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Solving the Energy and Sustainable development problem in Africa

By

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Abstract

Among the many problems faced by the Sub-Saharan African (SSA) region is poor energy supply to both firms and households. Noteworthy is the fact that over 90% of the population depend on Biomass. Clean energy supply in the SSA does not meet demand and this is the major problem. People are not concerned about climate change but rather whether they will be able to get some useful energy facilities for their household and industrial uses. However, these problems are occurring in the face of advanced and new energy facilities invented in many parts of the world. Despite the availability of sunlight for at least 10 hours a day and free moving wind, Africa and particularly the SSA is still facing energy supply problems. The international community has stepped up the fight against carbon releases due to any form of production. However, one observes easily that the developed world is surviving on energy provision from sources that are contributing to the pollution. USA, UK, China and RSA are some of the countries which are run on coal fired generators for energy provision. African states however are denied the opportunity and chance to first provide the energy and then begin to talk about sustainability. The paper observes that using her yet to be nurtured resource based potential for industrialisation; Africa is being imposed to follow a green growth path. This study explores the paradox of providing alternative energy to poor people while balancing the need to address climate change problems. The energy-sustainability mix of Africa is being over emphasised and with it the most important element of making energy available to the people is being overlooked. The paper concludes that the industrialisation of Africa is possible first with the provision of energy, and then after the fact, considering green growth.

Key Words: Energy poverty, Logit, South Lunzu

1.0. Introduction and background

Energy is a basic commodity in the same class as food, water and health, yet 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 amount of energy to function in the quest to maximise their objective functions. Households require energy light their homes when it is dark. They also need energy to cook and warm their meals and for 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.

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. Thirdly there is persistent energy poverty particularly in less developed countries drifting many economic agents to rely on unsustainable energy resources (Birol, 2007:2; Pegels, 2010:4945). Further, many households in less developed countries (LDCs) have very limited choices to make regarding alternatives of 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 the multilateral financial and development institutions. The organizations theorise that modern energy improves LDCs' livelihoods through facilitated water access, health and education services in rural areas, as well as the enhancement of primary agriculture and agro-processing industries and preservation of biodiversity (Karekezi & Kithyoma, 2003:6).

Following this impeccable function of modern energy facilities in changing 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 industrialization. Adopting more advanced production technologies that will provide to the world market finished products is one of the major ways that can lead to high economic growth (Kaluwa, 2011; Pack, 2003). However, as countries realise the importance of industry, so is the demand for energy increasing (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 and Malawi has underperformed on this part. By way of illustration, the total land area under forest cover declined from 46percent to 36percent between 1999 and 2009 (Kambewa & Chiwaula, 2010:9). This decline is attributed to cutting down of trees for firewood, charcoal burning, farming and housing projects. In other words energy systems have contributed to the largest part of 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 a reliable and dependable economic growth.

Industrialisation in Africa has moved at an alarmingly lower pace compared to the4 Instrial revolution of Europe in the 18th century. Therec are many reasons attributed to this slow case rangong from financial, ideological to resources. In the case of the latter, there is intermittent supply of energy for both households and firms in Africa which impedes proper planning for considerably bigger manufacturing projects to start. This paper analyses the state of energy poverty I Africa and proposes solutions to the problem emanating from African soil.

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 take the already poor households to a condition of pitiable livelihoods in Least Developed countries (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 suggest that there is lack of political will to discourage the use of traditional energy resources which are not environmentally friendly (Chineke & Ezike, 2010:680; Agba 2011:49). Biomass is for both entrepreneurship and household consumption creating the risk of political unpopularity to whosoever tries to stop this business especially in Malawi.

Strategies that can therefore have a strong influence to enable people demand RE sources will be important to energy poverty reduction (OECD & IEA 2010: 6).

Negative effects on supply of fossil fuels 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. Only less than 5percent of all the households have electricity and 25,000 apply for new connections every month where just about 1,000 get connected because the generation capacity of the Electricity Supply Commission of Malawi (ESCOM) is far lower such that it is failing to meet demand (GOM, 2011). In addition, the problem is also affecting Industry which due to lack of reliable power supply is facing problems to sustain 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.

The Electricity Supply Commission of Malawi (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 the imports of fuel. 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 the urban areas. The study aims at determining the forces behind choice of energy resources by using econometrics 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 emphasised on demand of energy facilities by rural households thereby neglecting urban households. This study is therefore important for three main reasons. Firstly, there is no empirical literature suggesting that introduction of RE to the economy will be profitable to the providing firms and agencies (Kambewa & Chiwaula, 2010:19; GOM, 2006:14). There is no experimental data in support of existence of demand for renewable energy in poor-urban areas. This study therefore for the first time in Malawi estimated Microeconometric energy demand models.

Secondly, adoption of RE in LDCs received no resistance (Chineke & Ezike, 2010:683; Karekezi & Kithyoma, 2003:8). It is of great interest that after several years since the discovery of alternative energy resources, Africans are yet to significantly adopt them (Matriot, 2001:691). This study assessed knowledge of other alternative sources of energy in urban-poor areas to determine socio-economic factors that might be influencing 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 suggest that overly, income and earning power is the single most important determinant 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 shrieked set from where 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 through and clear understanding of the abilities such a facility can go. 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 exists (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 analyze 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, there is a need to research the factors that are impeding on 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 of renewable energy and its various types 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 wager for sustainable development and green economic growth.

The main question this study addresses is how energy poverty can be eradicated in Africa in general and Malawi in particular to promote sustainable development by identifying the determinants of energy resource choices at the household level in the urban areas. The study aims at determining the forces behind choice of energy resources by using econometrics methods based on survey data modelling. These problems therefore lead to the following questions to be raised for 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?

2.0. 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 at most 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), Pachauri et al (2004), 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.

Table 2.1 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: IEA (2006B)

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. The 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 the Sub-Saharan Africa has the lowest electrification rate compared to the 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.

	Population without electricity millions	**Electrification rate** %	**Urban electrification rate** %	**Rural electrification rate** %
Africa	587	41.8	68.8	25.0
North Africa	*2*	*99.0*	*99.6*	*98.4*
Sub-Saharan Africa	*585*	*30.5*	*59.9*	*14.2*
Developing Asia	675	81.0	94.0	73.2

China & East Asia	*182*	*90.8*	*96.4*	*86.4*
South Asia	*493*	*68.5*	*89.5*	*59.9*
Latin America	31	93.2	98.8	73.6
Middle East	21	89.0	98.5	71.8
Developing countries	**1 314**	**74.7**	**90.6**	**63.2**
World*	**1 317**	**80.5**	**93.7**	**68.0**

* World includes OECD and Eastern Europe / Eurasia

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 Access to Electricity and Relying on Biomass in 2009 and 2012

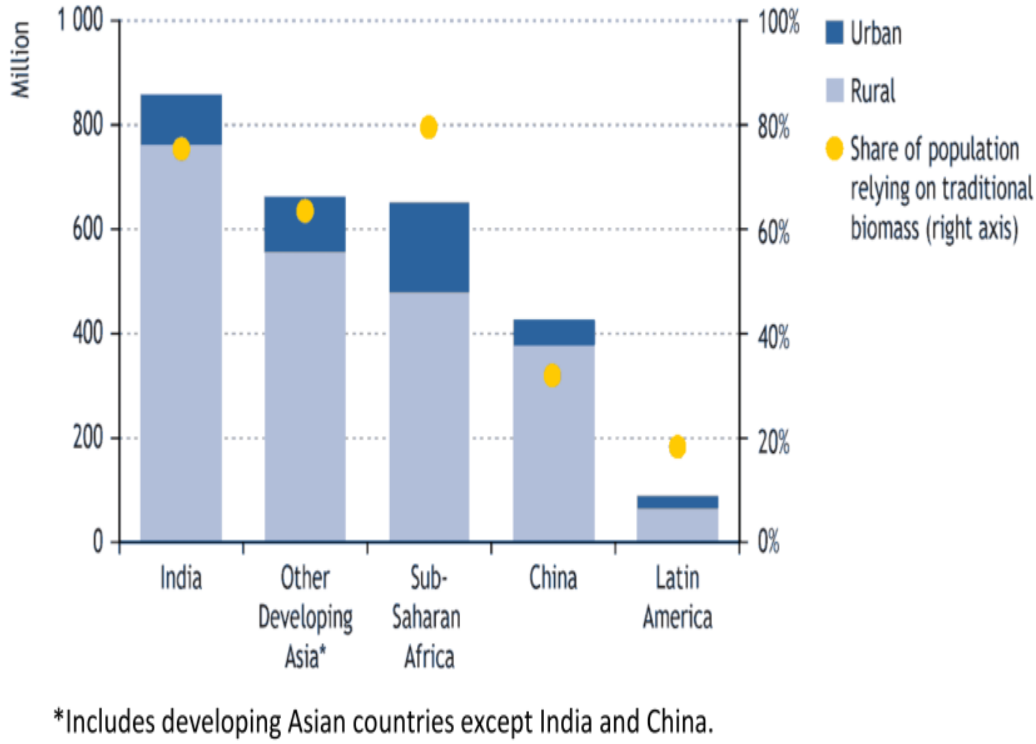
	Number of people lacking access to electricity	Number of people relying on the traditional use of biomass for cooking
Africa	587	657
Sub-Saharan Africa	585	653
Developing Asia	799	1937
China	8	423
India	404	855
other Asia	387	659
Latin America	31	85
Developing countries	1438	2679
World	1441	2679

Source: IEA (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 a bettered 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.

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.

Figure 2.1 Number and share of people relying on the traditional use of biomass as primary cooking fuel by region, 2009



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

3.0. INTERVENTIONS FROM THE MULTILATERAL INSTITUTIONS

What is the World Bank's financing by energy type?

Project Type	2007	2008	2009	2010	2011	2012	Total
Energy Efficiency	753	1,521	1,685	1,802	1,551	1,353	**8,666**
Renewable Energy	840	1,471	1,678	1,905	2,977	3,615	**12,487**
New Thermal Generation	364	1,087	987	4,287	290	690	**7,705**

Other Energy	717	1,015	1,702	2,019	1,783	1,369	**8,605**
Transmission & Distribution	458	1,605	1,204	2,208	1,397	270	**7,142**
Upstream Oil, Gas, Coal	729	972	1,076	725	182	880	**4,564**
WBG Energy Total	**3,862**	**7,670**	**8,332**	**12,947**	**8,181**	8,177	**49,168**

4.0. 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.

In the present case, one class of categorical models, a logistic regression, was estimated to go round 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).

Table 4.1 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 0f significance.

The following empirical model is suggested:

$$f(EPVY) = (exp\_tpt, exp\_food, exp\_sch, gender, educ, exp\_home, hhsize, hmsize, marital, \varepsilon)$$

This equation was estimated or implemented in a SATA 12 platform and results are presented in table 4.1 and 4.2 for odds ratios and coefficients respectively. The two tables are complementing each other to provide a reasonable assessment of the logit analysis of energy poverty in South Lunzu.

Table 4.2 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
Hhsize	0.1916424	0.1023459	1.87	0.061*
Hmsize	-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 0f significance.

The results in table 4.3 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 74.1 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 4.3 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 4.3 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 however 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 show that one is likely to be energy poor if they are male 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 4.3 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: calculations based on energy poverty and sustainable development survey in South Lunzu.

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 hhsize 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.

5.0. ANALYSIS OF ELASTICITIES FROM THE MULTINOMIAL LOGIT

Table 5.1 Marginal effects and elasticities for the MNL Model

		Income	Hmsize	Hhsize	Poor	wtps_moke	wtp_clean	Age	exp_food
Electricity	**dy/dx**	1.29E-07	0.000159	0.004565	-0.01023	9.27E-06	-2.7E-06	0.001325	6.18E-07
	ey/ex	0.29529	0.698885	1.192963	-0.67668	0.240047	-0.1213	2.722529	0.726859
LP Gas	**dy/dx**	1.96E-08	-5.58E-06	0.001283	-0.06809	-8.58E-06	7.83E-07	-8.09E-05	2.29E-07
	ey/ex	0.265456	0.224739	1.419508	-7.1756	-1.05368	0.125764	-0.13197	1.12386
Solar	**dy/dx**	-1.74E-08	-0.00014	0.000557	0.056434	2.23E-06	3.62E-07	0.000177	5.94E-08
	ey/ex	-0.42468	-3.22658	0.921623	9.104151	0.385825	0.078024	2.213175	0.225176
Charcoal	**dy/dx**	-1.44E-07	0.000478	-0.02818	-0.01599	5.87E-05	-3.43E-05	-0.00479	7.59E-08
	ey/ex	-0.18176	0.008459	-0.64666	-0.09141	0.113025	-0.15672	-0.87063	-0.10443
Firewood	**dy/dx**	-1.29E-07	-0.00031	0.006381	0.020812	-2E-05	1.05E-06	0.001767	-1.03E-06
	ey/ex	-0.32162	-0.70459	0.728578	0.222045	-0.33737	-0.00249	1.467737	-0.61532
EL_CH_WD	**dy/dx**	1.81E-06	0.001696	-0.00426	-0.00769	0.000017	1.72E-05	0.001219	2.99E-06
	ey/ex	0.270658	0.543468	-0.13192	-0.18061	0.022922	0.045301	0.232602	0.26045

Table 5.1 is a summary of marginal effects reported both as marginal and elasticities. According to 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 purposes of this study because they are easier to understand than the marginal and the coefficients. In table 5.1, 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 rise by 7 fold. Poor the mindset in this case is important to be addressed. People who believe 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 and so 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 at 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.

6.0. DESCRIPTIVE STATISTICS OF PREDICTED PROBABILITIES

As a step further with the analysis, 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 6 below. As table 6 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 town ship 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 6 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: Author's calculations based on results from the Multinomial Logit Model of energy choices

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.

7.0. 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 Annex 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 7 Test of statistical equality of the parameters

(1)	**-**	**[Electricity]income + [Electricity]hhsize = 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: Author's calculations based on Lunzu Township, Blantyre city, Malawi. Where *, **, and *** imply statistical significance at the 1 percent, 5 percent and 10 percent level of test

8.0. CONCLUSION AND SUMMARY

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 pone particular energy resource. According to the results of this study 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 study paid special attention to the analysis of energy demand choices in the face of several options. Multinomial logit model was employed to the cross section 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.

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