (Girdis & Hosteke 2005:12). The following subsection considers

the linkages through which a universal or wide access to cleaner and modern energy services can have on the MDGs through the targets.

3.6.1 MDG Target 1: Growth and Income Poverty Reduction

Modern energy services help drive economic growth by improving productivity and enabling local income generation through improved agricultural development and non-farm employment. Modern energy must be made available to all income groups, the poor and the rich alike, to improve not only economic but also social inequality (ESMAP 2000:25, ESMAP 2004b:24). Energy, when used productively, is particularly important to economic growth. Modern fuels and electricity, for example, help boost household income by providing lighting that extends livelihood activities beyond daylight hours (Modi *et al.*, 2006:17). Modern energy services power machines that save time and increase output and added value. By providing additional opportunities for employment, energy services also enable farmers to diversify their income sources, and thus mitigate the inherent risks associated with agriculture-dependent livelihoods. Energy is important in supporting productive activities in both formal and informal sectors. Clearly, the growth and development of any country is not possible without cleaner energy facilities.

Traditional energy facilities are expensive and as a result the poor who are the users of such services are drawn deeper into the poverty trap while the gap between them and the rich widens (ESAP 2003:10). The rich use more efficient and cleaner energy facilities which are cheaper and do not waste energy. Therefore, modern energy services contribute to economic growth by reducing unit costs (ESAP 2003:10). In general, commonly used resources such as batteries, candles, kerosene, firewood, and charcoal, are inefficient, they lose considerably high amounts of usable energy as they burn causing the users who are poor people to often pay higher unit costs for energy than do the rich. It follows therefore that the use of more efficient energy resources can trim down the larger percentage of household income spent on cooking, lighting, and keeping warm, thereby saving families much needed income for food, education, health services, and other basic needs (Modi *et al.*, 2006:19; Wilkins, 2002:24).

Further and in general, energy consumption is highly correlated with higher GDP per capita. Countries with higher GDP per capita are associated with higher levels of energy consumption (World Bank, 2009:9; Girdis & Hostetke, 2005:12). Depending on their level of development, industrialisation and economic activity in general, countries exhibit different energy consumption levels. By taking commercial energy consumption to proxy for total energy consumption in a number of LDCs, middle income and developed countries, the United Nations Development Programme (UNDP) shows that countries in the sub-Saharan Africa such as Kenya, Ethiopia, Chad, Senegal and Uganda, where the percentage of people living below US \$1 per day is higher and the GDP per capita is very low, energy consumption is also in lower levels. This compared to countries such as United States of America (USA), South Korea and China which are developed economies, the energy consumption is high (UNDP, 2000).

The macroeconomic environment of LDCs can improve if renewable energy resources are adopted. Increased use of renewable energy in combination with energy efficiency can help reduce both dependence on fossil fuels and imports, contributing to a more stable macroeconomic environment through foreign exchange savings (Wilkins, 2002:27). New projects for development, installation and management of RE facilities have the potential of creating new jobs thereby contributing to poverty alleviation in the community. This has potentials of developing other sectors within the vicinity of the project with even more employment possibilities.

At the household level the role of modern energy resources in directly contributing to economic growth and poverty reduction cannot be overemphasised. They create opportunities for income generation, and enable increased income from agriculture or animal husbandry by permitting water pumping for supplementary irrigation, which lessens the risks associated with rain fed agricultural systems and enables increasing crop and pasture productivity as well as switching to higher-value crops (World Bank 2009:9).

There are many ways in which modern energy can indirectly contribute to economic growth. Some of the overt linkages may come:

...in the form of freeing up time for other productive activities, improved health and education, improved access supply of clean drinking water, and reduced local environmental degradation. At the village, town, city and national scale, lack of reliable and affordable electricity supply [and other forms of modern energy] can also become an impediment to income-generating industrial, commercial, and service activities (Modi et al 2006: 21).

The current energy infrastructure in most African countries is not sufficient enough to assist in the creation of export processing zones, special facilities that are aimed at fostering the export sector by providing necessary resources such as machinery, warehousing, custom clearing, banking, legal, and telecommunication within the same vicinity (Ibid). These require huge investments in many aspects, such as energy supply, that is reliable and efficient at the same time. They are good initiatives which should provide employment. The linkages associated with such initiatives include a growing, dynamic and more flexible financial sector, revamped entertainment industry, and many other secondary industries which would lead to more employment. It follows therefore that without modern energy, economic growth is almost impossible.

Modern energy also improves productivity of human capital which is clearly evident in the developed world. For example, electricity can allow people to operate personal computers and file servers, and use telephones and the Internet, which can, in turn, lead to a large increase in the productivity of human labour. Tasks can be completed faster than imagined. A single trained professional can provide services to a much larger number of people with improved transport and ICT. Mechanical power or electricity that can then be used for mechanical power can also provide opportunities for businesses such as agro-processing, carpentry, welding and businesses that rely on refrigeration.

Further, the productivity of small and medium-scale enterprises (SMEs) that are the main source of jobs for the poor can be improved when reliable energy services are available. In many poor countries, microenterprises play a vital role in poverty reduction

and improvement of livelihoods through provision of employment to many people under the unskilled labour bracket. These also reduce migration of people to cities thereby reducing the speed of urbanisation. Rural electrification projects under a World Bank's Energy Sector Management Assistance Programme (ESMAP) were aimed at bringing modern electricity to the rural areas to create more towns near the people. Many people, when their incomes improve, migrate to areas with modern energy (ESMAP 1989:2, ESMAP 2002:4) facilities, such as electricity, for a better life. Taking the commodity to them is one way of improving the infrastructure facilities of the areas and keeping the money within the community. Electricity, by providing lighting that extends the workday and powering machines that increase output, raises the productivity of small household businesses and shops.

3.6.2 Eradicate Extreme Poverty and Hunger: Hunger (MDG Target 2)

Poor countries are faced with persistent food insecurity due to a number of reasons. Food secure countries have to solve another problem of providing fuel to cook the food. There are two problems there. As shown by the WHO, the nutrition value of people in poor countries comes from mainly cereals almost 95 percent of which has to be cooked before it is eaten. Most cooked food also requires water, which must be pumped and transported (ESAP, 2005:15). It is overt, therefore, that without heating energy in households, food may have to be consumed in its raw form, which might be a source of many sicknesses as cooking kills germs apart from making the food appetising.

Further, growing food crops also requires energy inputs for planting, irrigation, harvesting, and post-harvest processing. In most cultural practices, the primary responsibility of major cooking for household meals is given to women based on the social division of labour. The availability and use of both traditional and modern cooking fuels therefore have important linkages to hunger and hence the MDGs. For instance, the amount of energy required for cooking needs is commonly estimated at 1 gigajoule (GJ) 'into the pot' per capita per year per household, which can rise as high as 10 GJ per capita per year if inefficiency of cooking methods such as biomass burning over a three-stone fire is accounted for.

The poor in urban areas are vulnerable to changes in the supply and demand levels of energy resources which affect their prices. Among many major avenues of expenditure, obtaining cooking fuels takes up a large share of urban poor's earnings. Rising costs of imported fuels, firewood or charcoal can lead to a higher incidence of hunger since such increases prevent the poor from cooking and processing their food. The poorest families typically dedicate 80 percent of total household energy expenditure to fuels for cooking and heat, and only 20 percent for fuels and batteries to produce light (ESMAP 2002b, 9-12). This is because there is little choice whether or not to meet basic subsistence needs; they struggle for basic needs.

Rural area communities heavily rely on biomass fuels and farm waste which can be an important part of the energy supply. Many scientists, including the UN Millennium Project Task Force on Hunger, recommend replenishing soil fertility while incurring the lowest possible cost through practices that may otherwise use the biomass for cooking and heating (UN Millennium Project 2005b). Farm waste is burnt for heating, cooking and lighting instead of being applied to farms and gardens.

Apart from being a health hazard, use of modern fuels or improved stoves can allow a greater proportion of farm waste to be returned to the soil. Organic manure from animal waste is good natural fertiliser for crops. Considerably large amounts of foreign exchange required to purchase fertiliser from abroad could be saved by just following this process alone. In Malawi for example, 40percent of total foreign exchange earnings are used to import fertiliser every year (GOM 2010: 9).

Modern cooking fuels can also indirectly increase farm productivity by freeing up women's time and effort, particularly by reducing the work required for biomass collection, which is detrimental to the health of childbearing women (Khatami-Njenga, 2001, Mabona, 2001).

3.6.3 Eradicate Extreme Poverty and Hunger: Education (MDG Target 3)

Education is one of the key elements and vehicles through which poverty can be eradicated. An educated person easily plans for the future and has a greater likelihood

of being employed in a high earning job. Further, educated people's aspirations are in tandem with civilisation where processed goods are sold on the market. Education as an investment needs time for studying and class attendance. Access to clean cooking fuels frees time for education, time that would otherwise be spent by women and children collecting traditional fuels or in other menial work (Khatami-Njenga, 2001). Lack of electricity service is a disincentive for teachers, doctors and nurses to reside in rural areas and prevents children from studying at home.

In addition to the role of cooking, females also have a responsibility of collecting firewood and other farm residues for cooking while men bring the food home. Girls might spend time in forests, farms and mountains collecting firewood during class time (Mabona, 2001:5, Khatami-Njenga, 2001). For this particular group of school going girls, improved access to modern energy services can free time for going to school and for after-school study, apart from reducing the risk of unforeseeable attacks by wild animals and rape. Energy scarcity creates time pressure on children to collect fuel, to fetch water and to participate in agricultural work, and contributes to low school enrolment.

Educating the female child calls for a carefully planned constraint breaking mechanism to be brought up. In many ways, there is over dependence on female child labour for most household chores, which render her tired and unable to concentrate in class and home study. As shown by Schultz (1990), girls are constrained in their schooling, in part by the demands placed on their time. The use of modern energy resources, such as electricity might induce other advanced home appliances such as refrigeration could reduce households' dependence on the labour of girls.

Modern energy is not important for the female child and her mother only, but also boys and men in the same way. In addition, the ability to provide quality light thereby elongating study time without causing any health hazards is paramount. Modern energy brings telecommunication facilities closer to the people such that access to information and educational materials improves.

The provision of modern energy to a household is not the only sufficient condition to educating the girl child and indeed all women. Other factors such as increased income in general, distance to an educational facility, availability of text books and study materials, cultural aspects and food security are also important. As Glick and Sahn (1999) argue, increased income is also important, since even when electricity access is available in urban areas domestic work obligations continue to limit female schooling for the very poor.

For quality education to be achieved, especially in the rural areas, special incentives for young teachers need to be put in place to encourage them to go and work in such places. One of the most often cited factors affecting teachers' retention in rural areas is the lack of access to modern energy services, in particular lighting and power that enable a minimum quality of life and connectivity. Modern living standards, at the minimum, suggest the availability of at least a television set, a radio, clean lighting facility, clean and safe drinking water, cell phone and internet connectivity, and refrigeration.

Further, energy and ICT in schools can also enable access to educational materials through internet search engines, television and newspaper articles enabling distance learning, and continuing education for teachers and their family members. Such ambitious and quality teachers should be provided with modern energy facilities to benefit not only themselves but also the entire community through their service provision. Therefore it is imperative that in poverty reduction interventions, access to modern, clean and affordable energy resources should be at the heart of it all.

3.6.4 Gender Equality (MDG Target 4)

There are many benefits associated with improved access to modern energy facilities in the socio-economic development path. In general, increasing access to energy brings benefits for women in health, education, and productive activities - since it is they who spend more time than men cooking and collecting water and fuel. Modern cooking fuels free women from the burden of collecting and carrying large loads of fuel-wood and

from exposure to smoke from primitive cooking stoves. In reproductive health, modern energy enables a careful family planning mechanism, based on education to be obtained through increased hours of study in the home (ESAP, 2005:15; ESAP 2003:10).

In Malawi, for example, rural electrification programme brought many trading centres along with it and civilisation and access to information by both men and women. Women became part of the decision making process through advocacy media programmes on television and radio, facilities which were not available in the locality prior to the electrification programme. In the Nsanje district, the prevalence of HIV/AIDS dropped significantly and women take charge to decisions of when to conceive and get another baby (Interview with District Health Officer, April 2011).

It is overtly observable that access to energy services affects men and women differently, and the specific energy services used by men and women differ based on the economic and social division of labour in the workplace and at home. In the developed world, for instance, it would be hard to imagine a family today spending one or more hours every day gathering biomass such as wood, agricultural residues, and dung, when they could, instead, buy cooking fuel for the same purpose at a price that reflects income from five or fewer minutes of work (Medo, 2006:25). In LDCs, on the other hand, this is the burden of women and girls both at the household and community level whenever social gatherings require the use of power.

This is an unfair treatment of equality of humanity, considering that abilities are the same regardless of gender. The disproportionate amount of daily time and effort women and young girls spend gathering solid fuels and water for household chores could be used for other income-producing activities, family subsistence, or education. The time spent gathering biomass varies with geographic location, land ownership, the time of the year, climatic events, and loss of control over local resources. Women spend more time collecting firewood, making more trips to the market and water holes, collecting biomass and animal dung compared to men.

The time spent collecting fuel-wood also reduces the proportion of daylight hours otherwise available for other profitable activities and self-development of families. These hours may be critical to other income generating activities such as commercial foods vending, which is facilitated by improved heating and lighting; agricultural processing using mechanical power; beer brewing, and many trading activities (Medo 2006:27). The costs of energy inputs into these businesses are high and the lack of more-affordable alternatives limits the income-generating opportunities faced by women.

3.6.5 Health (MDG Targets 5–8)

Poor health of a nation is a worry for any government and development practitioners. Good health is one of the most important factors leading to the eradication of poverty in less developed countries. It has been said before that a healthy nation is a wealthy nation through the productive stock of human capital, both as thinkers and workers. There are close linkages between the quality of health services and the availability of quality energy services. There is increasing evidence that the burning of solid biomass fuels for cooking in indoor environments, especially using traditional stoves in inadequately ventilated spaces, can lead to an increased disease burden. For example, the World Health Organisation (WHO) now estimates that the impact of indoor air pollution on morbidity and premature deaths of women and children is the number one public health issue in many developing countries, particularly for the poorest segments of the population (Medo *et al.*, 2009). The greatest risk for a higher diseases burden due to unclean energy resources is faced by women and girls who do most of the cooking in households.

3.6.6 Environmental Sustainability (MDG Target 9)

Environmental sustainability is desirable and energy is at the centre of its achievement. The linkages between environmental sustainability and energy are through the production, consumption, transportation, storage and disposal of energy resources. The way energy is produced, distributed, and consumed affects the local, regional, and global environment through land degradation, local air pollution, acidification of water

and soils, or greenhouse gas emissions. There is a greater likelihood of both air and land degradation if biomass use is unsustainable and excessive. Trees and other plants, which are a major source of biomass, use carbon dioxide for their growth and food processes while oxygen is released as a by-product of the process. Further, the roots of trees and plants hold the soil together and improve the compaction of land. The leaves reduce the force of rain drops and wind strength. All these control possible land degradation, which without forest cover, should have been common.

The exploration, refinement, transportation and distribution of fossil fuel have some unavoidable detrimental effects on the environment. The major component of fossil fuels is carbon and for them to function, they need to be burnt. The largest chunk of by-product is carbon dioxide, which forms the larger proportion of greenhouse gasses emitted. The strong linkages between the between the state of the environment and production and use of all energy forms are central to the climate change debate, particularly the long-term impact on, and risks for, developing countries, with the likelihood that the poorest populations are increasingly vulnerable.

New technologies are being discovered to improve the situation. Petrol is now mixed with bio-fuels, such as ethanol, to reduce the amount of carbon dioxide emitted by petrol driven machines. The transportation of oil is environmentally friendly if it is done through pipelines than trucks and trains. Solar power can be used to light households and run their appliances. As much as energy activities are a major cause of global warming, there are solutions, and environmental sustainability can be achieved.

In conclusion, it has been shown that universal access to modern energy resources is central to achieving the MDGs. Virtually all the eight goals hinge on the availability of energy both at the household and industrial level. Access to modern energy facilitates economic development by easing basic household tasks. It helps to increase industrial and household productivity leading to economic growth and lower unemployment levels. School attendance improves and study times increases with a healthier environment. Women are empowered to venture into small and medium entrepreneurial activities;

they have more time to study time even for night adult learning thereby improving their employability.

Foods get cooked in a cleaner environment and at a much faster rate. The incidence of diseases is lowered with improved hygiene emanating from running water pumped using the modern energy facility available. Health centres in rural areas operate longer than without power such that risks of maternal mortality are reduced. Pressures on the environment are reduced and less greenhouse gases are emitted, thereby, ensuring environmental sustainability. Lastly, but certainly not least, is that electricity powers information technology facilities. This improves the flow of information via modern telecommunication facilities such as cell phones, charged by modern energy facility, television, radio, and internet services.

In view of the discussion above, based on literature reviews, this thesis recommends a ninth (9th) MDG of universal access to modern energy to be embraced by all development conscious nations. The next chapter reviews some of the important schools of thought in economic growth and development and links them to energy poverty.

3.7 SUMMARY AND CONCLUSION

Sustainable Development is an important element of economic growth policies and it is a global agenda. There are two approaches to SD. One approach considers the economic development more than other sectors of the society that it is the use of the current stock of resources that meets the needs of the present generation without compromising the ability of future generations to meet their own needs. In this view, SD is more narrowly comprehended by concentrating only on sustaining the stock of resources necessary to support and maintain life, not just for the current, but also for future generations. A much broader approach views SD as human activity that nourishes and perpetuates the historical fulfilment of the whole community of life on earth

What is common in both approaches is that present generation's consumption of

resources should not be at the expense of future generations. SD should mean improved wellbeing for both the present and future generations. SD advances development that is not only happening and desired to happen in future, but also needed by the community.

SD should also be understood to be a process that aims at maintaining or increasing the national wealth. Current generations just like the future ones are expected to define their own development goals. What is important is that such goals must not be attained at the expense of availability of the national wealth for the future generations. It is important, however, to spell out that, although the eight Millennium Development Goals are a good indicator against which less developed countries can measure themselves, so as to ascertain whether they are on the right path, a ninth MDG of universal access to modern, clean, sustainable and affordable energy for all must be included.

SD as embraced in MDGs targets is not achievable if governments do not address energy poverty at both the household and industry level. Apart from environmental sustainability the other MDGs, such as the eradication of poverty and hunger, gender equity, improved health and education services need modern, efficient and cleaner energy supplies. For example, households cannot eat uncooked food. Therefore, a food secure household is one that has enough energy to help with the final preparation. For non-commercial biomass, the provision of renewable and sustainable energy in households frees time for women to do other productive activities such as advancing in education and engaging in SMEs, thereby empowering them. This further improves their health status as they do not have to do heavy manual work by walking long distances in search of fuel wood.

Two approaches can be used to explain and find indicators for sustainable development. The first method envisages an economy as a set of capital segments namely financial, human, natural, productive and social capital which together forms the national wealth. One capital might change form to become one of the five, such that SD must be considered from a view point of the value of wealth of the nation. If wealth of a nation is depleting, then it means sustainable development targets are not being met.

The other approach, in essence, extends the capital method by considering the process of sustainable development as a set of maintained or improved subsystems, which coexist in a symbiotic manner. In this approach, the systems approach, small elements of the environment ranging from social to economic to environment are all considered at the same time and aggregate indices are avoided. Whilst in the capital approach, an aggregate index for sustainable development might be developed and observed over a period of time, the systems approach argues that sustainable development is not just about wealth being available, but also that which is needed by both the current and future generations. In which case, certain subsystems might become obsolete depending on the needs of the generations.

To achieve the MDGs and sustainable development in general, policies and strategies that will encourage the use of green energy, both at the household and industrial level, are important. Energy is important to eradicate poverty through improved education, health services, and employment. The linkages associated with many energy projects seem to suggest that there are more multiplier effect gains by engaging in green energy activities, especially for the less developed countries.

CHAPTER 4 ENERGY DEMAND AND CONSUMER CHOICE PROCESSES

4.1 INTRODUCTION

The theory of demand in microeconomics is probably one of the most studied from time immemorial. Other authors refer to demand analysis as price theory (Lipsey & Christal, 2010:10), while others refer to it as theory of the consumer. Consumer choice regarding commodities is premised on the assumption that people are rational social beings with well-ordered preferences. Given a set of consumer baskets, human beings prefer those with more goods to less. In theory, this is modelled as an objective function aimed at maximising utility (satisfaction) in the presence of constraints.

In theory, as suggested by Train (2003:20), the objective function is assumed to be a consumer basket containing goods and services, which brings a positive incremental utility at its consumption. The constraints are factors that would make it difficult, if not impossible, for the consumer to attain the highest desired utility. Then the consumer faces the problem of trying to maximise utility by going for the highest utility level. The budget line is the most probable constraint when consumers fail to attain the desired levels of utility.

In the energy sector, particularly in developing countries, the constraint stopping people from attaining the highest utility levels from consumption of clean energy goes beyond the budget constraint. Issues of availability and reliability are important in the decision set for energy consumers. As much as they may be poor by not having enough income to access the best energy resources, those who do have the income fail to do so because there are no alternatives to the traditional resources that they are dependent on.

This chapter reviews the theory of demand as it relates to the energy industry. The theory of utility maximisation is presented and the derived demand for energy resources

is explained. Other competition demand models are also examined, particularly the Quadratic Almost Ideal Demand System and the Multinomial Logit models.

4.2 DEMAND MODELS AND CONSUMER CHOICE THEORIES

This thesis used Engel functions to model the influence of income on demand for energy facilities at the household level.

4.3 THE ENERGY LADDER

This section reviews the theory of the energy ladder, which traces the energy choice behaviour of economic agents as their income and poverty levels improve. There is an enormous amount of literature, both theoretical and empirical views, suggesting that poor or no access to modern energy undermines people's productive undertakings or their efforts to raise their living standards without hassles (Barnes & Floor, 1996:500; IEA, 2007:5). IEA identifies two further obstacles to such efforts, namely the loss of time and money associated with reliance on traditional fuels. There is less time allocated for productive activities if firewood must be collected. In most African cultures the role of firewood collection is the responsibility of women and children, who must make sure that the household has enough wood for cooking, heating and, in some cases, curing tobacco and fish while men fend for food (Bugaje, 2004:609; Chineke & Ezike, 2010:683).

Other energy resources, however, are expensive, not only to acquire the initial investment but also operational costs. Costs associated with expensive energy sources imply lower expenditures on other necessities. In addition, there are negative impacts on human health from smoke produced by traditional biomass stove, on the environment from inefficient energy production, and in the form of inferior energy services, as in the case of light from kerosene not being sufficient for pupils' homework in the evening. On the whole, therefore, there is little welfare gain among the users of such sub-standard resources (Adkins *et al.*, 2010:1093; Zulu, 2010:3720).

Energy ladder theory suggests that the consumption of energy commodities can be modelled as the ascent of a “rural energy ladder” (Barnes & Floor, 1996:500). In general, such an ascent follows a movement away from the utilisation of traditional, dirty and depletable energy resources such as human, animal and bio-fuel power, to a mix of modern and cleaner energy resources. The transition from and/or to the inferior types of energy depend on a number of factors. For households, as income improves, the energy basket also changes from biomass to modern resources with superior properties such as electricity and gas. The agricultural and industrial sectors also move to superior energy resources as levels of development improve. This is ably supported by the energy ladder theory, reproduced below, which is an illustration that economic development and civilisation associate with the use of cleaner and more efficient sources of energy. Table 4.1 below provides a summary of the energy ladder.

The concept, as presented in Table 4.1, however, seems to suggest that income is the single most important factor that determines the transition through the levels of energy consumption. The studies cited above fail also to demarcate between inferior and superior types of energy. Generally, it is believed that those energy resources which are cleaner, efficient and effective at the same time are the most superior to those which are not. Choice of energy facility can be a function of many other factors such as age, education level of household bread winner, availability of the resource to the location and culture. Wüstenhagen *et al.*, (2006:2684) shows that social acceptance of any new technology, including renewable energy, is a constraint to their adoption not just income. This suggests that providing income to the energy poor community is not the only solution to the problem, there might be other factors to be seriously considered.

In response to the exposition of the concept, other empirical studies (Masera *et al.*, 2000; Jingchao & Kotani, 2010:8; Barnes & Floor, 1996:502) have shown that the energy ladder theory is objectionable, especially considering the model’s disregard of commonly observed multiple fuel uses and the persevering adherence to established, traditional techniques even in the face of modern alternatives.

Table 4.1 Summary of the Energy Ladder Transition

Income Stage	Low	Medium	High
<u>Households</u>			
Cooking	Wood, Residues, and Dung	Wood, charcoal, residues, dung, kerosene and biogas	wood, charcoal, biogas, LPG, Electricity and coal
Lighting	Candles and kerosene or none	Candles, kerosene, gasoline,	Candles, kerosene, electricity, batteries
Space Heating	Wood, Residues, and Dung (usually none)	Wood, Residues, and Dung	Wood, Residues, and coal
Other appliances	None	Electricity and storage cells (batteries)	Electricity, storage cells, solar panels and generators
<u>Agriculture</u>			
Tilling	Hand	Animal	Animal, gasoline and diesel (tractors and small tillers)
Irrigation	Hand	Animal	Diesel and electricity
Postharvest processing	Hand	Animal	Diesel and electricity
<u>Industry</u>			
Milling and mechanical	Hand	Hand and Animal	Hand, animal, diesel and electricity
Process Heat	Wood and residues	Coal, charcoal, wood and residues	Coal, charcoal, kerosene, wood and residues

Source: Barnes and Floor (1996:502).

In the 21st century, there has been a realisation that households in urban areas tend to use multiple energy resources for different purposes (Jingchao & Kotani, 2010:8). This is called fuel stacking, a situation where a household adopts many types of energy resources depending on the situation and other reasons. Apart from poverty, fuel stacking is also regarded as a hedging mechanism against possible failures in the supply chain of other cleaner fuel types especially in richer households. As alluded to before, there is unreliability of electricity in Malawi and indeed most developing countries.

The supply of liquid fuels such as petrol and diesel depends on availability of foreign currency which is usually scarce. Households in transition tend to use electricity for simple and inexpensive functions, which do not require high amounts of voltage such as lighting, refrigeration, radio, and television. Activities that are perceived to consume more electricity, such as cooking, water heating and ironing of clothes, are done using less efficient and relatively dirty energy resources such as fuel-wood and charcoal (Barnes & Floor, 1996:502).

There is also energy resource switching among households in poor countries. However, previous research shows that for such switching to take place, one of the most important determinants is the availability of other cleaner, and therefore superior, fuels (Mekonnen & Köhlin, 2008:2). This confirms that, although income might be available to economic agents, there is need for other energy facilities deemed superior to be readily available for any switching to take place. The energy ladder hypothesis, therefore, may not apply in communities where choices are not a function of earnings but rather the energy basket on the market.

The approach nonetheless serves to explain two dominant problems in the energy sector of LDCs. Firstly, there is widespread production and use of traditional energy sources, which pose economic, environmental and health problems. In developing countries most people are poor, meaning that the majority of the population cannot access modern energy resources. people still depend on the traditional non-renewable resources. Secondly, the access to modern energy sources, such as electricity, petroleum or gas products, is disproportionately strewn. Rural areas sometimes use firewood because they are too far away from the grid and/or their means of getting money is through the sale of yearly subsistence agriculture products. Cleaner energy facilities, therefore, are deemed more of a luxury than a necessity, thereby rendering global efforts such as the Kyoto Protocol of no value.

It is, therefore, imperative that energy projects for developing countries find strategies that would have two specific objectives; first, to make the production and use of

traditional fuels more sustainable and, secondly, to enhance the social transition to clean, modern fuels.

In order to achieve a positive social and economic transition, Barnes and Floor (1996) stress the roles of demand and local participation as driving forces. The authors accordingly attribute considerable importance to the creation of enabling conditions for income growth, the reduction of costs and increased access to modern fuels, while prices should in general reflect true scarcities rather than being subsidised. This, in real African settings, is not achievable. What is forgotten is that the rural masses do not value emissions as a problem that is affecting them, probably due to lack of knowledge. Generally there is no interest because, even if they are to be made available, high prices will not attract any of them to even think about such resources (supply is especially important in pricing of commodities in rural Africa, as compared to demand).

There are two features of successful energy interventions to note. Firstly, incentives for the development of agriculture and related industries should be present. Secondly, modern energy provision should relate to social and economic infrastructures, such as water supply, health interventions, education, and road works, which make energy provision more meaningful. In this view, energy provision is not a substitute for other development programmes but a contributing factor in development (IEE, 2007). The successful delivery of energy services is thus strongly related to the knowledge and understanding of local needs. If a rural leader is convinced that respiratory infections will be eliminated if people adopt cleaner energy, that there will be more water pumped and supplied to his/her people, and that health services at the local clinic or health centre will improve, then value will have been created. Research, including the current one, must understand that rural people do not require modern energy for cooking, watching television, or for communication purposes but rather for the basic social amenities such as agriculture, water, and health facilities.

The other uses of energy are secondary and more of a luxury. Consequently, energy's impact to development should be assessed in the capacity of a contributing factor. The implied yardstick of such assessment is the extent to which interventions contribute to

meeting local needs (ibid). Any new project that introduces advanced technologies, therefore, is likely to be positively welcomed if the facility changes the way of life in the provision of health, education and portable water. A lights only project cannot excite community leaders to fully embrace the project.

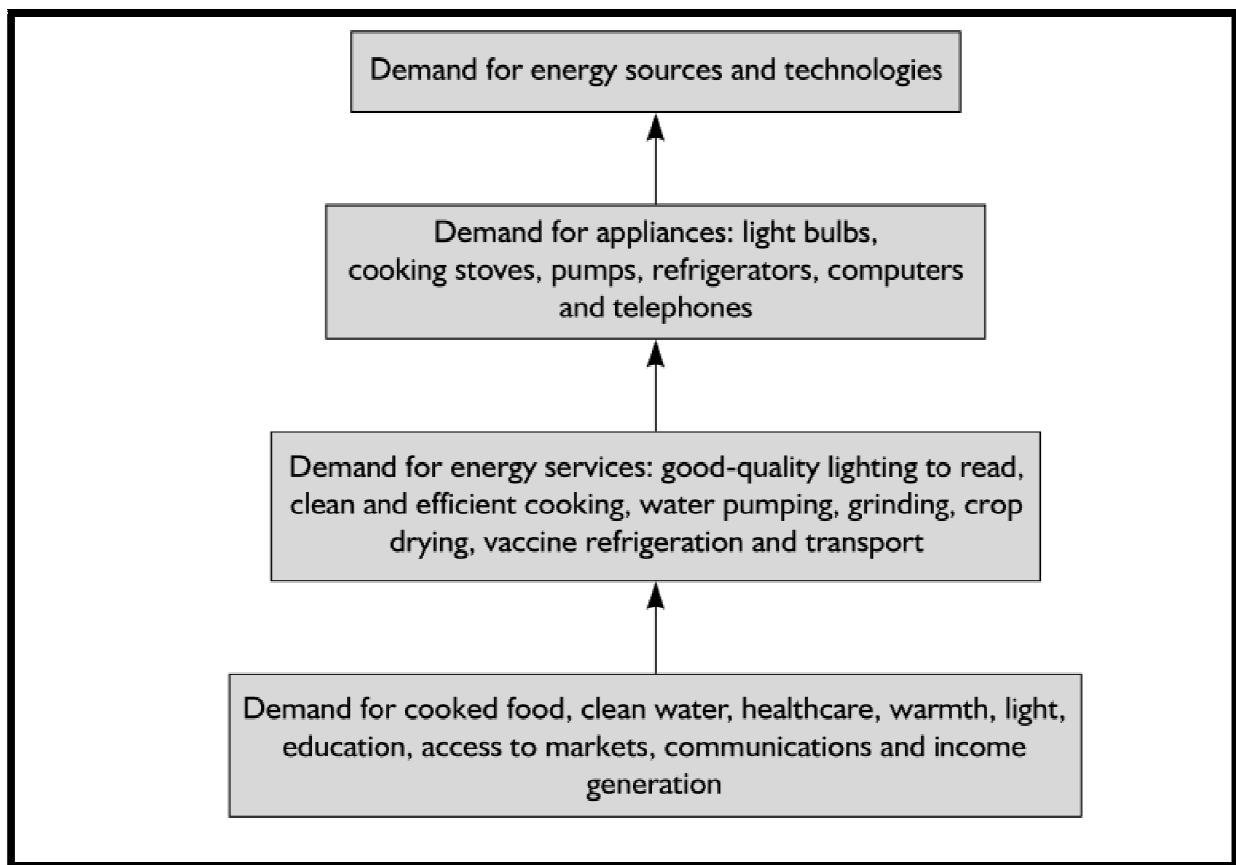
4.4 A REVIEW OF ECONOMICS OF ENERGY

Due to the important role that energy plays in any economy, particularly in driving most factors of production necessary for industrialisation of developing countries, a separate field in the social sciences was born as economics of energy or energy economics. Economics of energy is an important field that studies human utilisation of energy resources and commodities and the consequences thereof (Sweeney, 2000:3, Mills & Toke, 1985:3).

Economics studies the whole system of demand and supply of all commodities in different market structures. Energy is an essential commodity. Energy, however, is not demanded and supplied in its usable form, but rather energy sources that are traded on the market, (Mills & Toke, 1985:3; Sweeney, 2000:2) implying that energy is a derived commodity. For one to be sure that they have enough energy they must have resources that provide energy when ignited in different forms such as firewood, coal, sun, batteries and wind.

As Figure 4.1 shows, the desired commodity is not the energy resource per se but rather the service which the resource can provide, such as cooking food, room heating and lighting. There is demand for cooked food, clean water, warmth during winter, light and telecommunication services. These induce demand for energy to power the required appliances needed to satisfy the demand. At the end of it all, energy resources such as electricity, batteries, generators, firewood and petroleum are demanded (Wilkins, 2002:17).

Figure 4. 1 Model of derived demand for energy



Source: Wilkins (2002:17).

The behaviour of economic agents, as they try to maximise objective functions around energy as a commodity, is the focus of the subject matter of energy economics. Just like other fields of economics, such as health, agriculture, labour, industrial and finance; energy economics is receiving increased attention as civilisation increases its demand for this commodity. Nations are fighting for energy security and gathering resources together in artificial storage facilities to provide for future crisis. In other words, as Sweeney (2000:10) argues, energy is an essential commodity because without it human activity would be impossible.

Energy economics is a subject that can be tackled from both micro and macro perspectives. As a microeconomic phenomenon, the behaviour of economic agents in

deciding how to maximise utility from energy resources can be analysed using the fundamental microeconomic methods of having an objective function, such as a welfare or utility statement, which a consumer wishes to maximise (Jaccard & Dennis, 2006:96). On the other hand, macroeconomic approaches would analyse the fiscal, monetary and trade policies on demand and/or supply of energy needs in the economy.

Fiscal policy is crucial in the energy sector, especially in the least developed countries, through the conduct of tax legislations. Access to energy is also a factor of the tax regime. The higher the tax on consumption of energy, the lower the expected demand. Also, suppliers of energy resources are affected by how much tax they will be expected to pay from their profits. In addition, deliberate policies that are aimed at encouraging citizens to import renewable and alternative energy resources, such as energy subsidies and other levies, are all fiscal in nature. Subsidies reduce the marked price on the market for the benefit of the consumer, although questions of the source of funding for the subsidies have been the major concern of donor agencies.

Trade policy is probably the most controversial area in the modern era because the wealth of nations is affected by the nature of the trade policy that it chooses to take. As of the year 2012, the discussions about freeing up trade in both goods and services is receiving a tremendous resistance, especially from LDCs who reject an instant implementation of such a policy due to its envisaged effects of reducing revenue and stifling domestic industry.

The World Trade Organisation (WTO) was created to oversee all matters relating to the implementation of free trade agreements and policies among its member states. The package of free trade includes clauses in the General Agreement on Trade and Tariffs such as the Rule of Origin, Sanitary and Phytosanitary measures (SPS), and greater opening up to trade by reducing all import taxes to less than 5 percent by the year 2015 (WTO, 2004). These issues have an effect on the supply of new technologies for energy resources. LDCs have a limited capacity to produce goods such as solar panels, mini hydroelectric generators, petroleum propelled generators, and small windmills, to generate electricity at the community level. However, allowing imports of such

commodities at less than 5 percent import tax rates would reduce the capacity of government to raise enough revenue for the provision of public commodities and necessities, such as roads and medicines in hospitals. While the import taxes are raised, the same poor people whom government is saving, suffers by failing to access modern energy. It follows, therefore, that those trade policies that offer satisfaction to revenue authorities while not making the poor worse-off, should be identified and adopted.

In addition, the liberalised global economy has introduced potential benefits, especially in the sector of energy, for both households and industry. Goods and services, which under protectionist policies could not be accessed by many African countries, are now available in markets. The trading of carbon on the financial market has caused many industries to be cautious with the kind of energy solutions they wish to apply to production lines so as to avoid losing money as a way of punishment for polluting communities.

The regime of the exchange rate can also have an influence on the access and supply of modern energy resources in LDCs. Where the foreign exchange rate is fixed, the left wing economists would argue that the local currency becomes overvalued, making exports expensive. Imports become extremely difficult to access as the foreign currency becomes a scarce commodity due to under-pricing, leading to vendors withholding foreign currency in anticipation of a possible devaluation. As a result, new and advanced energy technologies may not be accessed by the population.

Monetary policy has an indirect influence on the access to energy by the poor, and its supply by firms. Monetary policy targets the level of money supply to influence the demand for commodities in an economy. The tools used are interest rates, open market operations (OMO) and liquidity reserve ratio (LRR). This would affect the supply of modern energy resources from the world market through the supply chain of investment funds. If there is no money in banks available to be loaned out to investors, then the supply side will be affected and, therefore, also access on the demand side.

For consumption, deliberate moves that support borrowing to purchase equipment for alternative energy resources must be devised and implemented to facilitate ownership. Apart from difficulties in accessing modern energy resources, poor people in most LDCs also face stiff challenges to access credit from financial institutions. Legislation is not flexible enough to let even those in formal employment obtain small loans for personal consumption.

Industrial policy is also of paramount importance in the area of energy economics. For example, the adoption of alternative fuels to run motor vehicles depends on the availability of the automobiles that have fuel systems compatible with the new energy resources, such as ethanol. It is a misplaced effort to have expensive and vocal promotions that encourage people to use ethanol when the market does not have the mechanics to do so.

Other factors that have necessitated a separate field of energy economics to be developed include soaring energy prices and the geopolitical turmoil of recent years. These factors have reminded experts of the essential role affordable energy plays in economic growth and human development, as well as the vulnerability of the global energy system to supply disruptions (Birol, 2007:2). Just like the aftermath of the 1970s oil shocks, Birol (2007:2) further argues that:

Safeguarding energy supplies is once again at the top of the international policy agenda. The threat to the world's energy security is real and growing. Analysis we have carried out at the International Energy Agency (IEA) shows that, in the absence of new government action, the consumption of oil and gas will continue to rise inexorably through to 2030, pushing up the need for imports and accentuating the consuming countries' vulnerability to severe supply disruptions and resulting price shocks. Much of the additional imports will have to come from the Middle East, along vulnerable maritime routes. In addition, the concentration of oil and gas production in a small group of countries with large reserves – notably Middle East producers and Russia – will

increase their market dominance and their ability to control the level of prices in the longer term.

This is a lucid indication that a separate field is required to solve the horrendous problems the world is facing in a more careful way. In addition, there seems to be mounting appetite for demand of oil and electricity, regardless of the ever rising prices on the world market. It is an obvious fact that, with every job created and an additional person born, the demand for electricity and oil also increases, thereby accelerating demand and further lowering supply.

The share of transport demand, which is price-inelastic relative to other energy services in global oil consumption, is expected to rise, making overall oil demand less and less responsive to movements in international crude oil prices (UNMP, 2005:20; Birol, 2007:3; IEA, 2006). The corollary is that prices would fluctuate more than in the past in response to future short-term shifts in demand and supply. The cushioning effect on the demand for subsidies to oil consumers, which remain big in many countries, contributes to the insensitivity of global oil demand to changes in international prices. Thus, by-and-by, price is becoming a less important determinant of energy products in the world.

Trends in energy supply since the turn of the 21st century also carry the threat of severe and irreversible environmental damage, including changes in global climate (IEA *et al.*, 2010:12; IEA, 2006; Birol, 2007:3). To the year 2030, emission of greenhouse gases is projected to rise by more than half mainly as a result of unchecked energy consumption. Of interest is that the bulk of the increase will come from developing countries, which were projected to overtake the OECD as the biggest emitters soon after 2010 (IEA *et al.*, 2010:12; Pegels, 2010:4945). There are two reasons for this. Firstly, developing countries are at the lower end of the development ladder. As shown by Rostow's growth theory, this is a takeoff point where economic growth is influenced by industrialisation through manufacturing (Todaro & Smith, 2006:300). This is unlike developed countries where economic activity is mainly in service industry such as information and communication technology.

Secondly, developing countries thrive and sustain life on energy resources that are, by their nature, heavy emitters of greenhouse gases (GHGs), such as coal for both industry and household. For those countries which have hydroelectric power, supply is intermittent, such that the use of generators that are propelled by oil is on the rise. This also increases the emission of GHGs. Further, transport systems which encourage the use of small passenger vehicles, are common in many African countries such as Tanzania, Malawi, Kenya and Zambia. Also, in these countries car ownership is a sign of prestige and wellbeing. Railways are poorly developed and unreliable. The dependence on oil, therefore, is expected to rise. Unfortunately, this is also at the household level where cleaner energy facilities are generally deemed expensive for cooking.

As the international community pushes for cleaner and renewable energy resources to reduce the overdependence on environmentally unfriendly resources, some authors are already predicting that the use of low or zero carbon energy sources will be widely adopted and the number of people depending on them is expected to rise rapidly (Manlove, 2009:2; IEA, 2010:21; ESMAP, 2006:11; World Bank, 2009:7). However, emissions will be driven higher by the inexorable growth in consumption of fossil energy, especially coal and oil. Coal is a slowly renewed mineral, yet many countries depend on it to generate electricity for both industrial and household use. Sustainable energy consumption, therefore, is compromised. It is, therefore, imperative that quick and practical interventions be implemented to stop African economic agents from satisfying their energy hunger with unclean energy.

Although energy is an integral component of all economic development endeavours in the world, its availability seem to have been given less attention at the multilateral institutions level. This is evident if scrutiny of the overarching development plan, as enshrined in the Millennium Development Goals, reveals that energy was either forgotten or overlooked. The Millennium Development Goals were developed in the year 2000 to put LDCs on a growth and development path that would reduce poverty by the year 2015. The next section examines the strong linkages that exist between the achievement of the MDGs and, just like IEA, UNDP and UNIDO (2010:15), this thesis

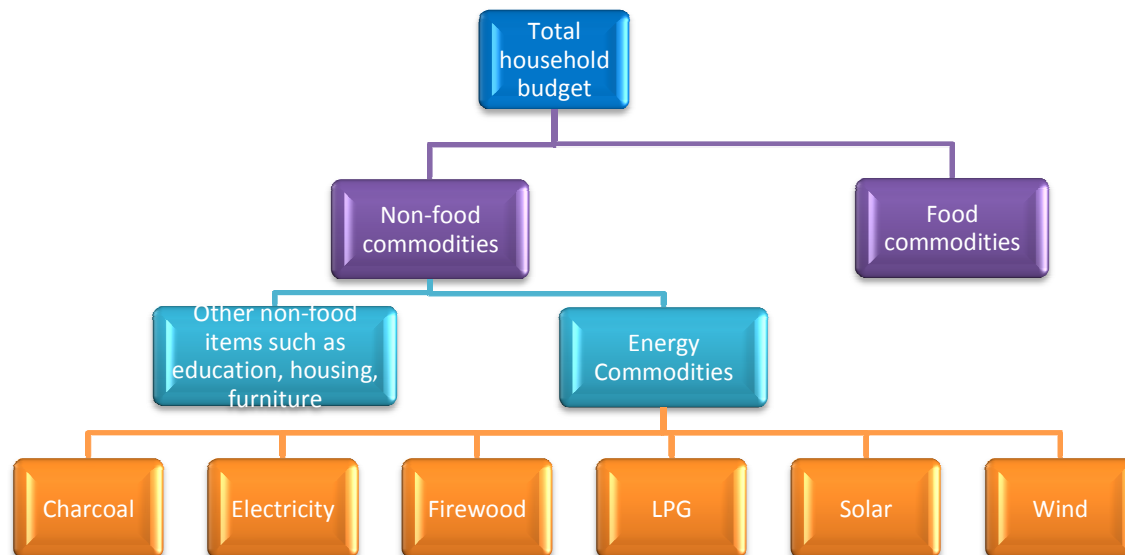
also argues that universal access to modern energy is an overarching MDG that is missing. The achievement of all the MDGs is not possible without a good level of access to modern energy by all. The access to modern, clean and safe energy resources by all people must be considered a universal and fundamental human right, which must not be compromised in any way. Just like hunger invites donations of different sorts, it is time energy poverty was accorded special attention, not just by the multilateral institutions but also governments worldwide.

4.5 ENGEL FUNCTIONS

To estimate demand elasticities, many studies in the past have adopted a complete demand system approach. This is where the quantity demanded of a particular type of commodity, typically dividing between food and non-food items are regarded as composite goods. These are called one-step approaches in the literature (Mustapha *et al.*, 2001:154, Radam *et al.*, 2005:30). However, following Yeong-Sheng *et al.* (2008:7), one of the best approaches in econometrically estimating commodity demand functions is to consider a two-step approach, which first of all divides the consumption decision between food and non-food commodities and then considers the specific commodity.

This thesis follows Rajmohan and Weerahewa (2007:61), where it was assumed that households first make their decision on the allocation of the total budget on composite commodities, broadly defined as food and non-food items. The non-food items are divided between energy and non-energy goods. The next step is to decide on which non-food items to allocate a share of their budget too. Among the energy commodities, a decision is also made regarding the total energy expenditure and how much to allocate on individual resources within the energy budget. Figure 4.2 depicts the general to specific transition of the analysis.

Figure 4.2 General to specific model of energy resource demand



Source: Author's compilation

In microeconomic theory, Engel curves explain the relationship between the quantity of a commodity demanded and the income of the household holding other factors, such as prices, at constant levels. However, with the developments in multiple regression models, other factors can be estimated together with the influence on income (Gujarati, 2004:202).

This thesis considered the relevance of the energy ladder theory, which postulates that there are inferior energy resources which are substituted for more efficient and superior resources as income of a household improves (Rajmohan & Weerahewa, 2007:59). It, therefore, follows from this hypothesis that households whose income levels are higher should be expected to choose those energy facilities which are deemed to be superior by the relatively low earning economic agents. In this thesis, superior energy resources imply those that are cleaner. Generally, biomass, including firewood, charcoal, plastics, crop residues, and animal dung, are considered dirty and, therefore, inferior for higher income households.

Budget elasticities, calculated using the coefficients estimated in the Engel function, are free measures of responsiveness of quantities demanded to a change in the total budget.

In this thesis, the use of Engel functions assisted in categorising the energy facilities as inferior, necessity or luxury, based on income levels. The first stage is an estimation of an Engel function, which is used to derive income elasticities. Following Yeong-Sheng *et al.* (2008:9), equation (4) below is specified.

$$S_i = \alpha_0 + \alpha_1 \ln X + \beta \ln P + \sum_k \gamma_k H_k + \varepsilon \quad (4)$$

Equation number (4) is a lesser form adopted after Deaton and Muellbauer (1980a), since it satisfies the adding-up property. For the purpose of the present thesis, the terms in equation number (4) are;

S_i ; Expenditure share of aggregate energy for each household i ,

X ; total expenditure of both energy and non-energy consumer goods and services,

H_k is a set of dummy variables, which are household specific, capturing both structural and demographic attributes of the respondents in the survey,

P is the price index for the n energy commodities, and

ε is an econometric error term which is assumed to be normally distributed with a mean of zero and a constant variance.

For robustness of the analysis of the effect of income on demand for energy commodities as a share of total expenditure, a quadratic Engel function is adopted, as suggested by Chern (2000), as quoted by Yeong-Sheng *et al.* (2008:9) as follows:

$$\ln x_i = \alpha_0 + \alpha_1 \ln X + \alpha_2 (\ln X)^2 + \sum_k \gamma_k H_k + \varepsilon \quad (5)$$

In equation (5) x is the total expenditure of the aggregate commodity, energy and the natural logarithm of total expenditure are squared so as to validate the second stage

demand model of the QUAIDS. For the purpose of estimation and analysing the demand for particular energy facilities, the thesis adopted the same as Rajmohan and Weerahewa (2007:61):

$$\ln E_{ij} \equiv \ln x_i , \quad (6)$$

Where, E_{ij} is energy budget share of fuel (energy) resource i in household j , and $\ln x_i$ is as defined in equation (5). A separate model for each of the energy resources under scrutiny was estimated. Thus, an Engel function for firewood, charcoal, electricity, solar power and LP gas were estimated separately from each other.

The ordinary least squares method was used to implement equation (6) using STATA 12 as an estimation tool. As a necessary step, income elasticity of demand for aggregate energy can be derived as,

$$e_y^{de} = \frac{\partial x}{\partial X} \frac{X}{x} \quad (7)$$

Using equation (5), the responsiveness of expenditure on total energy due to a change in income can be calculated as,

$$e_y^{AE} = \alpha_1 + 2\alpha_2 \log X \quad (8)$$

The next step will estimate the QUAIDS model for energy commodities in Blantyre.

4.6 ECONOMETRIC SYSTEM OF DEMAND MODELS: AIDS AND QUAIDS

The analysis of demand for commodities in economic theory appears simple on the surface but empirically there have been tremendous amounts of research to find a better solution for deriving demand functions. Microeconomic literature emphasises the need to begin from a utility maximisation position, where decisions are assumed to have occurred because satisfaction accruing to a consumer was believed to be optimal, subject to a number of constraints such as the budget line. Such preference orderings are arbitrary and imaginative. In this thesis, the theories of Muellbauer (1975) are

followed in that the starting point should be a demand decision based on rational decisions.

Following Banks *et al.* (1997), the research adopts the QUAIDS model to analyse the demand for energy facilities as a basket of competing commodities. Banks *et al.* was responding to the weaknesses of the Almost Ideal Demand System (AIDS) proposed by Deaton and Muellbauer (1980), which is probably the most popular framework for deriving household demand systems based on indirect utility methods. The strength of the model lies in the fact that the effects of prices on elasticity are easily estimated and, since it is derived from utility maximisation principles, there is more closeness to welfare theory than other alternatives.

As shown by Banks' *et al.* (1997), a QUAIDS model for household expenditure for commodity i is defined as:

$$w_i = \frac{p_i q_i}{m} \quad (9)$$

In equation (9), p_i is the price at which commodity i is purchased, q_i is the quantity purchased of good i and m is the total expenditure of all commodities in this demand system. In other words, w_i is the proportion of expenditure a household makes for a particular commodity i . The total of the sum of proportions should equal to 1(One). Thus:

$$\sum_{i=1}^k w_i = 1 \quad (10)$$

In other words, the total expenditure for the household is not more than its budget, holding all other factors constant.

Indirect utility in this model is given by the following function, as presented by Scott and Walker (2011:25), and Bopape and Myers (2007:3):

$$\ln V = \left\{ \left[\frac{\ln m - \ln a(p)}{b(p)} \right]^{-1} + \lambda(p) \right\}^{-1} \quad (11)$$

Demand is not affected by prices only, but also other sociological factors termed demographics. In which case then, household expenditure can be modelled as a function of utility and a vector of demographic elements specific to the agent in addition to prices. The following specification can be adopted at the theory level:

$$m = f\{C[U, h(p, d), p, d]\} \quad (12)$$

Just like the original AIDS model, as presented by Deaton and Muellbauer (1980:313-318), $\ln a(p)$ and $b(p)$ can be specified as the conventional translog and Cobb-Douglas price indices (equations):

$$\ln a(p) = \alpha_0 + \sum_{j=1}^K \alpha_j \ln p_j + \frac{1}{2} \left[\sum_{i=1}^K \sum_{j=1}^K \gamma_{ij} \ln p_i \ln p_j \right] \quad (13)$$

$$b(p) = \prod_{i=1}^K p_i^{\beta_i} \quad (14)$$

For economic theory consistency and to reduce the number of parameters to be estimated, several restrictions are imposed on the system. These restrictions include additivity, homogeneity and Slutsky symmetry. The implications based on the expressions are that:

- (i) $\sum_{i=1}^K \alpha_i = 1$,
- (ii) $\sum_{i=1}^K \lambda_i = 0$, and
- (iii) $\sum_{i=1}^K \beta_i = 0$, for additivity to hold since $\sum_{i=1}^K w_i = 1$.

To satisfy the Slutsky symmetry that implies that $\gamma_{ij} = \gamma_{ji}$, in a situation where Marshallian demand functions are homogeneous of degree zero in (p, m) , then it is proper to impose that:

$$(iv) \quad \sum_{ij} \gamma_{ij} = 0, \quad \forall i. \quad (15)$$

In equation (11), the function $\lambda(p)$ is specified as:

$$\lambda(p) = \sum_{i=1}^K \lambda_i \ln p_i \quad (16)$$

For equation (13) and (14), statement (ii) in equation set (15) holds.

If Roy's identity is applied to equation (7) in a way of transmitting it to control for varying preference structures and heterogeneity across households, demographic variables are incorporated as a vector $z_s = (z_1, \dots, z_L)$. As a result, QUAIDS budget share equations can be obtained as follows:

$$w_i = \alpha_i + t_i(d) + \sum_{j=1}^k \gamma_{ij} \ln p_j + \beta_i \ln \left[\frac{m^*}{a(p)} \right] + \frac{\lambda_i}{b(p)} \left[\ln \left\{ \frac{m^*}{a(p)} \right\} \right]^2 + \sum_{s=1}^L \delta_{is} z_s \quad (17)$$

Equation (17) is the one adopted by the thesis to empirically estimate and analyse the demand for energy commodities (resources) in Blantyre, Malawi. If one follows Banks *et al.* (1997) and differentiates the budget share equations with respect to $\ln m$ and $\ln p_j$ then the following QUAIDS expenditure and QUIADS uncompensated or Marshallian, price elasticities respectively can be derived as:

$$\mu_i \equiv \frac{\partial w_i}{\partial \ln m} = \beta_i + \frac{2\lambda_i}{b(p)} \left\{ \ln \left[\frac{m}{a(p)} \right] \right\} \quad (18)$$

$$\mu_{ij} \equiv \frac{\partial w_i}{\partial \ln p_j} = \gamma_{ij} - \mu_i (\alpha_j + \sum_k \gamma_{jk} \ln p_k) - \frac{\lambda_i \beta_j}{b(p)} \left\{ \ln \left[\frac{m}{a(p)} \right] \right\}^2 \quad (19)$$

Equation (18) and (19) are just intermediate results that are useful for the actual calculations. As suggested by Yeong-Sheng *et al.* (2008:10), and Bopape and Myers (2007:5), the expenditure elasticities are derived as;

$$e_i = \frac{\mu_i}{w_i} + 1 = \beta 1_i + \frac{2\lambda_i \log(x)}{\overline{w_i}} + 1 \quad (20)$$

And the uncompensated or Marshallian price elasticities are;

$$e_{ij}^u = \frac{\mu_{ij}}{w_i} = -\frac{\gamma_{ij}}{w_i} - [\beta 1_i + 2\lambda_i \log(x)] \frac{\overline{w_j}}{\overline{w_i}} - \delta_{ij} \quad \forall i, j = 1, \dots, n \quad (21)$$

Where δ_{ij} is the Kronecker delta that is equal to 1 (one) if $i = j$ and zero otherwise. Applying the Slutsky equation, the compensated or Hicksian price elasticities can be calculated.

$$e_{ij}^c = e_{ij}^\mu + w_j e_i,$$

4.7 UTILITY MAXIMISATION AND DISCRETE CHOICE ANALYSIS

The microeconomic basis for consumer energy demand relies on consumers' utility maximisation principles. Such an analysis assumes that:

- Consumers know their preference sets and ordering of the preferences;
- Preference ordering can be represented by some utility function; and
- The consumer is rational in that they will always choose a most preferred bundle from the set of feasible alternatives.

Following consumer theory, it is considered that an incremental increase in consumption of a good, keeping consumption of other goods constant, increases the satisfaction level but marginal utility (increment) decreases as the quantity of consumption increases. Moreover, maximum utility achievable given the prices and income requires marginal rate of substitution to be equal to the economic rate of substitution. This, in turn, requires that the marginal utility per dollar paid for each good be the same. If the marginal utility per dollar is greater for good A than for good B, then transferring a dollar of expenditure from B to A will increase the total utility for the same expenditure. It follows that reduction in the relative price of good A will tend to increase the demand for good A, and vice versa

As shown by Train (2009:11), discrete choice models describe decision makers' choices among alternatives. The decision makers can be people, households, firms or any other decision-making unit, while the alternatives might represent competing products, courses of action, or any other options or items over which choices must be made. To fit within a discrete choice framework, the set of alternatives, called the choice set, need to exhibit three characteristics. Firstly, the alternatives must be mutually exclusive from the decision maker's perspective. Choosing one alternative necessarily implies not

choosing any of the other alternatives (Train 2009:13, Cameron & Trivedi, 2005:463). The decision maker chooses only one alternative from the choice set.

Secondly, the choice set must be exhaustive, in that all possible alternatives are included. The decision maker chooses one of the alternatives. Lastly, the number of alternatives must be finite. The researcher can count the alternatives and eventually come to the end of counting. Where the options are not both exhaustive and finite, the researcher can find a way of grouping those not observable as 'other', thereby creating another alternative.

Discrete choice models are usually derived under an assumption of utility-maximising behaviour by the decision maker (Train, 2009:16, Cameron & Trivedi, 2005:467, Deaton, 1997:200-295). Thurstone (1927) originally developed the concepts in terms of psychological stimuli, leading to a binary probit model of whether respondents can differentiate the level of stimulus. Marschak (1960) interpreted the stimuli as utility and provided a derivation from utility maximisation. Following Marschak, models that can be derived in this way are called Random Utility Models (RUMs). It is important to note, however, that models derived from utility maximisation can also be used to represent decision making that does not entail utility maximisation. The derivation assures that the model is consistent with utility maximisation; however, it does not preclude the model from being consistent with certain forms of behaviour. The models can also be seen as simply describing the relation of explanatory variables to the outcome of a choice, without reference to exactly how the choice is made.

RUMs are an alternative of index function models (Green, 2003:669). Following Train (2009:19) and Green (2003:670), RUMs are derived as follows. A decision maker, labelled n , faces a choice among J alternatives. The decision maker would obtain a certain level of utility (or profit if it is a firm) from each alternative. The utility that decision maker obtains from alternative j is $U_{nj}, j = 1, \dots, J$. This utility is known to the decision maker but not, as we see in the following, by the researcher. Implementing the assumption that consumers are rational, the decision maker chooses the alternative that

provides the greatest utility. The behavioural model is therefore: choose alternative i if and only if $U_{ni} > U_{nj} \forall j \neq i$.

As indicated earlier, the researcher does not observe or feel the decision maker's utility. The researcher observes some attributes of the alternatives as faced by the decision maker, labelled $x_{nj} \forall j$, and some attributes of the decision maker, labelled s_n , and can specify a function that relates these observed factors to the decision maker's utility. The function is denoted $V_{nj} = V(x_{nj}, s_n) \forall j$ and is often called representative utility. Usually, V depends on parameters that are unknown to the researcher and, therefore, estimated statistically.

Since there are aspects of utility that the researcher does not or cannot observe, $V_{nj} = U_{nj}$. Utility is decomposed as:

$$U_{nj} = V_{nj} + \varepsilon_{nj},$$

where ε_{nj} captures the factors that affect utility but are not included in V_{nj} . This decomposition is general, since ε_{nj} is defined as simply the difference between true utility U_{nj} and the part of utility that the researcher captures in V_{nj} . Given its definition, the characteristics of ε_{nj} , such as its distribution, depend critically on the researcher's specification of V_{nj} . In particular, ε_{nj} is not defined for a choice situation *per se*. Rather, it is defined relative to a researcher's representation of that choice situation. This distinction becomes relevant when evaluating the appropriateness of various specific discrete choice models.

4.8 MULTINOMIAL LOGIT AND CHOICE MODELS

A researcher can adopt a particular specification of a discrete choice model depending on the assumptions that are advanced for the relationship. There have been other developments in the literature suggesting that the static and partial equilibrium analysis of survey data models in choice theory can be improved with the replacement of dynamic models (Kean & Wolpin, 1997; Aguirregabiria & Mira, 2010; Geweke & Kean,

2000). Dynamic discrete models have been used to analyse expected behaviour, following the Lucas critique, that most economic theory and analysis errs in predicting the future using historical behaviour (Kydland & Prescott, 1990; Kean & Wolpin, 1997; Aguirregabiria & Mira, 2010; Geweke & Kean, 2000; Heckman & Navarro, 2007; Rust, 1987). However, the scope of analysis that is required for such models is beyond the time and financial resources of this thesis, especially that the data required is panel in nature.

In the case of this thesis, there is a consumer basket of energy commodities which households have been observed to use. Using both stated and revealed preference experiments, the thesis should have adopted the Multinomial Logit (MNL) model which is very popular in the studies of more than two alternatives from which an economic agent is expected to choose. However, there are challenges with the MNL especially regarding the assumptions that underlie it. Consequently, the Random Parameters Model (Mixed Logit Model) is adopted for its flexibility.

However, the MNL model is first presented to soften the Random Parameters Logit (RPL) derivation process. Most of the material in this section is due to Train (2003:34), McFadden and Train (2000:1-24), Nevo (2000), and Cameron and Trivedi (2005:463). The MNL model is applicable where more than two alternatives are considered from which a decision maker is expected to choose. The MNL is a specialised model from a class of multinomial choice models.

As suggested by Luce (1959) as quoted by Train (2003), the MNL model can be specified as:

$$p_{ij} = \frac{e^{x'_i \beta_j}}{\sum_{l=1}^m e^{x'_i \beta_l}}, \quad (22)$$

Due to the fact that $\sum_{j=1}^m p_{ij} = 1$, a restriction is needed to ensure model identification and the usual restriction is that $\beta_1 = 0$ (Cameron & Trivedi, 2005:500).

Towards the end of the 21st century, researchers started to adopt the RPL (Mixed Logit model), which is a highly flexible model that can approximate any random utility model (McFadden & Train, 2000:7). The RPL model provides greater flexibility compared to other models in the class of discrete choice analysis, in that the random components of the utility specification may be assumed to have any distribution to the extent that modelling of unobserved heterogeneity, which results from unobserved factors such as tastes and attitudes, is made possible. Thus, the RPL model is considered to be the most available promising state of the art discrete choice model as of the year 2012 available.

As is the case with many microeconomic models, a mixed logit probability, as the RPL is sometimes called, can be derived from random utility-maximisation behaviour, which assumes that the coefficients (parameters) are stochastic (random). Here, the decision maker faces a choice among J alternatives. Utility of household n for energy (fuel) alternative j can be specified as:

$$U_{nj} = \beta'_n x_{nj} + \varepsilon_{nj} \quad (23)$$

In equation (23) x_{nj} are observed variables that relate to the alternative and the economic agent (in our case a household head and the entire household as a unit), β_n is a vector of parameters of the variables for household n representing that household's tastes and preferences, and ε_{nj} is a *random* term that is independent from irrelevant alternatives extreme value. The departure from MNL is that these coefficients vary across decision makers in the population. In other words, under standard logit specification the parameters are homogeneous for all the decision makers, which is unrealistic.

To proceed with the modelling process, it is important to note that there must be a density function $f(\beta)$ which is responsible for, and describes the distribution of the varying coefficients. This density is a function of a set of parameters θ that represent the statistical behaviour such as the mean and covariance of the β 's in the population.

As shown in Section 4.3.3, the household head, as a decision maker, has the knowledge of the value of their own β_n and ε_{nj} 's for all j and chooses alternative i if and only if

$$U_i > U_{nj} \forall j \neq i. \quad (24)$$

The researcher observes x_{nj} 's but not β_n or the ε_{nj} 's. If the researcher observed β_n , then the choice probability would be standard logit, since the ε_{nj} 's are iid extreme value. A continuous mixed logit (RPL) model is any model whose choice probabilities can be expressed in the form:

$$p_{ni} = \int L_{ni}(\beta) f(\beta) d\beta, \quad (25)$$

Where $L_{ni}(\beta)$ is the logit probability evaluated at parameters β :

$$L_{ni} = \frac{e^{V_{ni}(\beta)}}{\sum_{j=1}^J e^{V_{nj}(\beta)}} \quad (26)$$

and $f(\beta)$ is a probability density function. $V_{ni}(\beta)$ is the observed portion of the utility, which depends on the parameters β . It follows, therefore, that

$$V_{ni} = \beta' x_{ni} \quad (27)$$

To proceed with the development of a multinomial logit model, the density for each unobserved component of utility is (see section 4.7 above) is given by:

$$f(\varepsilon_{nj}) = e^{-\varepsilon_{nj}} e^{-e^{-\varepsilon_{nj}}} \quad (28)$$

and the cumulative distribution is given by:

$$F(\varepsilon_{nj}) = e^{-e^{-\varepsilon_{nj}}} \quad (29)$$

From the foregoing the probability that decision maker n chooses. Following Green (2003:721), the density and cumulative functions culminate into the following choice model:

$$Prob(Y_i = j|X_i) = \frac{e^{\beta_j' X_i}}{1 + \sum_{k=1}^J e^{\beta_k' X_i}} \text{ for } j = 0, 2, \dots, J, \beta_0 = 0. \quad (30)$$

Model in equation (30) is used to compute the probability that alternative j is chosen by an economic agent conditional on xi. Using equation number (30), log-odds ratios can be computed as follows:

$$\ln \left[\frac{P_{ij}}{P_{ik}} \right] = X_i'(\beta_j - \beta_k) = X_i' \beta_j \quad \text{if } k = 0. \quad (31)$$

The theoretical model in equation (30) is implemented using log-likelihood method that is defined for each individual, $d_{ij}=1$ if alternative j is chosen by individual i, and 0 (zero) if not, for J-1 possible outcomes. As shown by Green (2003:721), the log-likelihood can be generalised as:

$$\ln L = \sum_{i=1}^n \sum_{j=1}^J d_{ij} \ln Prob(Y_i = j). \quad (32)$$

For choice models in general and multinomial models in particular, the coefficients are difficult to interpret. Consequently, equation number (30) is differentiated to have marginal effects as a focus for interpretation. The marginal effects of the probabilities are given by:

$$\delta_j = \frac{\partial P_j}{\partial X_i} = P_j [\beta_j - \sum_{k=0}^j P_k \beta_k] = P_j [\beta_j - \bar{\beta}] \quad (33)$$

Following Train (2009:135), the RPL probability takes the form of equation (33) below after substituting equation (26) and (27):

$$p_{ni} = \int \left(\frac{e^{\beta' x_{ni}}}{\sum_j e^{\beta' x_{nj}}} \right) f(\beta) d\beta. \quad (34)$$

As can be observed in equation (27), the RPL probability is a weighted average of the logit formula evaluated at different values of β where the weights are given by the density function $f(\beta)$. Because a weighted average of several functions in statistics is

called a mixed function, mixed logit is a mixture of the logit function evaluated at different β 's with $f(\beta)$ as the mixing distribution.

The estimation of RPL is through simulation methods for any given values of θ . To do so, firstly, one draws a value of β from $f(\beta|\theta)$, and label it β^r , where superscript $r = 1$ referring to the first draw. The second step is to calculate the logit formula $L_{ni}(\beta^r)$ with this draw. The third step is to repeat the first and second steps in as many ways as possible and average the results. This average is the simulated probability:

$$\hat{p}_{ni} = \frac{1}{R} \sum_{r=1}^R L_{ni}(\beta^r), \quad (35)$$

Where R is the total number of draws, $\hat{p}_{ni}$ is an unbiased estimator of p_{ni} by construction and its variance decreases as R increases. It is strictly positive so that $\ln \hat{p}_{ni}$ is defined, thereby making it possible to approximate a log-likelihood function. Other important features are that $\hat{p}_{ni}$ is smooth and more than once differentiable with respect to parameters θ and x thereby enabling the calculation of elasticities. $\hat{p}_{ni}$ sums up to one over alternatives.

The next step is to insert the simulated probabilities into the log-likelihood function to give simulated log likelihood:

$$SLL = \sum_{n=1}^N \sum_{j=1}^J d_{nj} \ln \hat{p}_{nj}, \quad (36)$$

Where $d_{nj} = 1$ if n chooses j and zero otherwise. The maximum simulated likelihood estimator (MSLE) is the value of θ that maximises SLL.

The RPL (Mixed Logit) simulator can be seen as a logit-smoothed Accept-Reject (AR) simulator of any RUM. In short, draws of the random terms are taken, utility is calculated for these draws, the calculated utilities are inserted into the logit formula, and the results are averaged. However, due to limitations of data, this thesis adopted the multinomial logit model.

4.9 EMPIRICAL LITERATURE

Having reviewed theoretical literature from a conceptual level to more technical areas of energy economics and sustainable development, the chapter turns to an examination of empirical literature. There have been other studies related to the major areas of energy economics, energy poverty and sustainable development from descriptive analysis to more robust and elaborate econometric investigations, to which this section is devoted.

Reliability of energy supply is important for economic growth and development. Unfortunately, for most African countries the power supply sector is characterised by many inefficiencies starting from the generation, transmission and distribution phases, which all combined need an urgent reform program to abate economic losses associated with unreliable power (Charles, 2009:808; Kauffmann, 2004:2). In Malawi, lack of reliable electricity for businesses has resulted in a number of firms, and some households, using generators to substitute for the unreliable power supply from ESCOM. Millennium Challenge Account (MCA-M) constraint analysis found that about 50 percent of Malawian firms use generators and the average losses from power outages as around 10 percent of total sales (Mataya, 2010:6). In Nigeria, firms spend as much as 20 percent to 30 percent of their initial investments on acquisition of facilities to enhance electricity supply reliability, creating a significantly negative impact on the cost competitiveness of the manufacturing sector (Adenikinju, 2005:3). Ergonomically, countries must respond by providing answers in line with the thinking of the investors. Renewable energy is the best way of responding to the concerns of investors in these countries, if jobs are not to be exported to other countries. However, renewable energy facilities have the challenge of capacity to run industrial machinery where most of the equipment has huge power requirements.

One of the most elaborate studies on the economics of energy, and renewable energy in particular, is Stambouli's (2011) review of energy situation and expected trends for Algeria. This thesis provides an in-depth exposition of the history of energy markets in the world. Generally, Arab and North African states are the major producers of fossil oil used principally for motorised equipment such as automobiles. Stambouli (2011:4510)

suggests that, with the desert climate and landscape that largely make these states, renewable energy will be generated there. Wind and sunlight are not scarce resources in these states. In other words, this is a suggestion that the energy generation power house will not change in the future. The world will continue to depend on the Arabic region for the supply of energy although in a different form.

It is imperative to note that as human kind goes through different stages of the development path, so does the path and stages of energy consumed change in both quantity and quality. Goldenberg (1992) successfully argues that all facets of development are not possible without energy. With energy work is possible. As a society develops from basic subsistence creatures to more sophisticated, technologically advanced living organisms the amount of energy consumed also increases. With the increase in the amount of energy consumed comes the desire to use more reliable and clean energy resources, both at the household and industry level. However, with the ever increasing population in the world, there are demands and calls for better, clean and efficient energy facilities to be made available.

In a way of emphasising the role of energy in industrial growth and development, Chow *et al.*, (2003:1320) state that:

Energy is the lifeblood of technological and economic development. The energy choices made by (any country) and the rest of the world have ramifications for economic growth; the local, national, and global environment; and even the shape of international political alliances and national defence commitments.

This is a clear indication that countries in the modern era are willing to do whatever it takes in order to be energy secure. Energy poverty is also economic poverty of a country. The distribution of the world population is inversely related to the energy intensity in the world.

Accelerating development in sub-Saharan Africa (SSA) will require massive expansion of access to electricity, which as of the year 2012 reaches only about one-third of all

households (Deichmann *et al.*, 2010:15; Birol, 2007:3; ESMAP, 2006:12, IEA, 2010:10). Deichmann *et al.* (2010:8) developed a geographically explicit framework and used spatial modelling and cost estimates coming from engineering to determine where stand-alone renewable energy generation is a cost effective alternative to centralised grid supply. The results suggest that decentralised renewable energy will likely play an important role in expanding energy access in rural, unreachable areas of the world. This is a very important result for the SSA region as a whole. Policy planning in this region is largely at the national level although decentralisation programmes have developed and spread all over.

Availability and access to modern, alternative and cleaner energy facilities has been shown to be crucial in alleviating poverty in many parts of the world. Njenga (2001:6) analysed the economic effects of manufacturing, distributing and using Upesi cook stoves in Kenya. The thesis discovered that there were enormous cash savings among users of these modernised stoves. These savings stemmed from the relatively decreased amount of materials needed to provide heat for cooking. With the same amount of money, the users were now able to cook more food than before, implying an improvement in their welfare through consumer surplus. On the supply side, the study showed that income generated for stove producers and distributors increased. Manufacturing and supply of an alternative energy resource proved to be a good business venture.

Finding similar results, Mabona (2001:9), in studying the impact of the adoption of briquettes in Malawi, found that there was increased income for producers of the product and, most importantly, a lot of time was saved from not having to collect firewood in the forests. In addition, the risk of women being attacked by wild animals and robbers who would even rape them dropped dramatically. Njenga (2001) adds that with cleaner energy there is a great saving from health expenditures among users, since the risk of catching diseases such as tuberculosis are reduced.

Alternative energy is also beneficial in human capital development via the education path. Whereas before the adoption of cleaner energy in Nepal, Mali and Kenya, children

school drop-out rates were very high, studying for longer hours was impossible and most women spent time collecting firewood, these trends were reversed when modern energy resources were adopted (Rana-Deuba, 2001:18; Anderson *et al.*, 2005:8; Khatami-Njenga, 2001:11).

Further, there is documented evidence of the positive correlation between improved access to modern energy services and educational achievements. For example, in Mali, girls' scholastic achievements were measurably higher after the introduction of village level mechanical power for grinding, pumping, and threshing services (UNDP, 2004a:19; UNDP, 2004b:25).

A study by Foster *et al.* (2000:4) has shown that traditional energy facilities such as the use of batteries, firewood, charcoal and animal dung are expensive. These technologies are more expensive per efficient kilowatt-hour than hydroelectric power. Access to electricity could provide significant savings in energy costs for the population not yet connected to the grid. Using data from Guatemala, the authors provide a method for measuring the reduction in the price of energy that can be expected from access to electricity. It also provides estimates of the reduction in fuel poverty, which could be achieved with better access to electricity.

A case study by Misana and Karlsson (2001:5) show that access to modern energy services can greatly improve the profitability of these businesses as well as the quality and quantity of the traded product. For example, in West Africa, motorised mills increased the daily production of Shea butter by 200 percent, decreased fuel wood consumption for processing, and increased incomes significantly (ibid:8). Thus, an important way in which improved energy services contribute to gender equality, is by enabling productive work that is primarily undertaken by women to be accomplished quicker and tirelessly using modern machinery. Electrical grinding and pounding equipment, washing machines, electrical pots, and water pumping generators are just some of the examples.

Furthermore, female children benefited in Mala with the adoption of multifunctional platforms as child-labour rates for domestic chores dropped, thereby increasing school enrolment, attendance and improving female class performance. There was also a jump in the number of students entering secondary school (Brew-Hammond & Crole-Rees, 2004; Anderson *et al.*, 2005). In Brazil and Nepal, rural electrification projects improved children's study conditions, which are a very important factor in class performance, as human capital is being built for the future.

King and Alderman (2001) summarise studies that show that investment in running water and infrastructure saves time spent collecting water and fuel wood and do good to all household members in particular. Such infrastructure investments result in fewer interruptions to women's paid work and to girls' schooling. There is a lot of literature that shows that, in many developing countries including Africa, the adoption of renewable energy resources has minimised the gender inequality gap that existed before.

Modern energy resources, therefore, are a driver not only to environmental sustainability but also the most important MDG of reducing poverty by half by the year 2015. However, it must be noted and emphasised that access to modern energy technologies on its own is not the only driver for development. It must be holistically approached so as to mix with better macroeconomic environment and excellent policies that do not end on paper but are transmitted to the ground through sound implementation that is supported by a strong political will.

The barriers discussed above are not unique to Malawi alone but also to a number of geographical settings, especially those with similar characteristics. For the case of Pakistan, China and Malaysia, Mirza *et al.* (2002:927), Junfeng *et al.* (2002:11) and Poh and Kong (2002:31) respectively, have ably analysed barriers to the adoption of renewable energy in their respective localities.

There are still some sceptics within the poverty literature around the world who express worries about the adoption of renewable energies. Studies such as Foley (1981) and Mabona (2001), argue that the subsistence sector's poverty can be smoothly eradicated

if traditional renewable energy resources can be harvested and used efficiently. The Malawi Government supports the use of Briquettes and energy/firewood saving stoves that heat up with a minimal amount of the energy resources (GOM, 2012:20; Mobona 2001:5). There is a movement in Malawi that is promoting the use of efficient stoves before any modern renewable energy resources are marketed to the rural and urban poor people who cannot afford electricity for cooking.

As shown by Foley (1981), the major problem in solving energy poverty is to find quicker means and ways of replenishing forest cover. However, securing future wood supplies is a political, economic, and social problem. It involves other cross cutting issues such as land ownership, customary laws, and social organisation. Until these are resolved and wood fuel is being effectively replenished, demand reduction measures fail to reach the root of the problem, since they create no incentives for increased supply; if anything they may achieve the reverse. Before governments can fully consider banning the use of traditional resources of energy, a complete and conclusive research, development and demonstration must be carried out. Bang *et al.* (2000) and Abebaw (2007) further suggest that rural acceptability of these modern technologies still has to be tested and as the marketing plans are drawn, they should clearly advocate for the adoption of such resources because of the benefits that can be realised, not just perceived and theorised statements.

One of the main thrusts of this thesis is to measure the general acceptance of renewable energy resources in poorer societies in Malawi. A similar study was carried out in southeast Germany by Musall and Kuik (2011). This was a very important study that addressed whether wind energy ownership by the community can be important in inducing acceptance and, therefore, adoption and use of the technology. The authors investigated the possibility of having a good renewable energy facility in place in a particular community where the citizens are not interested at all. In which case, resources would not lead to the intended goal of reducing GHG emission and, of interest to the present thesis, increasing access to energy aimed at alleviating energy poverty in the society. This empirical research shows that a community ownership model of a RE project can have a positive effect on local acceptance. The research

design was based on a comparative case study, utilising a questionnaire-based survey. The results of the survey showed that a significant difference in local acceptance exists between the two areas surveyed. The residents of Zschadraß, where a community co-ownership model exists, are consistently more positive towards local renewable energy and also towards renewable energy in general. The results provide evidence that the co-ownership model is a means to reconcile local acceptance with the increased use of renewable energy in Germany. This is also a focus of the present thesis as in the survey, acceptance of RE in general will be gauged.

As shown by Mirza *et al.* (2010:928), the barriers to development of renewable energy can be broadly classified as policy and regulatory barriers, institutional barriers, fiscal and financial barriers, market-related barriers, technological barriers, and information and social barriers. These factors are also identified by other authors such as Junfeng *et al.* (2002:13), Poh and Kong (2002:34), Rogers *et al.* (2008:4223) and Zoellner *et al.* (2008:4140).

An important question is whether fuel wood collection—for use in rural areas, for sale in urban areas, or for charcoal production—causes or contributes to deforestation. Most studies identify the conversion of forests to agricultural use and their nationalisation—denying unorganised, underprivileged people, particularly women, access to natural resources—as the main drivers of deforestation (Leach & Mearns 1988; Sarin 1991; Lungu, 2009; ESMAP 2005a).

ESMAP (2005) and UNDP (2000) argue that depletion of the forests may also result from timber sales or commercial charcoal production. Furthermore, it appears that fuel wood scarcity may also result from deforestation caused by other factors. When a forest resource is severely depleted due to reasons other than fuel wood collection—continued fuel wood collection may indeed make the problem worse. This circumstance, along with already depleted soil, may create a situation where biomass waste or dung that could help restore the soil is used as cooking fuel. Interventions with modern fuels may offer a way out of this vicious circle.

In reviewing two decades of fuel wood crisis in Kenya, Mahiri and Howorth (2001) conclude that, in this context, the causes and dynamics of deforestation differ in urban and rural areas, suggesting local specificity. The problem of indiscriminately felling trees and the resulting environmental degradation may exist near urban centres. However, in rural areas the situation is intricately tied in with land use and control. Those who can consolidate land by building a fence are able to increase their wood supply, but those who cannot have declining access to fuel wood. In a meta-study, Geist and Lambin (2002) analyse the frequency of proximate causes and underlying driving forces of deforestation, including their interactions, as reported in 152 sub-national case studies from Asia (55 studies), Africa (19 studies), and Latin America (78 studies). Only in Africa does wood extraction for fuel wood contribute significantly to tropical deforestation.

Fear of running the risk of losing political power and authority has created an environment where democracy is not working effectively. In some countries, such as Malawi, there have not been ward councillors for close to a decade and all projects and interventions, including those for RE, depend on a centralised plan which has two main problems. Firstly, as ownership of forest cover is more common than before, deforestation is done at will. There is lack of local policies made and adapted for the good of the locals. As a result, more and more land is being left bare without any tree at all.

Secondly, elections are only at the national and constituency level such that members of parliament have taken up roles which are traditionally supposed to be done by the local authorities. Poverty reduction is now the main platform on which political campaigns and propaganda are made. Cutting down trees for firewood and charcoal is regarded as one of the methods through which people's poverty can be eradicated. Any attempt by a sitting member of parliament to tell people to stop this business may cost them the next election. Consequently, the process continues unsustainably.

Wustenhagen *et al.* (2007:2689) questions the efforts taken by authorities in government and business as they preach the good news of alternative energy resources. The news is really good whether proven or not, but what is not taken into

account is the societal nature and system with all its cultural and economic values. Household income, distance to the nearest main trading centre, education of head of household and other demographic and geographical factors are regarded as the main determinants of RE adoption (Jingchao, 2010:6; Wustenhagen, 2007:2685). However, other factors that are more social also have a bearing on acceptability of RE resources and projects. Other people can simply appreciate the good news about solar PVs and wind generation but may refuse to have them in their backyards. There are political elements associated with community projects. It depends on who is bringing the project and who is going to benefit.

It will be the lowest cost option for a minority of households in Africa, even when likely cost reductions over the next 20 years are considered. Decentralised renewables are mostly competitive in remote and rural areas, while grid connected supply dominates denser areas where the majority of households reside. These findings underscore the need to de-carbonise the fuel mix for centralised power generation as it expands in Africa.

In the absence of satisfactory supply, energy consumption per inhabitant is very low in Africa. The average is 0.5 tonnes oil equivalent per inhabitant, compared with 1.2 tonnes worldwide. Consumption is essentially composed of the exploitation of biomass, oil products and electricity, a secondary energy source produced by fossil and renewable energy sources. Modern energy sources, such as oil products and electrical energy, are essentially destined for industrial use and transport. Domestic energy consumption in Africa, therefore, consists largely of biomass use.

Wood and its derivatives constitute the energy source most used by African households, especially in the countryside, by virtue of their availability and the absence of private property rights over forest resources, which make them a virtually free resource at the individual level. The key driving factors for increasing renewable energy implementation in OECD countries are policies to mitigate climate change. In contrast, in developing countries, which are generally characterised by a high share of non-commercial (renewable) energy, particularly in Africa, rising fossil fuel prices and energy

security concerns, offer additional opportunities for renewable energy (*Binu et al.*, 2010:72).

Biswas (2011:55) picks one major activity of water pumping for both irrigation and domestic use in Bangladesh and concludes that RE can potentially play a role in the supply of safe water, where nearly 70 percent of the rural population does not have access to electricity. The interesting aspect of Biswas' study is its assessment of the possible application of renewable energy for pumping water from geologically safe deep tubewells to overcome limitations in existing water technologies in the arsenic-contaminated villages in Bangladesh. Biswas' study considers renewable energy, national grid electricity, and alternatives such as diesel engines as sources of power for both suction and submersible pumps in electrified and non-electrified villages. The study further assessed three locally and readily available renewable energy sources, namely human energy, biogas, and solar energy, as power sources for reciprocating and submersible water pumps. These renewable energy options were found not to be cost competitive with deep tubewells, which run off the national grid in electrified villages. However, electricity generated from biogas has the potential to power submersible pumps in non-electrified villages.

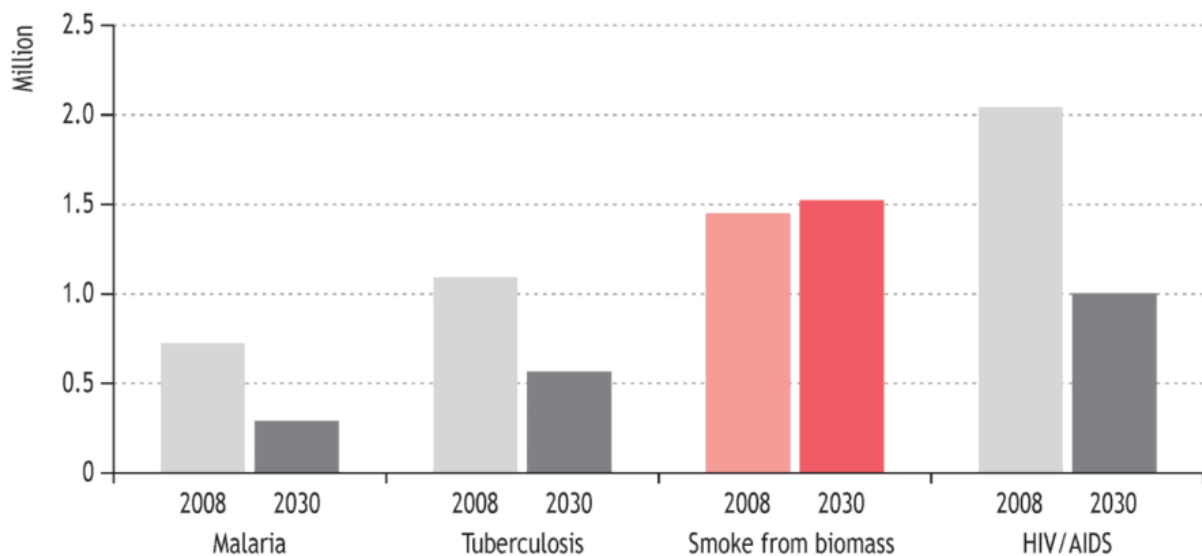
Sanders (2010) examined the energy options available for people in rural Nicaragua. The thrust of the study was to improve household energy use by exchanging tungsten light bulbs with energy savers serviced by gas in the tubes. Consequently, the community was able to save up to 17 percent of locally generated electricity from dirty generators (Sanders, 2010:2). Sanders' study further suggests that by saving energy, two important objectives were achieved. First, households were able to save money from bills which were higher previously and second, the amount of GHG emitted was reduced. The author concludes that governments and intervention agencies must consider strategies that can improve household and industrial energy use efficiency before introducing new technologies of renewable energy. This is a quick and less costly approach to reducing income and energy poverty while reducing GHGs.

Onoja and Idoko (2012:115) analysed the determinants of demand for fuel wood in rural areas of Kogi State, Nigeria. They collected data from eighty households and, using a Two-Stage Linear Squares (2SLS) method, they found that the most significant determinants of fuel wood demand in the study area was the price of fuel wood itself, the price of kerosene, household size and personal income of the head of household. They concluded by recommending that, among other things, a reduction of kerosene prices, investment in renewable energy, cooking gas and electricity and use of agricultural extension agents to educate farmers on sustainable farming be implemented.

Heavy reliance of urban households in sub-Saharan Africa on biomass fuels (such as woody biomass and dung) contribute to deforestation, forest degradation, and land degradation. This is partly because the use of these fuels in urban areas is one of the most important sources of cash income for people in both urban and rural areas (Mekonnen & Köhlin, 2008:1). The substitute for cleaner fuel energy, in the form of animal dung, further lowers productivity of land since dung is an important soil nutrient that can be used as fertiliser, further contributing to lower poverty levels.

As shown by the World Health Organization (WHO), persistent use of biomass for fuel energy in households is one of the major causes of health ailments in underdeveloped countries. The WHO estimates that about 1.5 million premature deaths in the world are the result of indoor air pollution (IEA, 2006:78), which is a consequence of by-products from energy resources such as burning rubber, paraffin, firewood, charcoal and candles. Recently, there has been substantial recent progress in measuring, examining, documenting, and identifying quantitative links between the use of solid cooking fuels and the associated disease burden (Ezzati & Kamen, 2001; von Schirnding *et al.*, 2002; Warwick & Doig, 2004).

Figure 4.3 Incidence of disease in developing countries



Source: IEA (2010)

Previous research and government interventions around the world seem to suggest that the major determinant for fuel choice is income (Barnes, 2006). Further, as Mekonnen and Köhlin (2008:2) observe, literature on household energy demand and choice show that households with low levels of income rely on biomass fuels, such as wood and dung, while those with higher incomes consume energy that is cleaner and more expensive, such as electricity. There are also households which are in economic transition from extremely poor to comfortable levels, especially in urban poor communities. These households generally rely on transition fuel, that is to say those fuels which are between traditional and cleaner (and more efficient) energy sources such as kerosene and charcoal (Ibid:2).

The debate concerning the environmental impact of energy use hubs mainly on GHG emissions as a key concern. It is essential to draw a distinction between fossil fuel used in the poorest LDCs, where energy consumption and GHG emissions are low both per capita and in aggregate, and where the primary concern is the local environment, and fossil fuel use in industrialised and rapidly industrialising countries, where per capita emissions and aggregate emissions are much greater and, therefore, more significant

on a global scale. This distinction is the basis for the principle of 'common but differentiated responsibilities' for emissions mitigation and reduction, which is at the heart of global accords on climate change. Much of the growth in fossil fuel consumption in developing countries will come from increased industrial and transport use as a result of economic growth. This growth will permit economic transitions, which in turn will decrease these countries' vulnerability arising from their present high dependence on land-based production activities such as agriculture and aquaculture.

Current fossil fuel consumption levels in tropical sub-Saharan Africa are so low that even if these countries increased at an annual rate of 10 percent overall, increased GHG emissions from sub-Saharan Africa are not likely to have any significant impact on the world climate. No mechanisms have been identified that suggest that the region's own GHG emissions will have feedback effects on climate locally. Moreover, natural gas and LPG produce far less potentially detrimental emissions, at least to the immediate user, than wood or dung. Furthermore, a switch to modern cooking fuels would not be limited by world resources or by GHG emissions, as Smith (2002) noted:

Even if all 2 billion people shifted to LPG for household fuel, it would add less than 2 percent to global greenhouse gas (GHG) emissions from fossil fuels. In terms of human health, a shift to LPG would actually result in a net reduction of human exposures to air pollution that would be substantially larger than today's total exposure from all fossil fuel emissions.

Therefore, when considered on a global scale, the energy source choices of the poorest countries are not the most threatening from an environmental perspective. Income is not the only determinant factor in fuel choice. Other factors are also identified in the literature. One of the fundamental barriers which are often faced in transferring technology to developing countries is that the technology being transferred is not appropriate to the local context and demands or is not adapted to the local environment. It is important to understand the local situation in developing countries and meet the required energy service demands with appropriate technology. The right combination of

energy sources and technologies must be identified for each situation. This might mean a combination of energy-efficient technologies powered by a range of renewables and fossil fuels, providing a range of energy services (Wikins, 2002:122).

Using data obtained from a random sampling in an explorative survey, Miah *et al.* (2011:3758-3764) compared rural and urban energy usage patterns in Bangladesh. Their study revealed that 100 percent of the households used biomass, 98 percent kerosene, 61 percent electricity, 23 percent LPG and 5 percent candles, in the rural areas. In the semi-urban areas, 100 percent of the households used electricity, candle and natural gas, 60 percent kerosene and 13 percent petrol. What is interesting, and will be applied to the present thesis, is the computation of the share of expenditure on energy resources to the whole consumption basket of the h/hs visited. However, Miah's study did not compute percentages since their main concern was the generally accepted measure of poverty as living below US \$1 per day on average. For instance, h/hs' mean expenditure for total energy was US \$ 5.34 (SE, 0.43) with total income US \$ 209 .84 (SE, 6.69) per month in the rural areas, while it was US \$ 6.20 (SE, 1.35) in the semi-urban areas with the total income of US \$ 427.76 (SE, 24.19) per month.

Using structural time series method (STSM), Dilaver and Hunt (2011:3117-3127), investigated the relationship between h/h electricity consumption, total final consumption and residential electricity prices in Turkey. Their main concern was to apply the STSM in modelling past residential demand for electricity in Turkey. Their study was very important, especially that it was only a third of known academic work emphasising modelling demand of energy, specifically electricity. Other studies being those by Halicioglu (2007) and Hamzacebi (2007), which separated the modelling of demand and the predicting of the future electricity demand, respectively. The contribution of Dilaver and Hunt's study was that they were able to come up with price elasticities of electricity demand for Turkey. The research undertaken here attempts to do the same but using discrete choice modelling.

The level of demand for energy in the future is a function of many factors. One of them is efficiency of energy from its production to use. In a similar fashion to Hamzacebi

(2007), Komiyama and Marnay (2008) carried out a country level predictive study for Japan's future energy demand to 2030. Japan enacted the revised energy conservation laws in 1999, which aimed at enhancing the use of energy efficient appliances, such as motor vehicles and household items (ibid:3). Filippini and Hunt (2010), also concerned with energy efficiency as an important function of demand levels, developed a model for both the OECD using panel data and each country in the panel.

In Japan, the number of appliances depending on electricity is expected to grow in each household since universally there is an increasing trend of appliance ownership. It was discovered that:

...by energy source, the demand for electricity grows due to the following factors: the increased number of electric appliances in each household; the market appearance of new electric appliances such as next-generation DVD recorders; and the use of air conditioners over a longer period of the year and longer hours of the day. With air conditioners becoming more efficient and electric water heaters and IH (Induction Heating) appliances attracting more consumers, there will be a shift in demand to electricity, which is more convenient and safer than other energy sources. Thus, electricity will be the only energy source for which the demand increases in residential sector; electricity will acquire a share of nearly 55 percent by 2030 from 44 percent in 2006. In electricity demand, its usage in plug load and space heating will expand to 2030. In service demand, the share of plug load is forecast to increase from 35 percent in 2006 to 42 percent in 2030. (Komiyama & Marnay, 2008:11).

Filippini and Hunt (2010) on the other hand use a stochastic frontier analysis (SFA) to analyse country level energy efficiency. The focus is on the measurement of energy efficiency as to whether a change in energy intensity should be regarded as a change in efficiency at all. In this regard therefore every care must be taken before a policy maker makes a decision based on energy intensity.

Lobel and Perakis (2011) developed a model for the adoption of solar photovoltaic technology by residential consumers in Germany. In particular, they assumed that consumers purchase these solar panels according to a discrete choice model. The technology adoption process is reinforced by network externalities, such as imitating customer behaviour, and cost improvements through learning-by-doing. Using their model, they develop a framework for policy makers to find optimal subsidies in order to achieve a desired adoption target with minimum cost for the system. They concluded by suggesting that renewable energy subsidies should be higher in the near future and the gradual phase-out of the subsidies should occur faster.

Ziegler (2010:13) empirically examined the determinants of demand for alternative energy sources and propulsion technologies in vehicles within the federal territory of Germany. He collected data using a stated preference discrete choice experiment with 598 potential car buyers. Several options and attributes were suggested and an econometric analysis, using the multinomial probit model, was employed. Some of the findings were that younger people, and people who usually purchase environment-friendly products, have a higher stated preference to purchase biofuel, hydrogen, and electric automobiles than other population groups. This thesis adopted 'age' and WTP for renewable energy facilities to capture similar influences on cooking energy technologies in a developing country.

Njong and Johannes (2011:340) performed a geographical distribution study to establish the distribution of households according to the major cooking energy types and by region or zone of residence in Cameroon. Following similar methods employed in this thesis, such as the Multinomial Logit model, they also investigated the main determinants of cooking energy choices. Their results indicated that the level of education, distance of the household from urban centres, whether or not the household owns the dwelling unit, and whether or not the dwelling unit is traditional or modern type are important factors that determine household cooking fuel choice. The study also revealed that firewood is the principal cooking fuel for the majority of households in Cameroon, especially in the rural zones and northern regions of the country. In a similar fashion, this thesis tests the same variables using the same methodology. The

departure point, however, is that in the present thesis an attempt to scientifically measure the extent of energy poverty among poor urban dwellers is emphasised rather than simply modelling the stated preferences.

Ouedraogo (2005:3787) collected survey data on household expenditures in Ouagadougou, Burkina Faso, which was used to analyse the factors determining urban household energy choices using a multinomial logit model just like the present project. Their study analysed sociological and economic variables of household energy preferences for cooking. The results of the study showed that the inertia of household cooking energy preferences were due to poverty factors such as low income, poor household access to electricity for primary and secondary energy, low house standard, household size, and high frequency of cooking certain meals, using wood fuel for energy.

Although Africa has the worst energy poverty levels, the future looks promising with the adoption of renewable energy. It is generally accepted that the world must move to cleaner and renewable energy resources if industrialisation and, therefore, economic growth is to be achieved. The African continent, surprisingly, has the greatest potential to generate energy for the future. In other words, the hope of the world in abating the energy problem lies in Africa, which has the most hours of sunlight covering the most, if not the whole, of the continent (Njoroge, 2011:11). North Africa, for instance, remains the bedrock for current energy needs with plenty of oil reserves in Libya. So, the power to negotiate for an economic muscle is in green energy and Africa must move fast to capitalise on its resources so that the rest of the world can depend on her.

In fact, through the Africa-EU energy partnership, Africa is already exporting bio-fuels to the European community, although there are problems with terms of trade, which are not favouring the exporter (Charles *et al.*, 2009:5550). The partnership, which was signed in Addis Ababa in 2008, has a number of specific elements. For Europe, the main aim is to import bio-fuels from Africa in order to diversify and increase the energy mix while meeting the global agenda of cutting GHG emissions by the year 2050. Africa,

on the other hand, is expected to benefit through proceeds from the export of the bio-fuels, whether processed or the raw materials.

This arrangement should quickly be annulled because knowingly or unknowingly, Africa is getting back into the vicious cycle where it plays the supplier of materials and not the finished product. The Europeans still have their land devoted to food production while they get the energy required for their agricultural activities from Africa. Rwanda's problems of depletable resources are similar to those of Malawi, with 90 percent of the people relying on biomass for cooking and heating (Borchers & Annecke, 2006:2).

4.10 SUMMARY AND CONCLUSION

The energy ladder theory in LDCs has challenges. While the hypothesis advances that income determines the energy mix of economic agents, in LDCs there are other problems, such as unreliability of available superior resources. There are load shedding programmes, which in many cases, leave few hours of power for people to use. In addition, electricity is usually not available during peak hours when people need it most to prepare their meals, watch television, iron their clothes, read and do school work. As a result, SD and the green revolution are under threat.

Other studies have shown, however, that the energy ladder theory holds where desired energy resources are available to [people. In Africa, in general, and Malawi in particular, the energy ladder theory does not hold because, much as there is a willingness for people to stop using biomass and adopt higher grade resources such as electricity, those resources are either not available or, where they are available, they are unreliable. For example, Malawi experiences an average of six blackouts per week of a minimum of 4 hours each (The Nation, 20 September 2012). These blackouts happen mostly during peak hours between 06:00 and 10:00 in the morning and 17:00 and 21:00 hours in the evening. Although a household might be connected to the grid, the reliability of electricity influences them to continue using biomass, thereby creating threats to sustainable development and green growth efforts.

Utility maximisation for the energy sector is not derived the resources that provides the

energy, but the energy itself. In this case, energy demand is, therefore, a derived phenomenon for consumers. They do not demand, for example, charcoal as an end in itself but the commodity which charcoal produces, given some chemical reactions. To analyse demand for energy resources, the traditional demand systems can be applied. This thesis adopted the Engel function analysis and static discrete choice methods.

The next chapter closely analyses the energy sector in Malawi. The chapter presents growth and development policies Malawi has followed since gaining independence in 1964 and traces energy policy and activities since before independence. The trajectory of economic policies and overarching development goals that have been set by the government of Malawi over the years are examined together with the strategies of implementing the plans especially as they relate to the energy sector.

CHAPTER 5 ECONOMIC AND ENERGY POLICY IN MALAWI

5.1 INTRODUCTION

Malawi is one of the poor countries in the world with a population of 13 million people according to the 2008 Population Census (NSO, 2009). Geographically, the country is in southern and central Africa, bordering Tanzania to the north-east, Zambia to the west and Mozambique to the south, south-west and south-east. Although it has been more than 45 years since the country received independence from Britain in 1966, the economic policy in general and the energy sector in particular has experienced dismal changes that have impacted negatively on the lives of the people.

As shown by the NSO-IHS-3 (2012:120), the installed electricity capacity is at 283 MW against an estimated demand of about 330 MW. People largely depend on biomass, especially firewood and charcoal, for their household and farm energy needs. The adoption of renewable energy has not been fast enough to accelerate the rate of economic growth for sustainable development. The effort to encourage green growth has not paid off in Malawi.

The questions this chapter set out to answer were: why is it that the energy policy in Malawi has not produced the desired results of providing affordable clean energy to everyone? What are some of the barriers to the adoption of renewable energy? What is the level of household and industry energy demand and how does demand compare with supply?

This chapter presents salient features of the economy of Malawi and profiles Blantyre city. Section 5.2 provides the geographical position of Malawi followed by Section 5.3, which presents the economic transition Malawi has undergone before gaining independence from Britain in 1964. Section 5.4 is a tracer of the evolution of electricity and power generation in Malawi, where the barriers both for demand and supply side are highlighted, relying on literature reviews. The history of energy policy and strategy

for Malawi in general is also examined. Section 5.5 provides detailed facts about the supply side and demand side of energy in Malawi. The section examines the amount of electricity and type that is demanded, first by households and, second by industry, before considering the sources of different energy resources. Section 5.6 analyses the supply side of energy market for Malawi. Section 5.7 digs deeper into the renewable energy efforts by Malawian authorities followed by Section 5.8, which presents costs of adoption and/or migration from traditional energy resources to renewable facilities. Section 5.9 concludes the chapter.

5.2 THE GEOGRAPHICAL POSITION OF MALAWI AND BLANTYRE CITY

Malawi is a member of the Southern African Development Community (SADC) as it lies to the south east of the African continent. It shares boundaries with Tanzania to the north, Zambia to the north-west and Mozambique in the south, south-east and south-west. Figure 5.1 depicts the Republic of Malawi's position in Africa.

Figure 5. 1 Map of Africa showing territorial boundaries of the republic of Malawi



Source: Infoplease Atlas found at <http://www.infoplease.com/atlas/country/malawi.html>

5.3 A REVIEW OF THE ENERGY SECTOR AND POLICY IN MALAWI

Malawi is one of the smallest and poorest countries in the world. It is a densely populated country with an annual per capita income of around US \$290 (Lea & Hanmer, 2009:2). About 80 percent of the population is clustered in rural areas where the predominant economic activity is subsistence agriculture on small farms with limited inputs. The country is landlocked with a predominantly agricultural-based economy.

Agriculture accounts for one third of GDP and 90 percent of export earnings, with tobacco contributing more than half of the total export money metric value.

Liberalisation came to Malawi through Structural Adjustment Programmes (SAPs) in the mid-1980s as a donor pushed policy aimed at freeing trade and economic activity. It was also aimed at relieving the grip of government in the business sector to concentrate on the provision of an enabling environment for business. The policy framework was coming on the heels of multiparty democracy. Previously, most corporate activities were in the hands of government. Government, through the Malawi Development Corporation (MDC), Agricultural Development and Marketing Corporation (ADMARC) and Press Corporation, owned many corporations from banks to manufacturing (Chirwa, 2000:80).

The argument, as advanced by the multilateral donor institutions, was that a liberalised economy would bring to the economy more foreign direct investment (FDI), which would increase competition and, in turn, quality products would be produced. Further, more firms meant that employment rates would be expected to increase thereby potentially reducing poverty rates among the people. However, the situation turned out with different results. For instance, the major liberalisation activity government undertook was to privatise state owned enterprises (SOE), which resulted in massive retrenchments. In addition, without the support of government, many of the privatised firms went under and retrenched more people. New hiring was not visible rendering a worsening poverty situation.

On the other hand, the population level in Malawi has been rising. In 1998, there were 13 million people and in 2008, the population and housing census estimate that there were 16 Million people in the country. It is disturbing, however, to note that such a staggering figure has 80 percent depending on subsistence agriculture on small customary land holdings.

The expected FDI only came in the form of new entrants on the stock market rather than new and fresh establishments. Mainly, the investors were interested in the banking sector (the Malawi Stock Exchange has 4 banks, three insurance companies, one

investment firm and two property firms out of the 16 listed. Further the bourse has only one manufacturing firm listed (Malawi Stock Exchange, 2012). The poverty situation, therefore, worsened instead of improving. In recent times, however, the poverty situation has been improving, although insignificantly.

The National Statistics Office (NSO) national aggregate poverty line was estimated to be at MK37 002 (about US \$142.32 using exchange rate of US \$1 = MK280) for both food and non-food items. As shown by the Integrated Household Survey number 3 (IHS 3), the national poverty rate is estimated to be at 50.7 percent, indicating that almost half of the population is poor. Compared to the IHS 2, this indicates that there has been a slight decrease in the poverty rate by 2 percent, from 52.4 percent reported in 2004/2005 (NSO-IHS3, 2012:204). Further, using a food poverty line of MK22 956 (about US \$82 using exchange rate of US \$1 = MK280), the IHS3 suggests that 25 percent of the population are ultra-poor. That is, about one in every four people lives in dire poverty, such that they cannot even afford to meet the minimum standard for daily-recommended food requirement.

At a regional level, Malawi is divided into three regions, namely the Northern, Central and Southern regions. As shown by NSO-IHS3 (2012:204), there is variation across regions in terms of poverty rates. Generally, the Southern region has the largest poverty rate (63 percent), implying that three out of five people live in poverty in the rural areas of the Southern region. The Northern region has the second highest proportion of poor people (60 percent). The Central region has the lowest proportion (49 percent) of poor people.

Further, dividing the country into urban and rural areas reveals prominent differences in poverty rates between urban and rural areas. About 17 percent of the population in urban areas is living in poverty, compared to 57 percent of the rural poor population. That is, approximately three out of every five people in rural areas live in poverty compared to only one out of every five people in urban areas. This, however, stems mainly from the measure of poverty which emphasises on income rather than resources

themselves. Purchased food, water and energy items for instance are bound to be available mostly in urban than in rural areas.

In term of urban centres, Lilongwe city (22 percent) has the largest incidence of poverty, followed by Zomba (16 percent), Mzuzu (16 percent) and Blantyre (8 percent) cities. By districts, those in the Southern region have more people who are poor than those in the Northern and Central regions. For instance, four out of five people in Chikhwawa and Nsanje are poor. A similar pattern is also observed across ultra-poor people in the three regions.

About 47 percent of the poor population in the country lives in the rural areas of the Southern region. About one in every three poor people comes from the rural areas of the Central region, while one in every ten poor people comes from the Northern region's rural areas. The Southern rural areas have a disproportionate share of the poor, reflecting the higher poverty rate in this region. Only 6 percent of the poor population in Malawi lives in urban areas (NSO-IHS3 2012:207). In rural areas, most people depend solely on subsistence agriculture for survival. Further, their education levels are generally lower and they do not have formal technical skills that would enable them to look for formal employment.

A historical perspective of the evolution of energy policy in Malawi should help to understand some of the disparities in the supply and use of energy resources. First, Malawi became a Republic on 6th July 1964 when she gained independence from her former colonial master, Britain (before this time, the country was called Nyasaland and it was part of the federation of Rhodesia and Nyasaland; an initiative by the British government that brought three colonies under one administration, namely Southern Rhodesia, Northern Rhodesia and Nyasaland).

At the time of independence, Malawi adopted many policy strategies in the running of the economy, justice and politics. The problem was to integrate the black community into the plans, as targets of development and economic growth leading to socio-economic transformation. In a way, to change the balance of economic power and

improve the lives of many, GOM compiled the first Statement of Development policies (DEVEPOL 1), that emphasised agriculture as the backbone of the economy. Government therefore deliberately introduced subsidies that enabled farmers to access farm inputs such as fertiliser and seeds at very affordable prices.

Government encouraged subsistence agriculture for both commercial crops such as tobacco and non-commercial crops such as maize. Senior government officials, however, were encouraged to own large farms to practice commercial farming. Strategic crops were identified as tobacco, tea and sugarcane to provide foreign currency and a linkage for the manufacturing sector to obtain raw materials. Soon, tobacco became the major export crop for the country. Maize was emphasised for food security purposes.

In DEVPOL 1, government emphasised a development pattern that was linked to the agricultural sector. The industrial sector was agro-based including the education and even political system. Tobacco became a strategic crop for international trade, followed by tea and sugar. At this time, the energy sector was very much underdeveloped. There was no modern electricity. Very few fossil fuel pumps could be noticed. Nearly all people in the rural and semi-urban areas depended on firewood for cooking, lighting and curing tobacco. Those in urban areas used paraffin lumps for lighting and cooking. Charcoal was introduced to the economy in the early 80s and its use was associated with average income earning households, as it was relatively expensive to acquire.

Firewood was obtained free of charge from government-owned forest reserves and common property in the hands of chiefs. The population of the country, at that time, was about 1 million people throughout the country. However, as the population increased, urbanisation due to migration of youthful Malawians looking for jobs started to exert pressure on the demand for services. Blantyre city council soon realised that there was a need to expand the boundaries of the city to accommodate more and more semi-civilised people, who were ambitious and educated. This also meant that the generally inferior supplies available at the time were no longer popular among the city residents because they represented low class and were difficult to use. As more and more educated young people flocked to the cities of Blantyre, Lilongwe and Mzuzu, lifestyles

also changed. These young people were mostly working class without any time to look for firewood in the forests. Charcoal became the most probable option for cooking as it was available on the local markets in townships.

Paraffin was mainly used for lighting in homes and later candles and cell powered lamps in relatively high income families. Very few could afford electricity connection from ESCOM for three main reasons. Firstly, ESCOM was yet to roll out a grid with a larger coverage than what was available. The argument ESCOM provided for such a problem was that most of the townships in the cities of Blantyre, Zomba and Mzuzu started as squatters and that is where most people stay. As such, there were no plans to introduce electricity to illegal settlements.

The second reason was that the cost of connection was very high for an average Malawian staying in a squatter. There was a requirement for those willing to have electricity connected to their homes to foot the bill for purchasing transformers, apart from paying for the connection and surveying fee. Thirdly, the wiring standards demanded by ESCOM before they certify for connectivity required that the house be properly roofed with iron sheets and well plastered with river sand and cement. In Malawi, these building materials are very expensive to acquire from shops, more so that they are all imported either in full or raw materials. In addition, there was a specific type of wire and main switch for the switchboard and pipes. All these factors brought together increased the cost of connectivity from ESCOM for the average Malawian. Since firewood was still free and charcoal affordable and readily available, there was no rationale for most people to die for electricity.

However, political pressure from the one party system of government forced ESCOM to roll out its grid to the illegal and poor settlements within urban trading localities in the rural areas. In rural areas, hummer mills were run using diesel and were very sparsely located such that most people used locally made mortar (*Mtondo*) to pound their maize into flour for pulp (*Nsima*), the staple food for most parts of the country.

In terms of entertainment and electronic media service, Malawi had only one radio station and there was no television. Used car batteries were for the well to do families for their radios. Dry cells, however, were the main source of power for radios. Sun powered radios were distributed by church organisations in other parts of the country for people to use for playing religious tapes. Sometimes, hand wound radios could be found in certain households, again provided by faith-based organisations. Televisions, cell phones and computers were a speculation in most, if not all homes.

By and by, the forests were being depleted; charcoal started to come from far places and became relatively more expensive than before. Firewood started to be sold on the market and government tightened security in and around forest reserves to control the rate of deforestation without providing an alternative. However, the cost and trouble of getting electricity was still higher compared to the cost of charcoal.

Other forms of energy, such as coal, gas and renewables, were not even known by most people. Gas, in particular, had a negative connotation to most people. They speculated that gas can explode if not handled properly; more so that to handle it was regarded as a very delicate process not worthy trying. As a result, pressure on wood as a resource for heat energy continued to mount in both the rural and urban areas.

5.4 HISTORY OF ELECTRICITY SUPPLY INDUSTRY IN MALAWI

Prior to 1948, Malawi had no commercial supplier of electricity. There were very few and small electricity generation using independent diesel powered generators for own consumption in very affluent colonial households. To some extent, some of the electricity generated was used to run machines in small private factories, lighting and heating government offices and other public institutions. Most of these small power plants were in the southern region of Malawi, particularly Zomba, since it was the capital city. There were also a few others in Blantyre, which had the most commercial activities and tea estates in Mulanje and Thyolo district, all of them in the southern region of the country.

There existed no government department or ministry responsible for all activities related to energy supply during this period. All biomass products were absolutely free for all and the population was relatively small, not enough to warrant any need for institutional structures aimed at managing activities of the energy sector.

Between 1948 and 1958, the demand for electricity increased as settlements swelled. Consequently, the number of diesel generators increased and, as a response the British government, established some institutional measures that saw electricity becoming a commercial commodity. In 1948, the Electricity Services Department (ESD) was instituted within the Ministry of Public Works (MPW). The mandate of ESD was to commercially undertake electricity generation, transmission and distribution (GOM, 2003:26). What was missing though was the regulatory framework to govern the commercial activities surrounding electricity. In 1953 when Malawi joined the Federation of Rhodesia and Nyasaland, Malawi (then called Nyasaland) adopted the Central Africa Safety Rules for Electricity as the governing instrument.

In 1957, the Electricity Supply Industry (ESI) went through a metamorphosis as the then colonial government enacted the first Electricity Act, 1958 with a number of main elements. Among them were first, the Electricity Act, 1958 established the Nyasaland Electricity Supply Commission (NESCO) which took over assets and liabilities of ESD and all the staff members; second, a reposition of all monopoly power in NESCO as the sole agency to generate, transmit and distribute electricity in the country and third, regulatory powers were given to NESCO. So, NESCO was a statutory corporation which was self-regulating. In 1963, the new Malawi government revised the Electricity Act, 1958 to ESCOM Act, 1963 and the name of NESCO was changed to the Electricity Supply Commission of Malawi (ESCOM).

Following the wind of change that was blowing in the country as a consequence of a democratic government and liberalisation of economic activities away from the grip of the executive and public institutions, the government of Malawi decided to liberalise the electricity supply industry. The process started by incorporating ESCOM and reorienting it to focus only on commercial activities (Ibid, 27). Social activities that were coordinated

by ESCOM, such as the Rural Electrification programme, were accordingly transferred to the Department of Energy Affairs (DoEA).

In 1998, the Electricity Act, 1998 was enacted in Parliament with major changes especially to the operations of ESCOM. This transition liberalised the electricity market by firstly, breaking the monopoly powers once held by ESCOM in the whole logistical chain of generation, transmission and distribution of electricity. Secondly, the market structure was to be unbundled by allowing a requirement for undertakers to obtain separate licenses for the very activities ESCOM was involved. Thirdly, the private sector was not, under the law, allowed to commercially market electricity to customers and consumers. Fourthly, and most importantly, the regulator powers enjoyed by ESCOM were stripped away from it and the Act established an independent national electricity regulator called the Electricity Council.

In general, the reforms that were effected in the ESI particularly ESCOM were aimed at introducing competition in the sector by conforming to the first and second theory of welfare economics. As the Washington consensus at the time, the multilateral financial institutions believed in policy prescriptions that followed the route of liberalisation as the only vehicle that would bring efficiency in the electricity market and, therefore, more welfare to the people. Currently in 2012, ESCOM is a registered limited company with 99 percent of the shares owned by government and 1 percent by another statutory corporation called the Malawi Development Corporation.

5.5 A LOOK AT MALAWI'S ENERGY DEMAND

This section turns the attention of the thesis to an examination of the relationship between energy demand and supply in Malawi. Specifically, the thesis draws a comparison between the demand and supply side of specific energy resources, namely biomass, electricity, coal, LP gas and petroleum, for the household sector and industry respectively. The section starts by discussing the details of energy demand at the household level in Malawi.

5.5.1 Energy Demand by Households

There are 13 million people in Malawi, according to the 2008 Census, of which 80 percent live in the rural areas averaging 4.5 people per household. As of the year 2012, household energy consumption accounts for 84 percent of the total energy used in Malawi, the dominant energy source being biomass (99 percent) (GOM, 2008). Although economic structures favour the urban over the rural population, both the urban poor and rural households, predominantly, use low efficiency end-use devices. The trend has not changed significantly. The rural households are characterised by high incidence of poverty accompanied by low availability and/or quality of modern infrastructure (Malawi Government, 2008). The majority of the households are dependent on agriculture for their livelihood. The predominant sources of energy are firewood and charcoal with 92 percent of the firewood collected free from the surrounding woodlands and gardens.

The low efficiency three-stone fire stove is the dominant firewood end-use systems for cooking (GOM, 2003). The high household preference for low efficiency firewood and charcoal end-use technologies threatens the sustainability of the environment due to deforestation and greenhouse gas emissions. The principal energy end-use application for paraffin and electricity in the urban households is illumination. 80 percent of electric lighting sub-circuits use incandescent lamps, which have the lowest efficiency of all types of lamps available on the market. A large number of urban households use the traditional low efficiency one-wick paraffin lamps for lighting (Malawi Government, 2012). However, the use of paraffin contributes to indoor air pollution and adversely affects the health of both adults and children. Electricity accounts for 0.5 percent of energy, while very little paraffin is used for lighting. Yet a study by Yang (2003) has shown that investment in energy, such as rural electrification programs have a very significant impact on economic development and poverty reduction in the rural areas. In other households, paraffin is used for fire start-ups together with plastic and rubber materials.

In urban areas, 84 percent and 65 percent of households use firewood and charcoal, respectively (Kambewa & Chiwawula, 2007:9). Other devices include candles and wood fire. The recently released Integrated Household Survey 3 confirms that, in both urban and rural areas of Malawi, solid fuels are common for cooking. Solid fuel refers to various types of solid material that are used as fuel to produce energy and provide heating, usually released through combustion. Almost all households (97 percent) use solid fuels for cooking in Malawi. The case is even more severe in rural areas where use of solid fuels is at 99 percent. The results of the IHS3 also show that the proportion of male and female-headed households that use solid fuels is almost equal at 97 percent and 98 percent, respectively. In terms of consumption quintiles, there is universal use of solid fuel in the lowest quintile while nearly 10 percent of households in the highest quintile use alternative means of cooking fuel other than solid fuels (GOM-NSO, 2012:120).

The most common source of cooking fuel in the country is firewood at 88 percent, followed by charcoal (9 percent), electricity (3 percent) and other means of fuel for cooking at 1 percent. Considering the nature of residence by development, urban areas have a rather low proportion of households using firewood as source of cooking fuel, registering 42 percent while rural areas have registered almost 96 percent. What is interesting is that more households in the lower consumption quintiles use firewood for cooking compared to households in the higher consumption quintiles. The northern region has the highest proportion of households using firewood as cooking fuel at 95 percent, while the central region comes second (90 percent) and, finally, the southern region that has recorded 84 percent use of firewood.

In terms of lighting, although paraffin is a rarely used source of cooking fuel in the country, the situation is different when it comes to lighting because paraffin is the most common source of lighting fuel (52 percent), followed by battery (27 percent), firewood and electricity (8 percent both) and the remaining, candles and others (5 percent and 1 percent, respectively). Rural areas have the highest proportion of households using paraffin as source of lighting fuel at 54 percent while only 43 percent of urban households use paraffin. The proportion of female-headed households using paraffin as

lighting fuel is higher than that of males at 57 and 50 percent, respectively. Across the regions, the southern region has the highest proportion of households using paraffin for lighting at 64 percent while the central comes second at 41 percent and then the south at 40 percent.

By sex of household head, the proportion of households with electricity grid within 100 meters is higher in male-headed households (22 percent) than in female-headed households (19 percent). The table also reveals that the higher the consumption quintiles the higher the proportion of households with electricity grid within 100 metres. The southern region is registered as having the highest proportion of households with electricity grid within 100 metres from their household with 25 percent.

It is worth noting that another study by the government of Malawi, conducted in 2009, has slightly different results. However, the differences are not significant from the ones reported by the National Statistical Office. For instance, GOM 2009 found that 89 percent of the population use firewood, 6.7 percent charcoal, 2.3 percent crop residues and animal dung, 1.4 percent electricity and 0.5 percent paraffin. Coal and LP Gas were not in use. However, the studies were conducted using different samples, sample sizes and at different periods. This thesis examined the same energy resources for South Lunzu Township in Blantyre city to ascertain whether there were any statistical differences.

Although 21 percent of households have electricity within 100 meters from their dwellings, only 7 percent of households in Malawi have electricity. In urban areas 33 percent households have electricity in their households; whilst in rural areas only 2 percent of households have electricity. Male-headed households are more likely to have electricity in their dwellings registering 8 percent, than female-headed households (5 percent). The proportion of households with electricity in the dwelling is much higher in households in the top consumption quintiles than in the bottom four quintiles (23 percent and more than 3 percent respectively) (NSO-IHS3, 2012:123).

Almost all primary schools in the rural areas and the majority of the urban public primary schools have no access to grid electricity. This denies the pupils the opportunity to study at night, which has a negative effect on the standard and quality of education, which is greatly compromised throughout the country. Where electricity is used, especially secondary schools and colleges, it is used mostly for lighting, heating and cooking. In some very rare cases, where resources permit, basic laboratory experiments are conducted and the understanding and interest in science subjects is further motivated.

Figure 5. 2 Charcoal trader at Nkolokoti Market place



Photo by Author, 21st January 2012.

Hydropower generation is the largest source of power in Malawi, mostly for the urban and rural-urban centres because the electricity supply grid is nearer. Solar, especially PVs, are used in modular form for telecommunications, lighting and water pumping in very rural areas where there is no grid power anywhere near. Solar power and petrol

driven generators are used in some parts of the cities due to irregular power supply as a back-up (Mataya, 2010).

In terms of fuel, ethanol is available locally in large quantities since it is a by-product in the sugar manufacturing industry, both at Nchalo and Dwangwa sugar plants. The government said that the country was on track to commence biodiesel production by the year 2009 from several jatropha projects in the central region, and sunflower plantations in the southern part of the country. The government also indicated that the Department of Science and Technology and Lilongwe Technical College were developing engine modifications that would allow conversion of cars to E100 sugarcane ethanol, where initial tests were scheduled to be completed by mid-2009.

5.5.2 Energy Demand by Industry

As already mentioned in Section 3.3, Malawi's industry is agriculture-based. Agriculture is the main employer, accounting for over 60 percent of formal jobs. The export market is also reliant on tobacco, tea and sugar. The demand for energy in industry is, therefore, mainly by this sector.

Table 5.1 Total National Energy Demand in Malawi, by Sector and Fuel Type

	Energy demand by fuel type (TJ/yr)					
Sector	Biomass	Petroleum	Electricity	Coal	Total (TJ/yr)	Total (Percentage/yr)
Household	127,574	672	1,798	5	130,049	83.20%
Industry	10,004	3,130	2,010	3,481	18,625	11.90%
Transport	270	5,640	35	15	5,960	3.80%
Service	452	558	477	174	1,661	1.10%
Total (TJ/yr)	138,300	10,000	4,320	3,675	156,295	
Total (Percentage/yr)	88.50%	6.40%	2.80%	2.40%		

Source: Government of Malawi; Malawi biomass energy strategy 2009.

As table 5.1 shows, energy demand by the industrial sector in Malawi is surpassed by that of households in general. Of the total energy demand, industry represents 12 percent, transport sector demands about 4 percent followed by 1 percent that is consumed by the service sector. Of the total demand for electricity, industry takes up nearly 50 percent. However, 10 percent of the industrial demand for energy is satisfied by electricity (Government of Malawi, 2009:20). This is because industry, which is mainly composed of the agriculture sector, requires more cost effective energy resources. Agriculture industries such as tea, bananas and tobacco, rely mainly on biomass, especially firewood, for most of the basic processes such as curing tobacco and drying tea.

A further observation of Table 5.1 reveals that biomass demand, at 88 percent, is indeed the most popular form of energy resource, followed by petroleum at 6 percent, electricity at 3 percent, and coal at 3 percent in that order. Petroleum is mostly demanded by the transport sector, followed by industry.

5.6 MALAWI'S ENERGY SUPPLY SIDE

Demand for energy resources in Malawi is balanced by supply from many sources, especially for biomass. In this case as, already discussed in chapter 2, biomass comprises of firewood, charcoal, animal dung and crop residues. By considering the biomass first as the main energy resource, many studies have shown that there is excess supply of the commodity and the trend is expected to continue for several years to the future. For instance, for the country as a whole, the estimated annual growth of stem, branch and twig wood is estimated to be 29.8 million m³ of solid wood (GOM, 2009:20). If this is compared to the annual demand for biomass, especially wood, which is estimated at 14.9 million m³, it clearly shows that the reliance on biomass is within sustainable limits in Malawi.

This however may not be the case as the estimation comprises of grass, shrubs that are generally not considered sources of energy, crop residues which double as manure for the field. In addition, distance to some of the areas where the resources might be

readily available may not be economical enough to suggest any form of availability. Further, some of the forests are protected, such that counting them as available resources for energy supply might be misleading. Almost all electricity in Malawi is generated from hydro turbines. With an installed power of 282 Mega Watts, the electricity is not enough to meet demand, which is estimated to be growing at 6 percent per annum (GOM, 2009). There are three river-propelled generation stations in Shire River and one in the Northern region.

Some industries burn coal to produce heat energy for their operations but the percentage is minimal. In addition, there is ethanol, which is a by-product of sugar production at two factories (Tchereni *et al.*, 2012: 5). This ethanol is added to petroleum, especially petrol, although most of it is exported to other parts of the world. All petroleum is imported from the Middle East through the ports of Beira and Nacala in Mozambique, and Dare Salaam in Tanzania.

There are also deposits of coal in Malawi, with four fields already under exploitation, which if allowed to operate at full capacity, could produce enough coal to generate electricity. There are proven coal deposits of about 20 million metric tonnes with estimated reserves of about 80 million tonnes. The quality of this coal is said to have energy values ranging between 17 and 29 MJ/Kg. However, demand for coal is generally higher than the supply such that the excess demand is met through imports from Mozambique.

Apart from the above sources, Malawi has solar power, wind energy and other biofuel resources such as *Jatropha*. However, these are used in very low quantities, especially for cooking, because, generally, they cost more to acquire and the equipment is not compatible with the eating habits of the potential users. This is renewable energy, which is more abundant and available to everybody in Malawi. However, it has not been harnessed so as to help in sustainable energy and development efforts. The thesis now turns to an examination of renewable energy policy thus far undertaken in Malawi.

5.7 MALAWI'S RENEWABLE ENERGY POLICY EFFORTS

The National Energy Policy and many other documents in the sector have not extensively tackled the area of renewable energy in Malawi. Renewable energy resources are still regarded as inferior and not yet at the strategic point where resources should be invested to abate the excess demand gap that exists.

In general, Malawi, just like most countries in the SSA region, is seen as well endowed with renewable energy sources. However, the proportion of renewable energy sources (excluding hydroelectricity) in the total energy balance has remained insignificant, approximately standing at 0.2 percent (Kambewa & Chiwaula, 2010:5). This is attributed to the prevalence of a number of technical, economic, skills, institutional and socio-cultural barriers. There is no wind turbine generation because the winds are inadequate for large-scale power generation. Some wind power is used for pumping water in Chikhwawa, Zomba, Mangochi and other lakeshore areas in the central and northern regions of the country.

5.7.1 Technical and Financial Barriers

Malawi lacks the capacity to manufacture, distribute, install and maintain renewable energy technologies. Most of the technologies are imported from many parts of the world, most notably China, Europe and the Republic of South Africa. This increases financial barriers in the form of import duties and surtaxes (between them contributing 45 percent of the financial challenges, foreign currency challenges and access to funding from financial institutions). There are no affordable and dedicated financial arrangements in banks and other financial institutions specifically meant for the energy sector. Also, there is lack of an entrepreneurial skill in the area and lack of available financial and investment opportunities specifically for RE facilities on the international market.

5.7.2 Institutional Barriers

That green energy is necessary for economic growth and sustainable development has been accepted, not only in rural Africa, but also globally. Adoption of green energy has become a global agenda mainly for adherence to the Kyoto Protocol aimed at cutting down GHGs by 50 percent by the year 2050. In Africa, this agreement has faced institutions that are not ready to take on the transition. Africa has very weak institutions to operate most of its programmes (Ali, 2005:16). There is a very strong link between strong institutions and poverty reduction.

As shown by North (1990), institutions in economics are differentiated from organisations in administrative studies. Institutions are the rules of the game. These may include rules and norms which society establishes as aspects that shape human interaction (North, 1990:3-5). They restrict behaviour, either formally or informally, such that building of strong and relevant institutions is part and parcel of the development process (Ali, 2005:1). The evolution of relevant institutions in Africa is slow and nonresponsive.

There is a lack of coordination and cooperation within and between various ministries, government departments, and other stakeholders that delays and restricts the progress in renewable energy development and dispatch through commercialisation. Absence of a central body for overall coordination of energy sector activities results in duplication of R&D activities. Distribution of goods and services does not get government support if politicians believe that they will not add value to the basket of votes. The lack of legislations and approved renewable energy policies leads to a situation where subsidies can mean biases and, often, no effective control of electricity prices. Non-incorporation of renewable energy issues in the regulatory policy, and lack of awareness among regulators, restricts technology penetration (Mirza, 2009:928).

It is, therefore, imperative that government must establish institutions that are not only visible, but also effective in acting as incentives for the business community to take RE technologies to the people. Consumers must be provided with institutions that will

encourage them to adopt RE technologies as superior resources to what they have previously believed to be adequate. Unfortunately, the available institutional set up seems to suggest that those who adopt alternative energy technologies at the household level are of low class.

Until 2006, Malawi had no standards and a regulatory framework to specifically look into issues of renewable energy technologies. The Malawi Energy Regulatory Authority (MERA) which took over all energy regulatory and licensing activities from the National Electricity Council now has a department especially for RE. Though, as of the year 2012, there are very few firms undertaking business in the supply, installation and maintenance of RE technologies. The market for RE is considered latent and untapped, usually supplying to very frustrated people who still considers hydro power as superior over RE. RE facilities are regarded as temporary measures to provide power whenever ESCOM has failed to do so due to load shedding or otherwise.

The absence of a code for best practices for RE technologies has brought into the country equipment of questionable quality with poor installation procedures and often without any maintenance. Until the time of writing, Malawi is a member of the World Trade Organisation (WTO), which has specific areas under Sanitary and Phytosanitary (SPS) Measures to control dumping-type of trade in substandard commodities. However, there are no standards to guide economic agents whenever they want to purchase RE facilities from abroad.

Furthering RE technologies in Malawi has not received the urgency needed by government, non-governmental organisations, and the private sector. There is no special policy and strategy for the RE industry, thereby having no proper direction and guidance. The private sector involved in the sector have a huge task of first of all sensitising people about the existence of the products and then informing them about the benefits, in which case the campaigns are highly commercial and expensive, increasing the cost to be borne by the customer and/or consumer.

5.7.3 Social-cultural Barriers

At the household level, women are the major users of energy yet the design and operation of some of the RE technologies are gender insensitive posing challenges to the speed of adoption of the technologies. Promotion of other technologies, such as the use of human waste for production of biogas, has difficulties regarding acceptance as they touch on cultural issues. In cultures such as those in Malawi, which are generally conservative, it is a mistake to introduce new products without community participation right from the beginning.

RE resources are regarded as a rural electrification tool, which typically implies that it is an inferior technology befitting rural, uncivilised and uneducated people. Hydroelectricity is perceived to be a commodity for the rich, educated and civilised people. As a result, pressure on the demand for electricity from ESCOM will not end if the urban population is excluded from the RE industry altogether.

5.7.4 Policy and regulatory barriers

Government policies and regulations can act as barriers to the adoption of energy in the society. These might be regulations and policies specifically for the energy sector or indirectly from other sectors, such as environment, foreign exchange and even cultural perspectives. Government must, therefore, be careful how policies and regulations are framed. Regulations are made for the purposes of control and smooth running of institutions, giving mandates and powers. In the energy industry, common regulations in Africa are aimed at controlling the use of firewood and charcoal to protect the environment, while at the same time, controlling the ever increasing demand for electricity in households by adopting and implementing load shedding programmes (Mataya, 2010). This defeats the whole purpose for which the regulations are made.

Policies and regulations aimed at the private sector to control the activities of commerce are crucial in the energy sector. The public sector in more liberal economic environments, which most African countries have adopted, are aimed at creating an enabling environment where commerce is not hampered as long as it is within the law of

the land. However, government should bring in deliberate policies that should encourage entrepreneurs to consider investing in making RE resources available to poor people. This adventure can only be taken head on by the corporate community if they are convinced that the return on their investment is worth the bother.

In Pakistan, for example, with the power purchase agreement structured at utilities buying power at fixed rates from generators, there may not be sufficient incentives for power generation from renewable sources with fluctuating cost (Mirza *et al.*, 2010:928). Lack of well-defined policies for private participation and delays in clearances and allotments for private sector projects hinders private participation in renewable energy projects.

5.7.5 Economic Barriers

Economic policy can be partitioned into three areas, namely fiscal, monetary, and trade and industrial policy. Financial problems are faced within the whole range of the energy industry from R&D to consumption/demand. For instance, the development of renewable energy technologies meet barriers in obtaining competitive forms of finance due to lack of familiarity and awareness of these technologies, high risk perception, and uncertainties regarding resource assessment (Junfeng *et al.*, 2002:11-20, Poh & Kong 2002:31-39, Mirza *et al.*, 2002:927-931). Financial institutions don't seem prepared to provide financing that is flexible enough to offer more challenging R&D. There is a lack of financial resources and proper lending facilities, particularly for small-scale projects. Investments in renewable energy technologies are not attractive under high-discount rates and short-payback periods. Under such conditions, generation options, that have relatively lower capital costs, shorter gestation periods, high efficiency, and availability are preferred.

The intermittent generation characteristics of renewable energy technologies and their site-specific nature may place the renewable energy developers in an unfavourable position regarding structuring of contracts for power transmission as compared to non-renewable energy developers. Intermittent generators may be required to pay higher

charges per kWh to transmit power. The site-specific nature of the renewable energy project may be a drawback under some transmission pricing schemes where the rates are based on the distance. The provision of financial support to renewable energy technologies is restricted to the investment cost of the technology. The lack of financial support for working capital requirements hinders operation and maintenance of the equipment, as well as setting up consumer service infrastructure.

5.7.6 Market-related barriers

Market requirements and R&D of renewable energy products are not matched. Therefore, product development is poor, and continues to be largely supply-driven rather than being responsive to user needs. This results in limited market penetration of renewable energy technologies. Subsidies to conventional fossil fuel energy resources give them an unfair advantage over renewable energy resources.

Market prices do not reflect environmental costs and damage and mask the striking environmental advantages of the new and cleaner energy options. The market reforms leading to setting up of an electricity market with competitive and reliable power supply tariff rationalisation and elimination of subsidies and grants may bring down the penetration of renewable energy technologies. Restructuring and unbundling under market reforms may reduce incentives for distributed generation. For biomass-based technologies, the barriers are unsustainable biomass supply, non-existent fuel market, unreliable supply of biomass, and frequent price fluctuations.

Lack of marketing infrastructure with promotion campaigns, after-sales service infrastructure, and quality control measures, among others for most of the renewable energy technologies restrict their market penetration. Lack of successful and replicable business models hinders renewable energy technology adoption.

5.7.7 Technological barriers

The current energy generation cost from renewable energy sources is high, due to high-capital cost and low capacity factor in comparison to conventional power-producing

options. The term “transaction costs” describes the outlay in time and money to obtain agreements, get approvals, make decisions, arrange financing, and other similar activities required to move a project from idea to reality. Transaction costs are a strong barrier to renewable energy development for two reasons. First, renewable energy projects are typically much smaller than fossil fuel projects. Many transaction costs are essentially “fixed”. That is, they are roughly the same for a small project as for a large one. Therefore, transaction cost per unit of energy produced from renewable energy projects is typically much higher than that from fossil plants, creating a competitive disadvantage.

Secondly, renewable energy projects typically are more complex in organization and in relationships to the grid than individual fossil fuel plants. They require agreement among more parties, involve either multiple products, or are fuelled by by-products and have broader connections with other aspects of community economic, social, and development affairs. Therefore, they inherently involve more complex analyses and negotiations.

Minimum standards in terms of durability, reliability, performance, etc., are lacking for renewable energy products, thereby affecting commercialisation of renewable energy technologies. There is a general lack of detailed renewable energy resource assessments and databanks. High potential of renewable energy supply sources exist in areas with low levels of demand due to developmental and socioeconomic patterns. This supply–demand mismatch, coupled with problems in transfer of power from such regions leads to a very large share of the potential remaining unexploited.

Non-availability of physical infrastructure, and transmission and distribution networks in potential sites of renewable energy supply leads to low exploitation of their potential. This is especially valid for wind, solar, thermal, and geothermal energy projects. Renewable energy sources such as hydro power are very often located in remote, dispersed and inaccessible areas that necessitate high-investment requirements in transmission lines for power supply.

The scale of operation of wind and solar technologies is constrained by matching supply with a load duration curve, leading to very low-plant load factors with a very high percentage of unused capacity. For ensuring reliable power supply, back-up power supply sources need to be set up, which increase the overall costs. Low peak coincidence factors for renewable energy technologies, especially for wind and solar, make them unreliable sources for power supply during the peak periods.

In the case of cogeneration, there are technical barriers in upgrading existing sugar mills, setting up of cogeneration facilities and supply of grid electricity. Also, seasonal operation of sugar mills leads to intermittent power supply from cogeneration projects and, therefore, utilities are unwilling to buy power from these units. Unstable electricity grids and their low operational reliability, create problems in power off-take from renewables.

Inadequate servicing and maintenance of equipment, along with low reliability in operations leads to very low-customer confidence and hampers technology adoption. The adoption of technologies or equipment may be unsuitable for the selected site, incompatible with existing system components, or substandard in quality. In most cases, the technology or equipment is imported, therefore, spare and replacement parts, when required, may not necessarily be readily available, especially in more remote locations. Difficulties in the estimation of socio-environmental costs for various alternate energy supply sources for full cost pricing of energy, restricts renewable energy development.

5.7.8 Information and social barriers

Lack of trained personnel for training, demonstration, maintenance and operations, along with inadequate awareness and information programs for technology dissemination, impedes renewable energy penetration. Information regarding renewable energy projects is not easily available, which deters further investments in renewable energy technologies. Community participation and local capacity building are restricted to just a few demonstration projects. This greatly restricts renewable energy development for decentralised applications in remote areas.

General information and public awareness in relation to new technologies and understanding the practical problems in implementing and maintaining renewable energy projects is limited. There is insufficient networking with local organisations for flow of credit with the result that most of the credit flows to the corporate sector, whose primary motivation is taking advantage of the financial incentives. This has disabled renewable energy promotion at the local level. Development of renewable energy resources is often subject to the availability of land. Access to and across traditional land has always posed a constraint that invariably requires resolution through extensive negotiations and, often, results in significant compensation payments.

5.8 COSTS OF CHANGE AND ADOPTION OF RENEWABLE ENERGY

Renewable energy as a paradigm in the world is relatively old and can be traced to as far back as the Nuclear age in the United States of America. In Africa, however, where information filtration is very slow, many people still do not have television sets or radios and access to newspapers is only a dream. Logistical challenges, due to poor road networks coupled with low income levels, creates problems for most Africans to access information. As a result, RE information is not fully comprehended by people so as to change their mind set toward considering using RE resources permanently.

Apart from the slow diffusion of important information, there are also perceived costs associated with new alternatives. There are social, economic, political, and even cultural costs, which are perceived. Jaccard and Dennis (2006:91-92) show that, for both consumers and business people, some new technologies are usually perceived to pose greater risks of failure or unforeseen operating problems, meaning that realised financial costs exceed anticipated financial costs.

In Africa, it is always important to adopt a technology which has been tried by the next door neighbour or at least being forced on an individual or the community. There is a need to sensitise the local community toward the advantages of adopting such new technologies. Unfortunately, officials responsible for such a programme will not have embraced the technology themselves. In Malawi, for example, of the 10 senior officers

randomly interviewed, only one of them has a solar panel for his parents in the country side (interview conducted by the author in Lilongwe, Malawi on 19th April, 2011).

In Mozambique, for example, as is the case with many other African countries, priorities are badly set to the extent that traditional energy resources are relied upon because there is no data that explains the energy use and sources (Cuvilas *et al.*, 2010:2145). There is much inefficiency in energy use. A lot of energy is wasted because of the technologies that are used, such as firewood and charcoal.

In the developed world, the story is different. Previous studies such as Hart (1995) and Menon and Menon (1997) on consumer behaviour in the United States of America shows that more and more consumers are now influenced by their concern for the impact environmental impact their purchasing decision will pose. As a result, many companies are now producing goods that are not only profitable, but also environmentally friendly (Hart, 1995; Menon & Menon, 1997; Osterhus, 1997 in Bang *et al.*, 2000:450). The most probable effect of these factors is that technology choices by businesses and consumers are affected by technology specific attributes that are important but difficult to estimate.

In moving with the global agenda of reducing GHG emissions, there is much literature supporting the adoption of renewable energy as compared to the 'business as usual' way of thinking about increasing access to oil, natural gas, and even electricity. Electricity generation requires the use of coal and oil lubricated generators, which are emitters of GHGs. In Africa, because of high levels of poverty and abundant sunlight that is available for at least 8 hours a day, the green energy solution lies in solar power (National Renewable Energy Laboratory USA, 2008:1). Additional emissions of GHGs would be avoided if RE technologies were used, instead of historical energy technologies, to meet the energy gap in Africa and the world in general.

For the US's Department of Energy, meeting the energy gap under the 'business as usual' scenario would increase annual emissions by 1,909 MMT-CO₂, nearly tripling the 2005 emissions of 45 African countries, which they worked on (1,035 MMT CO₂, EIA).

Deployment of RETs to meet energy demands across Africa could avoid GHG emissions and reduce climate vulnerability in regions heavily reliant on hydropower. While nontechnical barriers to deployment of PV and CSP technologies significantly impact energy choices, it is still very likely that solar-based renewable energy technologies can, and will, play a significant role in closing the energy gap in Africa (ibid:1).

5.9 SUMMARY AND CONCLUSION

Malawi is one of the smallest and poorest countries in the world. It is a densely populated country with an annual per capita income of around US \$290. About 80 percent of the population is clustered in rural areas where the predominant economic activity is subsistence agriculture on small farms with limited inputs. The country is landlocked with a predominantly agri-based economy. Agriculture accounts for one third of GDP and 90 percent of export earnings, with tobacco contributing more than half of the total export money metric value. Liberalisation came to Malawi through Structural Adjustment Programmes (SAPs) in the mid1980s as a donor pushed policy aimed at freeing trade and economic activity.

The National Statistics Office (NSO) national aggregate poverty line was estimated to be at MK37 002 (about US \$142.32 using exchange rate of US \$1 = MK280) for both food and non-food items. As shown by the Integrated Household Survey number 3 (IHS 3), the national poverty rate is estimated to be at 50.7 percent, indicating that almost half of the population is poor. Compared to the IHS 2, this indicates that there has been a slight decrease in the poverty rate by 2 percent from 52.4 percent reported in 2004/2005 (NSO-IHS3, 2012:204). Further, using a food poverty line of MK22 956 (about US \$82 using exchange rate of US \$1 = MK280), the IHS3 suggests that 25 percent of the population is ultra-poor.

As of the year 2012, household energy consumption accounts for 84 percent of the total energy used in Malawi, the dominant energy source being biomass (99 percent) (GOM, 2001). Although economic structures favour the urban over the rural population, both

the urban poor and rural households predominantly use low efficiency end-use devices. Of the total energy demand, industry represents 12 percent, transport sector demands about 4 percent, followed by 1 percent consumed by the service sector. Of the total demand for electricity, industry takes up nearly 50 percent. Biomass demand, at 88 percent, is indeed the most popular form of energy resource, followed by petroleum at 6 percent, electricity at 3 percent, and coal at 3 percent (in that order). Petroleum is mostly demanded by the transport sector, followed by industry.

Almost all electricity in Malawi is generated from hydro turbines. With an installed power of 282 Mega Watts, the electricity is not enough to meet demand, which is estimated to be growing at 6 percent per annum (ESCOM, 2011). There are three river-propelled generation stations in Shire River and one in the Northern region of the country. In addition, Malawi has solar power, wind energy, and other biofuel resources such as *Jatropha*.

Costs of renewable energy adoption include the slow diffusion of important information and perceived costs associated with new things. There are social, economic, political and even cultural costs, which are perceived. Jaccard and Dennis (2006:91-92) show that, for both consumers and business people, some new technologies are usually perceived to pose greater risks of failure or unforeseen operating problems, meaning that realised financial costs exceed anticipated financial costs.

In general, Malawi, just like most countries in the SSA region, is seen as well endowed with renewable energy sources. However, the proportion of renewable energy sources (excluding hydroelectricity) in the total energy balance has remained insignificant, standing at, approximately, 0.2 percent (Kambewa & Chiwaula, 2010:5). This is attributed to the prevalence of a number of technical, economic, skills, institutional, and socio-cultural barriers.

This chapter has presented a profile of the energy sector in Malawi, both from the demand and supply side. The discussion has confirmed that in Malawi, both in rural and urban areas, biomass remains the major source of energy. It was of particular interest to

note that, even in industry, biomass represents about 90 percent of the total energy demanded, which is on par with household levels. The history of power generation and supply from 1948 has been discussed, together with the barriers that are affecting the clear roll out of renewable energy activities. The next chapter presents the research design and methodology that was used to address the main objectives of the thesis.

CHAPTER 6 DEMOGRAPHIC, ECONOMIC AND ENERGY PROFILE OF SOUTH LUNZU

6.1 INTRODUCTION

Many studies in the area of poverty and socioeconomic development have concentrated on rural areas. In particular, energy poverty studies in many parts of the world have emphasised rural energy problems leaving out urban poor communities without better alternatives (Luoga *et al.*, 2000:244; Karekezi & Kithyoma, 2002:1075; Pegels, 2010: 4945; Abebaw, 2007:117). Due to high urbanisation rates in Africa, cities are swelling with many informal settlements.

Where many households hoped to depend on electricity, the supply has two main problems. Firstly, electricity supply in Africa, in general, and Malawi, in particular, is unreliable due to aging generation stations meant for smaller populations. In Malawi, for example, the generation capacity of about 283 MW was installed when the population was around 3 million in 1960s. Current electricity demand, however, is estimated to be around 340 MW per day, which creates pressure on the suppliers to ration electricity between households and industry (Government of Malawi - Malawi Growth and Development Strategy II, 2012:77).

Secondly, the cost and wiring standards required for a house to be electrified are not affordable to the average Malawian for two reasons. Firstly, many people are self-employed in relatively unsustainable small and micro business entities. For those formally employed, the income they get is too small to afford any decent house ownership schemes. Secondly, ESCOM requires that for a house to be electrified it must be built from brick. Most people stay in houses that are built from cheaper materials, rendering them unable to qualify for electrification.

This chapter presents a discussion of the results of the econometric analysis of energy poverty and sustainable development in Blantyre, Malawi. Prior chapters thus far laid

the foundation of the research by considering the theoretical basis and similar empirical studies in the past. Chapter 6 describes the procedures and methods this thesis adopted to perform the analysis in order to answer questions raised in Chapter 1.

In this chapter, Section 6.2 gives an expressive analysis of the data using descriptive statistics, such as the mean, maximum and minimum values, and standard deviation. Further, frequency tables and graphs, such as histograms, bar and pie charts were also brought into play. Section 6.3 contains a presentation of econometric demand systems. On energy demand systems, Engel functions were adopted. Discrete Choice models are followed by logistic regression and a multinomial Logit model of consumer behaviour as it related to energy commodities. The chapter concludes by presenting the results of the energy poverty computation together with the energy poverty gap. Employing the Logistic model, probabilities of households being energy poor are predicted. Stata 12 was used to implement the analyses.

6.2 SAMPLING TECHNIQUE AND QUESTIONNAIRE DEVELOPMENT

The data for this thesis was collected at the household level in South Lunzu Township in the city of Blantyre, Malawi, between December 2011 and January 2012. The sampling technique was multistage, starting with a purposeful country selection of Malawi because of its economic position, being one of the poorest countries in the world. In Malawi, Blantyre city was chosen as it had the highest population compared to other cities in Malawi. Furthermore, Blantyre is the hub of economic and manufacturing activities, implying that the demand for energy, both at the household and industry level, was expected to be higher than other cities.

A standard questionnaire, which is attached as Annexure B, was adapted from Sekhampu (2009:258). However the tool was fine-tuned to include questions regarding energy poverty. Further, it was observed that certain items such as social grants and child grants are not provided in Malawi. Consequently, questions relating to such items were removed. In addition, specific questions were added that addressed the energy

sector with specific attention to renewable energy, energy expenditure at the household level, types of energy facilities normally used, and access to modern facilities.

The questionnaire was pretested in Nkolokoti Township for reliability in gathering the intended information and data. As already indicated in Chapter 4, Nkolokoti Township has many things in common with South Lunzu Township, apart from being immediate neighbours. After each of the 8 interviewers visited at least three households, the questionnaire was further fine-tuned on two accounts. First, some of the questions were still capturing data using the South African Rand, which necessitated a change to the Malawian Kwacha in order to enhance understanding for respondents. Second, some of the questions were found to be long, redundant and difficult to explain in the vernacular, Chewa. However, the intended data and information was largely collected. After the changes, the questionnaire was then taken to South Lunzu Township where the study took place.

As shown by the Population Census of 2008 by the National Statistical Office, Blantyre city had a population of 661 256 persons. In particular, South Lunzu Township had 37 864 persons (NSO, 2009). The Census, however, could not state how many households were in South Lunzu. However, given an average household size of 5 people, according to the findings of this thesis, the sample represented about 23 percent of households in South Lunzu Township, which is fair coverage for decision making. Using random sampling, where one in every five households was visited, a total of 400 questionnaires were administered using face to face interviews to the head of household. The definition of head of household was according to cultural practice in Malawi where a husband is regarded as so. As such, the first person of contact at the household was the male spouse and where the male spouse was not available, the wife was requested to be interviewed.

6.3 DESCRIPTIVE STATISTICS OF CONTINUOUS SURVEY DATA

First, descriptive statistics of mean, minimum, maximum and standard deviation for continuous data was calculated, the results of which are summarised in Table 6.1.

Home size was represented by *hmsize*, and it was a measure of the size of dwelling unit in square metres. Interviewers, together with the respondents, were measuring the size of the house using tape measures to determine the actual size of the house. As can be observed from the table, the surveyed households had a minimum home size of 8 square meters, with a maximum of 540. The average home size, as measured by the mean, was 69 square metres with a standard deviation of 49.

Table 6.1 Descriptive Statistics for Continuous Data

Variable	Observations	Mean	Std. Deviation	Minimum	Maximum
Hmsize	318	68.92296	48.90312	8	540
Hhsize	319	5.003135	1.991331	1	14
wtp_clean	319	879.2194	3515.564	0	50000
wtps_moke	319	620.4389	1123.249	0	10000
pit_cost	319	429.7806	689.4695	0	4000
Educ	316	10.81646	3.122552	1	16
Income	317	41629.4	61871.6	0	570000
Age	319	38.36	11.815	14	82
Eexp	318	3570.314	2776.087	0	30000
Texp	316	51537.57	44525.82	5500	269800
Estb	316	0.088991	0.065064	0	0.594059

Source: Energy poverty and sustainable development survey, (2012)

Household size, which was represented by *hhsiz*e, was used to measure the number of inhabitants in a dwelling unit. The respondents were asked to provide the number of permanent members of the household who were staying at the dwelling unit at the time of the interview. Permanent residents included those members of the household who were away temporarily, such as students in boarding schools and patients admitted into hospitals. On average, each household had 5 people with a maximum of 14 and

minimum of 1. This compared relatively well with the estimated national household size by the National Statistical Office of about 4.5 persons (NDO-IHS3, 2012). A standard deviation of about 2 indicated that there were little disparities in the number of people in each of the households visited in the survey.

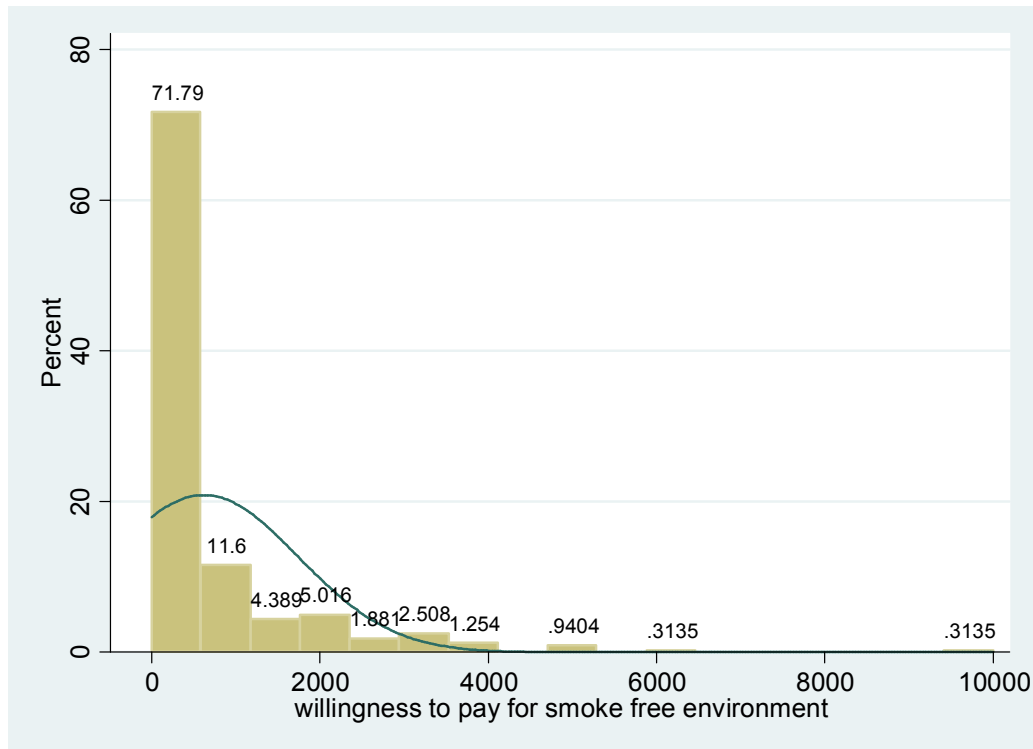
In terms of willingness to pay for a clean environment represented by *wtp_clean*, a standard deviation of 3516 indicated that there were very large disparities in the amount of money respondents were willing to part with to have their environment clean. This is easily observed from the table where one respondent was willing to pay up to MK50 000 (about US \$310 with a foreign currency exchange rate of MK161 = US \$1 as of December 2011 and January 2012), and yet others had no willingness to pay at all. On average, however, people in South Lunzu Township, as represented by the respondents in the sample, were willing to pay up to MK880.00 (US \$5.5 or ZAR44) in order to have their environment clean.

Related to willingness-to-pay for a clean environment, respondents were asked whether they were willing to pay for a smoke free environment. This was in regard to smoke from burning of wood and nearby factories. Willingness-to-pay for a smoke-free environment was represented by *wtps_moke* and in Table 6.1 the minimum was 0 and the maximum was MK10 000 (US \$71) with a standard deviation of 1123. The average willingness to pay for a smoke free environment was MK620 (US \$3.8).

Figure 6.1 shows the distribution of willingness-to-pay for a smoke free environment. Clearly, more than 70 percent of the respondents were not willing to pay anything for a smoke free surrounding. Although some were willing to pay something, most of them had a below average willingness-to-pay for a smoke free environment. This then raises the question of whether those people unwilling to pay anything for a smoke free environment, would be willing to stop using biomass for their daily household energy needs. It was an indication that external and direct effects of using inefficient energy facilities such as wood, charcoal, paraffin and farm residues were not appreciated as much to influence respondents to pay for their comfort. This is a challenge, therefore,

for sustainable development practitioners to advance the knowledge of climate change problems associated with the use of biomass.

Figure 6.1 Distribution of WTP for a smoke free environment

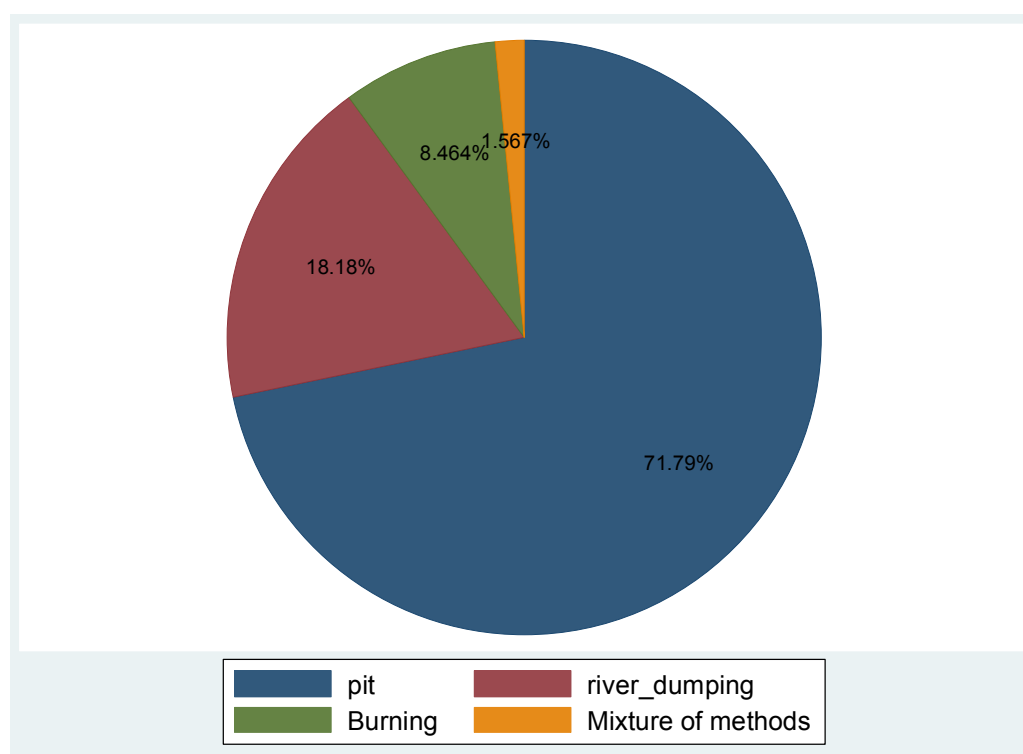


Source: Energy poverty and sustainable development survey, (2012)

On the other hand, residents of the area could feel that their environment is clean, without any need for further special programmes to wipe out the smoke.

The youngest head of household to be interviewed was 14 years old and the eldest was aged 82. The average age of the sampled respondents was about 38 with a standard deviation of about 11.9. Age was considered an important factor in consumer energy decisions because younger people were expected to demand more modern facilities as compared to older generations.

Figure 6.2 Distribution of waste management techniques in South Lunzu



Source: Energy poverty and sustainable development survey, (2012)

Figure 6.2 summarises waste management methods used by households in the Township. Out of the 319 households, 229, representing 72 percent, rely on a waste pit to keep away garbage, 18 percent take their refuse to a market place where the city council has a garbage collection point servicing the market, 8 percent dump it along river banks, and 2 percent use a mixture of methods, including burning of the garbage.

In Table 6.1, pit_cost represents the cost of digging one waste pit. For those who depend on a waste pit to dispose their home garbage, the average cost of the pit was MK690 (about US \$4.26) per pit. The most expensive pit was dug at MK4 000 (US \$25), while several others were self-dug by the members of the household. Other factors,

such as depth of pit, ground hardness, unregulated market for pit digging, and relationship of the economic agents, among others, were not taken into consideration. These factors could affect the price of the waste pit, however, this was not the main thrust of the thesis.

Education was measured by the number of years of formal schooling a head of household completed as of the time of the survey. It was represented by *educ*. Where it was reported that a head of household repeated a school year, it was recorded as one year. Therefore, the respondents were asked to state their level of education from which the number of years of formal schooling was inferred, following Malawi's education system. An individual would have spent 8 years of formal schooling if they stated that they had a Primary School Leaving Certificate, 10 years if they had a Junior Certificate of Education, and 12 years if they had a Malawi Schools Certificate of Education (MSCE) which is equivalent to O-Levels in the British school system. The most educated head of household had finished 16 years of progressive schooling, leading to a first degree, while the least educated had only 1 year of schooling. On average, head of households had 11 years of formal schooling, basically implying the completion of, at least, Junior Secondary School level.

Taking income earned by the head of household to proxy household earnings, the highest amount was MK570 000 (about US \$3519) per month, with the lowest making nothing at all. The average income for the sample's households was MK41 630 (about US \$257) per month. Income inequalities among the households were noted, as evidenced by a large standard deviation of 61872. Such a disparity in income distribution does not come as a surprise as the affordability of plots and accommodation in general attracts dwellers from all income groups. Generally, South Lunzu is regarded as a descent residential area with every plot facing a feeder road coupled with a relatively good water supply network, even though it is classified as a high density area (Blantyre City Assembly, 2007:3). These services, in themselves, attract the emerging middle class and lower class alike to mix hence the large inequalities.

Respondents were also grouped according to their income category to better understand the discrete distributive nature of income earnings. As can be observed from Table 7.2, about 31 percent of the heads of households had income levels between MK0 and MK15 000 (US \$94), and 32 percent earned incomes between MK15 001 and MK30 000 (US \$186). Those in the income group whose earning was between MK45 000 and MK60 000, were 29, representing about 9.1 percent of the sample. About 3.2 percent of the heads of households were earning between MK60 001 and MK75 000 per month, making it the smallest cluster.

The highest earning category with incomes above MK75 000 represented about 11.7 percent of the heads of households in the surveyed sample. Over 60 percent of the respondents in the sample reported that they were earning below the mean income level of MK41 630, implying that there were more people struggling to make ends meet in relative terms.

Table 6.2 Frequency Distribution among Income Groups Surveyed

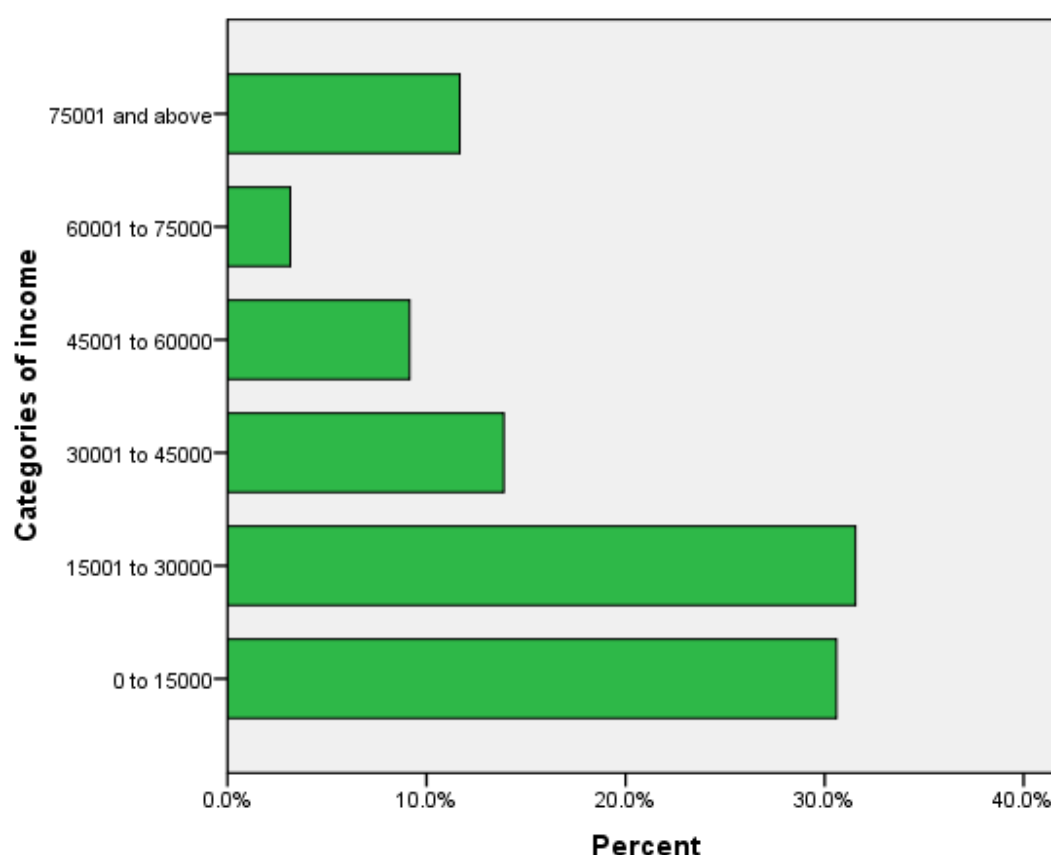
	Frequency	Percent
MK0 to MK15 000	97	30.6
MK15 001 to MK30 000	100	31.5
MK30 001 to MK45 000	44	13.9
MK45 001 to MK60 000	29	9.1
MK60 001 to MK75 000	10	3.2
MK75 001 and above	37	11.7
Total	317	100

Source: Energy poverty and sustainable development survey, (2012)

Total expenditure on goods and services was represented by *texp*. The relationship between total expenditure and income is depicted in Figure 6.3. The highest monthly expenditure recorded was MK269 800 (about US \$1665), with a minimum of MK5 500

(about US \$34) per month. It is of interest, however, to note that, in general, in all the areas surveyed there was over expenditure compared to the reported income except for Area 6. The average monthly household expenditure was MK51 538 (about US \$318), which is higher than an average monthly income of MK41 630 (about US \$257). Just like income, expenditure also had inequalities, with a standard deviation of 44525.82.

Figure 6.3 Frequency distribution of income groups in South Lunzu



Source: Based on energy poverty and sustainable development survey, (2012)

Table 6.3 shows that about 5 percent of the households reported that their total expenditure was between MK0 and MK15 000 (US \$94 at the maximum cut-off point), about 31 percent were spending between MK15 001 and MKMK30 000 (US \$188 at the maximum of the cut-off point), and about 17 percent were spending amounts of, at

least, MK75 000 (US \$466). It is worth noting that over 60 percent of the households were spending below the average expenditure level of the sample, which was MK51 538 (about US \$318). This parallels the income pattern of the sample, where about 60 percent were earning less than the mean income amount.

Table 6.3 Frequency distribution among total expenditure groups surveyed

	Frequency	Percent
MK0 to MK15,000	16	5.0
MK15,001 to MK30,000	108	34.1
MK30,001 to MK45,000	69	21.8
MK45,001 to MK60,000	39	12.3
MK60,001 to MK75,000	32	10.1
MK75,001 and above	53	16.7
Total	317	100

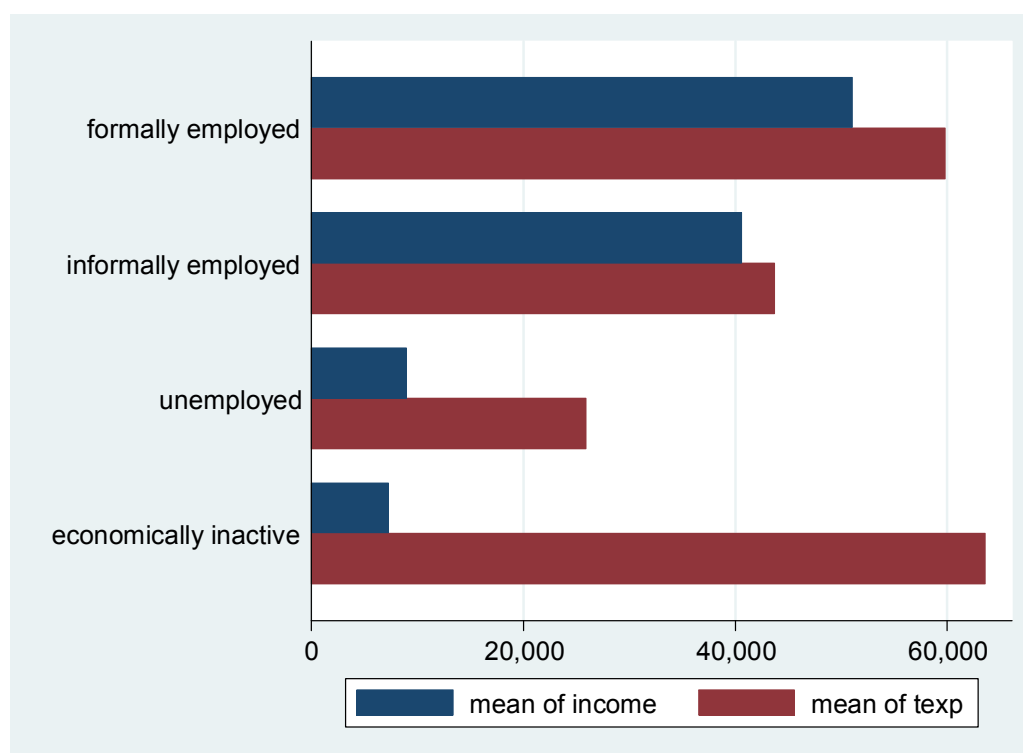
Source: Based on energy poverty and sustainable development survey, (2012)

Further, all income groups reported higher expenditures that exceeded their income levels, with those economically inactive spending the most, yet with the least income. Those formally employed were earning higher than all the other categories of employment status, as expected.

Variable *eexp* represented total monthly expenditure on energy commodities for each household. On average, as Table 6.2 shows, households were spending MK3 570 (about US \$23) per month on energy commodities and services. This included bill settlements, purchases of firewood, charcoal, and other fuels such as paraffin. The most spending household on energy needed MK30 000 (about US \$187) to satisfy their needs, while the least spending home needed no money resources at all to acquire energy facilities. Those households which reported zero expenditure on energy facilities relied on firewood collection from the nearby forests. It should be noted that this thesis

did not consider quantifying other means of costs, such as time spent collecting firewood and the inconveniencies caused during the process of energy facility acquisition.

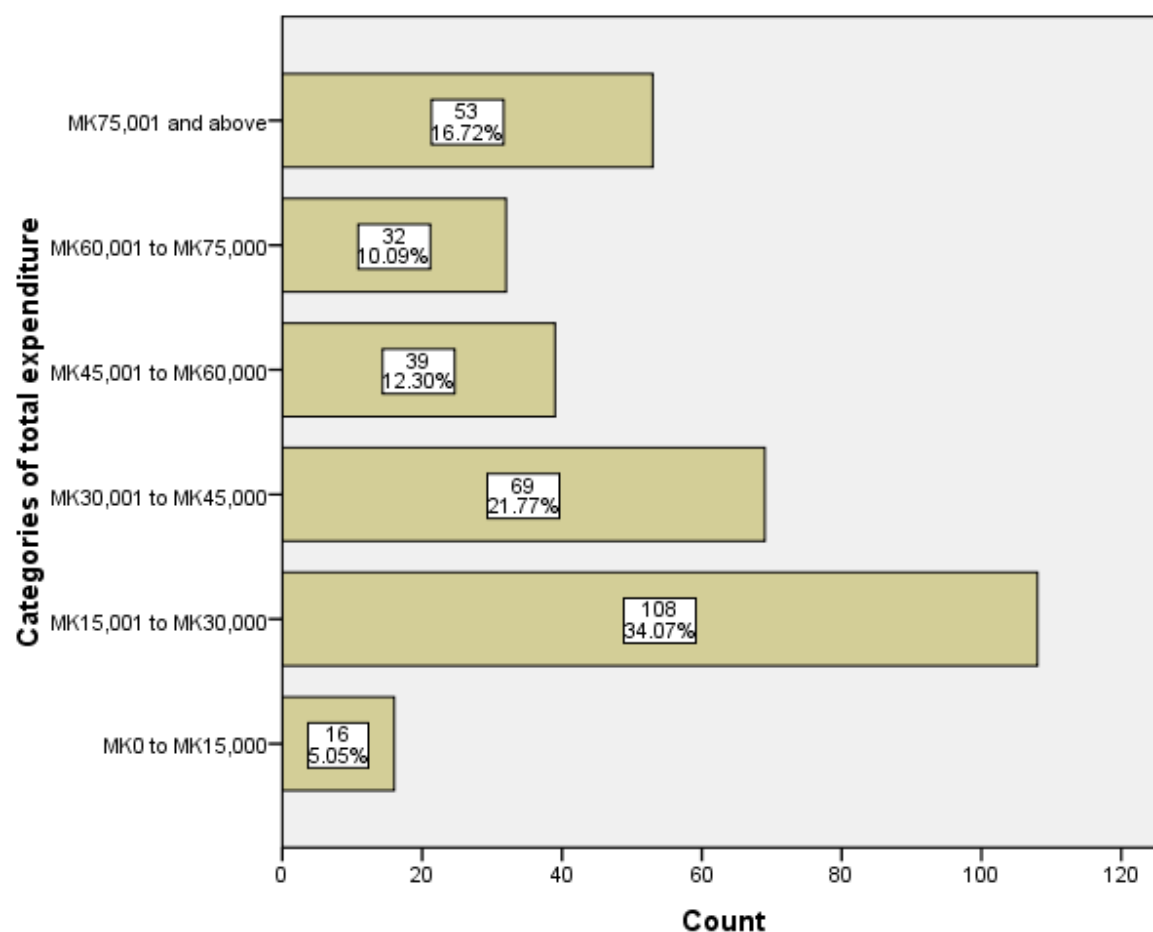
Figure 6.4 Employment status related to income and expenditure distribution



Source: Based on energy poverty and sustainable development survey, (2012)

Total cost of energy included an element of transport expenditure. For those with motor vehicles, expenditure on fuel per month was considered an expense on energy. For balance, those who commuted were also spending on transport, which was also considered as an expenditure on energy was. Having done so, as Table A.1.3 in Annexure A shows, the average total cost on energy commodities per household was MK9 644 (about US \$60), while the maximum cost was MK136 500 (about US \$848) against a minimum cost of MK170 (about US \$1). However, the standard deviation was relatively large at 11394.42.

Figure 6.5 Frequency distribution of expenditure groups

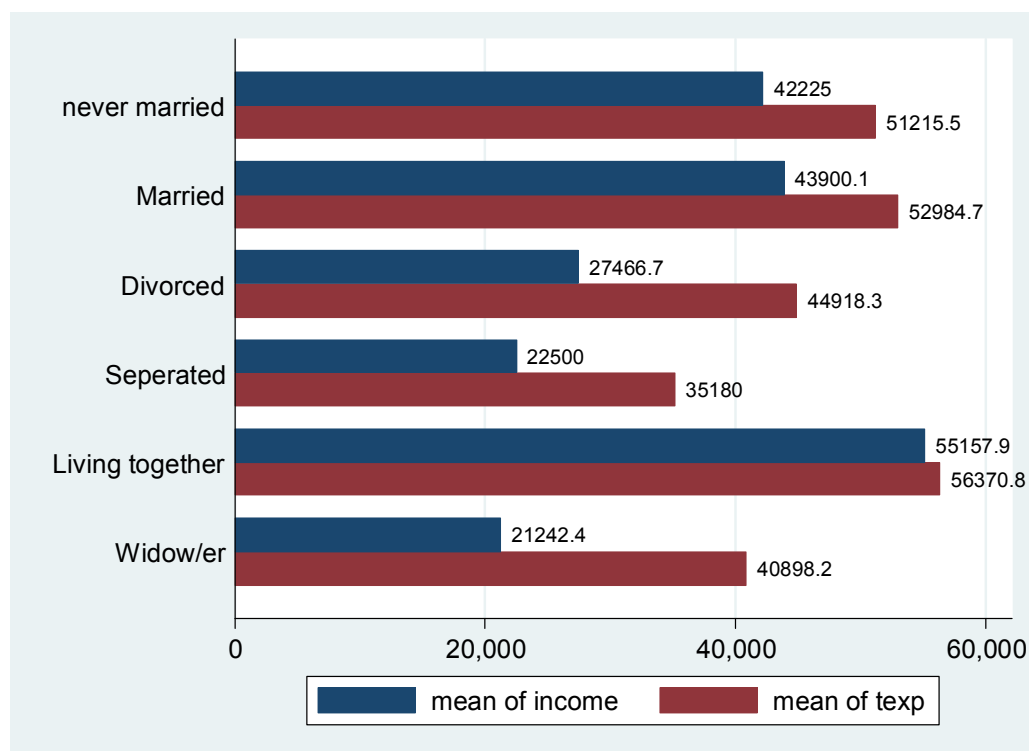


Source: Based on energy poverty and sustainable development survey, (2012)

A further analysis compared average income on the one hand, and average expenditure on the other hand, with marital status of the head of household. As Figure 6.6 shows, heads of household who have never married had an average income of MK42 225 (US \$256) and an average expenditure of MK51 216 (US \$310) per month. Married heads of households had an average income and expenditure of MK43 900 (US \$274) and MK52 985 (US \$331), respectively. The average monthly income and expenditure for heads of households who were divorced was MK27 466 (US \$171) and MK44 918 (US \$280), respectively. For separated heads of households, average income was MK22 500 (US \$140), and monthly expenditure averaged MK35 180 (US \$219).

Respondents who were living together, had the highest average monthly income level of MK55 158, and their monthly expenditure, averaging MK56 371, was also highest among the groups. Lastly, widows had the lowest average income level of MK21 242 (US \$133), and expenditure per month averaged MK40 898 (US \$255).

Figure 6.6 Distribution of income and expenditure by marital status



Source: Energy poverty and sustainable development survey, (2012)

6.4 DESCRIPTIVE STATISTICS OF CATEGORICAL DATA

Having profiled the population of South Lunzu Township with regard to continuous variables, the thesis turns to categorical data.

6.4.1 Summary statistics of Environmental Feeling

Respondents were asked to state their opinion on the cleanliness of the environment in which they live. About 209 respondents, representing almost 66 percent of the sampled heads of household, reported that the environment was clean, tidy and pleasant

compared to other townships. To them, the noise levels are bearable, the streets are relatively clean and free of litter, and the air was fresh without any need for improvements. As already stated in Chapter 4, South Lunzu is a relatively new area where the Blantyre City Assembly paved streets and provided social services, such as water and electricity. Every plot faces a street and the measurements are uniform compared to other Townships where many houses are built without following City Council's By-Laws (Blantyre City Assembly & UN-Habitat, 2007:5).

almost 11 percent of the respondents indicated that, to them, the environment was dirty, untidy and unpleasant, such that it needed urgent attention. From the sample, 12 respondents representing about 4 percent were indifferent, while 49 respondents representing 15 percent of the sample stated that the environment was not at the very best as it should be, but it could be attended to in a leisurely manner. However, 13 heads of household representing slightly above 4 percent of the sample, suggested that the environment was not as clean as it should be but it could be left as is, without any cleaning measures.

Table 6.4 Perception on condition of environment

Feeling of Environment	Freq.	Percent	Cum.
Clean and pleasant	209	65.52	65.52
Littered, untidy and dirty	36	11.29	76.8
Indifferent	12	3.76	80.56
something should be done to clean	49	15.36	95.92
it can be left as it is	13	4.08	100
Total	319	100	

Source: Energy poverty and sustainable development survey, (2012)

6.4.2 Respondent's Opinion on responsibility to clean the Township

As shown by the Blantyre City Assembly By-Laws, the responsibility of cleaning the surroundings within the jurisdiction of the Blantyre City Assembly rests in the hands of the Council (Blantyre City Council By-Laws, 1980). However, not all areas of the city get cleaning and sewerage service. South Lunzu is one of the Townships that do not benefit from this service.

The respondents were, therefore, also asked to give their opinion as to who they thought should be responsible for clean the surroundings. As shown in Table 6.4, 90 respondents, representing about 28 percent of the respondents, believed that it was the responsibility of the City Assembly (Municipality) to provide garbage collection services and all other basic cleaning facilities. Further, 42 respondents representing about 13 percent of the sampled households stated that a community committee should be set up to coordinate a continuous and voluntary street and environmental cleaning project. Of the respondents, 51 percent reported that households should be responsible for the cleaning of the area as a collective responsibility. In addition, 15 heads of household representing 5 percent of the respondents opted for a special once-off campaign coordinated by a nongovernmental organisation.

It was worth noting, however, that 8 heads of household representing about 3 percent of the respondents reported that street and environmental cleaning should be privatised by the City Council in order to achieve efficiency and effectiveness. This result was, however, not in agreement with an earlier thesis by Tchereni (2010:14), where privatisation of city cleaning services was favoured by 77 percent of the respondents with a willingness to pay for garbage collection averaging MK500 (US \$3) per month. It should be noted that in Tchereni (2010), there were only two options for garbage collection, namely City Assembly and private firms. By not mentioning the City Assembly, those who chose collective responsibility showed loss of confidence in the service the local city council has, so far provided, as far as cleaning of the Township is concerned.

Table 6.5 Summary of responsibility for cleaning the study area

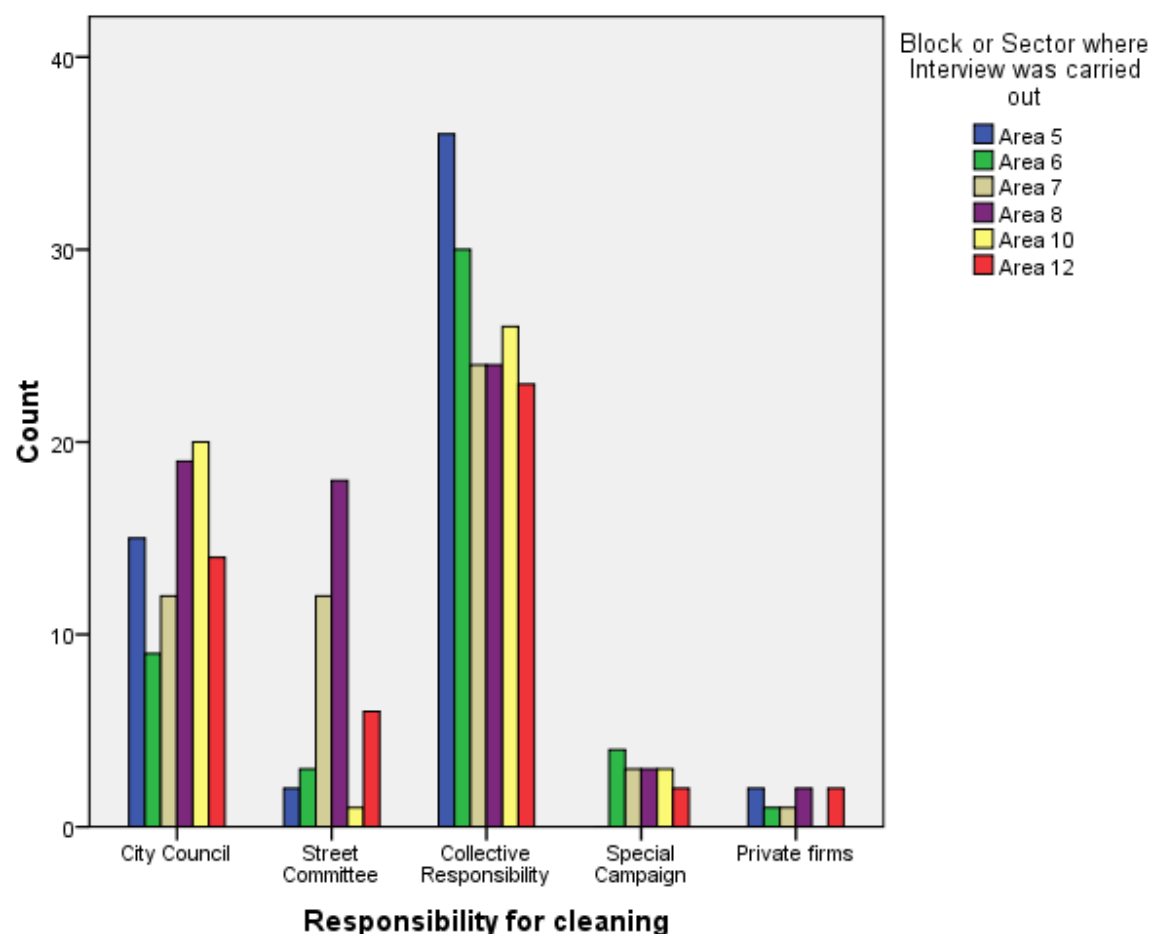
	Frequency	Percent
City Council	90	28.4
Street Committee	42	13.3
Collective Responsibility	162	51.1
Special Campaign	15	4.7
Private firms	8	2.5
Total	317	100

Source: Energy poverty and sustainable development survey, 2012.

The analysis went further to consider the opinions on responsibility of cleaning the surrounding environment by the area of residence within the Township. As already stated in Chapter 6 and the introduction to this chapter, the Township was demarcated into areas, or sectors, from number 1 to number 12 and the survey was implemented in 6 of the 12 sectors. As Figure 6.6 shows, residents in all the areas preferred the responsibility of making the environment clean, to be a collective responsibility, rather than leaving it in the hands of private firms.

The city council was the second choice to continue with the responsibility. Those who chose a special campaign were fewer in number compared to a once-off street campaign. In Area 10, fewer than 5 households opted for a street committee to be responsible. Further, the people of Area 10 in South Lunzu Township did not mention private firms to be responsible for the cleaning of the environment. Area 5 and 12, within South Lunzu Township, are the upcoming and new developments, where good dwelling units are being built. This probably explains the reason for more people in these areas to opt for private firms compared to the other areas.

Figure 6.7 Opinion on responsibility for cleaning by area of residence



Source: Energy poverty and sustainable development survey, (2012)

6.4.3 Energy Sources used for cooking needs

Table 6.6 is a summary of energy sources commonly used by the households. In total, the thesis administered 319 questionnaires, one to each household. Out of the 319 households, 2.9 percent frequently use hydroelectric power for cooking meals. Only 2 households representing 0.63 percent use LP Gas, and just 1 household representing 0.31 percent depend mostly on solar power. This is a worrisome development considering that solar power, electricity and LP gas are renewables and the percentage of those who use these resources combined is just about 3.84 percent.

Table 6.6 Percentage of households in relation to energy used for cooking

Cooking Source of Energy	Frequency	Percent	Cumulative Frequency
Electricity	7	2.19	2.19
LPG	2	0.63	2.82
Solar	1	0.31	3.13
Charcoal	80	25.08	28.21
Firewood	15	4.7	32.92
Electricity and Wood	79	24.76	57.68
Charcoal and Firewood	135	42.32	100
Total	319	100	

Source: Energy and Sustainable Development Survey, (2012)

On the other hand, energy facilities that are considered dirty, inefficient and a danger to health of people seem to be popular. For instance, charcoal and firewood is used by 80 households representing 25.08 percent of the sample, and 15 households representing 4.7 percent of the total sample, respectively. Most households use a combination of energy facilities, but still, those that are considered inferior are preferred. Of the sample, 135 households representing 42.32 percent use both charcoal and firewood to cook their meals. Based on these results, it shows that the use of renewable energy for cooking in Blantyre's South Lunzu has received very little response.

It is of interest to note that 79 of the households representing 24.76 percent of the sample used a combination of electricity, firewood and charcoal for energy needs to prepare their meals. In total, those who combine cooking energy sources represent 67.08 percent, indicating that there was more fuel stacking than reliance on one single

reliable resource. Households were not stable and satisfied enough to solely depend on a single resource to meet their cooking needs. Fuel stacking is a practice where economic agents mix different energy facilities for many reasons. Some of the reasons are the unreliability of the current resource. This is especially true in the case of electricity power cuts (black outs), which inconvenience people. As a way of hedging against such a phenomena households keep other sources of energy aside, such as charcoal, firewood, gas, paraffin or petroleum powered generators.

These results are within the ranges the Integrated Household Survey number 3 by the National Statistical Office (2012:120), which suggested that, at the national level, the most common source of cooking fuel in Malawi was firewood at 88 percent, followed by charcoal (9 percent), electricity (3 percent) and other means of fuel for cooking at 1 percent. Considering demarcation by place of residence however, NSO place of residence is considered, urban areas have a rather low proportion of households using firewood as source of cooking fuel, registering 42 percent, while rural areas have registered almost 96 percent.

6.4.4 Main source of energy for lighting homes

Table 6.7 summarises the percentage of households and their main energy resource used to light homes. Five categories, namely electricity, paraffin, candle and rubberised products, solar power, and batteries, were considered.

In this thesis, as Table 6.7 shows, it was found that for lighting purposes, 43 percent of the sampled households use electricity, 20 percent paraffin, and another 20 percent depend on candles and other rubberised products. Further, 15 percent of the sampled households depend on battery power to light their homes. This is in sharp contrast to results on cooking energy resources, especially regarding electricity, where 2.19 percent depend solely on electricity, and 24.76 percent of the households sampled use a combination of electricity on the one hand and firewood and charcoal on the other. This motivated a further analysis to consider the association between the resources for both cooking and lighting purposes.

Table 6.7 Main energy resource for lighting in homes

Energy source normally used to provide light in the household	Frequency	Percent	Cumulative percent
electricity	138	43.26	43.26
Paraffin	64	20.06	63.32
Candle and other rubberised items	63	19.75	83.07
Solar Power	6	1.88	84.95
Battery	48	15.05	100
Total	319	100	

Source: Energy poverty and sustainable development survey, (2012)

6.4.5 Association of Cooking and Lighting Energy Resources

A two way analysis was conducted to explore the relationship between cooking and lighting energy resources. Of interest was to find out whether those who use electricity for lighting also use it for cooking. The hypothesis under testing was that those who have electricity use it for lighting and not cooking because electricity is perceived as expensive and unreliable.

As Table 6.7 shows, out of the 319 households under scrutiny, only 6 of them were using electricity for both cooking and lighting representing about 2 percent of the sample. Of the entire sample, 1 household used solar power for both cooking and lighting, which was 0.31 percent of the sampled households. However, 131 households representing 41 percent of the sample use electricity for lighting and not cooking.

About 7 percent of the sampled households depended on charcoal for cooking needs but electricity was their source of light. Further, about 24 percent of the households depended on both electricity and charcoal for cooking needs on the one hand and electricity for lighting on the other hand. In addition, about 10 percent relied on fuel

wood, composed of a combination of both charcoal and firewood, for cooking but electricity was their main source of light energy.

Table 6.8 Association of cooking and lighting energy resources

Cooking Energy	Light					
	Electricity	Paraffin	Candle	Solar	Battery	Total
Electricity	1.88%	0.00%	0.00%	0.00%	0.31%	2.19%
LPG	0.31%	0.00%	0.00%	0.31%	0.00%	0.63%
Solar	0.00%	0.00%	0.00%	0.31%	0.00%	0.31%
Charcoal	6.58%	5.64%	6.58%	0.31%	5.96%	25.08%
Firewood	0.63%	2.51%	1.25%	0.00%	0.31%	4.70%
Elec & wood	24.14%	0.00%	0.63%	0.00%	0.00%	24.76%
Charcoal & wood	9.72%	11.91%	11.29%	0.94%	8.46%	42.32%
Total	43.26%	20.06%	19.75%	1.88%	15.05%	100%

Source: Energy poverty and sustainable development survey, (2012)

6.4.6 Income groups and cooking energy resource

A further analysis performed a cross tabulation between energy source commonly used for cooking on the one hand and income groups on the other. This was done to answer the question of whether richer households were spending their incomes on cleaner energy resources for cooking. The aim was to examine the relationship between energy source use and income groups. The results show that those in the income group between MK0 and MK15 000 do not use electricity only for their cooking needs and neither do they use LP gas and solar power. However, it shows that 59 of the households depend on a combination of charcoal and firewood. Of the households, 8 rely on a combination of electricity and fuel wood (here wood was combined with charcoal as one source).

Table 6.9 Source of cooking energy and categories of income

	Categories of income						Total
Source	0 to 15000	15001 to 30000	30001 to 45000	45001 to 60000	60001 to 75000	75001 and above	
Electricity	0	2	0	0	1	4	7
LP Gas	0	0	1	0	0	1	2
Solar	0	1	0	0	0	0	1
Charcoal	26	27	16	3	2	6	80
Firewood	4	10	1	1	0	0	16
Electricity and wood	8	13	12	15	7	21	76
Charcoal and wood	59	47	14	10	0	5	135
Total	97	100	44	29	10	37	317

Source: Energy poverty and sustainable development survey, (2012)

Out of the 37 highest earning households, 4 of them relied on electricity only for their cooking needs, 1 used LP gas, none used solar, 6 relied on charcoal. None of the top earning households considered firewood as their main source of cooking energy. The highest number of them, 21, relied on a combination of electricity and wood (here wood was combined with charcoal). In general, many households across all the income groups relied on a mixture of energy resources for their cooking needs with charcoal and wood being the most popular sources.

6.4.7 Employment Status of Head of Household

The choice of a particular energy facility might be a function of whether the head of household is formally employed or not. Table 6.10 is a summary of the distribution of employment status of the head of household. As can be observed in the table, 163,

representing about 52 percent of the sampled households, were formally employed at the time of the survey.

Table 6.10 Summary of employment status of head of household

Employment status of head of household	Frequency	Percent
Formal Employment	163	51.44
Informal Employment	112	35.78
Unemployed	24	7.67
Economically inactive	16	5.11
Total	313	100

Source: Energy poverty and sustainable development survey, (2012)

There were 112 respondents representing 36 percent who were active with informal employment, such as small and micro business enterprises, 8 percent were unemployed in any economic activity and 5 percent were economically inactive due to old age and sickness. Informal employment included trading in firewood, charcoal and paraffin in local market places. Some of the people were arbitragers, acting as middle people between suppliers from other places, mostly rural areas to urban dwellers.

6.4.8 Sector of employment of head of household

The employment status of the heads of household was also tabulated to analyse the sectors in which they were employed. Table 6.11 is a summary of the frequencies of heads of households according to the sector they are working in. As the table shows, the trading industry, as represented by retail and wholesale, was the highest employer for the heads of household in South Lunzu, with about 16 percent of the respondents employed in this sector. In this survey, about 32 heads of household representing about 16 percent were employed in the agriculture sector, about 2 percent were in the informal mining sector.

Table 6.11 Summary of employment sector of heads of household

Sector of employment	Frequency	Percent	Cumulative percent
Not Applicable	20	6.27	6.27
Agriculture	32	10.03	16.3
mining	7	2.19	18.5
manufacturing	38	11.91	30.41
Electrical, water and gas	35	10.97	41.38
construction	40	12.54	53.92
Wholesale, Retail	51	15.99	69.91
Transport	40	12.54	82.45
Finance	17	5.33	87.77
Community	37	11.6	99.37
other	2	0.63	100
Total	319	100	

Source: Energy poverty and sustainable development survey, (2012)

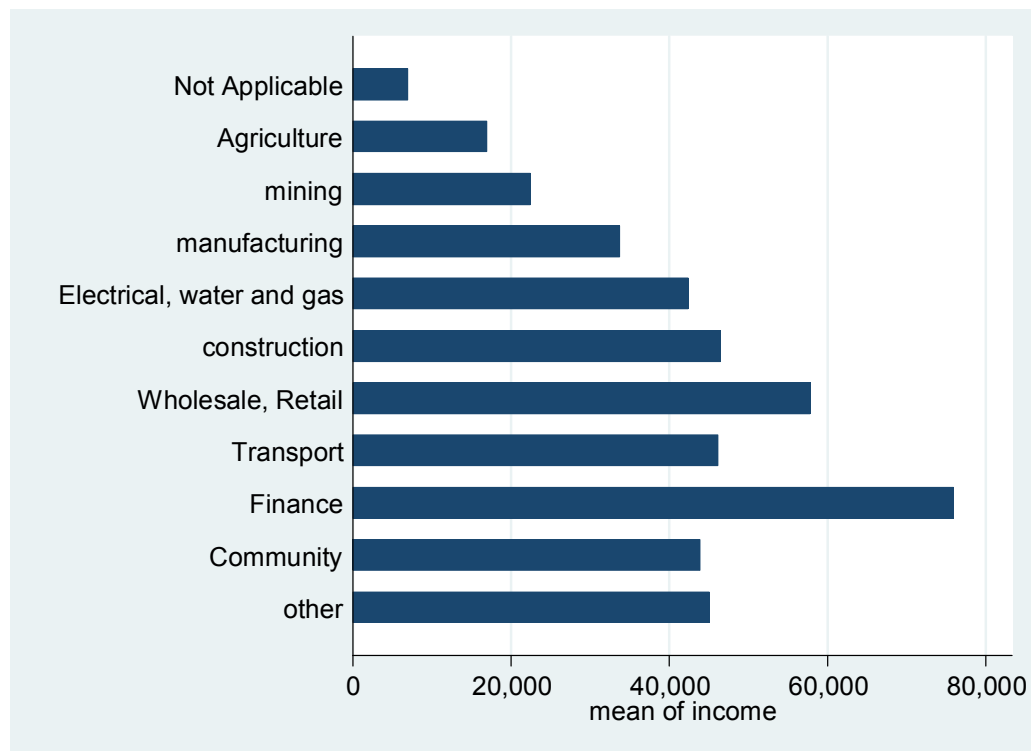
It is important to note at this stage that the type of mining involved in this area is for building materials such as river sand, building stones and quarry stone.

Almost 12 percent of the respondents were employed in the manufacturing industry, 11 percent were artisans in electrical, plumbing, carpentry and motor vehicle mechanics. The construction industry employed about 13 percent of the respondents. Just like the construction industry, the transport sector also employed about 13 percent of the sampled respondents; about 6 percent of the population were working in finance related positions; and 12 percent were involved in community development. Finally, about 1

percent of the sample was in other professions not defined and close to 7 percent was economically inactive.

6.4.9 Relationship between Income and sector of employment

Figure 6.8 Distribution of income by employment sector



Source: Energy poverty and sustainable development survey,(2012)

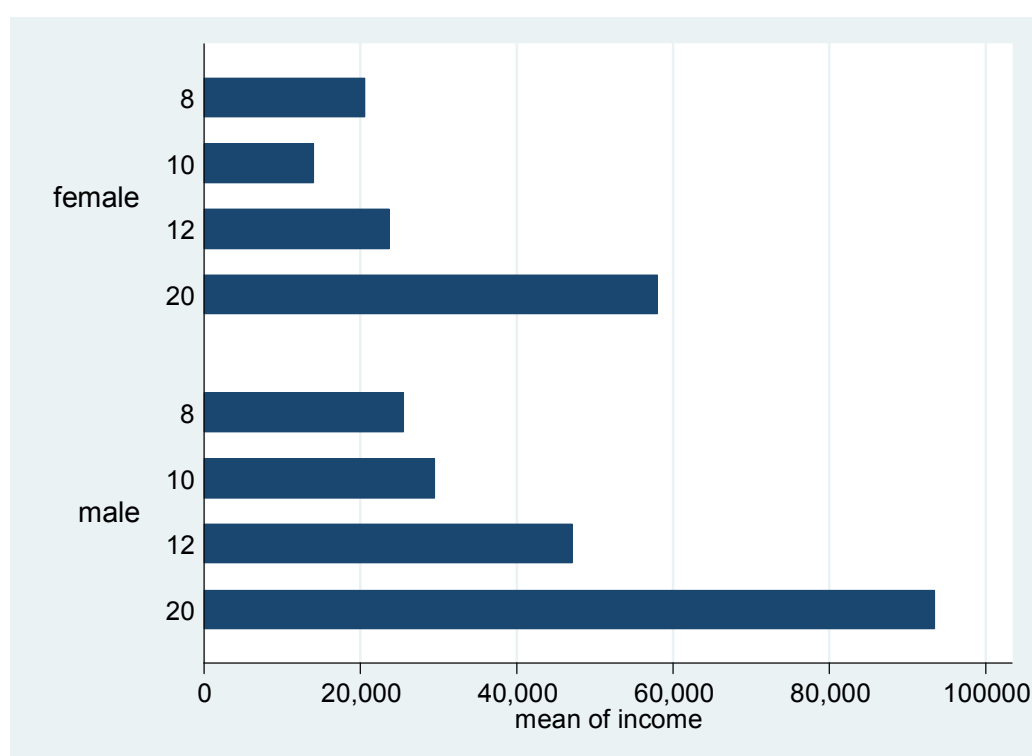
To further understand the employment dynamics of the area, the thesis went further to analyse the sectors in which employees were earning higher incomes. Figure 6.8 summarises the distribution and, as can be observed, sampled residents working in finance related jobs had the highest monthly average income level of close to MK80 000 (US \$500), followed by those in wholesale and retail sector with almost MK60 000 (US \$375).

The agriculture sector offered the least pay, averaging just below MK20 000 (US \$125) per month; mining industry just above MK20 000 (US \$125); and the manufacturing

sector offered an average of MK30 000 (US \$190). The artisans in fields such as electrical, plumbing, gas, welding and carpentry were almost on par with those in community development and other undefined sectors with their incomes averaging just above MK40 000 (US \$250).

6.4.10 Relationship between Income, Education and gender

Figure 6.9 Distribution of income by gender and education level



Source: Energy poverty and sustainable development survey, (2012)

Figure 6.9 reports a summary of the relationship between income and education level of the head of household on the one hand, and income and gender of the head of the household on the other hand. As Figure 6.9 shows, for female headed households the highest average income was about MK58 000 (US \$363) per month with an education level of above 12 years of schooling. For the male counterparts with the same level of education, the average income was almost MK75 000 (US \$469). Further, the

distribution in figure 6.8 suggests that for male heads of household, higher levels of education were associated with higher levels of income also.

The picture for female heads of household is similar to that of male heads of household although for those who went up to grade 10 their average income was slightly lower. In general, male heads of household had higher average income levels compared to female heads of household with the same level of education. For instance, for those who went up to grade 12, females had an average income of about MK13000 (US \$81) per month compared to their male counterparts whose income averaged about MK45000 (US \$281) per month.

6.5 RENEWABLE ENERGY PROFILE OF SOUTH LUNZU TOWNSHIP

This section profiles the renewable energy sector for South Lunzu Township to provide an in-depth analysis of the energy facilities commonly used, knowledge of the energy facilities and also the preferences for alternative energy resources.

6.5.1 Knowledge of Renewable Energy

Table 6.12 Respondent's knowledge of renewable energy

Respondent knows or heard about alternative energy	Household tried renewable energy		
	No	Yes	Total
No	109	1	110
Yes	158	51	209
Total	267	52	319

Source: Energy poverty and sustainable development survey, (2012)

The heads of household were asked two questions aimed at measuring the level of knowledge of renewable energy and use for their household needs. As table 6.12 shows, it was found that 109 of the heads of household representing 34 percent said

that they had no idea what renewable energy was and that they have never used any form of renewable energy in their life. About 158 households representing 50 percent of the respondents reported that they knew something about renewable energy but they had never tried it; they have knowledge of renewable energy but they have never used any resource that could be described as a renewable energy resource.

Of the 319 households visited, 51 of them (representing 16 percent) had ever used a renewable energy resource for their household needs.

6.5.2 Preference of alternative energy source if introduced

The thesis went further to find out the most preferred alternative energy resource if they were to be introduced to South Lunzu Township. In the questionnaire questions number 19 to 26 were framed to obtain this information. An assumption was made that where the respondents may not have used renewable energy before in their lives, they may have heard or seen it working in another area. Table 6.13 summarises results in both frequencies and percentages.

Table 6.13 Respondent's preference of renewable energy

Preferred alternative energy if introduced	Frequency	Percent
Solar	224	70.22
Wind	28	8.78
Geothermal	40	12.54
Petroleum	16	5.02
Biofuel	4	1.25
Not interested in anything	7	2.19
Total	319	100

Source: Energy poverty and sustainable development survey, (2012)

As Table 7.13 shows, 224 respondents representing about 70 percent of the sampled households indicated that they would prefer solar power to other sources of energy, 28 representing 8.8 percent mentioned that they would opt for wind power, 40 interviewees representing 12.5 percent opted for geothermal, and slightly above 5 percent chose petroleum. Solar energy is a popular source of energy in Malawi as can be seen from the results of this thesis. Geothermal was yet to be tried in Malawi as at the time of the survey. Petroleum products were associated with high risk of causing fires and, as such, they could not be relied upon as new sources of energy. Only 4 respondents mentioned biofuels, representing slightly above 1 percent of the sample and 7 of them representing about 2 percent were not interested in any renewable energy product.

6.5.3 Preference of renewable energy source by gender

Table 6.14 Preference of renewable energy resource by gender

Introduced	Female	Male	Total
Solar Power	81 (70.43%)	142 (69.95)%	223
Wind Power	13 (11.30)%	22 (10.84)%	35
Geothermal	11 (9.57)%	29 (14.29)%	40
Petroleum	7 (6.09)%	9 (4.43)%	16
Biofuels	3 (2.61)%	1 (0.49)%	4
Total	115 (100%)	203 (100%)	318

Source: Energy poverty and sustainable development survey, (2012)

Table 6.14 further tabulates frequencies and percentages of respondent's preference of renewable energy resources categorised by gender of the head of the household interviewed. It can be observed from Table 7.12 that about 70 percent of females preferred solar power, which was the almost the same for males at about 70 percent. It was also almost the same percentage of 11 percent for both male and female headed households that preferred wind energy.

Geothermal was preferred by about 10 percent of the female heads of household while about 14 percent of male heads of household opted for it. Petroleum was a preferred energy resource by about 6 percent and 4 percent of the female and male headed households, respectively. Finally, 3 percent of the female heads of household preferred biofuels and less than 1 percent of the male heads of household opted for biofuel.

6.5.4 Reasons for not using preferred renewable energy resource

Table 6.15 summarises the reasons why the heads of households were not using their preferred energy resource. Table 6.15 further disaggregates the reasons to analyse the particular preferred energy resources, given the reasons in Table 6.15 for not using it.

When asked why the preferred renewable energy facility was not being used, 52 percent of respondents indicated that their preferred renewable energy resource was expensive. Of the 166 respondents who mentioned expensive, 125 representing 73 percent had solar power as their preferred resource; 10 representing about 6 percent preferred wind energy; 24 representing about 15 percent favoured geothermal; 6 representing about 4 percent chose petroleum; and slightly below 1 percent preferred biofuels.

The picture, therefore, is that there are more people who would want to use solar power in their households but they generally do not use it because they perceive it to be an expensive resource. As a result, they still use the other available resources, which have shown to be biomass, affecting the environment and their own welfare too. There were also people willing to adopt wind energy and geothermal but they perceived their preferred energy resources to be expensive.

For the other reasons, 79 respondents representing about 25 percent of the sampled heads of household, reported that their preferred renewable energy resource was not available on the market for them to buy and test. Of the 79 who indicated unavailability of their resource, 58 representing about 73 percent preferred solar power; 14 representing about 18 percent chose wind power; 2 representing about 3 percent opted for geothermal and biofuels; and 3 representing about 4 percent favoured petroleum.

About 24 respondents representing 7.5 percent indicated that they do not understand how their preferred renewable energy resource works and what it needs in order for it to be used effectively. Out of the 24 who indicated that they do not understand their preferred energy resource, 13 representing 54 percent preferred solar power; 3 standing for 13 percent chose wind power; 6 representing 25 percent favoured geothermal; and 2 heads of household representing 8 percent chose petroleum.

Table 6.15 Respondent's reason for not using renewable energy

Reason for not using the renewable resource now	Frequency	Percent	Cumulative
Expensive	166	52.04	52.04
Not available	79	24.76	76.80
Don't understand them	24	7.52	84.33
Not seen them working	14	4.39	88.71
Not reliable	15	4.70	93.42
Satisfied with current resource	21	6.58	100
Total	319	100	

Source: Energy poverty and sustainable development survey, (2012)

In Table 6.15, about 14 respondents representing 4 percent of the sample pointed out that they have heard about their preferred energy facility but they had not seen it working and such they could not fully commit their resources to buy and try it. Out of the 14 heads of households in this category, 7 representing 50 percent chose solar power; 6 representing 43 percent of the households favoured wind power; and 1 representing 7 percent preferred geothermal. Further, out of a total of 319 respondents, 15 believed that their preferred renewable energy resource was not reliable enough for the purposes they wanted it. This represented 4.7 percent of the total sample. Out of the 15, 10 heads of households representing 67 percent preferred solar power; 2 representing 13 percent opted for geothermal and petroleum; and 1 representing 7 percent opted for biofuels.

This means that there is willingness for people to purchase some form of renewable energy but there is a belief that the abilities are limited.

Finally, another group composed of 6.6 percent of the sampled respondents stated that they were satisfied with the energy resources they were using at the time of the interview, although they too had a preferred renewable resource. For those satisfied with the resource they were using, 11 representing 52 percent preferred solar power; 2 heads of households representing about 10 percent chose wind power, 5 respondents representing 24 percent preferred geothermal; and 3 respondents 14 percent favoured petroleum.

Table 6.16 Two-way analysis of RE preference and reason for not using them

Preference of RE if introduced	reason for not using Preferred RE						
	Expensive	Not available	don't understand	Not seen	Not reliable	Satisfied	Total
Solar Power	125	58	13	7	10	11	224
Wind Power	10	14	3	6	0	2	35
Geothermal	24	2	6	1	2	5	40
Petroleum	6	3	2	0	2	3	16
Biofuels	1	2	0	0	1	0	4
Total	166	79	24	14	15	21	319

Source: Energy poverty and sustainable development survey, (2012)

This supports the notion that there is a belief that many sources of renewable energy can only do certain things, such as lighting only or operating small appliances such as radios but not cooking, ironing and refrigeration. This limitation poses a challenge to marketers, non-governmental organisations, government agencies, academia, and community leaders to bring awareness to the people of other strengths certain renewable energy resources are capable of doing by producing enough energy for

important needs such as cooking meals at the household. There seems to be more options for lighting homes than there are for cooking needs and these energy facilities, which have the ability to heat and cook meals, need to be highlighted to potential consumers.

6.5.5 Willingness to stop using Biomass

As explained in Chapter 1, some forms of biomass, such as firewood and charcoal are commodities that have an appeal to the poor in many developing countries such that politicians face problems to influence such people to stop using them (Chineke & Ezike, 2010). Entrepreneurs regard this commodity as a money spinner by considering the amount of people that are interested to use it while consumers look at it as the only available resource that is affordable (Ethio Resource Group Pvt Ltd, 2007:21).

Table 6.17 Respondent's Willingness to stop using biomass

Willingness to stop using Biomass	Frequency	Percent
No	63	19.75
Yes	256	80.25
Total	319	100

Source: Energy poverty and sustainable development survey, (2012)

This prompted the thesis to investigate whether the respondents were willing to stop using biomass as main energy resources in their households if other better resources could be introduced. Table 6.17 summarises the results of that question and from the table, 256 heads of household representing about 80 percent of the respondents said that they were willing and ready to stop using biomass, against 63 respondents representing just fewer than 20 percent who said that they were not willing to do so.

6.5.6 Expected Action to Prompt Respondent to stop using Biomass

Regarding the actions the people would want to see to prompt them stop using biomass, 69 of the respondents representing about 22 percent of the sample indicated that government should put a mechanism that will ensure that; first, the use of biomass class of energy resources is banned. Secondly, those using biomass should be punished under a law.

Just above 47 percent (151 respondents) said that government should subsidise renewable energy so that even poor people can afford to purchase it. Since most people regard renewable energy as expensive and that electricity supplied by ESCOM is unreliable, they believe that they can abandon firewood and charcoal for renewable energy if the price is at the same level with what they spend on their energy budget. The gap, therefore, must be subsidised by government.

There were ten heads of households representing slightly above 3 percent who indicated that it is important for government and other authorities to consider heavy campaigns that should sensitise people to the dangers households face by continuing to use biomass. Such dangers could include health hazards, loss of time, possible desertification of the land, and climate change consequences.

Another group of respondents, totalling 17 representing slightly more than 5 percent of the sample, believed that sensitising people on the advantages of renewable energy could go a long way to influence them stop using biomass and opt for RE. A considerably large group of 23 respondents representing about 23 percent of the sample, suggested that the solution is for authorities to provide reliable electricity that is also affordable. The unreliability of electricity is what makes them have an energy mix with biomass as a fallback position.

Table 6.18 Expected action to prompt respondent stop using biomass

expected action to prompt respondent stop using Biomass	Frequency	Percent
Ban them	69	22
Subsidise alternative energy	151	47.34
Sensitise people on dangers of Biomass	10	3.13
Sensitise people on advantages of renewable energy	17	5.33
Provide reliable energy	72	22.57
Total	319	100

Source: Energy poverty and sustainable development survey, (2012)

6.5.7 Perception on Wellbeing

Table 6.19 Perception on well-being

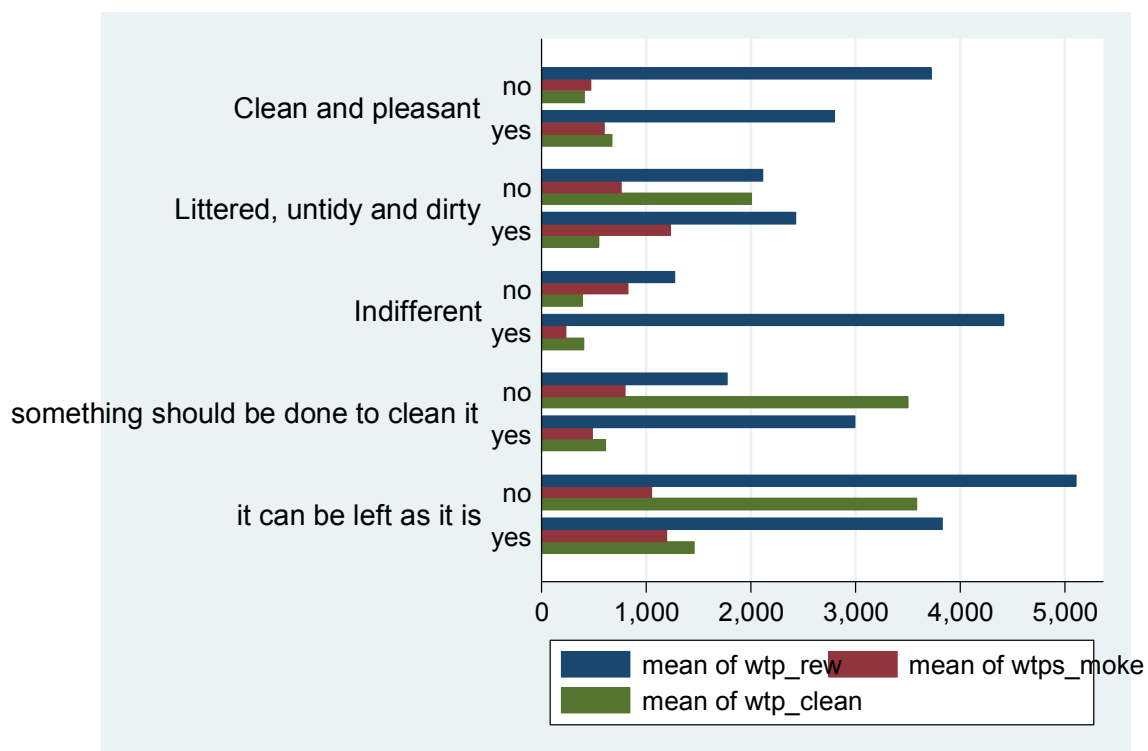
Perception on wellbeing	Frequency	Percent
Not Poor	159	50
Poor	159	50
Total	318	100

Source: Energy poverty and sustainable development survey, (2012)

The thesis went further to investigate the perception regarding level of poverty. This was done to establish whether people do not use renewable energy because they consider the resources to be for the rich. Certain energy facilities, such as electricity, solar, wind power, and LP gas could be regarded as superior and luxurious at the same time by those who consider themselves to be poor. As a result, they may not use such facilities and concentrate on unclean and inefficient products such as firewood, charcoal, rubber, and plastics because they are considered affordable and available for the poor people.

As can be seen from Table 6.19, there was an even distribution of the perceptions. About 50 percent of the sample declared that they regard themselves as being poor. The same proportion, 50 percent, also regard themselves as not being poor.

Figure 6. 10 Relationship between WTP for RE and WTP for Smoke free Environment by poor and environmental feeling



Source: Energy poverty and sustainable development survey, (2012)

A further analysis that was necessary was to compare the relationship between willingness-to-pay for renewable energy facilities, willingness-to-pay for a clean environment and willingness-to-pay for a smoke free environment, on the one hand as they relate to the perception of wellbeing and environmental feeling on the other hand. The aim was to analyse whether those who believe to be poor also have a lower willingness-to-pay for renewable energy, smoke free environment and a clean environment, respectively. Figure 6.10 shows that for those respondents who believed not to be poor and believed that the environment was clean and smoke free had a mean

WTP for renewable energy of slightly above MK3 700 (US \$23), a lower WTP for both a smoke free environment and a clean environment of less than MK500 (US \$3). Indeed, as it was expected, households who do not have any problem with the environment would not be willing to pay anything to improve an already better situation for them especially where they deem themselves as not being poor. On the other hand, those who believed to be poor and that their environment was clean had lower level of WTP for RE, smoke free environment and a clean environment.

The figure further reveals that respondents who were indifferent about the state of the environment and believed themselves to be poor had the second highest average WTP for RE, after those who believed not to be poor and had no problems with the environment, although it did not necessarily mean that it was pleasant. The latter group had a mean WTP for RE of slightly above MK5 000 (US \$31), compared to the former whose WTP for RE was MK4 500 (US \$28). This result suggests that those who believe themselves to be better off on the wellbeing ladder can also afford to pay for renewable energy commodities.

Of interest to note was the result that those who believed that the environment was not pleasant, that it was dirty, untidy and polluted had a relatively smaller WTP for RE. The opposite should have been expected since such people would want the environment to be clean and, therefore, willing to pay higher amounts of money resources to be comfortable. This suggests that as much as there were households which were not happy with the use of unclean energy facilities that pollute, they were also not willing to pay for a clean and smoke free environment. This does pose a business dilemma for corporate entities interested in selling RER products, as people who do not have any problem with the environment were the ones with a higher WTP, which does not necessarily imply ability to pay and willingness to purchase. Such households are difficult to predict their motivation to purchase or acquire any RE facility, such as solar power system.

However, if this figure is read together with Table 6.18, it is observed that almost 47 percent of the households believed that subsidising RE systems would make them

cheaper and, therefore, affordable for them to consider acquiring. Further 22 percent opted for the provision of reliable clean energy for them to stop using biomass. In this regard, therefore, it shows that for the adoption of RE to be achieved at a higher rate, it is important to consider a number of factors such as reliability of the present clean power supplies over and above necessary energy subsidies to those who are willing to pay for the services.

6.6 SUMMARY AND CONCLUSION

The need for clean energy resources is important for socioeconomic development of communities. People willing to have a clean environment demand clean and renewable energy resources. For the case of South Lunzu Township, based on the results of the analysis in this chapter, the following was highlighted:

- The people of South Lunzu Township in the city of Blantyre were using biomass for their cooking needs. In this sample, out of the 319 households, 2.9 percent frequently use hydroelectric power for cooking meals. A small group representing 0.63 percent use LP Gas and just 1 household representing 0.31 percent depend mostly on solar power. This is a worrisome development considering that solar power, electricity and LP gas are renewables and the percentage of those who use these resources combined is just about 3.84 percent.
- The use of biomass for cooking needs was, however, lower compared to the national level of the most common source of cooking fuel in Malawi, which was firewood at 88 percent, followed by charcoal (9 percent), electricity (3 percent), and other means of fuel for cooking at 1 percent.
- Considering demarcation by place of residence, however, NSO place of residence is considered, urban areas have a rather low proportion of households using firewood as a source of cooking fuel, registering 42 percent while rural areas have registered almost 96 percent.
- Of the sample, 42 percent use both charcoal and firewood to cook their meals. Based on these results, it shows that the use of renewable energy for cooking in Blantyre's South Lunzu has received very little response.

- It is of interest to note that 24.76 percent of the sample used a combination of electricity, firewood and charcoal for cooking energy needs. In total, those who combine cooking energy sources represent 67.08 percent, indicating that there was more fuel stacking than reliance on one single reliable resource.
- About 70 percent of the sample preferred solar power to other sources of energy; 8.8 percent opted for wind power; 12.5 percent opted for geothermal; and slightly above 5 percent chose petroleum. Solar energy was, therefore, a popular source of renewable energy in South Lunzu Township.
- 79 respondents representing about 25 percent of the sampled heads of household reported that their preferred renewable energy resource was not available on the market for them to buy and test
- About 24 respondents representing 7.5 percent indicated that they do not understand how their preferred renewable energy resource works and what it needs in order for it to be used effectively.
- About 14 respondents representing 4 percent of the sample pointed out that they have heard about their preferred energy facility but they had not seen it working and, as such, they could not fully commit their resources to buy and try it.
- Another group composed of 6.6 percent of the sampled respondents stated that they were satisfied with the energy resources they were using at the time of the interview, although they too had a preferred renewable resource.
- Further, out of a total of 319 respondents, 15 believed that their preferred renewable energy resource was not reliable enough for the purposes they wanted it. This represented 4.7 percent of the total sample.
- Regarding the actions the people would want to see to prompt them to stop using biomass, 69 of the respondents representing about 22 percent of the sample indicated that government should put a mechanism that will ensure that, first, the use of biomass class of energy resources is banned. Secondly, those using biomass should be punished under a law.
- Just above 47 percent (151 respondents), said that government should subsidise renewable energy so that even poor people can afford to purchase.

- About 3 percent of the sample indicated that it was important for government to engage in heavy campaigns that should sensitise people to the dangers households face by continuing to use biomass.
- 5 percent of the sample believed that sensitising people on the advantages of renewable energy could go a long way to influence them to stop using biomass and opt for renewable energy. A considerably large group of 23 respondents representing about 23 percent of the sample suggested that the solution is for authorities to provide reliable electricity that is also affordable.
- About 50 percent of the sample declared that they regard themselves as being poor. The same proportion, 50 percent also regard themselves as not being poor.

Having analysed the data descriptively, the thesis turns to econometric analysis to test null hypothesis number one to five as set in chapter one. The first stage is to consider Engel functions to analyse the effect of income on each one of the energy facilities under study. Then consumer behaviour follows, beginning with an estimation of an energy poverty line based on economic methods. The energy poverty line was used to identify two categories, namely, those who were deemed to be energy poor and those not lacking. Then a Logit model for energy poverty was estimated.

CHAPTER 7 AN ECONOMETRIC ANALYSIS OF ENERGY POVERTY AND DEMAND

7.1 INTRODUCTION

The state and level of energy poverty in Africa, in general, and Malawi, in particular, is alarming. The International Energy Agency (2009:6) reported that 554 million people did not have access to electricity in Africa in 2008. Sub-Saharan Africa had the highest number of people without electricity at 547 million, compared to North Africa, which had 7 million people with electricity. A further observation shows that the sub-Saharan region has more people lacking access to modern electricity, with 653 million people out of a total of 657 million, representing 24 percent of the world total number of people still relying on biomass for their cooking needs (IEA Energy Statistics, 2009).

Over the period 2006-2011, Malawi has implemented a number of programmes in the energy industry, including the training of 400 biomass briquette makers, 100 briquettes stove producers, and the establishment of 24 briquette stove production centres, among others. Government further rehabilitated two hydro power generation stations that added an extra 40 MW of electricity. Despite these programmes, the National statistical Office, through its Integrated Household Survey 2011-2012, reported that as of the year 2012, household energy consumption accounts for 84 percent of the total energy used in Malawi, the dominant energy source being biomass (99 percent) (GOM, 2001).

According to the NSO-IHS-3 (2012:120), the installed electricity capacity is at 283 MW against an estimated demand of about 330 MW. People largely depend on biomass, especially firewood and charcoal, for their household and farm energy needs. Further, Chapter 7 of this thesis revealed that, in the case of South Lunzu Township in the city of Blantyre, people were using biomass for their cooking needs. In this sample, out of the 319 households, 2.9 percent frequently use hydroelectric power for cooking meals. A small group representing 0.63 percent use LP Gas, and just 1 household representing 0.31 percent depend mostly on solar power. This is a worrisome development

considering that solar power, electricity and LP gas are renewables and the percentage of those who use these resources combined is just about 3.84 percent.

In addition, the attainment of the MDGs also rests on the availability and access to affordable energy for all people. To achieve the MDGs, and sustainable development in general, policies and strategies that will encourage the use of green energy, both at the household and industrial level, are important. Energy is important to eradicate poverty through improved education, health services and even provide employment to many people with a variety of skills.

The state of energy poverty seems to be in need of immediate attention. The questions to be answered are: what is the level of energy poverty in South Lunzu Township? Why is there energy poverty in Malawi in general and South Lunzu Township to be specific? What are the determining factors of the level of energy poverty in the Township? Are some of the energy facilities really inferior to others?

This is the thrust of Chapter 8, which first identifies some of the socioeconomic factors that determine the demand for particular types of energy resources. The aim was to analyse the income elasticities of energy resources and classify those resources as inferior, normal or superior. Secondly, the chapter identifies some of the socioeconomic factors that determine levels of energy poverty after measuring the level of energy poverty for South Lunzu Township based on the data obtained through a survey.

7.2 RESULTS OF ENGEL FUNCTION ANALYSIS OF DEMAND

The theory of demand postulates that there are many factors that influence the quantity of a commodity demanded by a consumer. There are endogenous and exogenous factors of demand. Endogenous factors are those which affect quantity of a commodity demanded and it is represented by a point on the demand curve and changes of which lead to a change of a point along the demand curve. On the other hand, exogenous factors shift the demand curve either to the left or right, thereby, indicating a change in demand as opposed to quantity demanded (Lipsey & Chrystal, 2011:60).

To analyse the effects of income on the quantity demanded of each one of the energy facilities considered in the thesis, Engel functions were adopted. Engel functions, as already stated in Chapter 4, are important in two ways. Firstly, they are used to analyse the behaviour of quantity of a commodity demanded as income changes. In this way, although income is treated as an exogenous factor in price theory, Engel functions allow the researcher to treat it as an endogenous explanatory variable. Income becomes the variable on the X-axis affecting quantity demanded on the Y-axis.

Secondly, the behaviour of the quantity demanded due to changes in income help economists in classifying commodities as inferior, necessity or superior. Inferior commodities are those whose demand decreases as income of an economic agent increases. Normal goods are those whose quantity demanded increases as income of an economic agent rises. Some energy facilities might be inferior to others and yet others might be superior or normal commodities. The income elasticity of demand is easily calculated using Engel functions analysis. The income elasticity of energy resources measures the percentage change in the quantity demanded of an energy commodity, such as electricity, due to a percentage change in income of the head of household.

As already outlined in Chapter 4, Section 4.5, the thesis adopted an Engel model represented by equation (1), following Yeong-Sheng *et al.* (2008:9), which is reproduced below.

$$S_i = \alpha_0 + \alpha_1 \ln X + \sum_k \gamma_k H_k + \varepsilon \quad (1)$$

Equation (1) is a lesser form adopted after Deaton and Mueller (1980), since it satisfies the adding-up property. For purposes of the present thesis, the terms in equation (1) above are;

S_i ; Expenditure share of aggregate energy for each household i ,

X ; total expenditure of both energy and non-energy consumer goods and services,

H_k is a set of dummy variables which are household specific capturing both structural and demographic attributes of the respondents in the survey, ε is an econometric error term, which is assumed to be normally distributed with a mean of zero and a constant variance.

In this thesis, the following variables represented in table 7.1 were used to explain the expenditure behaviour of households on fuel-wood and electricity. In the spirit of equation (1), the dummy variables in H_k and continuous variables in X are presented and explained in Table 7.1

Table 7.1 Explanation of variables used in the analysis

EPVY	Categorical variable for energy poverty: 1 if household is energy poor and 0 otherwise
exp_tpt	Expenditure on transport.
exp_food	Monthly expenditure on food
exp_sch	Monthly expenditure on education
gender	Gender of the head of household
Educ	Number of years in formal schooling for head of household
exp_home	Monthly expenditure on housing including rentals and city rates
hhsz	Number of permanent residents in a dwelling unit (household) at the time of interview
hmsz	Size of dwelling unit (house) in square metres
marriage	Marital status of head of household, 0 represented unmarried and 1 married

7.2.1 Engel Function Analysis of Demand for Fuel-wood

Table 7.2 reports results of the Ordinary Least Squares regression for Engel function analysing the effect of income, employment status, total expenditure on energy resources, household size, home size, respondent's perception on their well-being, age of the head of household, education level of the head of household, and marital status of the head of household, on fuel-wood expenditure.

Table 7.2 Engel function analysis of demand for fuel-wood

ebs_wood	Coefficient	elasticity	Standard Error	t-statistic	P> t
eexp	-.00003	-0.172	0.00000556	-5.79	0.000***
income	-0.000000826	-0.0755	0.000000255	-3.24	0.001***
employment	0.0305	0.0396	0.04335	0.7	0.483
hhsize	-0.0034	-0.0258	0.007145	-0.48	0.631
hmsize	-0.0005	-0.058	0.000304	-1.65	0.100*
poor	0.0537	0.04	0.028098	1.91	0.057*
Age	-0.0037	-0.217	0.00121	-3.03	0.003***
educ	-0.0127	-0.214	0.004744	-2.67	0.008***
gender	-0.0430	-0.043	0.031189	-1.38	0.169
marriage	0.064	0.0717	0.032462	1.96	0.05**
_cons	1.1137		0.085555	13.02	0.000***
R-Squared	0.32		Adjusted R-Squared	0.30	
F(10, 304)	14.38		Prob. > F	0.000	

Source: Energy Poverty and sustainable development Survey, 2012.

Where *, **, and *** means coefficient was statistically significant at the 10%, 5% and 1% level Of significance.

The reliability of the Engel function for the demand of fuel-wood was tested using coefficient of determination called the Adjusted R-Squared and the F-Statistic, which analyses the variability of the dependent model where all the explanatory variables are used to explain the behaviour of the dependent variable collectively. In Table 7.2 the R-Squared was about 32 percent, with the adjusted R-Squared necessary for multiple regression analysis of about 30 percent, which are acceptable levels considering that

the data set used was cross-sectional. This means that about 30 percent of the variations in the expenditure on fuel wood are explained by the model.

Further, the F-Statistic which tests the null hypothesis that the variables used in the model are collectively of no importance in explaining the behaviour of the dependent variable was statistically significant at the 1 percent level. The value of the F-Statistic was 14.38. Therefore, the null hypothesis is rejected in favour of the alternative, that collectively, the independent variables, namely total expenditure on energy resources, income, employment status, household size, home size, respondent's perception on their well-being, age of the head of household, and education level of the head of household are important in explaining the level of expenditure on fuel-wood at the household level in South Lunzu Township. This model can be relied upon to explain consumer behaviour of demand for fuel wood in Blantyre holding other factors constant.

In Table 7.2 *ebs_wood*, the dependent variable, represented the energy budget share of wood which included charcoal as a proportion of the total expenditure of the household; *eexp* was total expenditure on all energy resources; *income* represented income earned by head of household, *hmsize* was the size of the dwelling unit measured in square metres, *poor* was a dummy variable representing the respondents' opinion on whether they believe to be poor or not as a state of well-being or poverty, *Employment* Status represented a situation of employment and marriage represented marital status of the head of the household visited in the survey.

Table 7.2, together with Table A4 in Annexure A shows, the slope coefficient of *eexp* was negative and statistically significant, even at the 1 percent level of rejection point (99 percent level of confidence) to reject the null hypothesis that there is no relationship between total expenditure on energy commodities and demand for fuel wood. This implies that there is a negative relationship between household total expenditure on energy on the one hand, and fuel wood as an energy facility on the other hand.

The slope coefficient between *eexp* and *ebs_wood* was -.00003. In elasticity terms, a 1 percentage increase in total expenditure on energy facilities led to 0.17 percent

decrease in demand for fuel wood. In this case, the demand for fuel wood is inelastic to changes in income for the people of South Lunzu in Malawi. Demand was responding by less than the amount of expenditure change. Therefore, apart from fuel wood being an inferior commodity, due to the negative relationship between income and its expenditure, there is an element of it being a necessity to the people probably indicating the demanded commodity coming from fuel wood, which is energy. Energy is a necessity without which life cannot be impossible. In addition, the availability and pricing of the commodity favours those who are poor, thereby making it more inelastic to any slight changes in income.

The results on *eexp* are confirmed by the negative relationship between *income* and *ebs_wood* with a t-statistic that is statistically significant at the 1 percent probability value of rejecting the null hypothesis that there was no influence and relationship between the two variables. As income of the head of household grows, there is a tendency to lower the expenditure on biomass and higher expenditure on cleaner energy facilities could be observed. There could be an income substitution effect on biomass energy resources, such as fuel wood. Higher income households tend to spend less on fuel wood than lower income households.

Further, fuel wood income elasticity was -0.08. This entails that a 10 percent increase in income would lead to a 0.8 percent decrease in demand for fuel wood. Fuel wood, therefore, is indeed an income inelastic commodity. Although an increase in income is expected to lead to a decrease in demand for fuel wood, the decrease was less than the increase in income. Although fuel wood is an inferior commodity, judging by the negative elasticity, the relationship is inelastic to warrant a strict expectation that any slight increase in the level of income of the head of household will be associated with a drop in expenditure for fuel-wood.

The implication of this result is that wood is an inferior energy commodity whose demand decreases as income level of a household improve. This gives hope that, although most people in Blantyre use fire wood and charcoal for their cooking needs, it is not by choice but rather their level of income is low that they simply use biomass for

purposes of survival. Given more income, or indeed as microeconomic theory of price predicts, by putting in place a mechanism that will ensure that the price of other more superior energy facilities is low enough through subsidies for instance, will influence a migration from biomass to cleaner fuels.

The other variables of interest were home size and employment status. At the 10 percent level of significance, home size was statistically significant to reject the null hypothesis that there was no influence and relationship between the size of dwelling unit and expenditure on wood fuel. The slope coefficient for home size was -0.00052 with an elasticity of -0.058, meaning that for every 10 percentage increase in the size of the dwelling unit there was almost a 0.6 percent drop in demand for fuel wood. As in income and expenditure on energy resources, the relationship between expenditure on fuel wood and size of dwelling unit was also inelastic, meaning that the percentage change in the dwelling unit was higher than the percentage change in the expenditure for fuel wood.

The perception of the head of household on whether or not they were poor was important in explaining the expenditure on firewood. At 10 percent level of significance, the results reject the null hypothesis that there was no influence and relationship between the belief that a household is poor and expenditure on fuel wood. The slope coefficient was positive at about 0.0537. However, the relationship was also inelastic with an elasticity of 0.04. Fuel wood was believed to be an energy commodity for those who believed to be poor although the relationship was inelastic.

Age of the head of household was found to be negatively related to the expenditure on fuel-wood. The slope coefficient was -0.00371 with an elasticity of -0.217. The relationship was also inelastic although statistically significant at the 1 percent level of significance to reject the null hypothesis that there was no influence and relationship between expenditure on fuel wood and age of head of household. The negative indicated the transformation respondents could have been going through as time progressed, in that the older a head of household was, the lower the desire to use inefficient energy resources holding other factors constant.

Education level of the head of household was also tested as to how it related to expenditure on fuel wood. At the 1 percent level of significance, the results reject the null hypothesis that there was no influence and relationship between the two variables. The slope coefficient of -0.0127 with an elasticity of -0.214 meaning that increasing education level by 10 percent, expenditure on fuel wood was expected to drop by 2 percent.

Marriage, which represented marital status of the head of household, was statistically significant at the 5 percent level to reject the null hypothesis that there was no relationship or any influence between marital status of the respondent and their expenditure on electricity as an energy resource. The slope coefficient was 0.064 with an elasticity value of 0.0717. This means that male-headed households were more likely to demand electricity for their household needs compared to female heads of household.

Three variables, namely employment status, gender of the head of household and household size, were not statistically significant to reject the null hypothesis that they do not affect expenditure on fuel wood. However, if employment was regarded as a factor variable with four categories namely, formally employed, informally employed, economically inactive, and unemployed, the results reveal that informally employed was positively related to expenditure on fuel wood and statistically significant at the 10 percent level to suggest that the more unemployed people the Township could have, the higher the demand for fuel wood. These results were reported in the Annexures as Annex 5.

The major finding from this section is that fuel wood in South Lunzu Township was an inferior commodity, which was expected to be demanded in lesser quantities with increases in incomes of heads of household. There were also other factors that were found to be important in explaining the demand for fuel wood such as age, education level and home size.

7.2.2 Engel Function Analysis of Demand for Electricity

Table 7.3 reports results of the Ordinary Least Squares regression for Engel function analysing the effect of total expenditure on energy resources; income; employment status; household size; home size; respondent's perception on their well-being; age of the head of household; gender; marital status of head of household and education level of the head of household; and marital status, on electricity expenditure. According to the energy ladder hypothesis, electricity is an energy resource that represents high quality in the sense that it is clean and efficient (Barnes & Floor, 1996:467).

Compared to fuel wood, electricity was found to be a normal energy commodity in the sense that higher income households used more electricity than lower income households. As Table 7.3 shows, there was a positive relationship between *ebs_elec* and *eexp*. This relationship was also statistically significant at the 1 percent level of rejecting the null hypothesis that there was no influence and relationship between expenditure on electricity and total expenditure on energy basket. The slope coefficient was 0.0000336 with an income elasticity of demand for electricity estimated to be about 0.5346 indicating that on average, increasing household income by 1 percent would lead to a 0.53 percent rise in the demand for electricity as an energy commodity.

The relation between expenditure on electricity and income was also positive and statistically significant at the 1 percent level to reject the null hypothesis that there was no influence and relationship between the two variables. The income elasticity of demand for electricity was about 0.15 and also positive. This means that a rise in income by 1 percent was associated with a rise in the demand for electricity of 0.15 percent, holding other factors constant. Although the relationship was inelastic, the positive relationship confirms that, for South Lunzu Township in the city of Blantyre, the energy ladder hypothesis holds.

Due to the statistically positive relationship between income and expenditure on electricity, it could be concluded that electricity was a 'normal good' in the sense that increases in income are associated with more households using it. Those with lower

incomes tend to use less electricity but as their incomes increase, they shift from traditionally inefficient resources such as firewood to cleaner ones such as hydroelectric power.

Table 7.3 Regression estimates of Engel Function analysis for electricity

ebs_elec	Coefficient	elasticity	Standard Error	t	P> t
eexp	0.0000336	0.5346	0.00000514	6.54	0.000***
income	0.000000823	0.14985	0.000000236	3.48	0.001***
employment	-0.0109	-0.0492	0.04012	-0.27	0.786
hhsz	-0.0025	-0.0715	0.00661	-0.37	0.71
hmsz	0.0008	0.37202	0.00028	2.84	0.005***
poor	-0.0434	-0.1379	0.026	-1.67	0.096*
Age	0.00293	0.6355	0.00112	2.62	0.009***
educ	0.02528	1.68973	0.00439	5.76	0.000***
gender	0.02332	0.05125	0.02886	0.81	0.42
marriage	-0.0418	-0.1589	0.03004	-1.39	0.165
_cons	-0.3219		0.07917	-4.07	0.000***
R-Squared	0.4247		Adjusted R-Squared	0.4057	
F(8, 306)	22.44		Prob. > F	0.000***	

Source: Energy Poverty and sustainable development Survey, (2012).

Where *, **, and *** means coefficient was statistically significant at the 10%, 5% and 1% level Of significance.

Home size, as represented by hmsz, was statistically significant at the 1 percent level. It, therefore, implies that the bigger the house the more likely the household was demanding more electricity. The elasticity of demand for electricity due to changes in

home size was estimated to be 0.372 with a slope coefficient of 0.0008. Electricity, therefore, was found to be inelastic with small changes in the size of a dwelling unit. A 1 percent increase of a dwelling unit was associated with a 0.372 percent rise in demand for electricity.

The perception on poverty represented by 'poor' was statistically significant at the 10 percent level of statistical significance to reject the null hypothesis that believing to be poor might lead to less demand for electricity. This relationship was negative, meaning that the more an economic agent considers themselves to be poor the less electricity they would demand as a regular source of energy. The slope coefficient was -0.0434 with an elasticity of -0.1379.

There was a positive relationship between electricity demand and the level of education of the head of household, which was also statistically significant at the 1 percent level of significance to reject the null hypothesis that education level does not influence expenditure on electricity. Education level of the head of household was also the only variable that had an elastic relationship with demand for electricity with an electricity value of about 1.69 and a slope coefficient of 0.025. This means that increasing the education level of the head of household by 1 percent could lead to a 1.6 percent increase in the demand for electricity in South Lunzu Township.

Four variables, namely gender, marital status, employment status and household size, were statistically insignificant to reject the null hypothesis that they did not influenced the demand for electricity among the respondents, even at the 10 percent level of significance. A further analysis on employment status by having four groups, namely '*formally employed*', '*informally employed*', '*unemployed*' and '*economically inactive*', however, revealed that diving the variable into only two categories of employed and unemployed produced limited results.

For example, there was a negative relationship between employment status and amount of electricity demanded, which was statistically insignificant even at the 10 percent level of rejection. The hypothesis that formal employment is necessary for a

greater reliance on electricity is accepted against the null that informal activities matter for clean energy demand. The belief that formal employment brings stability and certainty in future incomes increases the confidence of bread winners to consider substituting electricity for other facilities such as firewood and charcoal.

Table 7.4 Association between employment status and cooking energy

Employment status of hh	Source of energy normally used for cooking							
	Electricity	LPG	Solar	Charcoal	Fire wood	Electricity & Biomass	Charcoal & Firewood	Total
Formal	6	1	0	40	5	48	62	162
Informal	0	1	1	30	7	21	53	113
Unemployed	1	0	0	7	2	3	13	26
Inactive	0	0	0	3	0	6	7	16
Total	7	2	1	80	14	78	135	317

Source: Energy poverty and sustainable development survey, (2012)

Table 7.4 shows that none of the respondents who were informally employed in their own activities, such as SMMEs, were using electricity as their main source of energy for cooking compared to 6 respondents of those that were formally employed. However, even those that were formally employed indicated that they were relying on charcoal and a combination of charcoal and firewood. For instance, 62 respondents representing about 38 percent of those who were formally employed reported that they relied on firewood and charcoal for cooking needs, 48 representing 30 percent of the formally employed respondents relied on a combination of electricity on the one hand and firewood and charcoal on the other. About 40 formally employed respondents representing 25 percent solely depended on charcoal compared to 27 percent of those that were informally employed.

For those unemployed, only 1 household were still depending solely on electricity for their cooking needs, none of them used LP gas and solar power. Further, 7 of them depended on charcoal, 2 on firewood, and 3 were combining biomass with electricity and 13 were mixing charcoal and firewood.

7.3 ANALYSIS OF DETERMINANTS OF ENERGY POVERTY

Continuing with the analysis, the thesis now turns to measures and determinants of energy poverty. As already alluded to in Chapter 2, there are many measures of energy poverty that can be adopted. This thesis adopted energy expenditure methods to identify those who are energy poor compared to the others. Energy poverty measures calculated in this way are referred to as Economics Measures (Pachauri *et al.*, 2004:2084). In expenditure terms, a household is considered to be energy poor if 10 percent or more of its expenditure is on energy facilities (Fahmy, 2011:2). This definition, therefore, demands a clear explanation and data on energy expenditure at the household level and total income.

7.3.1 Expenditure approach of measuring energy poverty

Expenditure on energy is calculated by adding together all the money-metric costs incurred to fetch energy facilities. These include:

- iii. Transport cost to and from the place of fetching the energy facility;
- iv. Actual purchase cost of the facility;

The formula for this calculation is given by:

$$EEX_{ij} = ETPT_{ij} + APC_{ij} \quad (30)$$

Where EEX_{ij} total expenditure on energy facility i by household j ; $ETPT_{ij}$ is transport expenses incurred towards the acquisition of energy facility i by household j ; and APC_{ij} is the actual purchase cost of energy facility i by household j . since the expenditure on transport as a recurrent activity mainly involves purchases of energy, ETPT includes transport expenses the household incurred per month. For those who commute, bus

fares are a direct function of the price of petrol and diesel on the energy market. Those who use bicycles and walking could not be captured as energy conversion factors could not be identified to assist with the process. Particularly, walking and cycling do not involve the use of energy whose cost can be quantified in monetary terms. For those who used cars for travel, the cost of petrol and diesel was added.

Table 7.5 provides a summary of energy poverty statistics using the income or economics approach. From the table, 62 households representing about 19 percent of the sample were not energy poor. These households were spending less than 10 percent of their income on energy commodities, including transportation. On the other hand, a significant number was found to be energy poor. Out of a total of 319 households, 257 were found to be energy poor representing about 81 percent of the sample.

Table 7.5 Frequency for energy poverty

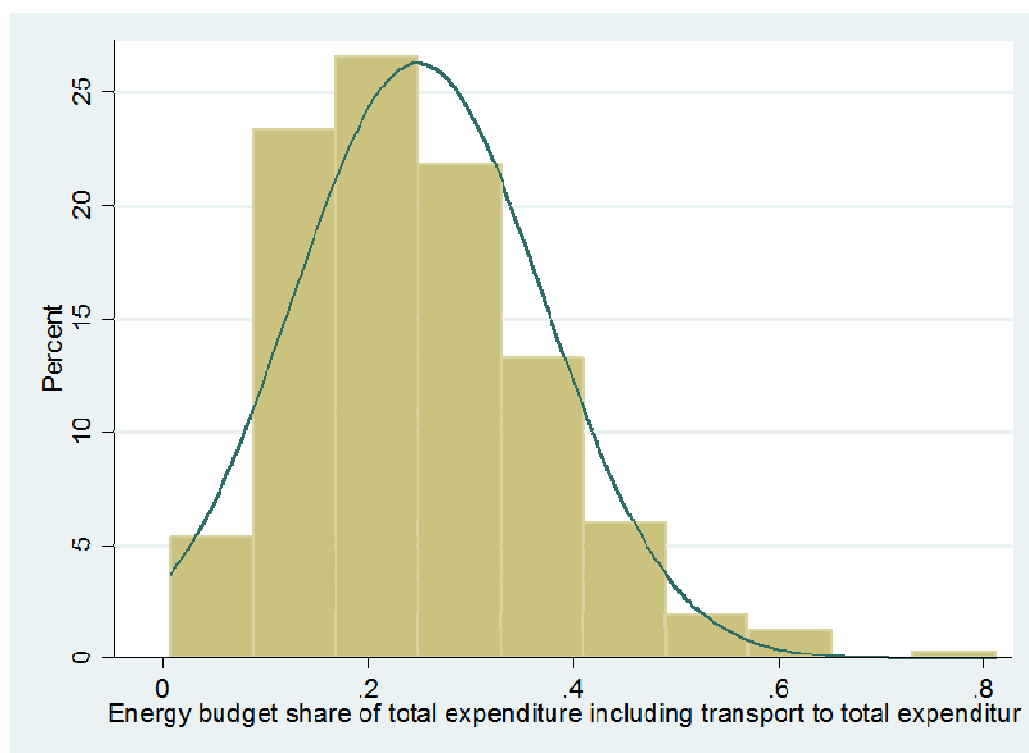
Energy Poverty Dummy Variable	Frequency	Percent	Cumulative frequency
Energy well-off	62	19.44	19.44
Energy Poor	257	80.56	100
Total	319	100	

Source: Energy Poverty and Sustainable Development survey data, (2012).

Figure 7.1 shows the distribution of the share of energy expenditure as a percentage of household's total monthly expenditure. As can be observed, the distribution is normal with a mean of around 18 percent and a standard deviation of 0.11. The minimum and maximum share of energy expenditure in the total household expenditure was 0.74 percent and 63 percent respectively. This shows that it is 'normal' for a household to be energy poor in South Lunzu Township with little variability among those sampled for the thesis.

As another measure of energy poverty Pachauri and Spreng (2003:4), Pachauri *et al.* (2004:2084) and Fahmy (2011:2), used access to electricity to proxy for clean energy. Among the heads of households sampled, 43 percent of the households had electricity connectivity and the rest, 57 percent did not have electricity connectivity from the grid. However, most of those who had electricity could not afford to use it for cooking. Mostly, electricity was used to provide light and run other basic appliances such as electronic gadgets, refrigerators and radios. This thesis adopted the first measure of spending more than 10 percent of income on energy facilities.

Figure 7.1 Distribution of expenditure share of energy in household budget



Source: Energy poverty and sustainable development survey, (2012).

A third measure of energy poverty borrows from the income poverty literature to compute a relative energy poverty line using descriptive statistical methods. A relative measure of energy poverty was performed where the mean of the cost of energy was computed. Those whose cost of energy was found to be below the average were

deemed as energy poor and those above the mean were well-off. Following this method, as Table 7.6 shows, the number of people in energy need drops to 199 representing about 62.4 percent of the sampled households, while that of households deemed not energy poor were 120 representing about 37.6 percent. These results are not far from each other. Using the two methods, the story is still the same that in South Lunzu Township at least 60 percent of the households could be classified as being energy impoverished.

Table 7.6 Relative energy poverty summary frequencies

Relative Energy Poverty	Freq.	Percent	Cum.
Energy-well-off	120	37.62	37.62
Energy-poor	199	62.38	100
Total	319	100	

Source: Energy Poverty and Sustainable development Survey, (2012)

Consequently, an econometric analysis of the factors that influence the level of energy poverty in South Lunzu was performed, relying on inferential statistical methods to interpret the results. A dummy variable, EPVY, representing energy poverty was created, taking on the value of 1 if a household was found to be energy poor and 0 otherwise.

7.3.2 Econometric Analysis of Energy Poverty

Those who were deemed to be energy poor were identified based on the energy expenditure budget of the household. Households whose energy expenditure budget exceeded 10 percent were regarded as being energy poor and, therefore, they were coded 1, and those who were spending less than 10 percent on energy facilities got a code of 0 (zero). A binary variable was consequently created, which renders the reliance on Ordinary Least Squares (OLS) method of regression analysis, unfit. In such a case, OLS does not give results that are best, linear and unbiased estimators. Some

of the results are, in fact, undefined (Gujarati, 2004:580). Consequently, qualitative methods that try to analyse qualitative (categorical) data become handy and useful.

Table 7.7 Logit regression of energy poverty reporting odds ratios

EPVY	Odds Ratio	Standard Error	z-score	P> z
exp_tpt	1.000813	0.0001414	5.75	0.000***
exp_food	0.999898	0.0000241	-4.23	0.000***
exp_sch	0.9998948	0.0000246	-4.28	0.000***
Gender	1.208059	0.4834722	0.47	0.637
Educ	1.009247	0.0619943	0.15	0.881
exp_home	0.9999675	0.000056	-0.58	0.562
Hhsize	1.211237	0.1239652	1.87	0.061*
Hmsize	0.9969889	0.0055973	-0.54	0.591
Marital	1.266643	0.1802742	1.66	0.097*
_cons	1.477119	1.331087	0.43	0.665

Source: Energy poverty and sustainable development survey, (2012)

Where *, **, and *** means coefficient was statistically significant at the 10%, 5% and 1% level of significance.

In the present case, one class of categorical models, a logistic regression, was estimated as a way around the problem (other methods can also be adopted, such as probit and tobit models (Tchereni *et al.*, 2012:12)). This class of regressions use predictors to estimate probabilities that an event does or does not occur relying on similar inferential statistical methods as in OLS (Train, 2009:10; Cameron & Trevedi, 2005:20; Gujarati, 2004:580; Green, 2003:663; Pundo & Faser, 2006:28).

Based on the theoretical model, as presented in Section 4.8 in Chapter 4, the following empirical model is suggested:

$$f(EPVY) = (exp\_tpt, exp\_food, exp\_sch, gender, educ, exp\_home, hhsz, hmsz, marital, \varepsilon)$$

This equation was estimated or implemented in a STATA 12 platform and the results are presented in Table 7.7 and 7.8, for odds ratios and coefficients respectively. The two tables are complementary to each other to provide a reasonable assessment of the logit analysis of energy poverty in South Lunzu. The variables used are shown in Table 7.1.

Table 7.8 Logit regression of energy poverty reporting coefficients

EPVY	Coefficient	Std. Err.	z	P> z
exp_tpt	0.0008125	0.0001412	5.75	0.000***
exp_food	-0.000102	0.0000241	-4.23	0.000***
exp_sch	-0.0001052	0.0000246	-4.28	0.000***
Gender	0.1890151	0.4002057	0.47	0.637
Educ	0.0092042	0.0614263	0.15	0.881
exp_home	-0.0000325	0.000056	-0.58	0.562
Hhsz	0.1916424	0.1023459	1.87	0.061*
Hmsz	-0.0030156	0.0056142	-0.54	0.591
Marital	0.2363704	0.1423243	1.66	0.097*
_cons	0.3900933	0.9011377	0.43	0.665

Source: Energy Poverty and sustainable development Survey, (2012)

Where *, **, and *** means coefficient was statistically significant at the 10%, 5% and 1% level of significance.

The results in Table 7.9 show that there is a positive and statistically significant relationship between energy poverty and transport expenditure. The null hypothesis that the level of transport expenditure does not affect the level of energy poverty is, therefore, rejected at the 1 percent level of statistical significance and the alternative hypothesis, that there is a relationship, is accepted. The results in Table 7.8 suggest that the odds ratio of 1.0008 was in favour of transport expenditure to increase the energy poverty level for a household holding other factors such as change in income constant.

In terms of elasticity, as reported in Table 7.9, the relationship between transport expenditure and energy poverty was inelastic. Increases in transport expenditure were not likely to lead to any shifts in expenditures. For example, a 1 percentage increase in transport expenditure could increase energy poverty by 0.2 percent.

There was a statistically negative relationship between food expenditure, as represented by `exp_food`, and energy poverty rejecting the null hypothesis of no relationship between the two. At 1 percent level of significance, the odds ratio predicts that households which spend more on food are likely to be better off in energy access. As Table 7.11 shows, for every 1 percentage points increase in food budget, there is likely to be a 0.49 percentage decrease in energy poverty.

At 1 percent level of statistical significance, the null that there is no relationship between expenditure on education and energy poverty is rejected and the alternative hypothesis, that there is a negative relationship between the two variables, is opted for. In terms of elasticity, the relationship is inelastic as increasing education expenditure by 1 percentage points is likely to lower energy poverty by 0.19 percent. Said differently, low energy poverty levels are likely to be associated with higher expenditures in education for members of household as funds are released from spending on energy and the gains are moved towards improved and quality education.

There was a positive relationship between gender and energy poverty, although the association was statistically insignificant to reject the null hypothesis that there is no

relationship between the two variables. The odds ratio, however, shows that one is likely to be energy poor if they are male rather than female. Culturally, men do not go to the forest to fetch firewood the way women do in Malawi and many other parts of Africa. The gender elasticity of energy poverty is inelastic at 0.02 percent. That means a 1 percent increase in males is expected to increase energy poverty by 0.02 percent.

Table 7.9 Analysis of elasticities of the logit model

	ey/ex	Std. Err.	z
exp_tpt	0.20	0.03	5.9
exp_food	-0.49	0.13	-3.68
exp_sch	-0.19	0.06	-3.13
Gender	0.02	0.05	0.49
Educ	0.02	0.12	0.15
exp_home	-0.02	0.03	-0.55
Hhsize	0.18	0.09	1.97
Hmsize	-0.03	0.07	-0.52
Marital	0.11	0.06	1.78

Source: Energy poverty and sustainable development survey, (2012).

At any level of standard statistical significance, education of the head of household could not be a statistically significant factor in explaining the behaviour of energy poverty in South Lunzu, although there was a positive relationship between level of education and energy poverty. This result is strange considering that higher education levels are associated with higher income levels and, therefore, the energy share in the expenditure budget should be smaller.

There was a statistically insignificant relationship between home expenditure, as represented by exp_home, and energy poverty. Higher expenditures on accommodation were likely to be associated with lower energy poverty levels. In terms of elasticity, an

increase in home expenditure by 1 percent was likely to lead to a 0.02 percent decrease in energy poverty. Households that were spending higher amounts of their income on housing were likely to be less energy poor compared to those that were staying in low cost accommodations.

Household size, represented by *hysize*, had a statistically significant positive relationship with energy poverty at the 10 percent level of significance. The odds were that it was more likely for a household with more members to be energy poor than those with fewer members. The household size elasticity of energy poverty was inelastic at 0.18, implying that a 1 percent increase in household poverty was likely to increase energy poverty of the household by 0.18 percent.

There was a negative relationship between size of the dwelling unit, as represented by *hmsize*, and energy poverty. The relationship, however, was statistically insignificant to suggest that the size of the dwelling unit (house) can be relied upon to explain the behaviour of energy poverty at the household level in South Lunzu. However, although insignificant, the negative relationship suggests that households dwelling in larger houses were likely to be less energy poor compared to those living in smaller units.

On marital status, which was represented by *marital*, the relationship was positive and statistically significant at the 10 percent level of significance suggesting that homes with married couples were more likely to be energy poor than those who were not.

7.3.3 Evaluation of the Energy Poverty Regression Model

The model was then evaluated for overall reliability after the individual impact assessment as outlined above. Unlike OLS models where model overall evaluation is done through the coefficient of determination (R-Squared) and the F-Statistic, logistic analysis relies on other statistics to analyse the reliability of any model. The Log-Likelihood Ratio test, which is distributed as a Chi-Square, is computed to test the overall performance of the model. Table 7.10 presents the results of the Log-likelihood ratio test. The Chi-Square, having lost 9 degrees of freedom, was 131.54 and it was statistically significant to reject the null hypothesis that the overall explanatory power of

the model could not be relied upon. The predictors in the logistic regression were collectively important in explaining the behaviour of energy poverty in South Lunzu.

Table 7.10 Log-likelihood Ratio Test of the Logistic regression

Logistic regression	Number of observations	316
	LR chi2(9)	131.54
	Prob > chi2	0.000***
	Pseudo R2	0.4204
Log likelihood		-90.68

Source: Energy poverty and sustainable development survey, (2012)

Where *** means statistically significant at the 1% level. The Pseudo coefficient of determination (Pseudo R-squared) was 42, percent implying that the model explained about 42 percent of the deviations in the probability of energy poverty in South Lunzu. As Table 7.11 shows, the null hypothesis that the model was a good fit to explain the deviations in the behaviour of energy poverty, is accepted even at the 10 percent level of significance. The value of the HL statistic was 3.4 with the probability to accept the null hypothesis of about 91 percent.

Table 7.11 Results of Chi-Square test of goodness of fit

number of observations	316
Hosmer-Lemeshow chi2(8)	3.4
Prob > chi2 = 0.9069	0.9069

Source: Energy poverty and sustainable development survey, (2012)

A further goodness of fit test that is recommended for logistic regressions in the literature is the Hosmer-Lomeshow (HL) Chi-square statistic (Peng, Lee & Ingersoll, 2002:5). The statistic is distributed as a Pearson Chi-square and evaluated through a log-likelihood estimation calculated from a 2 x g table of observed and expected

frequencies. Where g is the number of groups formed from expected probabilities of each one of the observations.

7.3.4 Correlation analysis of the energy poverty parameters

A test of linear relationship between the parameters of the energy poverty results was conducted. The reason is that existence of linear relationships among the variables could lead to results that are not reliable as the coefficients could be depending on each other. In the literature, this is referred to as the presence of multicollinearity which, when severe, has two possible negative consequences: the estimators fail to define the value of the parameters and, if there are results of the parameters, they tend to be over inflated (Gujarati, 2004:341).

Table 7.12 Correlation matrix of the logistic coefficients

	EPVY							
e(V)	exp_tpt	exp_food	exp_sch	Gender	educ	exp_home	hhsz	Hmsz
exp_tpt	1							
exp_food	-0.3	1						
exp_sch	-0.66	0.03	1					
Gender	-0.04	-0.18	0.06	1				
Educ	-0.002	-0.08	-0.06	0.06	1			
exp_home	-0.17	-0.21	0.06	-0.02	-0.17	1		
Hhsz	0.16	-0.15	-0.34	-0.05	-0.003	0.07	1	
Hmsz	-0.24	0.03	0.05	0.08	-0.16	-0.03	-0.05	1
Marital	0.15	-0.03	-0.16	0.24	-0.022	0.11	-0.08	-0.05

Source: energy poverty and sustainable development survey, 2012

The results in Table 7.12 show that there was no serious linearity between any of the coefficients of the variables. The highest correlation coefficient was -0.66 between the

estimated coefficients of expenditure on transport (exp_tpt) and expenditure on education (exp_sch), followed by -0.34 between estimated coefficients of expenditure on education and expenditure household size (hhsz). The least correlation coefficient was between the estimated coefficients of education levels (educ) and expenditure on transport (exp_tpt) at -0.002.

7.3.5 Regression of predicted probabilities of energy poverty

The predicted probabilities from the logistic regression were computed as a post estimation process aimed at validating the model further. The correlation coefficients between the predicted probabilities (pr) and the predictors are presented in Table 5.11.8. As the table shows, the relationship between expenditure on transport and the predicted probabilities was positive at 37 percent. A negative correlation was reported between expenditure on food, expenditure on schooling and expenditure on housing. The correlation was small at 1.13 percent and 8 percent between predicted probabilities on the one hand and gender and household size, respectively, on the other.

Further, the relationship was tested through OLS methods, the results of which are presented in Table 7.13. The relationship was positive and statistically significant at the 1 percent level for expenditure on transport. It was negative and statistically significant to reject the hypothesis that there was no relationship at all with the dependent variable, predicted probabilities for expenditure on food and school.

Table 7.13 Correlation coefficients between predicted probabilities (PR) and the predictors

	exp_tpt	exp_food	exp_sch	gender	Educ	exp_home	hhsz
Pr	0.3659	-0.214	-0.156	0.0113	0.1094	-0.074	0.0846

Source: energy poverty and sustainable development survey, 2012

Higher probabilities of a household being energy poor were expected the higher the level of education of head of household and this was statistically significant to reject the hypothesis of no relationship between the two at the 120 percent level.

Again, the higher the household size and the size of the dwelling unit, the higher the probability the household was going to be energy poor holding other factors constant. Highly educated people are less likely to consider using inferior and dirty energy facilities such as paraffin, firewood and charcoal. The cleaner facilities were observed to be relatively expensive hence the probability of educated people being energy poor was expected to be higher. At the 10 percent level of statistical significance this relationship was statistically important to reject the null hypothesis of no relationship with predicted probabilities.

Table 7.14 Regression results for predicted probability of energy poverty

Pr	Coefficient	Std. Err.	t-Ratio	P> t
exp_tpt	0.00001	0.000001	9.07	0.000***
exp_food	-0.000006	0.000001	-7.24	0.000***
exp_sch	-0.000004	0.000001	-5.24	0.000***
Gender	0.02232	0.02654	0.84	0.4009
Educ	0.00874	0.00416	2.1	0.0366**
exp_home	-0.000004	0.000003	-1.62	0.1072
Hhsize	0.01507	0.00616	2.44	0.0151**
Hmsize	0.00061	0.00027	2.26	0.0246**
Marital	0.00605	0.00887	0.68	0.4952
_cons	0.64672	0.06129	10.55	0.000***

Source: energy poverty and sustainable development survey, 2012.

Larger household sizes were associated with higher probabilities of being energy poor in South Lunzu among the sampled households. Energy demands rise with more people in the household as there is greater need for water heating and more food being cooked among other needs. As Table 7.14 suggests, household size was an important factor in determining the probability of energy poverty. At the 5 percent level, the hypothesis that there was no relationship between probability of being energy poor and household size was rejected statistically.

As shown by the results in Table 7.14, gender, expenditure on housing and marital status cannot be relied upon as important predictors of the probability of energy poverty in South Lunzu. Statistically, the null hypothesis that there was no relationship between the three variables and predicted probability was accepted even at the 10 percent level of significance

7.4 CHAPTER AND SUMMARY CONCLUSION

Energy poor people use biomass, not as a matter of choice, but because it is available and affordable. In real terms though, biomass is not cheaper, it is not affordable. In South Lunzu Township, biomass was found to be an inferior energy commodity whose demand was declining with increases in income. Households with higher income levels preferred cleaner energy resources such as electricity. The energy ladder hypothesis was confirmed to be valid for the case of South Lunzu Township in the city of Blantyre because, first there was a negative relationship between income of the head of household and quantity demanded for paraffin and fuel wood. In addition, there was a positive relationship between incomes on the one hand and quantity demanded for electricity and LPG on the other hand. However, apart from income, there are other factors that affect the demand for particular energy facilities.

South Lunzu Township is an energy poor community with more than 80 percent of the households living below the energy poverty line. In this area, more than 40 percent of the households depend on biomass for their cooking needs. For those who have

electricity, only less than 10 percent use it for both cooking and lighting, about 70 percent of the households did not rely on electricity for their cooking needs.

In terms of factors that affect the level of energy poverty, which include expenditure on transport, income levels, age of the head of household, education level of head of household, household size and home size, relate differently. The results of this thesis in Chapter 8 show that gender, expenditure on housing and marital status cannot be relied upon as important predictors of the probability of energy poverty in South Lunzu.

Expenditure on education was associated with lower levels of energy poverty. Households who spent more on schooling were also spending more on food items and their expenditure on energy resources was less than 10 percent of the total expenditure per month. In addition, those households which spent more on food were also likely to be energy well-off. This could be explained in the sense that higher expenditures on food might imply that the household was also well-off in terms of income poverty.

Chapter 9 follows with a further micro econometric analysis for energy choices. This analysis employed the Multinomial Logit Model, first introduced by Luce (1959), for seven cooking options available to respondents.

CHAPTER 8 MICROECONOMETRICS OF ENERGY CHOICE

8.1 INTRODUCTION

The theories of consumer behaviour in microeconomics suggest that man, as a social animal, is rational whenever choices are presented. For energy, rationality implies that resources deemed superior in providing more energy at an affordable price should be preferred. As shown by Bhattacharya (2011:47), the microeconomic basis for consumer energy demand relies on consumers' utility maximisation principles which assume that:

- Consumers know their preference sets and ordering of the preferences;
- Preference ordering can be represented by some utility function; and
- The consumer is rational in that she will always choose a most preferred bundle from the set of feasible alternatives.

Following consumer theory, it is considered that an incremental increase in consumption of a good, keeping consumption of other goods constant, increases the satisfaction level but this marginal utility (or increment) decreases as the quantity of consumption increases. Moreover, maximum utility achievable, given the prices and income, requires marginal rate of substitution to be equal to the economic rate of substitution. This, in turn, requires that the marginal utility per dollar paid for each good be the same. If the marginal utility per dollar is greater for good A than for good B, then transferring a dollar of expenditure from B to A will increase the total utility for the same expenditure. It follows that reduction in the relative price of good A will tend to increase the demand for good A and vice versa (Mills & Toke, 1985:20; Batchaya, 2011:47)

Chapter 7 analysed the data set on three fronts namely, descriptive analysis, Engel functions and the determination of the energy poverty level. Further, the analysis analysed the determinants of the energy poverty levels as predicted through a logit regression model. This chapter takes the analysis further to examine consumer behaviour as choice of energy facilities for cooking to be decided upon. A MNL was

employed and interpretation was based on statistical inference, marginal effects and elasticities calculated for each one of the seven outcomes available to the respondents.

8.2 CHOICE THEORY AND MULTINOMIAL LOGIT MODELS

The theory on Multinomial Logit models is presented in Section 4.4 of Chapter 4. Briefly, MNL models are a class of regression models where the dependent variable is categorical with at least three outcomes. These models emanate from the theory of consumer behaviour where an economic agent aims at maximising utility in the face of constraints. In the present case, the consumer has seven possible choices to make for cooking energy needs at the household level. Faced with budget limitations, availability, efficiency issues and other variables, the consumer chooses an outcome.

A limitation of the Multinomial (MNL) models is that discrimination among the m alternatives reduces to a series of pair wise comparisons that are unaffected by the characteristics of alternatives other than the pair under consideration. This, literally, reduces the MNL model to a binary choice logit model between any pair of choices. There are, therefore, a series of equations being estimated, which are imbedded in the MNL. This weakness of MNL is known in the literature as the red bus–blue bus problem, or more formally, as the assumption of independence of irrelevant alternatives (IIA). It can be tested by a Hausman specification test (Cameron & Trivedi, 2005:503; Hausman & McFadden, 1984:1221).

As a consequence, much of the econometric literature for categorical data has focused on alternative, unordered models that do not have this weakness. However, this thesis estimated the MNL because, firstly, the other models such as the Random Parameters (RPL) require the use of panel data, which the present thesis could not collect due to time and budgetary constraints. Secondly, other models, such as the Nested Logit model require well defined stages in the manner that decisions are made. This thesis had straight forward survey data which could be handled well without problems. The specification doubts were cleared through a Hausman specification test which revealed that the null hypothesis of presence of IIA could be rejected.

8.3 RESULTS OF THE MULTINOMIAL LOGIT MODEL

Results of the multinomial logistic model (MNL) are reported as a split table labelled 9.1 through 9.6 because included in one; the table could have been long and difficult to read.

8.3.1 MNL results focusing on outcome electricity

Table 8.1 gives the part of the results for the outcome ‘Electricity’ compared to the base outcome which was automatically chosen by Stata to be Electricity and charcoal. Since ‘Electricity and Charcoal’ was a preferred option for cooking needs for over 42 percent of the households (see Table 6.5 in Chapter 6), it was chosen as the base category to which the other six categories were compared. The coefficients were reported as Relative Risk Ratio rather than simple coefficients for a more meaningful interpretation, since discrete choice models are more concerned with predictions and estimations of probabilities that one event occurs on condition of the other (Cameron, & Trivedi, 2005:450).

As shown by Green (2003:670) and Cameron and Trivedi (2005:450), the relative risk ratio is the ratio of the probability of choosing one cooking energy outcome category over the probability of choosing the baseline category. The RRR is also known as the Odds ratio in binary models such as logistic or logit. Since the MNL is a series of equations, exponentiating the linear equations, which is the same as calculating the exponential of the coefficient, gives the relative risk ratio of obtaining a unit change in the independent variable (Cameron & Trivedi, 2005:450).

Similar studies that employed MNL include Pundo and Fraser (2006:24) who employed a multinomial logit model to investigate the factors that determine household cooking fuel choice between firewood, charcoal, and kerosene in Kisumu, Kenya. Their empirical results indicated that level of education of the wife, the level of education of the husband, type of food mostly cooked, whether or not the household owns the dwelling unit, and whether or not the dwelling unit is traditional or modern, are important factors that determine household cooking fuel choice. The present thesis goes further to

include not three but seven possible cooking outcomes and the household characteristics were also increased.

Table 8.1 Results of the multinomial logit model for outcome ‘electricity’

	COOK SOURCE	RRR	Standard Error	Z	P> z
Electricity	Income	1.00007	0.00000612	2.54	0.011**
	Hmsize	1.017479	0.0061	2.89	0.004***
	Hhsize	1.217355	0.22143	1.08	0.28
	Poor	0.264390	0.26213	-1.34	0.18
	wtp_smoke	1.000612	0.00043	1.42	0.155
	wtp_clean	0.999855	0.0003	-0.49	0.625
	Age	1.074593	0.04124	1.87	0.061*
	exp_food	1.00005	0.00002	2.56	0.01**
	_cons	0.000034	0.000087	-4.07	0.00***
Firewood and Charcoal		(base outcome)			

Source: energy poverty and sustainable development survey, 2012

Where *, **, and *** imply statistical significance at the 1 percent, 5 percent and 10 percent level. As Table 8.1 shows, the relative risk ratio for one unit increase in the variable *income* was 1.00002 for choosing electricity as a cooking energy facility compared to a combination of firewood and charcoal. This relationship was statistically significant at the 5 percent level to reject the hypothesis that income is not an important factor influencing choice of electricity for cooking in the household. The results also show that the probability of electricity being chosen as a cooking energy facility rises with increases in income levels. In terms of elasticity, a 1 percentage increase in income has the expectation of increasing the probability of household using electricity by 0.3 percent. This is an inelastic relationship, although it was statistically significant at the 10 percent level.

A 1 percentage increase in the size of the dwelling unit (home size) also had a potential of increasing the probability of household using electricity for its cooking needs compared to a combination of firewood and charcoal by 0.70. Again the relationship was inelastic but statistically significant at the 5 percent level. The RRR was also in the favour of the use of electricity with increases in dwelling unit. This was expected since *ceteris paribus*, large houses are owned or occupied by relatively higher earning individuals who demand electricity as a normal commodity compared to the inefficient fuel wood.

Although statistically insignificant, household size also seems to have a positive relationship with choice of cooking facility, as electricity compared to electricity and charcoal together. The probability that a household that was larger would opt for electricity as its cooking energy facility was expected to be higher compared to smaller households.

The relative risk ratio of choosing electricity over firewood and charcoal combined for cooking needs was 0.264390 for variable poor and it was statistically insignificant to reject the hypothesis that the perception of wellbeing influences the choice of electricity over firewood and charcoal combined in South Lunzu Township. This does not come as a surprise, since the supply side of electricity in Malawi is more irregular than normal.

8.3.2 MNL results focusing on outcome liquefied petroleum gas

Table 8.2 presents results of the multinomial logit model focusing on LP gas. It should be pointed out that this table should be read together with the other tables from 8.1 to 8.6, as they are essentially the same table split to fit in the pages. As Table 8.2 shows, all the predictors, apart from expenditure on food, were statistically not important in influencing the choice for LP Gas over the combination of outcome 'Firewood and Charcoal'. The relative risk ratio (RRR), however, was in favour of income, household size, home size, and WTP for a clean environment.

Table 8. 2 Multinomial logit model focusing on outcome ‘LP Gas’

	COOK SOURCE	RRR	Standard Error	z	P> z
LP_Gas	Income	1.000015	1.3E-05	1.17	0.244
	Hmsize	1.010456	0.01589	0.66	0.508
	Hhsize	1.274321	0.65506	0.47	0.637
	Poor	6.26E-07	0.00041	-0.02	0.982
	wtp_smoke	0.9985383	0.00335	-0.44	0.663
	wtp_clean	1.000134	0.00026	0.51	0.608
	Age	0.9978311	0.10705	-0.02	0.984
	exp_food	1.00007	3.3E-05	2.11	0.035**
	_cons	0.0002328	0.00118	-1.64	0.1
Firewood and Charcoal		(base outcome)			

Source: Energy poverty and sustainable development survey, 2012

Where *, **, and *** imply statistical significance at the 1 percent, 5 percent and 10 percent level. Although not statistically significant, the above 1 RRR indicates that for an increase in these variables, there is an expectation that LP Gas will be preferred to a combination of firewood and charcoal. These results are in agreement with studies by Onoja and Idoko (2012:119) and Cayla *et al.* (2011:7878), where the demand for LP Gas was found to respond positively to changes in income.

8.3.3 MNL results focusing on outcome Solar

For outcome ‘solar’ as an energy facility for cooking, the results are as shown in Table 8.3. The RRR for variable ‘Income’ was 0.9999 and it was not statistically significant. The less than 1 RRR, however, seems to suggest that increases in income have an expected outcome of reducing the probability that a household chooses solar as an energy facility for cooking needs. Solar energy in this case is regarded as a commodity

for the poor and uncivilised households. As a matter of prestige, the use of solar power is expected to be associated with those in lower income brackets. It was interesting to note that all the variables were not statistically significant to reject the hypothesis that they were not important in determining the probability that a household chooses solar for its cooking needs over firewood and charcoal combined.

Table 8.3 Results of the multinomial logit model focusing on Outcome ‘Solar’

	COOK_SOURCE	RRR	Standard Error	Z	P> z
Solar	Income	0.999998	0.0000384	-0.05	0.964
	Hmsize	0.961197	0.0546014	-0.7	0.486
	Hhsize	1.15339	0.5094732	0.32	0.747
	Poor	8.69E+07	1.32E+11	0.01	0.99
	wtp_smoke	1.000846	0.0009461	0.89	0.371
	wtp_clean	1.00008	0.0006547	0.12	0.903
	Age	1.060452	0.0993914	0.63	0.531
	exp_food	1.000026	0.0000601	0.42	0.671
	_cons	1.02E-11	1.55E-08	-0.02	0.987
Firewood and Charcoal		(base outcome)			

Source: Energy poverty and sustainable development survey, 2012.

Where *, **, and *** imply statistical significance at the 1%, 5% and 10%.

8.3.4 MNL results focusing on outcome Charcoal

The results for outcome charcoal confirm that, in South Lunzu Township, charcoal is regarded as a higher and better energy commodity compared to a combination of charcoal and firewood. The RRR of greater than 1.0 suggests that an increase in income also increases the probability of a household opting for charcoal only for

cooking needs, compared to a combination of charcoal and firewood. This relationship, however, was statistically insignificant to reject the null hypothesis that income does not have any influence on the choice of charcoal as a cooking energy facility.

Table 8.4 Results of the multinomial logit model for outcome ‘charcoal’

	COOK SOURCE	RRR	Standard Error	Z	P> z
Charcoal	Income	1.000004	5.56E-06	0.73	0.463
	Hmsize	1.007348	0.0041799	1.76	0.078*
	Hhsize	0.842547	0.0703422	-2.05	0.04**
	Poor	0.8457198	0.2486062	-0.57	0.569
	wtp_smoke	1.000407	0.0001776	2.29	0.022**
	wtp_clean	0.9998144	0.0001322	-1.4	0.16
	Age	0.9786352	0.0135062	-1.56	0.118
	exp_food	1.000009	0.0000148	0.61	0.543
	_cons	1.391139	0.9205154	0.5	0.618
Firewood and Charcoal		(base outcome)			

Source: Energy poverty and sustainable development survey, 2012.

Where *, **, and *** stand for statistical significance at the 1%, 5% and 10%. Size of dwelling unit was statistically significant at the 5 percent level to reject the null hypothesis that size of house influence consumers to choose charcoal for cooking energy provision over firewood and charcoal combined.

An environmentally important result is where willingness-to-pay for a smoke free environment had a strong influence on the choice of charcoal as opposed to firewood

and charcoal combined with a RRR of above one but rather weaker. This suggests that those who had a higher WTP for a smoke free environment had the higher probability of using charcoal compared to a combination of charcoal and firewood for cooking purposes. The remaining variables, namely age of head of household, expenditure on food, and WTP for a cleaner environment had weaker influence on the choice of charcoal as a cooking facility.

8.3.5 MNL results focusing on outcome Firewood

Results for outcome ‘firewood’ are shown in Table 8.5. The rest of the variables, apart from age of the head of household, were statistically insignificant in influencing the probability that firewood was the outcome of choice compared to the base outcome of ‘Firewood and Charcoal’ combined. Older heads of household were likely to choose firewood as an energy resource for their household compared to younger heads of household.

The RRR for variables household size, poor, and age were above 1. For poor, it means that the probability of the head of household choosing firewood as an energy resource was higher the more they considered themselves poor. The weak and statistically insignificant RRR for income suggests that heads of household with higher income levels were less likely to consider firewood as their energy resource compared to the base outcome of Firewood and Charcoal combined.

A RRR of less than 1 for home size also suggests that the larger the size of the dwelling unit, the less likely the head of the household could be expected to choose firewood as an energy resource compared to Firewood and Charcoal combined. Higher expenditures on food were also likely to be associated with lower probabilities of choosing firewood for an energy resource by the head of household.

Table 8. 5 Multinomial logit model focusing on outcome ‘firewood’

	COOK_SOURCE	RRR	Standard Error	Z	P> z
Firewood	Income	1.000001	0.0000134	0.05	0.958
	Hmsize	0.9969821	0.0098938	-0.3	0.761
	Hhsize	1.109337	0.1396677	0.82	0.41
	Poor	1.594377	0.9372467	0.79	0.427
	wtp_smoke	0.9996836	0.0005437	-0.58	0.561
	wtp_clean	0.9999887	0.0003316	-0.03	0.973
	Age	1.040055	0.0223444	1.83	0.068*
	exp_food	0.9999836	0.0000367	-0.45	0.654
	_cons	0.0159083	0.0206996	-3.18	0.001
Firewood and Charcoal		(base outcome)			

Source: Energy poverty and sustainable development survey, 2012.

Where *, **, and *** stand for statistical significance at the 1%, 5% and 10% level.

8.3.6 MNL results focusing on outcome ‘Electricity, Charcoal and Wood’

A combination of electricity, charcoal and firewood was considered because, as literature suggests, the unreliability of present energy commodities, such as increasing load shedding, influences economic agents to consider a mixture of efficient and inefficient facilities. This is called fuel stacking in the literature (Rajmohan & Weerahewa, 2007:60). In Table 8.6, the results suggest that there is a positive expectation that the increase in income increases the probability that the choice of electricity, charcoal and firewood will be opted over the combination of firewood and charcoal only.

Table 8. 6 Multinomial logit focusing on ‘electricity, charcoal and wood’

	COOK_SOURCE	RRR	Standard Error	Z	P> z
Electricity, Charcoal and Wood	Income	1.000015	4.96E-06	3.02	0.003***
	Hmsize	1.015195	0.0042143	3.63	0.000***
	Hhsize	0.9339082	0.0794773	-0.8	0.422
	Poor	0.7072317	0.2342729	-1.05	0.296
	wtps_moke	1.000262	0.0001816	1.45	0.148
	wtp_clean	1.000043	0.0000759	0.56	0.574
	Age	1.007142	0.0143441	0.5	0.617
	exp_food	1.000027	0.0000133	2.05	0.041**
	_cons	0.0643945	0.0481027	-3.67	0.000***
Firewood and Charcoal		(base outcome)			

Source: Source: Energy poverty and sustainable development survey, 2012.

Where *, **, and *** stand for statistical significance at the 1%, 5% and 10% level of test. The results show that the higher the level of income the higher this probability. Statistically, it shows that this probability was strong at the 1 percent level of significance to reject the null hypothesis that income has no influence in fuel/energy stacking at the household level in South Lunzu Township.

Expenditure on food was also statistically significant to suggest that it has a strong influence on the probability that a combination of electricity, charcoal and firewood is chosen for purposes of cooking over a combination of just two facilities, namely charcoal and firewood. The size of dwelling unit was also statistically significant to suggest that the probability of a household to opt for a fuel mix of the three facilities was

higher with every increase in the size of the house. The RRR was also relatively larger at 1.02.

8.4 ANALYSIS OF ELASTICITIES FROM THE MULTINOMIAL LOGIT

Table 8.7 Marginal effects and elasticities for the MNL model

		Income	Hmsize	Hhsize	Poor	wtps_mok e	wtp_clea n	Age	exp_foo d
Electricity	dy/d x	1.29E- 07	0.00015 9	0.00456 5	- 0.01023	9.27E-06	-2.7E-06	0.00132 5	6.18E-07
	ey/e x	0.29529	0.69888 5	1.19296 3	- 0.67668	0.240047	-0.1213	2.72252 9	0.726859
LP Gas	dy/d x	1.96E- 08	-5.58E- 06	0.00128 3	- 0.06809	-8.58E-06	7.83E-07	-8.09E- 05	2.29E-07
	ey/e x	0.26545 6	0.22473 9	1.41950 8	-7.1756	-1.05368	0.125764	- 0.13197	1.12386
Solar	dy/d x	-1.74E- 08	- 0.00014	0.00055 7	0.05643 4	2.23E-06	3.62E-07	0.00017 7	5.94E-08
	ey/e x	- 0.42468	- 3.22658	0.92162 3	9.10415 1	0.385825	0.078024	2.21317 5	0.225176
Charcoal	dy/d x	-1.44E- 07	0.00047 8	- 0.02818	- 0.01599	5.87E-05	-3.43E-05	- 0.00479	7.59E-08
	ey/e x	- 0.18176	0.00845 9	- 0.64666	- 0.09141	0.113025	-0.15672	- 0.87063	-0.10443
Firewood	dy/d x	-1.29E- 07	- 0.00031	0.00638 1	0.02081 2	-2E-05	1.05E-06	0.00176 7	-1.03E- 06
	ey/e x	- 0.32162	- 0.70459	0.72857 8	0.22204 5	-0.33737	-0.00249	1.46773 7	-0.61532
EL_CH_W D	dy/d x	1.81E- 06	0.00169 6	- 0.00426	- 0.00769	0.000017	1.72E-05	0.00121 9	2.99E-06
	ey/e x	0.27065 8	0.54346 8	- 0.13192	- 0.18061	0.022922	0.045301	0.23260 2	0.26045

Source: Energy poverty and sustainable development survey, 2012.

Table 8.7 is a summary of marginal effects reported both as marginal and elasticities. As shown by StataCorp LP (2011:1221), the marginal effects and elasticities are calculated at the mean point for each variable for each outcome. The elasticities for each outcome are interpreted for the purpose of this thesis because they are easier to understand than the marginal and the coefficients. In Table 8.7, dy/dx represents a marginal effect and ey/ex represents point elasticities.

For outcome 'electricity' the variables income, home size, willingness-to-pay for a smoke free environment, age of the head of household, and expenditure on food had a positive elasticity. However, only age of the head of the household was elastic with an elasticity of 2.7 implying that a 1 unit increase in age was expected to increase the probability of electricity being chosen as a cooking facility by more than twice. For the other variables, the expected probability of choosing electricity as a cooking variable due to a change in, say, income, home size, willingness-to-pay for a smoke free environment, and expenditure on food was expected to increase less than the increase in the variable itself. Willingness-to-pay for a clean environment had a negative elasticity which was also inelastic.

Income was positive but again inelastic for outcome LP Gas, implying that a one unit increase in income was expected to increase the probability that a household chooses LP Gas for their cooking needs over the base category of 'electricity and wood' combined. A similar result is observed for variable home size and willingness-to-pay-for-clean-environment. An elastic relationship is observed for the perception of wellbeing at the household level. Where a household perceives itself to be poor, the probability that LP Gas will be substituted for 'electricity and wood' was expected to increase 7 fold. Poor mindset must be addressed. People who are believed to be poor regard LP gas as a luxury, which can be easily substituted by a combination of electricity and wood.

WTP for a smoke free environment was also elastic at -1.1 implying that a one unit increase in the WTP for a smoke free environment was expected to lower the probability of LP Gas being chosen as a cooking energy facility over the base outcome by more than a unit. Further, expenditure on food was positively elastic at 1.1 implying that for

every one unit increase in expenditure for food, the probability of choosing LP Gas as a cooking facility was expected to increase by more than a unit. In addition, household size was also elastic with an elasticity of 1.4, suggesting that every additional family member had the chance of increasing the probability of LP Gas being chosen for purposes of cooking by more than a unit.

For some of the variables, outcome 'solar' behaved as a luxury commodity considering the high level of elasticity observed for some of the variables. For instance, home size was negatively elastic at -3.22, suggesting that a unit increase in the size of the household could reduce the probability of the household choosing solar as a cooking energy facility by three fold. In addition, the perception of wellbeing was very elastic with an elasticity of 9.1. So too was age of the head of household with an elasticity of 2.2. The other variables, namely expenditure on food, willingness to pay for a clean environment, willingness to pay for a smoke free environment, household size, and income were inelastic although with a positive sign apart from income. The negative elasticity for income implies that solar is regarded as an inferior commodity whose demand is expected to be lower with increases in income, although not significantly.

None of the variables were elastic regarding the outcome 'charcoal'. Negative elasticities were reported for size of dwelling unit, perception on wellbeing, willingness-to-pay for a clean environment, willingness-to-pay for a smoke free environment, age of household and expenditure on food. A one unit increase in these variables lowers the probability of charcoal being chosen as an energy facility for cooking by less than a unit and, therefore, increasing the probability that the base outcome facility is opted.

Apart from age of the head of household, all the other variables were inelastic for outcome 'firewood'. The elasticity of variable age on outcome 'firewood' was 1.5, meaning that a one unit increase in the age of the head of household increases the probability of firewood being the preferred source of energy for cooking needs of the household as opposed to outcome 'electricity and wood' combined.

The inelastic relationship between the base outcome on the one hand and household size and perception of wellbeing on the other was negative. It was also negative for expenditure on food, willingness-to-pay for smoke free environment, willingness-to-pay for a clean environment, income and home size.

All the variables were inelastic for the outcome 'electricity, charcoal and firewood' combined compared to the base outcome of 'electricity and charcoal'. It was also interesting to note that, apart from household size and perception on wellbeing, the other variables had a positive elasticity. For instance, a one unit increase in income was expected to lead to a less than unit increase in the probability that outcome 'electricity-charcoal-wood' was chosen compared to the base outcome of 'electricity and charcoal'. The next section is a summary of predicted probabilities of choosing each one of the outcomes based on the MNL model.

8.5 DESCRIPTIVE STATISTICS OF PREDICTED PROBABILITIES

As a further step with the analysis, just like the logit model for energy poverty, in Chapter 8, probabilities were predicted following Cammeron and Trivid (2005:502). These were predicted probabilities of a head of household choosing a particular energy resource. Results of the descriptive statistics analysis are presented in Table 8.7. As Table 8.7 shows, the highest mean probability was for outcome 'electricity, firewood and charcoal' which had a maximum value of about 0.9928 (about 99 percent). However, the standard deviation was higher at 0.1906. The average probability of choosing outcome 'electricity, firewood and charcoal' was about 24 percent.

Charcoal was the next highly probable energy facility to be chosen for cooking in South Lunzu Township with a maximum probability of 0.7329 (about 73 percent) with a standard deviation of 0.1171 and an average probability, as measured by the mean of 0.2524. Two outcomes, 'electricity' and 'firewood and charcoal' were third and fourth, respectively, with maximum probabilities of 0.6757 (about 68 percent) and 0.6712 (about 67 percent). However, electricity had a lower average probability of 0.0221 (about 2 percent) compared to firewood and charcoal with an average probability of

being chosen of 0.4259 (about 43 percent) of the sampled heads of household. Solar had the least maximum probability to be chosen as an energy resource by the heads of household with a maximum probability of 0.0656 (about 7 percent). The average probability of choosing solar was 0.0032 (about 0.3 percent).

Table 8. 8 Descriptive statistics of the predicted probabilities for the outcomes

Variable	Mean	Standard Deviation	Min	Max
Electricity	0.0221	0.0529	0.0000504	0.6757
LP_Gas	0.0063	0.0369	3.75E-14	0.4851
Solar	0.0032	0.0084	1.76E-23	0.0656
Charcoal	0.2524	0.1171	0.0000238	0.7329
Firewood	0.0473	0.0488	9.88E-08	0.4008
Electricity, charcoal and wood	0.2429	0.1906	0.0304015	0.9928
Firewood and charcoal	0.4259	0.172	9.49E-06	0.6712

Source: Source: Energy poverty and sustainable development survey, 2012.

The least probable outcome was solar energy followed by LP Gas. These two facilities had the least chance of being chosen to provide household energy needs. Of interest was firewood, which had one of the smallest probabilities of being considered for energy needs in South Lunzu. Truly, this reflects the theory of the energy ladder which puts fuel wood at lower levels. Its continued use is, therefore, a matter of desperation among the people.

8.6 VALIDATION OF THE MNL MODEL

The procedure was to test whether the coefficients of the variables were different from zero. The alternative hypothesis, therefore, is that the coefficients or parameters were not statistically equal to zero. The statistic used in the literature is the Likelihood ratio test which measures the lambda given by a Chi-square of the form:

$$\chi^2 = -2[L(Br) - L(Bu)],$$

The results are shown as Tables A6 through A8 in the Annexure to this report. The results show a Chi-Square statistic of 80.81 with 48 degrees of freedom lost. The p-value was 0.0021, which suggests that at the 1 percent level of statistical significance, the null hypothesis is rejected and the alternative hypothesis that the parameters were not statistically equal to zero is accepted.

- Chi-Square (48) = 80.81
- Prob > chi-Square = 0.0021

Table 8.9 Test of statistical significance of the parameters

(1)	-	[Electricity]income + [Electricity]hhsz = 0
(2)	-	[Electricity]income + [Electricity]poor = 0
(3)	-	[Electricity]income + [Electricity]wtps_moke = 0
(4)	-	[Electricity]income + [Electricity]wtp_clean = 0
(5)	-	[Electricity]income + [Electricity]Age = 0
(6)	-	[Electricity]income + [Electricity]exp_food = 0
		chi2(6) = 6.96
		Prob > chi2 = 0.3248

Source: Source: Energy poverty and sustainable development survey, 2012.

Where *, **, and *** means statistical significance at the 1%, 5% and 10% level

8.7 SUMMARY AND CONCLUSION

Behavioural economics argues that human beings are social animals that are rational in that more of a good is preferred than less. This principle is limited when the energy sector in developing countries is considered. For Malawi, where energy poverty is

rampant, quantity of the commodity is not enough. Quality of the commodity that supplies energy matters as well.

There are many options from which consumers can choose energy products to use for their household needs. The list includes firewood, charcoal, paraffin, briquettes, agricultural residues, electricity, solar power, wind energy, liquefied Petroleum gas. A combination of the resources was more common in South Lunzu Township compared to a reliance of one particular energy resource.

As shown by the results of this chapter, where a Multinomial Logit analysis was adopted to analyse energy choice behaviour of residents of South Lunzu Township, the income of the head of household, age, home size, and expenditure on food were important factors that affected the probability that electricity was chosen as an energy resource for the household.

Outcome 'electricity' the variables income, home size, willingness-to-pay for a smoke free environment, age of the head of household, and expenditure on food had a positive elasticity. However, only age of the head of the household was elastic with an elasticity of 2.7, implying that a 1 unit increase in age was expected to increase the probability of electricity being chosen as a cooking facility by more than twice. For the other variables, the expected probability of choosing electricity as a cooking variable due to a change in, say, income, home size, willingness-to-pay for a smoke free environment, and expenditure on food was expected to increase less than the increase in the variable itself. Willingness-to-pay for a clean environment had a negative elasticity, which was also inelastic.

In conclusion, this chapter paid special attention to the analysis of energy demand choices in the face of several options. Multinomial logit model was employed to the cross sectional data and the results show that, in general, there was a greater probability for firewood and charcoal to be used at the household level given the other outcomes of energy. There were other variables, which were inelastic to some of the

outcomes. The next chapter finalises this report by providing discussion, conclusion and policy recommendations/implications emanating from the results of the thesis.

CHAPTER 9 SUMMARY AND CONCLUSION

9.1 INTRODUCTION

Energy is central to the achievement of the MDGs. Sustainable development requires sustainable supplies of energy resources that do not put future generations at the risk of zero supplies. In sub-Saharan Africa, the main energy resource is biomass, both in rural and urban areas. Being an economy based primarily on agriculture, Malawi is not an exception. Biomass is constantly becoming unsustainable for both industry and household use. This thesis set out to analyse the demand for energy resources in Blantyre, Malawi.

Sustainable Development (SD) is an important element of economic growth policies and it is a global agenda. There are two approaches to SD. One approach considers economic development more than other sectors of the society that it is the use of the current stock of resources that meets the needs of the present generation without compromising the ability of future generations to meet their own needs. In this view, SD is narrowly comprehended by concentrating only on sustaining the stock of resources necessary to support and maintain life, not just for the current, but also future generations. A much broader approach views SD as human activity that nourishes and perpetuates the historical fulfilment of the whole community of life on earth

What is common in both approaches is that present generation's consumption of resources should not be at the expense of future generations. SD should mean improved wellbeing of both the present and future generations. SD advances development that is not only happening and desired to happen in future, but also needed by the community.

SD should also be understood to be a process that aims at maintaining or increasing national wealth. Current generations, just like the future ones, are expected to define their own development goals. What is important is that such goals must not be attained at the expense of availability of the national wealth for the future generations. It is important, however, to spell out that, although the eight MDGs are a good indicator on

which less developed countries must focus and measure themselves against, in order to ascertain whether they are on the right path, the eighth MDG of universal access to modern, clean and affordable energy must be included with clear targets and time frames.

SD, as embraced in MDGs targets, is not achievable if governments do not address energy poverty at both the household and industry level. Apart from environmental sustainability, the other MDGs, such as the eradication of poverty and hunger, gender equity, improved health and education services need modern, efficient and cleaner energy supplies. For example, households cannot eat uncooked food. Therefore, a food secure household is one that has enough energy to help with the final preparation. For non-commercial biomass, the provision of renewable and sustainable energy in households frees time for women to do other productive activities such as advancing in education and engaging in SMEs, thereby empowering them. This further improves their health status as they do not have to do heavy manual work by walking long distances in search of fuel wood.

Two approaches can be used to explain and find indicators for sustainable development. The first method envisages an economy as a set of capital segments namely financial, human, natural, productive and social capital, which together forms the national wealth. One capital might change form to become one of the five such that SD must be considered from a view point of the value of wealth of the nation. If wealth of a nation is depleting then it means sustainable development targets are not being met.

The second approach, in essence, extends the capital method by considering the process of sustainable development as a set of maintained or improved subsystems which coexist in a symbiotic manner. In this approach, the systems approach, small elements of the environment ranging from social to economic to environment are all considered at the same time and aggregate indices are avoided. Whilst in the capital approach, an aggregate index for sustainable development might be developed and observed over a period of time, the systems approach argues that sustainable

development is not just about the wealth being available but also that which is needed by both the current and future generations. In which case, certain subsystems might become obsolete depending on the needs of the generations.

To achieve the MDGs and sustainable development in general, policies and strategies that will encourage the use of green energy both at the household and industrial level are important. Energy is important to eradicate poverty through improved education, health services and even provide employment to many people with a variety of skills. The linkages associated with many energy projects seem to suggest that there are more multiplier effect gains by engaging in green energy activities especially for the less developed countries.

9.2 OVERVIEW OF THE THESIS

The overall objective of this thesis was to measure energy poverty for households in Malawi in general and Blantyre in particular and econometrically estimate demand for energy facilities. Specifically, the thesis aimed to:

- (i) Establish the knowledge levels of the existence, benefits and costs of RE sources among households in Blantyre, Malawi;
- (ii) Review the history of energy policy in Malawi;
- (iii) Investigate household responsiveness of energy demand due to changes in income in Blantyre;
- (iv) Determine and compute energy poverty measurement index;
- (v) Econometrically estimate energy demand models;
- (vi) Examine the impact of household social and economic characteristics on energy choices; and
- (vii) Consider energy policy options and recommendations for Malawi in general.

Using inferential statistical methods, these hypotheses were tested by employing t-statistics, F-statistics, z-scores and the Chi-square evaluated at the 1 percent, 5 percent and 10 percent levels of significance.

In summary, Chapters 6 and 7 presented the analysis and results of the study starting from descriptive statistics, tabulations of associations to econometric models. The method of sampling and data collection was also discussed. This chapter provides the conclusion and policy recommendations of the econometric analysis of energy poverty and sustainable development in South Lunzu (Blantyre).

9.3 RESEARCH METHODOLOGY AND DATA USED

9.3.1 Theoretical basis of the thesis

This thesis was based on four main theories to create the hypotheses that were empirically tested. First, the thesis reviewed the techniques of measuring energy poverty and what determines it. Energy poverty can be measured by considering economics, engineering or a hybrid of both methods. These measurement techniques are borrowed from the mainstream studies of income poverty. The economics approach was adopted for this thesis where an agent's expenditure on all energy resources is compared to the whole consumer basket of the household. Engineering methods require that energy conversion factors be identified to fully quantify the expenditure on energy facilities in monetary terms. Further, data on the amount of energy resources acquired by economic agents is obtained for the purpose of applying it to the conversion factors.

Secondly, sustainable development was also reviewed and linked to the achievement of the MGDs. Nearly all MGDs cannot be a success story where biomass is still the major source of energy needs in households around the world. Where the rate at which biomass, which in the case of an urban community is firewood and charcoal made from trees, is harvested at a faster rate than regeneration, sustainable development could not be achieved. Also, the MDGs depend on the availability of affordable and clean energy resources to all people. There is a need for clean energy resources to be available for school pupils to complete their homework, women to be empowered, agricultural activity to be improved and health services to be enhanced.

Thirdly, consumer theory of demand was also reviewed beginning with an exposition of economics of energy. All consumers were assumed to be rational in that maximising of utility from consumption of energy is their objective, subject to a number of constraints. These constraints include the budget line. However, for the case of the energy market in developing countries, there are other constraints such as availability and reliability of energy resources. Therefore, the theory of consumer maximisation for the energy sector in Malawi in particular and developing countries in general could not hold.

Lastly, following consumer maximisation theory, the thesis went further to review discrete choice models. There are binary models such as the logit, probit and tobit models where the dependent variable is qualitative with two outcomes. This theory was applied with the logistic regression on energy poverty dummy variable. Other models such as the multinomial logit consider cases where the categorical variable has more than two outcomes. For the respondents in South Lunzu Township, about five outcomes could be chosen for household energy needs.

9.3.2 The empirical process

Random Sampling was used to collect survey data in Blantyre City, a high density area of South Lunzu (SLT). SLT has twelve sectors each with about 500 households. Households were randomly chosen and in total, the survey collected data through questionnaire administration to 319 heads of household and their spouses. The cross sectional data was subjected to a three stage analysis. First, descriptive statistics of continuous data and frequency distribution for discrete data were computed and interpreted. A pictorial examination of the data was also employed using pie charts, bar graphs, histograms and box plots.

Second, regression analysis using Engel curve framework to identify energy commodities which are inferior and those superior to others was done. Third, was discrete choice analysis using both logistic and Multinomial Logit models for binary and polynomial dependent variables, respectively.

9.4 THE FINDINGS AND CONTRIBUTIONS OF THE THESIS

9.4.1 Economic and energy status of South Lunzu Township

The findings of this thesis are, in many ways, similar to a number of similar studies that were carried out in a number of areas around the globe. Firstly, the descriptive statistics showed that indeed, the number of people that depend on biomass even in an urban location is still higher. In Chapter 6, the thesis set out to descriptively examine the percentage of people relying on different energy resources for cooking and lighting at the household level.

9.4.2 Analysis of energy demand

Two methods of measuring energy poverty were adopted. The first one considered any household whose cost of energy was more than 10 percent of its total expenditure as being energy poor. Using this method, over 90 percent of the households were found to be energy poor. The second method adopted techniques from income poverty analysis, especially relative poverty line where the average of cost of energy for all the households was computed. All households whose cost of energy was less than the mean, which was regarded as the energy poverty line, were treated as being energy poor relative to others in South Lunzu. Using this method the thesis found that slightly above 60 percent of the population could be regarded as being energy poor.

As expected, firewood and many other biomass energy facilities were found to be inferior commodities agreeing with results from other studies such as (Rajmohan & Weerahewa, 2007:60). With increases in income there was a higher probability that more clean energy facilities such as electricity and solar would be opted over fuel wood. The perception of poverty was an influencing factor on the type of energy resource that was demanded by a household. For example, those households whose head believed to be poor were most likely to demand biomass compared to those who did not (Chapter 6 and 7).

These results were similar to the national survey by the National Statistical Office's Integrated Household Survey number three which concluded that in Malawi, which found that in urban areas, 84 percent and 65 percent of households use firewood and charcoal, respectively (Kambewa & Chiwawula 2007:9). Other devices include candles and wood fire. The recently released Integrated Household Survey 3 confirms that in both urban and rural areas of Malawi, solid fuels are common for cooking. Solid fuel refers to various types of solid material that are used as fuel to produce energy and provide heating, usually released through combustion. Almost all households (97 percent) use solid fuels for cooking in Malawi.

The case is even more severe in rural areas where use of solid fuels is at 99 percent. The results of the IHS3 also show that the proportion of male and female-headed households that use solid fuels is almost equal at 97 percent and 98 percent, respectively. In terms of consumption quintiles, there is universal use of solid fuel in the lowest quintile while nearly 10 percent of the households in the highest quintile use alternative means of cooking fuel other than solid fuels (GOM-NSO, 2012:120).

The most common source of cooking fuel in the country is firewood at 88 percent, followed by charcoal (9 percent), electricity (3 percent) and other means of fuel for cooking at 1 percent. Considering nature of residence by development, urban areas have a rather low proportion of households using firewood as source of cooking fuel registering 42 percent, while rural areas have registered almost 96 percent. What is interesting is that more households in the lower consumption quintiles use firewood for cooking compared to households in the higher consumption quintiles. The northern region has the highest proportion of households using firewood as cooking fuel at 95 percent while the central region comes second (90 percent), and finally the southern region that has recorded 84 percent use of firewood.

This thesis also found that for light, 43 percent use electricity, 20 percent paraffin, and another 20 percent candle, 15 percent battery power, followed by only a handful using solar and other sources of energy. This is in sharp contrast, especially regarding electricity, where 2.9 percent solely depend on electricity and 24.76 percent of the

households sampled use a combination of electricity on the one hand, and firewood and charcoal on the other. These results compare well with previous studies such as the National Statistical Office's IHS3 and Kambewa and Chiwaula (2010).

For instance in terms of lighting, although paraffin is a rarely used source of cooking fuel in the country, the situation is different when it comes to lighting because paraffin is the most common source of lighting fuel (52 percent), followed by battery (27 percent), firewood and electricity (8 percent both) and the remaining, candles and others (5 percent and 1 percent respectively). Rural areas have the highest proportion of households using paraffin as source of lighting fuel at 54 percent while only 43 percent of urban households use paraffin. The proportion of female-headed households using paraffin as lighting fuel is higher than that of males at 57 and 50 percent, respectively. Across the regions, the southern region has the highest proportion of households using paraffin for lighting at 64 percent while the central comes second at 41 percent and then the south at 40 percent.

This thesis also found that solar power is the most popular among many possible alternative energy resources with 70 percent of the sampled respondents in South Lunzu reporting that they have ever heard or seen the facility (Chapter 6). Solar was followed by wind energy and Geothermal, in that order. Following the knowledge levels, also over 70 percent preferred solar power as their choice of alternative energy given three factors that first, it should be locally available, second it should be affordable and third it should be the type that can be used for cooking as well.

In terms of the energy poverty levels, using an economics measure that every household that was spending more than 10 percent on of its income on energy facilities was energy poor, the thesis found that in South Lunzu Township, more than 90 percent of the households could be considered energy.

A relative measure of energy poverty was also performed where the mean of the cost of energy was computed. Those whose cost of energy was found to be below the average were deemed as energy poor and those above the mean were well-off. Following this

method, about 62.4 percent of the sampled households could be considered in energy poverty while that of households deemed not energy poor were 120 representing about 37.6 percent.

9.4.3 Econometric analysis of energy choice

Chapter 8 employed a multinomial logit model to the cross sectional data to analyse the factors that influence the probability that a particular energy resource is chosen by a household. This was an effort to address the fifth specific objective of this study. The results show that, in general, there was a greater probability for firewood and charcoal to be used at the household level given the other outcomes of energy. There were other variables, which were inelastic to some of the outcomes.

There are many options from which consumers can choose energy products to use for their household needs. The list includes firewood, charcoal, paraffin, briquettes, agricultural residues, electricity, solar power, wind energy, liquefied Petroleum gas. A combination of the resources was more common in South Lunzu Township compared to a reliance of one particular energy resource.

As shown by the results of this chapter, where a Multinomial Logit analysis was adopted to analyse energy choice behaviour of residents of South Lunzu Township, the income of the head of household, age, home size, and expenditure on food were important factors that affected the probability that electricity was chosen as an energy resource for the household.

Outcome 'electricity', the variables income, home size, willingness-to-pay for a smoke free environment, age of the head of household, and expenditure on food had a positive elasticity. However, only age of the head of the household was elastic with an elasticity of 2.7 implying that a 1 unit increase in age was expected to increase the probability of electricity being chosen as a cooking facility by more than twice. For the other variables, the expected probability of choosing electricity as a cooking variable due to a change in say income, home size, willingness-to-pay for a smoke free environment, and expenditure on food was expected to increase less than the increase in the variable

itself. Willingness-to-pay for a clean environment had a negative elasticity, which was also inelastic.

9.5 CONCLUDING REMARKS

This thesis had four main questions to address. First, it showed the knowledge levels of renewable energy and its capabilities together with the willingness to use it. The thesis then proceeded to identify which energy resources were considered inferior by urban poor consumers. It further measured energy poverty using conventional measurements apart from showing the relationship between energy poverty and socioeconomic factors. In addition, the thesis went on to model the choice of energy resources using micro econometric techniques. These questions were addressed successfully by this research.

Energy poverty is a situation that needs urgent attention especially in SSA. The attainment of the MDGs cannot be a success story without proper and universal access to modern, clean and efficient energy in sustainable quantities and quality. Renewable energy should be extended to urban societies and those RE facilities that can provide enough power to be used even for cooking must be provided by adopting relevant policies at any cost. Industrialisation of Malawi, and SSA in general, will depend on sustainable use of resources, which cannot be attained without adoption of renewable energy.

9.6 POLICY RECOMMENDATIONS

Stemming from the findings and contributions of this thesis, several recommendations about energy market and policy can be made to achieve sustainable development in Malawi.

9.7.1 General Policy Recommendations

This thesis recommends that there be an increased supply of and access to modern, efficient and clean energy resources to enhance the process of sustainable

development in Malawi. That renewable energy policy should concentrate on rural areas, is an oversight which must be reversed by considering widening the target.

More power generation plants should be built to increase the supply of electricity to both industry and households. Further, the energy regulatory framework needs to be improved and changed to include severe punishments on those who use polluting energy facilities.

9.7.2 Specific Policy Recommendations

First, the 2003 Malawi Energy Policy did not tackle the issue of renewable energy in Malawi. Simple briquettes and emphasis on biomass as a renewable energy should be halted and, instead, it is imperative that government team up with the private sector and non-governmental organisations to promote the adoption of modern renewable energy in households and industry. The notion that renewable energy facilities such as solar power and wind energy are tenets of rural energy solutions must be removed from the policies and programmes of government. Instead urban households should be encouraged to adopt such facilities for two main reasons. Firstly, a considerable number of them are willing to pay for renewable energy facilities such as solar power and secondly, their knowledge and access to information is superior.

Secondly, it is clear from the results of this research that energy poverty is a long term phenomena and it is affected by the amount of education on the environment, sustainable development and abilities of other resources. The school system should, therefore, be used beginning from early years of schooling such as primary schools to plant the knowledge of dangers of relying in biomass for energy needs at the household level. Teach them while they are young, when they grow they shall practice.

Government needs to subsidise the price of renewable energy just like it does for electricity. For electricity, as shown in chapter 3, the government of Malawi's controls does not necessarily subsidise the cost of electricity, but rather through the Malawi Energy Regulatory Authority, it controls the pricing of the so called major energy commodities such as petroleum (petrol, diesel and paraffin) and electricity. These

controls are taking place for commodities which are unreliable (in the case of electricity generation, and distribution), unclean and expensive on the world market (oil). In addition both electricity and oil are unsecured commodities in Malawi especially from external macroeconomic shocks such as crude oil increases. The solution, therefore, lies with the subsidies on forms of renewable energy that are sustainable, such as solar power, which is the most popular and wind power.

Collaboration between government and the financial sector must be encouraged in specific objectives. Particularly, this thesis recommends that in line with a subsidy programme, the mainstream financial sector to create financial packages specifically tailored for the energy sector. The electricity supply in Malawi is intermittent and unreliable while at the same time providing a burden for people to meet every month bills. For renewable energy, there are no bills to be paid once the initial cost has been settled. Soft loans for the energy sector would be in order with government negotiating on behalf of consumers.

Related to the financial imports of solar power, facilities should be allowed to take place without any import tariffs. Further, entrepreneurs who are interested to venture into the business of not only importing but also assembling solar panels, wind turbines and other renewable energy resources need to be given special tax breaks. These policies will reduce the initial cost of renewable energy resources. At the current cost, both real and perceived, households do not find it cost effective and affordable enough to even think about adopting these facilities for their daily needs.

The results of Engel functions showed that for the urban poor societies, biomass, as represented by firewood, is an inferior commodity meaning that as incomes rise, people would want to use more advanced, cleaner and efficient resources. However, it is the reliability of the current resources which still forces consumers to continue using biomass. It is therefore recommended that government should endeavour to team up with the private sector to bring to Malawi renewable energy resources. There are few firms supplying some of the renewable energy commodities which render them expensive and unaffordable. This probably explains why for most people, renewable

energy is perceived as expensive. A deliberate policy that will bring competition to the energy market will lower the costs and this coupled with subsidies, reduced import taxes and available financing for the energy sector should lead to more people opting for renewable energy thereby reducing the appalling levels of energy poverty not only in the urban areas but also across the country.

Chapter 6 addressed the fifth objective of econometrically modelling the energy choice to determine the behavioural chance that certain energy resources are opted. Since there is a greater probability that, given all the other choices in the thesis, namely electricity, charcoal, solar, LP gas, firewood and a combination of electricity and biomass; there is a higher probability that charcoal and firewood are chosen, Government needs a campaign to erase the mindset of people. This campaign must be massive with proper alternatives in place.

In view of the theoretical discussion in Chapter 3, which established a clear link between energy poverty and sustainable development, this thesis recommends a ninth (9th) Millennium Development Goal of universal access to modern energy, to be embraced by all development conscious nations. It is clear that most countries have not travelled well on the MDGs path due to a number of reasons. Economic growth has not been high enough to meet the desired trickle down effects. Another reason is that, in countries for which the MDGs were made, there is rampant energy poverty influencing the slow and, in some cases, a zero achievement on the MDGs. For example, women empowerment cannot be achieved where the precious time of mothers and girls is spent collecting firewood. Children's future cannot be a realised dream where they still go home to do their school homework in darkness. Therefore, in the year 2015 when world leaders will be pondering on another set of goals and strategies, it is recommended that universal access to clean, efficient and affordable energy resources must be considered a goal on its own, targeting the year 2025.

9.7 OPPORTUNITIES FOR FURTHER RESEARCH

One of the major objectives of this thesis was to measure energy poverty among poor urban societies in Malawi. Although this objective was achieved, the method of measurement could be bettered if methods being proposed by others such as Pachauri and Spreng (2003) were used. However, the approaches being suggested imply that specific energy consumption be recorded by the researcher. In the absence of energy conversion factors and data on quantities rather than cost of energy being recorded, this could not be achieved. It is, therefore, suggested that future research should consider adopting these new approaches.

Second, was also a methodological limitation where static discrete choice models were adopted to predict probabilities that certain energy choices are made at the household level. This falls short of the Lucas critique, which argues that dynamic modelling must be adopted where predictions are to be done (Kydland & Prescott, 1990:7). Such modelling, in the case of consumer behaviour, is available through the Random Coefficients model. However, as pointed out in Section 6.2, this modelling behaves better with panel data than cross section only.

Lastly, the link between energy poverty and sustainable development has been established in this thesis. However, the linkage relied on measures of sustainable development which were static and perception based. It is hoped that for future research, the task of adopting more scientific and reliable measures of sustainable development will be adopted, together with dynamic modelling techniques.

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ANNEX A1

Table A 1 Frequency and Bar Chart for Environmental Feeling

Feeling of Environment	Frequency	
It is clean and pleasant	209	*****
It is littered, untidy and dirty	36	*****
Indifferent – No opinion	12	***
Something should be done to clean it	49	*****
It can be left as it is	13	***
Total	319	

ANNEX A2

Table A 2 Frequency Table for Environmental Feeling Categories

	Frequency	Percent
Clean and pleasant	208	65.6

Untidy and littered	36	11.4
Indifferent	12	3.8
Something should be done	48	15.1
It can be left as it is	13	4.1
Total	317	100

Table A 3 Summary statistics for household's total cost of energy

Variable	Obs	Mean	Std. Dev.	Min	Max
CoE	317	9643.754	11394.42	170	136500

ANNEX A3

Table A 4 Frequency and Bar Chart for Experience of Air Pollution

Experience of Air Pollution	Frequency	Histogram
<i>Not affected</i>	168	*****
<i>Slightly affected</i>	25	*****
<i>Affected</i>	87	*****
<i>Badly affected</i>	38	*****
<i>Unbearable</i>	1	
<i>Total</i>	319	

ANNEX A4

Table A 5 Engel Function Analysis including Paraffin and LP Gas

		Coefficient	Mean	Elasticity
Paraffin	Lnexpen	-0.00095	0.0733	-0.0129580
	Lnincome	-0.01296	10.329	-0.0012548
	Hmsize	-0.00024	68.923	-0.0000035
Wood	Lnexpen	-0.15535	0.708	-0.2195702
	Lnincome	-0.10149	10.329	-0.0098261
	Hmsize	-0.00060	68.923	-0.0000087
Electricity	Lnexpen	0.14830	0.215	0.6895048
	Lnincome	0.11298	10.329	0.0109388
	Hmsize	0.00084	68.923	0.0000121
LP Gads	Lnexpen	-0.00800	0.004	-1.9600784
	Lnincome	0.00147	10.329	0.0001421
	Hmsize	0.00001	68.923	0.0000001

ANNEX A4

Figure A 2: Frequency and Bar Chart for View on New Cooking and Heating Technology

Key:

1. Not making fire: using electricity for cooking and heating
2. Making Charcoal/Firewood but not interested
3. Making Charcoal/firewood and interested
4. Using paraffin and not interested
5. Using paraffin and interested

Table A 6 Frequency and Bar Chart for Method of managing household waste

method of Managing household waste	Frequency	
Waste Pit	229	***** *****
City Council	58	*****
Riverside dumping	27	*****
Burning	5	*
Total	319	

Table A 7 Correlation Coefficients for the socioeconomic variables

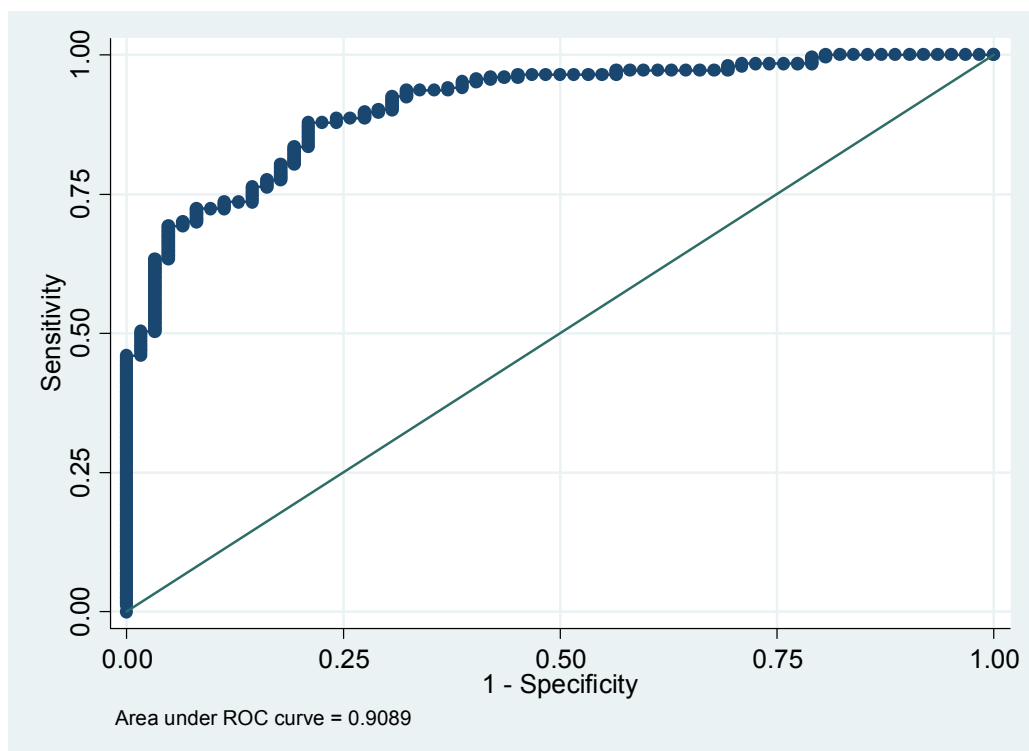
	ebs_wood	ebs_elec	income	hmsize	hhsiz	emply	poor	Age	eexp	educ	gender	Marriage
ebs_wood	1											
ebs_elec	-0.8674	1										
income	-0.3693	0.4217	1									
hmsize	-0.2799	0.3555	0.2728	1								
hhsiz	-0.13	0.0962	0.0807	0.1524	1							
emply	0.1113	-0.1738	-0.2166	-0.1118	0.0249	1						
poor	0.1385	-0.1545	-0.0697	-0.0967	0.0254	0.1121	1					
Age	-0.1809	0.153	0.0208	0.0864	0.1616	0.1072	0.0765	1				
eexp	-0.4388	0.4722	0.3735	0.2615	0.1938	-0.0671	-0.0585	0.0411	1			
educ	-0.2863	0.4311	0.3034	0.2636	0.0051	-0.2188	-0.1715	0.0453	0.1582	1		
gender	-0.1584	0.1667	0.2174	0.0892	-0.0165	-0.2488	0.042	-0.045	0.2108	0.1321	1	
marriage	0.0587	-0.023	0.0608	-0.0043	0.0292	-0.1858	0.0019	-0.0519	0.0624	0.0365	0.2132	1

Table A 8 logit EPVY exp_tpt exp_food exp_sch

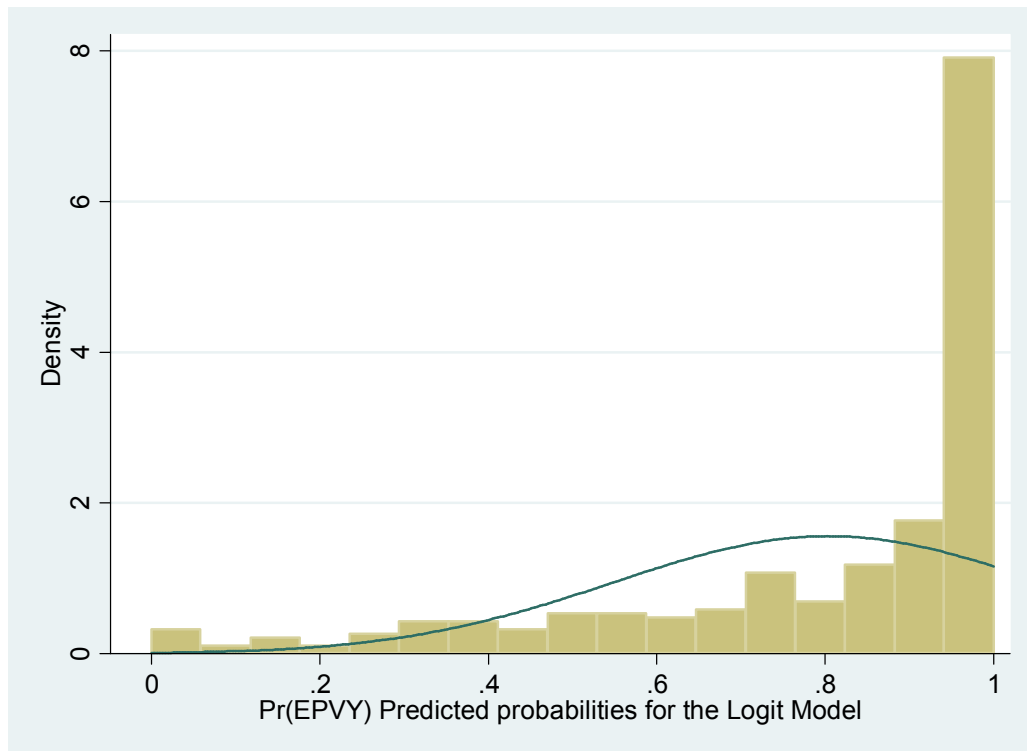
EPVY	Coef.	Std. Err.	Z	P> z 	[95percent Conf.	Interval]
exp_tpt	0.0007281	0.0001225	5.94	0	0.0004881	0.0009682
exp_food	-0.0001024	0.0000222	-4.61	0	-0.0001459	-0.0000588
exp_sch	-0.0000833	0.0000217	-3.85	0	-0.0001257	-0.0000408
_cons	1.928707	0.3737342	5.16	0	1.196202	2.661213

Calculations based on Energy Poverty and Sustainable development Survey in South Lunzu data

Area under ROC curve



Histogram of Predicted Probabilities of the Logistic Regression for Energy Poverty Dummy Variable



ANNEX 5

Table A 9 Engel function analysis of demand for fuel-wood with employment status as a factor variable

OLS for ebs_wood	Coefficients	Standard Errors	T	P> t
<i>Ineexp</i>	-0.15535	0.025269	-6.15	0.000***
<i>Inincome</i>	-0.10149	0.019252	-5.27	0.000***
<i>hmsize</i>	-0.0006	0.000315	-1.91	0.057*
<i>Poor</i>	0.033804	0.029316	1.15	0.250
<i>Informal Employ</i>	0.058727	0.030979	1.9	0.059*
<i>Unemployed</i>	-0.12539	0.073016	-1.72	0.087*
<i>Inactive</i>	0.003169	0.122108	0.03	0.979
<i>_cons</i>	3.002422	0.225811	13.3	0.000***

Adjusted R-Squared : 0.33, Probability > F : 0.000

ANNEX 6

Table A 10 MNL Model validation

-1	[Electricity]income = 0
-2	[LP_Gas]income = 0
-3	[Solar]income = 0
-4	[Charcoal]income = 0
-5	[Firewood]income = 0
-6	[Electricity_Charcoal_and_Wood]income = 0
-7	[Firewood_and_Charcoal]o.income = 0
-8	[Electricity]hmsize = 0
-9	[LP_Gas]hmsize = 0
-10	[Solar]hmsize = 0
-11	[Charcoal]hmsize = 0
-12	[Firewood]hmsize = 0
-13	[Electricity_Charcoal_and_Wood]hmsize = 0
-14	[Firewood_and_Charcoal]o.hmsize = 0
-15	[Electricity]hhsiz = 0
-16	[LP_Gas]hhsiz = 0
-17	[Solar]hhsiz = 0
-18	[Charcoal]hhsiz = 0
-19	[Firewood]hhsiz = 0
-20	[Electricity_Charcoal_and_Wood]hhsiz = 0
-21	[Firewood_and_Charcoal]o.hhsiz = 0
-22	[Electricity]poor = 0
-23	[LP_Gas]poor = 0
-24	[Solar]poor = 0
-25	[Charcoal]poor = 0
-26	[Firewood]poor = 0

ANNEX 7

-27	[Electricity_Charcoal_and_Wood]poor = 0
-28	[Firewood_and_Charcoal]o.poor = 0
-29	[Electricity]wtps_moke = 0
-30	[LP_Gas]wtps_moke = 0
-31	[Solar]wtps_moke = 0
-32	[Charcoal]wtps_moke = 0
-33	[Firewood]wtps_moke = 0
-34	[Electricity_Charcoal_and_Wood]wtps_moke = 0
-35	[Firewood_and_Charcoal]o.wtps_moke = 0
-36	[Electricity]wtp_clean = 0
-37	[LP_Gas]wtp_clean = 0
-38	[Solar]wtp_clean = 0
-39	[Charcoal]wtp_clean = 0
-40	[Firewood]wtp_clean = 0
-41	[Electricity_Charcoal_and_Wood]wtp_clean = 0
-42	[Firewood_and_Charcoal]o.wtp_clean = 0
-43	[Electricity]Age = 0
-44	[LP_Gas]Age = 0
-45	[Solar]Age = 0
-46	[Charcoal]Age = 0
-47	[Firewood]Age = 0
-48	[Electricity_Charcoal_and_Wood]Age = 0
-49	[Firewood_and_Charcoal]o.Age = 0

ANNEX 8

-50	[Electricity]exp_food = 0
-51	[LP_Gas]exp_food = 0
-52	[Solar]exp_food = 0
-53	[Charcoal]exp_food = 0
-54	[Firewood]exp_food = 0
-55	[Electricity__Charcoal_and_Wood]exp_food = 0
-56	[Firewood_and_Charcoal]o.exp_food = 0
	Constraint 7 dropped
	Constraint 14 dropped
	Constraint 21 dropped
	Constraint 28 dropped
	Constraint 35 dropped
	Constraint 42 dropped
	Constraint 49 dropped
	Constraint 56 dropped



University of Malawi-
Polytechnic

Dear Sir/Madam,

ENERGY POVERTY AND SUSTAINABLE DEVELOPMENT SURVEY IN BLANTYRE

Thank you very much for taking some of your precious time to respond to this questionnaire. The University of Malawi in collaboration with North-West University of RSA is conducting a study on “Energy Poverty and Sustainable Development in South Lunzu”. The main aim of the study is to get perceptions and views regarding the energy sector in Malawi so that solutions that should assist in improving access of modern energy facilities be found.

This survey is a key method for the study and you have been randomly chosen to participate by answering a few questions here in. The interview should take about 25 minutes. We request you to please participate in the survey. Please note that the study is purely academic and the information you will provide will be strictly confidential. The results will be reported as a group and not an individual. Be assured that your participation in this study will not deprive you of any benefits you enjoy in any way from any public or nongovernmental organisation.

If you have any questions, please do not hesitate to call 0888 550 710, 01603271, 0881094427 or University of Malawi, Malawi Polytechnic, Management Studies department and ask for Mr Tchereni or Dr. Sankhulani.

Sincerely,

B. Tchereni
Study Coordinator

ENERGY POVERTY AND SUSTAINABLE DEVELOPMENT SURVEY IN BLANTYRE: HOUSEHOLD QUESTIONNAIRE DECEMBER 2011

N.B.: The information in this questionnaire will be treated in strict confidence. (December 2011-January 2012)

South Lunzu	Area/Village:	Date:	Questionnaire no:
	Plot number:	Interviewer:	

Please note that the Head of the Household should preferably answer this questionnaire.

A: BACKGROUND INFORMATION

1. What is the position of the respondent in the Household? Cross *

Head of household	Spouse	Child	Extended family member	Boarder

2. Size of dwelling unit in Square Metres?

3. How many people stay permanently in the household?

4. How long have you (respondent) stayed in South Lunzu or Nkolokoti Township (years)?

B: ENERGY AND ENVIRONMENTAL

5. How do you feel about the environment in which you stay? (Mark 2 options) *

1. It is clean and pleasant	2. It is littered, untidy and dirty	3. Indifferent – No opinion	4. Something should be done to clean it	5. It can be left as it is

6. If you feel it should be cleaned up, who should take the initiative and responsibility? (* More)

1.The municipality	2. A street committee	3.Everyone should be made responsible	4. A campaign should be organised	5. Other: explain

7. If you would have the money, what would you be prepared to pay monthly to have your environment cleaned up?

8. How do you experience, especially in winter, the smoke levels (air pollution) in your area? *

1. Not affected	2. Slightly affected	3. Affected	4. Badly affected	5. Unbearable (Severely Affected)

9. If you are making fire for cooking & heating purposes, would you like to be introduced to technologies that will reduce the smoke levels at your house? *

1. Not making fire: using electricity for cooking & heating	2. Making coal / wood fire: but not interested	3. Making coal / wood fire: And interested	4. Using paraffin: Not interested	5. Using paraffin: Interested

10. What would you be prepared to pay monthly to have your environment smoke-free?

- a) What % of the smoke pollution do you think comes from industry? and coal fires?
- b) Number of persons in your household whose health is affected by air pollution?
- c) What are most of them suffering from? (e.g. coughing, asthma, etc)

11. How do you manage your household waste?

Waste Pit	City Coucil	Riverside Dumping	Burning	Do not

12. How much do you spend to have a waste pit dug?

13. How many times in a year do you dig a waste pit?

14. What energy source do you normally use for cooking and heating?

	Always	Often	With others	Don't know	sometimes	Never
Electricity						
LPG Gas						
Solar						
Charcoal						
Firewood						
Plastic						
Paper/carton						
Animal Dung						
Wind						
Other						

15. For those not used, please give two reason?

16. Do you know other sources of energy apart from what you use often?

Yes	No

17. What energy source do you normally use for .lighting?

ESCOM	PARAFFIN	RUBBER AND PLASTIC	SOLAR	BATTERY	Other specify

18. Apart from the normally used source above, what else have you ever used for lighting? Please state

19. Have you ever heard about alternative energy resources?

Yes	No

Yes	No

20. If yes, have you ever Tried them?

21. If yes under what conditions?

Unreliable Current Resource	Expensive current resource	Scarcity of current resource	Environmental Concerns of current resource	Just trying	Other specify

22. Has any member of your family bought any renewable energy facility within the past three years?

Yes	No

23. If other alternatives of energy were introduced to you, which one would you want to use?

Solar	Wind	Geothermal	Fuel	Biofuel	Other Specify

24. Why are you not using it now?

Expensive	Not available	Don't Understand them	Not seen them working	Not reliable	Current resource satisfied	

25. Which of the following do you know or have heard about? (Please encircle as many as the

respondent know)

- (a) Solar Power
 - (b) Solar Farm
 - (c) Wind Power
 - (d) Wind Farm
 - (e) LPG Gas
 - (f) Other; please specify
-

26. For those you have heard about, what are their limitations?

27. Would you like to stop using biomass?

Yes	No

28. What do you think should be done for you to stop using Firewood and Charcoal?

Ban them	Subsidise alternative Energy	Sensitise people on dangers of them	Sensitise advantages of RE	Reliable electricity

29. Do you believe it's the responsibility of government, Local council or yourself?

Yes	No
Yes	No
Yes	No

30. Have you ever been involved in burnt bricks business at any point in your life?

31. Do you still do it?

32. How much firewood (in tonnes) did you use in your last oven burnt?

Yes	No
Yes	No

33. Should government stop/ban the burning of bricks for construction industry?

34. Would you like banks and other Financial Institutions to provide energy loans for the poor?

35. If you had MK300,000 to spend on your energy immediate needs, which resource would you go for and why?

Solar	Wind	Geothermal	Fuel	Biofuel	Other Specify

36. If you had money, how much would you be willing to pay for an alternative energy resource per month other than charcoal, firewood and electricity?

D: CONSUMPTION

37. How much of the following items does your household buy per month & about how much does your household spend on these items per month?

Product	Kilograms / litres per week	Kilograms / litres per month	Kwacha per week	Kwacha per month	Super market ✓	Market ✓
1. Maize Meal						
2. Bread						
3. Meat / chicken						
4. Vegetables						
5. Milk						
6. Washing powder						
7. Charcoal						
8. Paraffin						

38. How does your household spend their income monthly?

Bought where?

Item	Rand per month	Name of shop	Town	Market	
Housing (Rent/Bond/Mortgage)					1
Water					2
Firewood					
LPG Gas					
Electricity					3
Other energy (coal, paraffin etc)					4
Food					5
Cleaning materials					6
Cigarettes & Tobacco					7

Beer, wine & spirits					8
Transport:		Total			9
Taxi.....					
Minibus.....					
Car.....					
Other.....					
Clothing					10
School					11
Entertainment					12
Medical Expenses					13
Insurance					14
GAMBLING: Lotto.....					15
Horseracing.....					16
Casino					17
Other					
Savings					18
Licenses (e.g. TV, Vehicle)					19
Rates and taxes					20
Housekeeping Services (e.g. Garden)					21
Telephone.....					22
Cell.....					23
Car Repayment					24
Loan repayments					25
Furniture					26
Other: Specify					27

D: EMPLOYMENT & EDUCATION STATUS

39. How does your household earn their income monthly?

1. Number of people in the household								
2. Composition of members (Code list 2)								
3. Age of each member in years								
4. Sex (Male = 1; female = 2)								

5. Marital Status (code list 5)								
6. Highest qualifications (still at school) (Code list 6)								
7. Qualifications (not at school) (Code list 7)								
8. Employment Status (Code list 8)								
9. Sector of employment (Code list 9)								
10. Owner of company	Govt	White	Asian	Coloured	South African	Black Malawian	Black West African	Don't know
11. (10 – 17 for <u>unemployed</u> only) Skills of unemployed (list 10)								
12. Duration of unemployment in years								
13. Willingness & type of Skills Training required (code list 10)								
14. What is the Unemployed doing presently								
15. Do you have matric exemption?								
16. If persons would like to study further: preferences (list 15)								
17. Preferences to start self-sustaining activities (list 10)								
18. Minimum wage required to take a job								
19. Income: Wages/salaries per month (Take home pay) Formal								
20. Pension/Remittance								
21. Child Grant from Government								
22. Other Grants from Government								
23. Help (family/relatives/etc) Also help in kind								
24. Informal activities								
25. Subsidies (e.g. Housing)								
26. Interest/dividends								
27. Other (Specify)								
28. Are you employed within Blantyre?								

40. How do you cope with increasing food prices (inflation)? _____

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41. Has any member of your household operated a SMME / still operating one? If so, what kind of SMME? (Also distinguish between formal and informal)

Yes	No

Yes	No

42. Taking into account your skills (or that of your household members), would you or someone in your household (unemployed persons) be interested in starting your own business or rather work together with others in a cooperative?

Own business	Cooperative

43. What kind of business would you like to start? _____

44. If you would like to start your own business, what kind of support do you think you will need?

45. Do you see any business opportunity in the energy sector?

Yes	No

46. Do you think you will get a job if you are better trained?

Yes	No

47. What kind of training do you need? _____

48. Were any members of your household retrenched in the last year?

Yes	No

49. What was the reason for the retrenchment?

50. Where were they working at the time of the retrenchment?

51. Do you have enough income to support your family

Yes	No

52. Would you engage in an illegal activity to have money to support your family?

Yes	No

53. Do you consider yourself poor?

If yes, how would you define your poverty?

Yes	No

54. Do you think crime is a problem in the Township?

Yes	No

55. Do you normally have three meals every day?

Yes	No

56. Do you think the government is doing enough to create jobs?

Yes	No
Yes	No

57. Do you know of any employment generating programme initiated by the City Council?

Yes	No

If yes, what kind of programme? _____.

58. Do you think the City Council has ensured adequate service delivery in your Township?

If no, give an area of improvement

Yes	No

: _____.

Thank you very much for taking your time to participate in the study.