An Investigation of Multidimensional Energy Poverty amongst South African Low-income Households.

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Abstract

This paper empirically assesses multidimensional energy poverty for low-income households in South Africa using the four waves of the National Income Dynamic Survey (NIDS). The study adopted the Nussbaumer et al. (2011) methodology, the multidimensional energy poverty index (MEPI), to estimate energy poverty on 10 801 low-income households. The results indicated that low-income households in rural areas are more energy deprived than those in the urban areas. However, the MEPI score across the years in low-income urban and rural households depicts a moderate state of energy poverty. The implication of moderate energy poverty could be that the aim of electrifying poor households by the government and making modern energy affordable (through the free basic electricity policy) is significant but has not yet achieved considerable success. Further, low-income households in both rurality are mostly deprived in the dimension of heating fuel. The study recommended that suitable measures to combat energy poverty be rural-urban specific.

Keywords: Energy poverty, Multidimensional Energy Poverty Index, low-income, South Africa

1 Introduction

Energy poverty pervades many, if not all elements of poverty and it is one of the biggest social problems of the 21st century (Srivastava et al. 2012). Energy poverty is a growing concern especially amongst low-income populations in developing countries (Pachauri and Spreng 2011). For developing countries, energy poverty has been defined with respect to accessibility to electricity, which is widely recognised as central to practically all aspects of sustainable development including, agricultural and industrial development, health care, water provision, communication and education (Bazilian et al. 2010; United Nations Development Program 2010). Therefore, in developing countries, having no access to electricity, or not being able to afford it, and relying on traditional fuels, constitutes energy poverty (International Energy Agency et al.

2010; Sovacool 2012). Thus, the provision of electricity is recognised as a critical foundation to eradicate energy poverty (International Energy Agency 2010; Nussbaumer et al. 2012). Unfortunately, the current state of electricity access, particularly in Africa, remains critically low (Sokona et al. 2012; International Energy Agency 2010). A large proportion of the population in developing countries exists under conditions of energy poverty (Pereira et al. 2011; Sokona et al. 2012).

In the South African context, energy poverty is also a challenge. Mohapi (2016) confirms that 'the majority of the country's citizen live in outright poverty or are vulnerable to becoming poor'. As such, the issue of energy poverty (or poverty) in South Africa is well known. Energy poverty in the South African context has been defined as a lack of access to modern energy services necessary for human development (Ismail 2015; Kohler et al. 2009). The services are defined as household access to electricity, clean cooking, and space heating facilities (e.g. fuels and stoves that do not cause air pollution in houses) (Ismail 2015; Kohler et al. 2009). Although South Africa boasts lower rates of energy poverty than most of its neighbours, it remains an example of a country struggling to develop its economy and provide opportunities for people to extract themselves from energy poverty (Ferriel 2010; Ismail and Khembo 2015). Ferriel (2010) stated that there are 12.5 million rural and urban households in the country not connected to the national electricity grid, in addition to the millions that are connected to the grid but are not able to pay for electricity. Households at the low-income level (low-income groups are classified as earning R0 – R18 000 per annum or households with an income below R1 500 per month) are mostly those that cannot afford sufficient electricity to improve their welfare (Ismail and Khembo 2015).

One of the objectives of the government of South Africa is to increase accessibility to modern energy (especially electricity) as it leads to an eradication of energy poverty. Thus, electrifying rural and urban low-income households, which had been deprived of access to electricity during the apartheid period (Department of Energy 2013). The Department of Minerals and Energy (DME), through the national electrification programme was to ensure energy poverty alleviation by providing for effective energy utilisation. Despite increased efforts by the government, the wellbeing of South African households, in general, more than two decades after the end of the apartheid era is still unrealised (Godfrey et al. 2016). The national electrification program was to encourage the newly electrified households to shift from using wood, paraffin, candles and batteries to electricity for their household needs (Department of Energy 2015; Swart and Bredenkamp 2012). There is a need therefore to have an understanding of the state, most especially, of low-income households in both rural and urban areas with respect to energy poverty.

A metric that can be used to quantitatively assess and track progress on energy poverty amongst low-income households represents an essential support tool. A new tool developed to evaluate energy poverty is the multidimensional energy poverty index (MEPI), which captures the set of energy deprivations that may affect an individual or household (Nussbaumer et al. 2012). The MEPI has not been used to examine energy poverty in low-income households in South Africa. Thus, this study aims to investigate if low-income South Africa households are in a state of energy poverty, and to determine which rurality are most affected and to track progress.

The rest of the study is organised as follows. Section two provides some definitions and a brief overview of the related literature. The data and methodology are presented in section three. Section four has a discussion of the results and the final section gives a conclusion and recommendations.

2 A brief literature review

2.1 Definitions

Energy poor/non-poor households are defined as households that cannot/can meet their basic energy needs by estimating a minimum limit of energy consumption (Pereira et al. 2011).

The incidence of multidimensional energy poverty is the percentage of people/households who are energy poor whilst the average intensity of energy deprivation is the average percentage of dimensions in which energy poor household are deprived (Alkire and Foster 2011).

Energy deprivation is defined as the constraint(s) on people or households' choices to access basic energy services (Pachauri et al. 2004).

2.2 South Africa's energy policy

The Department of Energy acknowledged that household access to adequate energy services for cooking, heating, lighting and communication is a basic need. This is because clean, efficient, affordable and reliable energy services help in reducing energy poverty. Thus, the Department of Energy, alongside the national electrification programme, has made energy poverty an issue of policy focus (Ismail and Khembo 2015) and launched Free Basic Electricity (FBE) in South Africa in 2003, an official government social welfare policy (Ruiters 2011). The policy ensures free access to basic electricity for poor households. The FBE policy allocates 50kWh of free electricity per month to poor households connected to the national electricity grid. It was anticipated that the introduction of the FBE policy would address affordability problems related to the use of electricity and would encourage low-income households (or poor households) to move towards using electricity for their domestic energy services.

2.3 Measures of energy poverty in South Africa

Metrics that can be used to quantitatively assess and track progress on energy poverty amongst low-income households therefore represents an essential support tool. In addition, measuring energy poverty could enable a geographical mapping of where it is more severe and therefore to direct resources accordingly. Further, some scholars argued that understanding the various dimensions of deprivations experienced by households in a state of energy poverty could help government focus on specific programmes (Ismail and Khembo 2015; Vermaak et al. 2013). Having energy poverty measured at appropriate intervals could determine whether energy poverty relief programmes are effective (i.e. moving households out of energy poverty) and to track households' wellbeing (Department of Energy 2012; Ismail and Khembo 2015). Attempts have been made to measure (in terms of quantification and assessment) energy poverty in South Africa (Department of Energy 2013; Vermaak et al. 2013). The approaches that have been implemented include the energy expenditure approach, the thermal efficiency approach and the subjective approach.

2.3.1 The energy expenditure approach

Energy expenditure is calculated as the share of total household income or expenditure spent on energy (Department of Energy 2009; Fahmy 2011). The South African Department of Energy (2009, 2010) adopted the measure that a household is energy-poor if it spends 10% or more of its income on domestic energy needs. According to Statistics South Africa's 2010-11 Income and Expenditure Survey, expenditure on electricity, gas and other energy carriers accounts for 2.6% of annual consumption expenditure on average for households in the country (Statistics South Africa 2012). Therefore, assuming a 10% energy expenditure for low-income households seems a reasonable assumption, given it is approximately four times the national average. Thus, households with energy expenditures exceeding this threshold are considered to be energy poor. The Department of Energy (2012), using this approach, found that on average, South Africans spend 14% of their total monthly household income on domestic energy needs. Thus, 47% of South Africans households were found to be energy poor as they spend more than 10% of their income on domestic energy needs.

2.2.2 The thermal efficiency approach

The thermal efficiency approach is commonly used in European countries. This measure of energy poverty relies on assessment of the condition of one's place of residence in terms of thermal comfort levels relative to social needs (Fahmy 2011; Hills 2012). The approach involves the evaluation of the physical structure and the conditions of a dwelling unit focussing on the amount of energy required to heat the home to an acceptable standard, which typically represents a notable determinant of domestic energy costs. The Department of Energy (2012), using this approach, found that 49% of households in South Africa were thermally inefficient. In addition, following the method of Hills Fuel Poverty Review in the United Kingdom, a household was considered energy poor if the household had both low incomes and a thermally inefficient dwelling (Hills 2012). The Human Science Research Council (2012), measured energy poverty, choosing a 60% of median per capita monthly income of R642 (2012 Rand value) as the threshold of lower income. This means that a household is defined as energy poor if it is thermally inefficient, and has a per capita monthly income of less than R642 per month. The result, following this approach, showed that 26% of households were energy poor.

2.2.3 The subjective approach

The subjective approach represents another way in which energy poverty has been measured and examined. The approach involves using a survey to determine whether households are experiencing difficulty in affording the cost associated with meeting basic energy requirements. The question asked is if the amount of energy the household has is less than adequate, just adequate or more than adequate for their lighting, cooking, heating requirements (Department of Energy 2013; Fahmy 2011). The responses were put together in a summated scale ranging from 0 (adequate on all four items) to 4 (inadequate on all four items). Therefore, the subjective approach is based on a headcount measure that identifies the number of households as energy poor, which can be measured and monitored over time. Following this approach, the Department of Energy (2013) identified 66% of South African households as being energy poor in 2012.

From the measures of energy poverty employed in South Africa, it is evident that empirical work on multidimensional energy poverty is yet to be attempted. Using a multidimensional approach to measure energy poverty, especially for low-income households, allows a focus on energy services by measuring their energy deprivation and decomposability (urban vs rural). In addition, examining the impact of the FBE policy in addressing energy poverty through a multidimensional approach will make it imperative to have an understanding of their degree of deprivation of access to energy services.

2.4 The evaluation of the Multidimensional Energy Poverty Index in developing countries

Many empirical studies relating to energy consumption, poverty and the environment have been carried out (Barnes et al. 2011; Bhidey and Monroy 2011; Kaygusuz 2011; Pereira et al. 2011; Sagar 2005; Srivastava et al. 2012). However, empirical works on energy poverty are still relatively few; they include Barnes et al. (2011), Nussbaumer et al. (2011, 2012 and 2013) and

Sher et al. (2014). The MEPI is to let countries know how energy poor they are, from the direct measurement of useful energy requirements at the various demand type of the households (Iddrisu and Bhattacharyya 2015; Nussbaumer et al. 2011). Below are two examples from previous studies that have used the MEPI in a developing country context. The selection of a city (Addis Ababa, Ethiopia) and a zone (in Nigeria) as a case study was with the objective of deriving insights from the structure and selected determinants of energy poverty in different capacities.

Bekele et al. *(*2015) used primary data and employed a multistage stratified random sampling technique to identify the data sources. Bekele et al. (2015), following the works of Nussbaumer *et al.* (2011) and Edoumiekumo et al. (2013), constructed a MEPI for the residents of the capital city, in Ethiopia. The MEPI was determined using four dimensions and having five energy poverty indicators, which included energy for cooking activities, indoor air pollution, access to electricity, owning energy appliances and using energy appliances (Bekele et al. 2015). Higher weights were assigned to the indicators of more importance (dimension of energy for cooking) while the other dimensions were assigned equal weights (Bekele et al. 2015). The combination of the deprivation counts must exceed a pre-defined threshold line (which was 0.3 for the study) (Bekele et al. 2015). The MEPI was calculated to be 57.99%, implying that the households in Addis Ababa are energy poor, having little or no access to modern energy for cooking, do not have their own appliances and do not use energy appliances (Bekele et al. 2015). The remaining 42.01% households are classified as multidimensionally energy non-poor, implying that they have access to modern energy carrier for cooking and use different energy appliances and are thus, benefiting from modern energy supply (Bekele et al. 2015).

Edoumiekumo et al. (2013), used secondary data collected during the National Standard Survey (NLSS) of households in the South-South zone of Nigeria, and adopted a multi-stage stratified sampling technique. Following the work of Nussbaumer et al. (2011), a MEPI was constructed using two dimensions and having three energy poverty indicators which include access to modern cooking fuel, indoor pollution and access to main electricity or electricity from a generator (Edoumiekumo et al. 2013). A higher weight was assigned to the indicators of more importance (dimension of energy for cooking) while the other indicator was assigned a lower weight (dimension of energy for lighting) (Edoumiekumo et al. 2013). Thus, the combination of the deprivation counts has to exceed a pre-defined threshold line (which was 0.5 for the study). The MEPI for the zone was estimated to be 75.1% (energy poor) implying that three-quarters of the households in the zone have no access to modern energy for cooking and no electricity access or electricity from generator (Edoumiekumo et al. 2013). The remaining 24.9% households were classified as energy non-poor, implying that they have access to modern energy carrier for cooking and have access to electricity or electricity from generator (Edoumiekumo et al. 2013).

3 Data and method

The study uses the National Income Dynamics Survey (NIDS), which began in 2008 (the baseline wave), with a nationally representative sample of 28 000 individuals residing in 7 300 households across the country. The NIDS is the first national longitudinal panel study of individuals and households established by The Presidency of South Africa (Leibbrandt et al. 2009; NIDS 2012). A stratified two-stage cluster sampling design has been adopted for this survey and it continues to be repeated every two years with the same group of households or individuals using a combination of household, adult, child and proxy questionnaires (Brown et al. 2012; Leibbrandt et al. 2009; NIDS 2012). Since this study focused on low-income households, a total sample of 10 801 observations was appended (using the four waves: wave1- 2008, wave2- 2010, wave3- 2012 and wave4- 2014) for the analysis. Data analysis is done on weighted data so that the results obtained are representative of the entire population and the quantitative software package STATA version 12 was employed.

For the analysis and measurement of energy poverty of South African low-income households, the study uses the Multidimensional Energy Poverty Index (MEPI), proposed by Nussbaumer et al. (2011). The technique of MEPI is derived from the literature on multidimensional poverty measures from the Oxford Poverty and Human Development Initiative (OPHI) (Alkire and Foster 2007, 2009, 2010; Alkire and Santos 2010). The multidimensional energy poverty approach measures the proportion of the population that is multi-dimensionally energy poor (incidence) and the average intensity of their deprivation of energy (intensity). Multidimensional poverty can be estimated by multiplying the incidence of poverty by the intensity of energy deprivation.

Measuring energy poverty through the choice of energy poverty dimensions, indicators and setting weights to different indicators of the dimensions may lead to different poverty levels across a population (Nussbaumer et al. 2012). The first step was to check the correlation structure of the energy poverty indicators. The energy poverty indicators include electricity access, energy for cooking, heating and lighting, ownerships of landline telephone, cell phone, radio, television, computer, fridge and washing machine. The correlation coefficients for each pair of the indicators is given in Table 1.

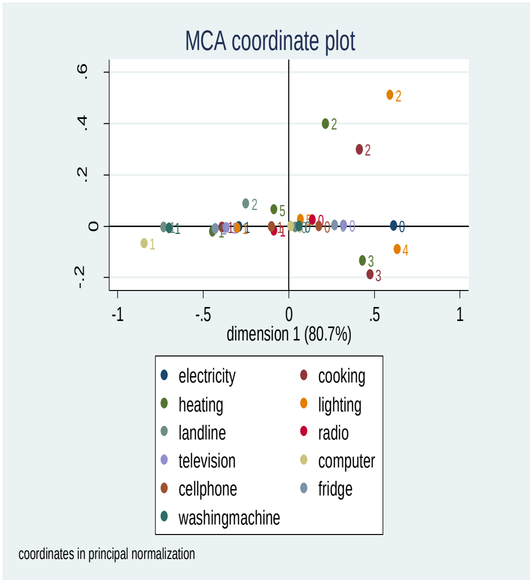
Table 1: Correlation Matrix of Energy Poverty Indicators

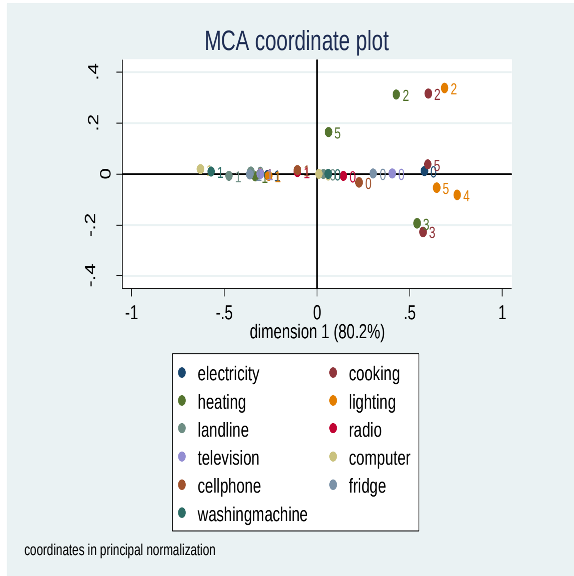
	Year			
	2008	**2010**	**2012**	**2014**
Energy Poverty Indicators				
electricity access	cooking (-0.624) heating (-0.321) lighting (-0.866) television (0.450) fridge (0.423)	cooking (-0.553) heating (-0.354) lighting (-0.735) television (0.424) fridge (0.409)	cooking (-0.528) heating (-0.344) lighting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

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

Following the rule of thumb by Spearman (1910) or Pearson (1920), a correlation coefficient between +/- .00 to .30 is considered a negligible correlation. For example, Table 1 shows that between 2008-14, electricity access has a very high correlation with cooking and lighting, a moderate correlation with television and fridge and a low correlation with heating. High correlations, according to Mukaka (2012), denote that the two energy poverty indicators moved in a very similar manner over these years, implying that the two indicators are highly correlated with each other over time. On the other hand, if the correlation between the energy poverty indicators is low, then it is unlikely that they share common factors.

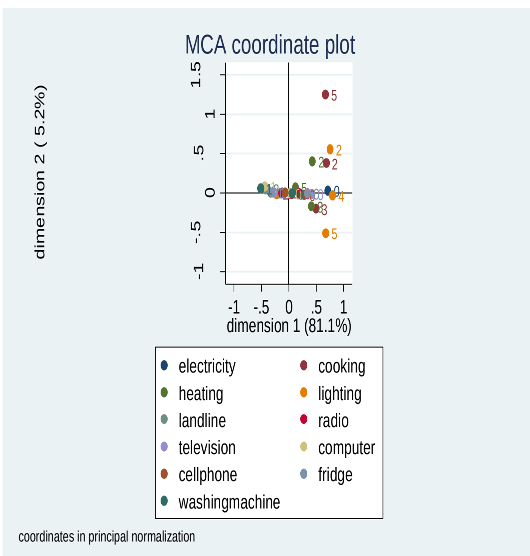
Motivated by the concern of strong correlation by some of the energy poverty indicators and to avoid double counting, a statistical technique was employed to choose the energy poverty indicators and their corresponding weights. The variables representing the multidimensional energy poverty indicators in the dataset used for this research are in ordinal/categorical forms for which Principal Component Analysis (PCA) is not a priori an optimal approach (Wardhana 2010). Multiple Correspondence Analysis (MCA) is more suited to discrete or categorical variables and therefore employed in choosing the energy poverty indicators and to assign weights in constructing the multidimensional energy poverty index. Figure 1 shows the MCA results.

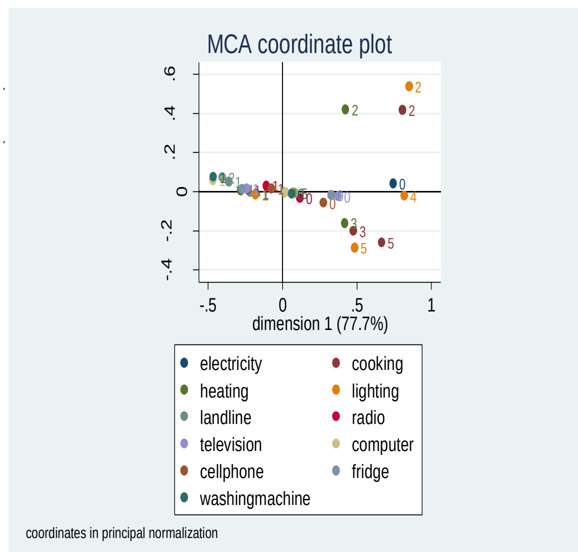




MCA coordinate plot 2008

MCA coordinate plot 2010





MCA coordinate plot 2012

MCA coordinate plot 2014

Figure 1: MCA coordinate plots for 2008-14

From Figure 1, a pattern is seen in all the plots about clustering of some variables. The variables that clustered together in the four waves include electricity (electricity access), landline, television, lighting and computer. Some variables clustered together in only two or three waves, which include heating, radio and fridge. The remaining variables (cooking, cell phone and washing machine) either clustered together only in one wave or did not form a cluster at all.

According to Le Roux and Rouanet (2010), the implication of the clustering together of variables in MCA coordinate plots is compatibility with others. In other words, the variables are related.

Based on the MCA statistical approach, the MEPI is constructed using six dimensions made up of six major indicators of energy deprivation, which are similar to those used in Nussbaumer et al. (2011). Table 2 shows the selected six dimensions and their six indicators with cut-offs and their assigned weight.

Table 2: Selected dimensions and respective indicators with cut-offs, including relative weights in parentheses

Dimension	Indicator (weight)	Variable	Cut-off (Situation of deprivation)
Cooking	Modern cooking fuel (0.30)	Type of cooking fuel	A household considered poor/deprived if using any fuel beside electricity (or generator), LPG, or solar for cooking purposes.
Lighting	Modern energy lighting (0.35)	Type of energy source used for lighting	A household considered poor/deprived if the household uses any energy source beside electricity (or generator), LPG or solar for lighting purposes.
Heating	Modern heating fuel (0.05)	Type of heating fuel	A household considered poor/deprived if using any fuel beside electricity (or generator), LPG or solar for heating purposes.
Services provided by means of household appliances	Basic appliance ownership (0.10)	Has a fridge	A household considered poor/deprived if the household has no fridge.
Entertainment/Education	Entertainment/Education appliance ownership (0.10)	Has a radio	A household considered poor/deprived if the household has no radio.
Communication	Telecommunication means (0.10)	Has a cell phone	A household considered poor/deprived if the household has no cell phone.

Further, for a household to be identified as energy poor, the combination of those deprivation counts has to exceed a pre-defined threshold line (energy poverty line). The choice of the energy poverty line, k, is crucial to the extent that it determines the conclusions for energy poverty comparisons (Barnes *et al.* 2010). In this study, the energy poverty line is estimated by own calculations by multiplying the lower bound poverty line (LBPL) and the upper bound poverty line (UBPL) values for 2014 with the average household size (3.8 people), as recorded in the 2010/2011 Income and Expenditure Survey (Bhorat *et al.* 2011; Statistic South Africa 2012). The resulting value is estimated as a percentage of total number of households. Based on this calculation, the multidimensional energy poverty line, k equals 1/3 (which is 0.33). A household is considered as energy poor if the sum of weighted deprivation count is greater than or equal to 0.33. If the household's sum of weighted deprivation is less than 0.33, the household is classified as energy non-poor. See Table A1 in Appendix A to view the sensitivity analysis to test the multidimensional energy poverty cut-off line. The MEPI is computed as follows:

The headcount energy poverty is measured through the following equation:

$$HCR = (NEP/NEP + NNEP)\ W_i \quad (1)$$

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

NEP is the number of energy poor;

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

W_i is the estimated weight

The energy poverty intensity is estimated using the following equation:

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

Where:

A is the intensity of energy poverty;

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

k is the multi-dimensional energy poverty line; and

q is the average un-weighted deprivation share of people who suffer from energy poverty of at least *k*.

MEPI is therefore calculated as:

$$MEPI = HCR * A \quad (3)$$

4 Results and discussion

The first part of this section reveals the descriptive statistics of low-income households in South Africa, starting with a presentation and discussion of their socio-economic and demographic characteristics. The purpose is to give a picture of the characteristics of low-income households. It also extends to present the status of low-income households in energy related basic household activities with due emphasis on some variables used for constructing the MEPI. Finally, the section gives the results of the analysis of energy poverty using a multidimensional approach. Table 3 shows the socio-economic and demographic characteristics of the low-income households in South Africa.

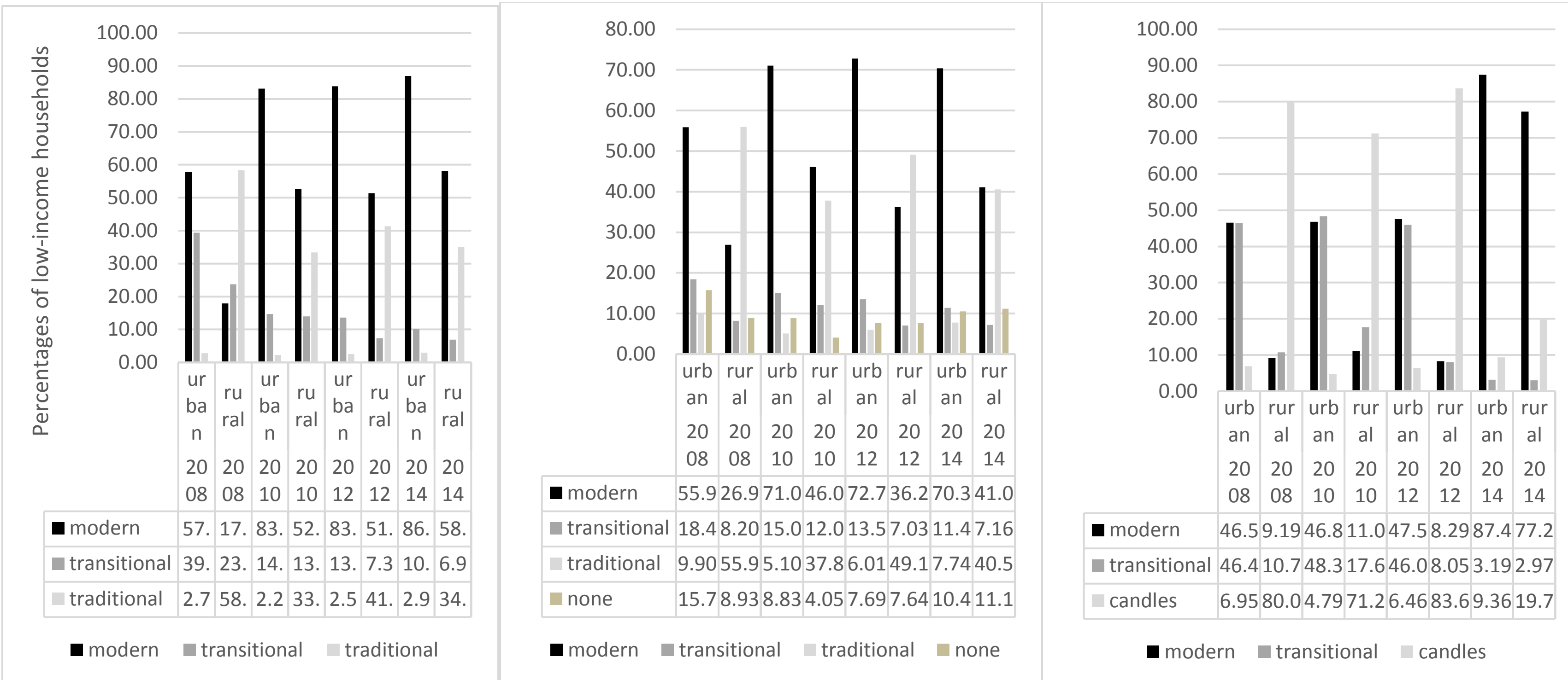
Table 3: Socio-economic and demographic characteristics of low-income household's in South Africa, 2008 -14. n = 10 801

	Percentage of Low-income Households
Population Group (Household respondent)	
Black African	89.29
Coloured	9.55
Asian/Indian	0.35
White	0.82
Gender (Household respondent)	
Female	73.37
Male	26.63
Rurality	
Urban	43.83
Rural	56.17
Household Size (Persons)	
1 - 4	72.91
5 - 10	25.95
11 - 15	1.05
16 and above	0.05
Dwelling Type (Household)	
Modern dwelling	67.82
Traditional dwelling	19.24
Informal dwelling	12.93

Table 3 shows that most low-income households are Black African (89.29%). The population group with the smallest proportion of low-income households is the Asian/Indian (0.35%). The gender variable shows that nearly three-quarters of respondents (73.27%) were female. Table 3 also indicates that rural dwellers were more likely to be low-income households (56.17%) compared to urban dwellers (43.83%). These findings align with the description given by Mohapi (2016) that the poorest South Africans are black, female and rural. The most common household size amongst low-incomes in South Africa was 1 – 4 persons (73% of the sample). Only 27% of low-income households have larger household sizes (5 and above). The dwelling type shows that 67.82% of low-income households have modern dwellings (a structure built according to approved plans with concrete blocks including a house on a separate stand, a flat or apartment, a townhouse, a room in a backyard or flatlet). Informal dwellings (typically built with found materials such as corrugated iron, cardboard, plastic, etc., and not approved by a local authority as a permanent dwelling) was found to be the smallest category (12.93%).

In addition to looking at the socio-economic and demographic characteristics of low-income households in South Africa, it is important to understand the differences in energy choices between rural and urban low-income households. The basic domestic activities within a household considered with respect to urban-rural differences are cooking, heating and lighting. Figure 2 shows the choices of energy use for cooking (Panel1), heating (Panel2) and lighting (Panel3) by South African low-income households in both rural and urban areas from 2008 – 14.

It is interesting to see that rural households used more of modern energy carriers for cooking across the years. There was an especially sharp increase in the use of modern energy carriers by rural households from 2008 – 10 (17.94% to 52.73%). In 2008, more than half of rural households (58%) used traditional energy carriers for cooking. However, in rural low-income households, the use of modern energy carriers for cooking is gradually taking over from transitional or traditional energy carriers. The percentages of low-income rural household's using traditional energy carriers across the years are higher compared to low-income households in urban areas. Both rural and urban households seldom used transitional energy carriers except for 2008, that urban households use more of transition energy carriers (39.38%). In 2014, both rural and urban households had the highest usage of modern energy carriers for cooking, with 86.91% and 58.10% respectively.



Panel1: cooking Panel2: heating Panel3: lighting

Figure 2: Urban-rural differences and energy choices for cooking, heating and lighting

Low-income rural households in South Africa used more traditional energy carriers for heating compared to other types of energy carriers. In 2014, however, the rural low-income households were more inclined to using both traditional (40.58%) and modern energy carriers (41.09%). Low-income urban households on the other hand used more of modern energy carriers for their space heating and 2012 has the highest percentage (72.79%). Further, low-income urban households rarely use traditional energy carriers for heating, with 2010 having the lowest percentage of households in this category (5.10%). In both rural and urban low-income households, few households (ranging from 4% to 16%) did not utilise an energy source for their space heating from 2008 – 14. The use of transitional energy carriers by both rural and urban low-income households varies from 7% to 18%.

Low-income households in urban areas mostly used modern and transitional energy carriers for their lighting from 2008 – 12. In rural areas, low-income households use candles as their main source of lighting from 2008 – 12. However, in 2014, the majority of low-income households in the rural areas (77.29%) and urban areas (87.45%) choose modern energy carriers for lighting. The proportion of low-income households using transitional energy carriers for lighting in 2008 – 12 is substantially higher in urban areas, which seems not to agree with previous studies that urban households consume smaller shares of transitional energy sources than rural households do (Palit et al. 2014).

The results of Multidimensional Energy Poverty Index for South African low-income households is discussed next. According to Nussbaumer et al. (2013), an experience of acute degree of energy poverty is when MEPI exceeds 0.7 and a low degree when the MEPI is less than 0.3. A MEPI greater than 0.3 but less than 0.7 indicates moderate energy poverty. For comparison, the MEPI results is outlined based on the rurality of low-income households across the four waves (Table 4).

Table 4: Cross-sectional analysis of MEPI (2008-14): Urban low-income vs rural low-income

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

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

Table 4 shows the percentage of energy deprivation among the low-income households in urban and rural areas. The low-income rural households are indeed deprived with respect to energy services compared to those in urban areas as their average intensity value ranges from 0.59 to 0.62. As such, low-income households living in rural areas have a higher percentage of energy deprivation than among those living in urban areas for each year of analysis. However, whilst the percentages of low-income households in rural areas that are energy deprived started reducing after 2010, the percentages for urban areas is increasing after 2010. This is contrary to expectation as urban populations have access to higher quality energy services than rural populations. The rising energy poverty in urban areas could be an increased migration of rural low-income households to the urban settlements indicating a struggle by the government to keep pace with the increasing demand of the fast growing population.

The MEPI results across the years in low-income urban and rural households vary between 0.36 and 0.62. This indicates that low-income households in both urban and rural areas are in a state of moderate energy poverty. The moderate state of energy poverty amongst low-income populations is not as anticipated considering the energy programmes and policy targeted towards the low-income households in South Africa.

As discussed earlier, different approaches have been used in South Africa to measure energy poverty. Using the energy expenditure approach, 47% of South African households (not low-income households) were found to be energy poor in 2012. The thermal efficiency approach showed that 49% of South African households were energy poor in 2012. Lastly, the subjective approach identified 66% of South African households as being energy poor in 2012. All these percentage lies within a moderate state of energy poverty, following the energy poverty scale proposed by Nussbaumer et al. (2013). Even though these previous approaches does not disaggregate into sub-groups (rural-urban) as the MEPI does, one can say that energy poverty is still an issue in South Africa. Table 5 shows the panel analysis result of MEPI for both low-income households in the urban and rural areas.

Table 5: MEPI for low-income households

	Population share	Adjusted multidimensional headcount (HCR)	MEPI = HCR*A
Urban	39	99.2	39.0
Rural	61	99.5	61.0

Amongst low-income households in urban and rural areas, 39% and 61% are multidimensionally energy poor respectively. The result validates the cross-sectional analysis of MEPI.

Examining energy poverty at the level of energy services (or dimensions) is to show how households are energy poor and it could determine where policy interventions should be directed. This information can be used for targeting each dimension if one wants to reduce energy poverty for the low-income households in South Africa. The dimensional deprivation reveals that any attempts to solve the problem of energy poverty for low-income households should target each dimension with varying degrees of emphasis. Figure 3 presents the panel result of dimension-wise breakdown of energy poverty.

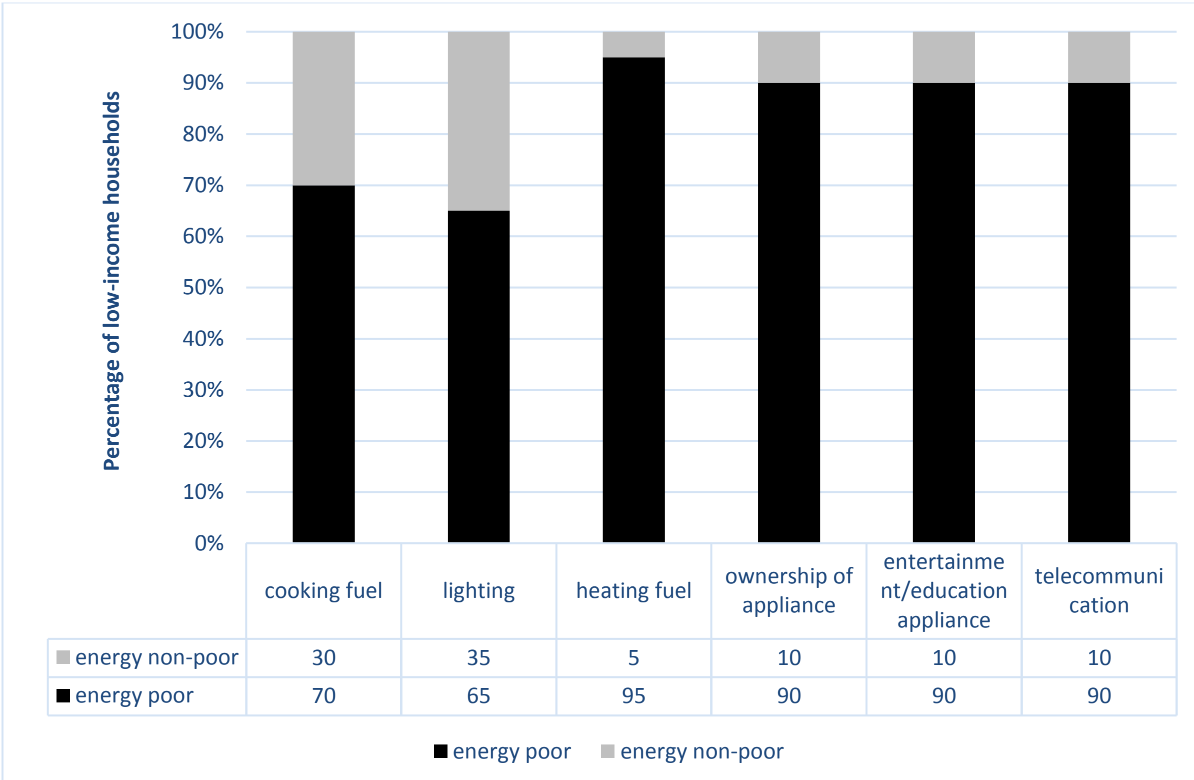


Figure 3: Dimension wise breakdown of energy poverty

Low-income households in both rural and urban areas are mostly deprived in heating fuel dimension (95%) and least deprived in lighting (65%). Results further show that 90% of the low-income households in both the urban and rural areas are deprived in terms of home appliances, entertainment/education appliance and telecommunication.

5 Concluding remarks and recommendation

This study shows that South African low-income households residing in both urban and rural areas are in a state of moderate energy poverty using the multidimensional energy poverty index (MEPI) approach. Low-income households are the main feature in addressing energy poverty. However, the needs of urban low-income households (especially those residing at periphery of the cities) vary widely and are different from rural low-income households.

The percentage of households who are energy poor as measured by the MEPI is increasing for low-income households in the urban areas is suggesting the problem of urbanisation. The percentage of the country's population (according to the Institute for Futures Research, University of Stellenbosch in 2013) residing in urban areas is approximately 64%. This therefore shows a struggle to keep pace with the increasing energy demand of this fast growing population. There is a need to implement different solutions for both the rural and urban low-income households to addressing their energy welfare.

The study also revealed that the major energy dimension in explaining energy poverty within the low-income households is heating fuel. One likely reason for this could be affordability of using a modern energy source for heating, which generally uses more fuel than other dimensions, such as lighting and cooking. According to Practical Action (2010), space heating is all about energy balance. Promoting and supporting the use of modern energy carriers for this energy service leads to less wood fuel being collected for heating (Practical Action 2010). One such way to promote and support the use of modern energy carriers for heating for example is by upgrading the appliance (heaters) to a more efficient appliance, which can save the consumer money and energy.

The study, firstly, recommends that energy policies, programs and projects be targeted as precisely as possible in order to help those who need it most (the low-income households) and thus be able to meet the specific energy needs either for low-income households in the rural or urban areas. Secondly, suitable measures to combat energy poverty should be urban-rural specific, taking into consideration the rapid population growth in the urban areas. Further, addressing the issue of affordability for urban and rural low-income households might require subsidising other modern energy carriers (such as, liquefied petroleum gas, solar energy or biofuels).

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References

Alkire, S & Foster, J, 2010. Designing the Inequality Adjusted Human Development Index (IHDI). *OPHI Working Paper* 37, Oxford University.

Alkire, S & Foster, J, 2009. *Counting and Multidimensional Poverty Measurement*; University of Oxford: New York, NY, USA.

Alkire, S & Foster, J, 2007. *Counting and Multidimensional Poverty Measurement*; University of Oxford: New York, NY, USA.

Alkire, S & Santos, EM, 2010. Acute Multidimensional Poverty: A New Index for Developing Countries. Oxford Poverty and Human Development Initiative. Working Paper No. 38. Available at: http://www.ophi.org.uk/wp-content/uploads/ophi-wp38.pdf.

Barnes, DF, Khandker, SR & Samad, HA, 2011. Energy Poverty in Rural Bangladesh. *Energy Policy*. 39(2): 894–904.

Bazilian, M, Nussbaumer, P, Cabraal, A, Centurelli, R, Detchon, R, Gielen, D, Rogner, HH, Howells, M, McMahon, H, Modi, V & Nakicenovic, N, 2010. Measuring Energy Access: Supporting a Global Target. Expert Meeting Galvanizing Political Commitment for Universal Energy. The Earth Institute, New York, NY, USA.

Bekele, G, Negatu, W & Eshete, G, 2015. Energy Poverty in Addis Ababa City, Ethiopia. *Journal of Economics and Sustainable Development*. 6(3): 26-34.

Bhide, A & Monroy, CR, 2011. Energy Poverty: A Special Focus on Energy Poverty in India and Renewable Energy Technologies. Renew Sustainable Energy Reviews. 15(2): 1057-1066.

Brown, M, Daniels, R, De Villiers, L, Leibbrandt, M & Woolard, I, 2012. National Income Dynamics Study Wave 2 User Manual. Southern Africa Labour and Development Research Unit, Cape Town.

Department of Energy, DoE, 2013. Integrated Resource Plan for Electricity (IRP) 2010-2030. Update Report 2013. Pretoria: Department of Energy.

Department of Energy, DoE, 2012. A Survey of Energy-Related Behaviour and Perceptions in South Africa: The Residential Sector.

Available at: http://www.energy.gov.za/files/media/Pub/Survey

Department of Energy, DoE, 2009. Socio-Economic Impact of Electrification: Household Perspective.

Edoumiekumo, SG, Tombofa, SS & Karimo, TM, 2013. Multidimensional Energy Poverty in the South-South Geopolitical Zone of Nigeria. *Journal of Economics and Sustainable Development*. 4(20): 96-103.

Fahmy, E, Gordon, D & Patsios, D, 2011. Predicting Fuel Poverty at a Small-Area Level in England. *Energy Policy*. 39(5):4370-4377.

Ferriel, A, 2010. Free Basic Electricity. A Better Life for All. Johannesburg: Earthlife Africa.

Godfrey, EB, Gordon, ND, Knight, LC, Aber, JL, Allen, L & Ritcher, L, 2016. Which Eligible Households get Grants? Demographic Correlates of Receipt in South Africa. *Development Southern Africa*. 1-16.

Hills, J, 2012. Getting the Measure of Fuel Poverty. Final Report of the Fuel Poverty Review. Centre for Analysis of Social Exclusion, London School of Economics and Political Science.

Human Science Research Council and Department of Energy, 2012. *A Survey of Energy Related Behaviour and Perceptions in South Africa.*

Iddrissu, I & Bhattacharyya, SC, 2015. Sustainable Energy Development Index: A Multi-Dimensional Indicator for Measuring Sustainable Energy Development. *Renewable and Sustainable Energy Reviews.* 50: 513-530.

International Energy Agency, IEA, 2010. World Energy Outlook, Paris.

International Energy Agency, IEA, United Nations Development Program, UNDP, United Nation Industrial Development Organisation, UNIDO, 2010. Energy Poverty. How to make Modern Energy Access Universal. 3-39.

Ismail, Z, 2015. An Empirical Estimation of Energy Poverty in Poor South African Households. *Journal of Economics and Sustainable Development*. 6(13): 184-192.

Ismail, Z & Khembo, P, 2015. Determinants of Energy Poverty in South Africa. *Journal of Energy in Southern Africa.* 26(3): 66-78.

Kaygusuz, K, 2011. Energy Services and Energy Poverty for Sustainable Rural Development. *Renewable and Sustainable Energy Reviews*. 15: 936-947.

Khandker, SR, Barnes, DF and Samad, HA, 2012. Are the Energy Poor also Income Poor? Evidence from India. *Energy Policy*. 47(2): 1-12.

Leibbrandt, M, Woolard, I. & de Villiers, L. 2009. Methodology: Report on NIDS wave 1. *Technical Paper,* vol. 1.

Kohler, M, Rhodes, B & Vermaak, C, 2009. Developing an Energy-Based Poverty Line for South Africa. *Journal of Interdisciplinary Economics*.

Miah, MD, Foysal, MA, Koike, M & Kobayashi, H, 2011. Domestic Energy-use Pattern by the Households: A Comparison between Rural and Semi-Urban Areas of Noakhali in Bangladesh. *Energy Policy*. 39(6): 3757-3766.

Mohapi, BJ, 2016. The Social Sector of the expanded Public Works Programme as a Strategy to Alleviate Poverty amongst Vulnerable Groups in Gauteng. Development Southern Africa. 33(5): 644-657.

Nussbaumer, P, Nerini, FF, Onyeji, I & Howells, M, 2013. Global Insights Based on Multidimensional Energy Poverty Index (MEPI). *Sustainability*. 5(4): 2060-2076.

Nussbaumer, P, Bazilian, M & Modi, V, 2012. Measuring Energy Poverty: Focusing on What Matters. *Renewable Sustainable Energy Reviews.* 16: 231–243.

Nussbaumer, P, Bazilian, M, Modi, V & Yumkella, K, 2011*. Measuring Energy Poverty: Focusing on What Matters*. Oxford Poverty and Human Development Initiative (OPHI), University of Oxford: New York, NY, USA.

Pachauri, S & Spreng, D, 2011. Measuring and Monitoring Energy Poverty. *Energy Policy.* 39(7): 7497-7504.

Pachauri, S, Mueller, K, Kemmler, A & Spreng, D. 2004. On Measuring Energy Poverty in Indian Households. *World Development*. 32(12): 2083-2104.

Palit, D, Bhattacharrya, SC & Chaurey, A, 2014. *Indian Approaches to Energy Access in Energy Poverty: Global Challenges and Local Solutions*. Oxford University Press. 238-245.

Pereira, MG, Freitasa, MAV & Da Silva, NF, 2011. The Challenge of Energy Poverty: Brazilian Case Study. *Energy Policy*. 39(1): 167–175.

Ruiters, G, 2011. Developing or Managing the Poor: The Complexities and Contradictions of Free Basic Electricity in South Africa (2000-2006). *Africa Development*. 36(1): 119-142.

Sagar, AD, 2005. Alleviating Energy Poverty for the World's Poor. *Energy Policy*. 33: 1367- 1372.

Sokona, Y, Mulugetta, Y & Gujba, H, 2012. Widening Energy Access in Africa: Towards Energy Transition. *Energy Policy*. 47(1):3–10.

Sovacool, BK, 2012. The Political Economy of Energy Poverty: A Review of Key Challenges. *Energy for Sustainable Development*. 16: 272-282.

Srivastava, L, Goswami, A, Diljun, GM & Chaudhury, S, 2012. Energy Access: Revelations from Energy Consumption Patterns in Rural India. *Energy Policy*. 47(4): 11-20.

Statistics South Africa, 2012. CPI History 2012 base year. T. B1. Pretoria, Statistics South Africa.

Swart, D & Bredenkamp, B, 2012. The Challenge of Addressing Household Energy Poverty. Conference Paper Presented at "Towards Carnegie" in University of Cape Town, September 3-7.

United Nations Development Program, UNDP, 2010. Human Development Report. New York.

Vermaak, C, Kohler, M & Rhodes, B, 2013. Developing an Energy-Based Poverty Line for South Africa. *Journal of Economic and Financial Sciences*. 7(1): 127-144.

Appendix A

Table A1: A panel result of energy poverty intensity, incidence and MEPI for different values of k, urban and rural areas

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

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