Investigating household energy poverty in South Africa by using unidimensional and multidimensional measures

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By

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Abstract

The ability to access affordable, reliable and modern energy services presents a pathway to social and economic development. Yet, the lack of access to modern energy services is widespread in sub-Saharan Africa and developing Asia. Following the declaration to achieve universal access to energy by 2030 in the United Nation's Millennium Development Goals and Sustainable Development Goals – several tools have emerged tracking and monitoring energy access and energy poverty. Earlier efforts have focused on measuring energy poverty from a unidimensional perspective while recent efforts have focused on a multidimensional measurement. However, the growing trend in tracking and monitoring energy poverty using multidimensional indicators has been applied limitedly in the context of South Africa. Part of this has been associated with the lack of detailed and reliable survey data. With access to detailed survey data, this study aimed to evaluate household energy poverty in South Africa by using both unidimensional and multidimensional measures.

This study constructed the energy budget share, also known as Tenth-Percentile Rule (TPR) (unidimensional) and the multidimensional energy poverty index (MEPI) using data from wave 1 (2008) and wave 4 (2014-2015) of the National Income Dynamic Study (NIDS) of South Africa. A 10 percent threshold was used for the energy-budget share while a 0.3 cut-off point was used for the MEPI. This study first computed national-level estimates of household energy poverty, and subsequently decomposed these estimates by province, household income poverty status and household location (urban versus rural). A sensitivity analysis was performed to test for the stability in ranking of provinces when the energy poverty threshold of the TPR was varied from 7 to 13 percent, and the energy poverty cut-off k of the MEPI was changed from 0.2 to 0.4. The Spearman rank correlation coefficient was determined for each pair of ranking of provinces to establish the strength of correlation.

Based on the TPR measure, results show that 21 and 13 percent of South African households lived in energy poverty in 2008 and 2014-2015, respectively. The MEPI measure indicates that 37 and 19 percent of the households lived in energy poverty in 2008 and 2014-2015, respectively. Limpopo province had the highest rates of energy poverty in 2014-2015 with values of 25 percent (using TPR) and 52 percent (using MEPI). This study also found that by 2014-2015, only 23 percent (using the TPR) and 46 percent (using the MEPI) of energy poor households lived below the food poverty line of R430. Further, this study found that household energy poverty has reduced in rural areas and by 2014-2015, only 18 percent (using

TPR) and 49 percent (using MEPI) of households located in rural areas lived in energy poverty. The lowest observed value of the Spearman rank correlation coefficient was 0.90. It is concluded that the overall household energy poverty has reduced in South Africa between 2008 and 2014-2015. The TPR gives lower estimates of energy poverty than the corresponding values obtained from the MEPI measure. There is negligible effect of varying the threshold values (within the studied range) of the TPR and k.

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List of Abbreviations

CPI	Consumer Price Index
CSEPI	Correlation Sensitivity Energy Poverty Index
DHS	Demographic and Health Survey
DOE	Department of Energy, Republic of South Africa
ESMAP	Energy Sector Management Assistance Program
FBE	Free Basic Electricity
FPL	Food Poverty Line
GHS	General Household Survey
IEA	International Energy Agency
LBPL	Lower Bound Poverty Line
LMS	Living Standard Measure
LPG	Liquid Petroleum Gas
MEPI	Multidimensional Energy Poverty Index
MPI	Multidimensional Poverty Index
MTF	Multi-Tier Framework
NDP	National Development Plan
NIDS	National Income Dynamics Study
OPHI	Oxford Poverty & Human Development Initiative
PSLM	Pakistan Social & Living Standards Measure
SALDRU	Southern Africa Labour & Development Research Unit
SDGs	Sustainable Development Goals
TEA	Total Energy Access
TEIT	Total Energy Inconvenience Threshold
TPR	Tenth-Percentile Rule
UBPL	Upper Bound Poverty Line
UK	United Kingdom
UN	United Nations

Chapter 1

Introduction

1.1 Background

The ability to access energy services has become an important component, if not a precondition, for addressing global developmental challenges in poverty eradication, climate change and inadequate healthcare schemes (Bensch, 2013; DOE, 2014; Reddy, 2015). The lack of access to modern energy services, across global contexts, is common in sub-Saharan Africa and developing Asia (IEA, 2015; IEA, 2016). In Africa, recent estimates show that 620 million people are living in energy poverty while 730 million people rely heavily on the use of traditional fuels (such as animal dung and firewood) for their cooking needs (IEA, 2015). Energy poverty refers to a state of not having access to modern energy services or carriers (Bhatia & Angelou, 2014). Evidence suggests that the drivers of household energy poverty are political economies, income differentials, changes in affordability, institutional and infrastructural constraints, among others (Pachauri & Spreng, 2011; Bouzarovski & Petrova, 2015; Ismail & Khembo, 2015).

On the international platform, the United Nations (UN) has set a target to achieve universal access to energy by 2030 (AGECC, 2010). Recently, the UN reaffirmed this goal[1] in the adoption of the 17 Sustainable Development Goals (UNDP, 2016). However, global trends in energy poverty alleviation are deteriorating in both pace and scale (Nussbaumer, Bazillian & Modi, 2012) — exhibiting uncertainty, if ever these targets will be reached. The International Energy Agency (IEA) also submits that the continuance of such trends would leave some households trapped in energy poverty by 2030 (IEA, 2010). A household is considered trapped in energy poverty if the household engages in a vicious cycle of using unclean fuels due to deprivation of clean and affordable energy, which often, is as a result of being a low-income household (IEA, 2015).

South Africa has realized household electrification rates of 85% through Eskom (the national energy utility supplier) and government supportive policies (DOE, 2015a). Despite

[1] SDG (Sustainable Development Goal) 7: Ensure universal access to affordable, reliable and modern energy services for all by 2030 (UNDP, 2016)

such achievements, the Department of Energy estimates that between 40 and 49% of households are still energy poor (DOE, 2015b). According to Statistics South Africa's General Household Survey (GHS), 15 percent of households considered as energy poor rely heavily on unclean energy sources (such as traditional biomass) for cooking and heating purposes (Stats SA, 2014a). It is therefore evident that high electrification rates, especially for low-income households, do not necessarily increase household welfare or reduce energy poverty if households are unable to afford electricity services (Sustainable Energy Africa, 2014; Groh, Pachauri & Narasimha, 2016).

In line with the targets[2] outlined in the National Development Plan (NDP), the Department of Energy has set targets of achieving universal access to energy through household electrification rates of 97.2% by 2025 (DOE, 2015a). Yet, several supply-side constraints continue to pose a threat towards reaching this target within the prescribed timeframe (National Development Plan, 2010). For instance, failure to collect revenues by municipals to pay for the cost of distribution have the potential to slow efforts towards achieving this goal (Sustainable Energy Africa, 2014).

It has therefore become necessary to identify or develop tools that can effectively track and monitor the progress made towards alleviating energy poverty. In theory, the process of constructing the tools and metrics necessary to measure energy poverty depends on how it is defined (Schuessler, 2014). Various definitions have emerged over the years, and yet to date, there no one standard definition of energy poverty (Nussbaumer *et al.*, 2012; Bensch, 2013; IEA, 2015). Understanding how energy poverty is measured has however become quite central towards any concerted efforts directed to its alleviation (Pachauri & Spreng, 2011). The backlog towards reaching consensus on what should be a standard definition of energy poverty can be associated with at least 3 things that still remain vague: firstly, the meaning of energy access; secondly, the most applicable metrics to use when tracking energy access; and thirdly, how to design the right metrics to track it (Groh *et al.*, 2016).

Nevertheless, there have been several attempts to measure energy poverty through the construction of energy poverty indicators. Some of these indicators have initially taken the form of unidimensional metrics describing energy poverty from a single dimensional perspective. For example, an energy poverty line or an estimated amount of energy required to live a basic daily life (Bazilian *et al.*, 2010). Unidimensional indicators are straightforward,

[2] The National Development Plan (2010) targets electrification rates above 90% by 2025.

easy to interpret and therefore provide unbiased information in a single dimension. Yet, they have undergone criticism following the work of Sen (1999) in his conceptualization of the Capability approach. Sen (1999) argues that poverty is an intangible concept driven by multiple deprivations in more than one dimension. Therefore, it is prudent to treat poverty as a phenomenon that is rather, multidimensional. This highlights the fact that, unidimensional measures are narrow and therefore, cannot adequately provide a full depiction of energy poverty.

In this respect, several multidimensional indicators, also known as "dashboard" indicators, have emerged within the literature providing rich and decomposable information about energy poverty (Nussbaumer *et al.*, 2012). Notwithstanding such explanatory power, multidimensional indicators have been criticised for producing poor estimates due to the existing lack of available and reliable detailed micro-level data (Bensch, 2013). Critics have also argued that the complex undertaking of deriving a multidimensional estimate easy to draw meaning from is subject to misspecification if the researcher lacks the technical skills (Bensch, 2013). Additionally, sceptics have argued against metrics that have many explanatory variables with several outcomes as a potential challenge towards proposing a process for policy. Nussbaumer, Bazilian, Modi and Yumkella (2011) however argue that having more than one explanatory variable may prove beneficial, especially in cases where a classification of multiple deprivation is required for comparison between regions or groups.

An additional, yet, critical drawback to multidimensional indicators is the so-called *curse of dimensionality* – a situation in which the number of dimensions' increase to a level where performing joint analysis becomes perverse (Bensch, 2013). Such drawbacks have prompted researchers and practitioners to develop indices that are composite in nature. By definition, composite indices are single numerals estimated from an aggregation of a number of variables, which are meant to represent a dimension (Nussbaumer *et al.*, 2011). The theoretical underpinning behind developing a composite index is to allow for the creation of an index that not only aggregates information in an easy way to use, but also provides estimates that can be used in cross-country comparisons when benchmarking performance (Brazilian *et al.*, 2010).

The construction of most metrics of energy poverty measurement have strongly been linked to a lack of physical access to modern energy services (Pachauri & Spreng, 2011). Some measures have focused on the optimal amount of energy required for consumption in order to live a basic life, whereas other measures have focused on estimating an energy poverty line in determining who is energy poor or not. However, what most of these measures have in common is that they are all constructed based on a unique set of assumption, and therefore, tend to vary across countries, regions, or different socioeconomic factors (Pachauri & Spreng, 2011).

Following the growing trend in tracking and monitoring energy poverty using multidimensional indicators, very limited work seems to have been applied in the context of South Africa. Part of this could be the lack of reliable and detailed survey data. In South Africa, the Department of Energy makes use of a 10 percent energy-budget share index, also known as "*Tenth Percentile Rule*" – an index that suggests that a household is energy poor if it spends more than 10 percent of household income on energy services (DOE, 2009; 2013). However, the energy-budget share index has undergone criticism in the international literature. The critique questions the relevance of the index, particularly in developing countries where the poor mostly use firewood, an energy source that is not accounted for in monetary terms. Therefore, under this measure, energy poor households are often incorrectly captured as non-poor. The flawed analysis that results has negative implication on policy and in particular, policy intended to target energy poor people that are instead erroneously captured as non-energy poor.

As pointed out above, it is evident that the process of tracking and monitoring the progress made towards alleviating energy poverty is constrained by a number of factors. These include, but are not limited to, the lack of a standard definition of energy poverty within the literature, as well as the lack of consensus regarding what the standard features of a measure of energy poverty should be (Bensch, 2013). Further, and still from a methodological viewpoint, the lack of reliable and good quality detailed survey data tends to affect this process (Nussbaumer *et al.*, 2012). Although several international measures of energy poverty exist, common in all of them is the inadequacy to account for the fact that energy poverty tends to be different between countries that are developed and developing, or those that are either rich or poor.

Given the above, a two-fold problem emerges. First, energy poverty metric such as multidimensional metric have not been widely applied in South Africa. This study therefore measures energy poverty in South Africa using different metrics from the literature by employing a quantitatively descriptive and evaluative research methodology. Second, there is a limited understanding of the geographical, socioeconomic and temporal incidence of energy poverty in South Africa, other than the rate of electrification. This serves as a primary motivation to this study. However, this is a fairly simplistic and crude proxy to use to understand the full extent of energy poverty. There is a need to better describe and measure the trends in energy poverty in South Africa not only at a particular cross-section, but also over time.

1.2 Aim and Objectives

The aim of this study was to evaluate household energy poverty by systematically constructing two metrics using an identical form of survey data.

To realize this aim, the following objectives were formulated:

- To estimate national-level household energy poverty in South Africa using the energy budget share (Tenth-Percentile Rule) and multidimensional energy poverty index.
- To describe the geographic, socioeconomic and temporal incidence of household energy poverty by subgroups using the energy budget share (Tenth-Percentile Rule) and multidimensional energy poverty index in South Africa.
- To perform a sensitivity analysis of the two measures of energy poverty.

1.3 Dissertation Organization

This dissertation is henceforth organized as follows. Chapter 2 provides a review of the literature on energy poverty, starting with a discussion on the conceptualization of energy poverty and the different ways of measuring energy poverty. This chapter also reviews previous studies that have estimated energy poverty using the various metrics. Chapter 3 outlines the research methodology used in the study, how the research was designed, followed by a detailed discussion of the type of data used, and how the data was analysed and interpreted. Chapter 4 presents the results and a discussion of the data commencing with a description of the data used to construct the metrics, followed by a presentation of national-level and subgroup estimates of energy poverty. This chapter further conducts a sensitivity analysis; and ends with a detailed discussion of the results. Chapter 5 draws conclusions from the study and provides policy recommendations.

Chapter 2
Literature Review

This chapter reviews the literature used in the study commencing with an in-depth discussion of the conceptual framework for understanding energy poverty. This is followed by a review of several definitions of energy poverty in view of identifying a working definition for this study. Subsequently, this chapter explores the various ways of quantitatively operationalising energy poverty while acknowledging some of the practical limitations associated with these measures. This chapter concludes with a review of previous studies that have quantitatively estimated energy poverty from an international as well as South African context.

2.1 Conceptualising Energy Poverty and Energy Access

The definition of energy poverty is contested because of the lack of an internationally-accepted and internationally-adopted standard definition describing how it should be defined and the dimensions required to develop such a metric (IEA, 2016). Although studies (Bravo *et al.*, 1979; Boardman, 1991; Foster, Tre & Wodon, 2000; Nussbaumer *et al.,* 2012; Day, Walker & Simcock, 2016) have dedicated immense efforts towards standardizing the definition of energy poverty, its intricacy has not generated consensus among practitioners and researchers.

Based on the literature, energy poverty can be defined as the lack of access to modern energy services (Bhatia & Angelou, 2014). Modern energy services refer to the use of clean and reliable fuels as opposed to traditional biomass (UNDP, 2005). However, key to this simplistic definition is the term "access" – denoted in the online Oxford English Dictionary (OED) as "the right or opportunity to use or benefit from something" (OED Online, 2016). In the field of energy poverty, the lack of access has come to be understood across multiple definitions. Most of these definitions have been conceptualized based on factors such as the absence of freedom to choose affordable, safe, reliable and environmentally friendly energy sources (Gonzalez-Equinox, 2015). Additionally the lack of access to modern energy services concerns the lack of access to good quality and adequate supply of energy services, as well as the physical availability of modern energy services. Whatever the definition, these factors go on to impact socioeconomic factors such as poverty and the quality of life (Gonzalez-Equinox, 2015). In this section, this study attempts to review the various definitions of energy access with the aim of motivating for a working definition for this study.

2.1.1 Definitions of Energy Poverty and Energy Access

Taking the literal definition of "access" from the Oxford English Dictionary – as the freedom to use something – posits the theory that the physical availability of modern energy carriers[3] is a strict requirement for energy access. Basic energy needs cannot solely be met by the physical availability of modern energy carriers if for instance, quantities are inadequate and supply is of poor quality. Regardless, it can be argued that it is better to have some form of access, than not to have access at all. Such a contestation highlights the fact that defining what constitutes as modern access to energy services becomes challenging without normative guidelines that empirically and theoretically justify what the minimum threshold of use should be (Pachauri, 2011).

Therefore, defining a dimension like adequacy becomes complex given that energy usage varies between countries or regions, or even among people of diverse economic and social stature. For instance, the minimum threshold of energy use may vary depending on whether a country is developed or developing. Evidence has shown that developed industrialized countries are likely to consume more energy than developing countries (Stern, 2004). Similarly, the literature (Reddy, 2000; Tewathia, 2014) has also shown that wealthy households with diverse assets and appliances consume more energy than less wealthy households. In other words, the minimum threshold of use will vary among different countries or households. In the following sections, this study provides a discussion of several approaches to defining energy access: from a single dimension to a multidimensional perspective.

2.1.1.1 *Supply-Side Approaches*

From existing supply-side approaches, four common approaches in the energy poverty literature are used to define energy access. The first supply-side approach focuses on the physical availability of modern energy fuels; including modern energy carriers as a single dimension of energy access. Modern energy fuels (such as electricity, kerosene, Liquid Petroleum gas [LPG], charcoal and biofuels) have a greater degree of reliability, cleanliness and efficiency when compared to traditional biomass fuels (such as dung and firewood) (UNDP, 2005). In this definition, access is viewed in terms of the availability of modern energy fuels

[3] Falk *et al.* (1983) define an energy carrier as an energy form or substance that does not generate energy, but stores energy in the form of liquid, gas, heat and solid fuels, including electricity.

and carriers which help meet the basic cooking, heating and lighting needs of a household (IEA, 2010). This approach considers physical availability of energy as an indicator of improved level of service with non-existent negative effects of poor quality or reliability (Mirza & Szirmai, 2010). As previously underlined, this definition offers a one-dimensional view of energy access and does not account for other dimensions such as affordability, minimum energy requirements, quality or reliability, which have come to be relevant in the discourse (Bravo *et al.*, 1979; Boardman, 1991; Reddy, 2015) on energy poverty. Therefore, it may be problematic to rely only on this definition of energy access. It can create uncertainty when defining energy access from a spatial point of view. For instance, it is unclear whether the metric refers to the physical availability of modern energy carriers or fuels at the household or community level (Pachauri, 2011). The definition of physical availability has much to do with the geographic location of a household or community. This means defining access through this assumes that supply is within close proximity.

The second supply-side approach, also known as "*the Bravo Measure*", is the physical energy requirements approach, which defines energy access by measuring the amount of energy required to carry out basic cooking, lighting and heating activities in a household (Bravo *et al.*, 1979). This approach therefore considers a household as energy poor if the amount of energy it uses is below a certain predetermined threshold. However, estimating the minimum energy requirement is rather a technical process and often adopts a more engineering-like methodology. Yet, several studies (Krugman & Goldemberg, 1983; Goldemberg, Johnson, Reddy & Williams, 1985) have employed this method. For instance, the estimates from a study by Goldemberg *et al.* (1985) propose that 500 watts per person of direct primary energy is required to fulfil basic energy needs. Such estimates are based on a set of holistic assumptions about basic needs. For instance, the study by Goldemberg *et al.* (1985) makes several assumptions about the size of the appliances used, and about the energy intensities and efficiencies of these appliances. However, in cases where basic needs vary, due to varying socioeconomic factors such age, gender, household composition or time period, among other factors, these assumptions would either underestimate or overestimate the minimum energy requirement (Pachauri, 2011).

To estimate the diversity of basic consumption requirements, here are other estimates from other sources. At national level, countries (including South Africa and India) have proposed minimum energy consumption thresholds. In 2003, the South African government (through the Department of Energy) introduced the Free Basic Electricity (FBE) policy, which afforded poor South African households a credit of 50 kilowatt-hours per month of grid electricity on their prepaid meters (DOE, 2003). However, FBE has not been established as an adequate minimum consumption threshold but rather a threshold at which the subsidy has been set. In India, what was first a government study under the Ministry of Power, was implemented as policy in the Rural Electrification Plan of 2006 with estimates proposing that each household needed a minimum energy consumption of 365 kilowatt-hours each year to achieve national-wide electricity access by 2009 (Government of India, 2005). On the international platform, IEA (2010) proposed that each person required 100 kilowatt-hours per month (an approximated 1200 kilowatt-hours a year) to meet basic energy needs. From the above discussion, it is obvious that estimates of physical energy requirements differ between individuals, households and even between countries. An explanation to this lies in what should be considered as a minimum energy requirement. The answer remains unclear because considering a minimum energy requirement is a subjective process that could vary based on several factors. For instance, minimum energy requirements could vary based on individual or household income, asset composition, whether developed or developing country, including geographic location (such as rural or urban).

The third supply-side approach defines access in terms of reliability of energy supply. In the case of energy access, reliability is defined as a measure of the capability of an energy supplier's system to meet the demand for the customer (Reddy, 2015). For instance, customers with electric-grid connections may still experience physical unavailability of electricity in a day owing to planned or unplanned interruptions. Even with carriers such as LPG (liquid petroleum gas), access may be limited. This could, for example, occur due to limited distribution networks that result in the intermittent supply of LPG (Sifo, 2009). This shows the degree to which households become vulnerable to the intermittent supply of energy carriers.

While the rationale may be to classify households as energy poor if they are faced with unreliable supply of energy carriers, defining energy access using reliability as a dimension is complex. Since there is no consensus on what constitutes as unreliable supply, limited research has been carried out on this dimension. For instance, there is often limited data on quality of electricity supply and the number of planned or unplanned power-cuts. Of the few available studies, a study by Kateregga (2009) in Uganda has however revealed that the costs of not providing reliable and good quality energy services are high socially and economically. For instance, a stack of unclean energy fuels will accompany irregular supply of electricity. However, most tend to be traditional biomass, especially in rural areas since LPG tends to be limited. The use of traditional inefficient fuels (such as wood) delays the process of cooking – leading to lengthier exposure to smoke which is dangerous and affects the health of women and the children in their daily care (Van der Kroon, Brouwer & van Beukering, 2013; Reddy, 2015). It affects budgetary planning in poor households (for instance, poor households are faced with the decision whether to stack on cheap traditional biomass or pay for energy carriers such as LPG or electricity, which might not be reliably available). Moreover, the study by Kateregga (2009) showed that households were less willing to pay for energy carriers. This meant that poor households perceived unclean fuels are more reliable. Reverting to the use of unclean energy services by households would hinder the goal of universal access to modern energy services. A delimiting factor to this method is that currently, there is limited consistent data that can suffice a definition of energy access from the perspective of reliability (Pachauri, 2011). Normally, the national electricity provider collects such data. In the study by Reddy (2015), the data on outage range in minutes was collected from the Government of India's Ministry of Power. Even with this data, experts and practitioners indicated that the data on outages should be much higher than was reported. This shows how data paucity affects defining access from a reliability point of view.

The forth supply-side approach defines energy access in terms of the deprivations people face. A study by Nussbaumer *et al.* (2012) defines energy poverty and the lack of energy access in terms of the multiple deprivations such as access to electricity, modern cooking fuel, access to a cooking space without indoor pollution, telecommunication means (landline or mobile phone), entertainment/education (radio or television), and household appliance ownership. In other words, they employ a multidimensional approach to understanding energy poverty: analysing energy poverty from more than one dimension.

2.1.1.2 *Affordability Approach*

From the previous approaches, it was established that physical availability of modern energy carriers is a precondition for energy access. However, only having the physical availability of modern energy carriers does not necessarily imply that an individual or household can afford to pay for energy services. Therefore, defining energy access in terms of affordability requires that prices at which modern energy services are supplied should be welfare driven such that the poorest of households can also afford it (Pachauri, 2011). This is achieved when capital costs and operating expenses match prevailing income and wealth levels.

2.1.1.3 *Basic Needs and Capabilities Approach*

The works of Amartya Sen (1999) and Martha Nussbaum (2011) conceptualize the so-called *capabilities approach* in economic development. It was argued that development should be seen as having the freedom to make choices based on one's capabilities to achieve what they value as a decent life. In the framework of energy poverty, the capabilities approach states that lack of access to modern energy services should not be viewed only as reaching a certain level of per capita use of energy. Not only does the lack of access to modern energy services imply a lack of basic energy needs (such as cooking and lighting), but also it is a deterrent to development because it affects the right to good health, education and the ability to participate economically and politically (Gonzalez-Eguino, 2015).

Based on research by international non-governmental organizations, Practical Action (2012) defines energy access by focusing on the minimum thresholds in actual service levels, as opposed to energy terms such as those noted in the definition on physical requirements of energy services. Practical Action focuses on six core categories of basic energy services, which include lighting, cooking and water heating, space heating, information and communication and earning a living.

These service-based definitions of energy poverty and energy access are by far, the most comprehensive definitions in the literature. While viewing energy poverty and access from a multidimensional perspective, they acknowledge the importance of access to modern energy services not only as a means to meeting basic energy needs, but also as priority to improving overall well-being. At the same time, a multidimensional definition of energy access offers greater understanding of the service gaps and the course of policy action.

However, a recent study by Day *et al.* (2016) has advanced the capabilities theory in an attempt to best define access to energy by contesting that a definition of energy access can only be widely applicable if it is not based on a fixed conception of energy services or energy sources. In this new approach, Day *et al.* (2016: 260) define energy poverty as "*an inability to realise essential capabilities as a direct or indirect result of insufficient access to affordable, reliable and safe energy services, and taking into account available reasonable alternative means of realising these capabilities*".

To this end, they argue that the capabilities approach provides a much better definition and understanding of energy poverty. Though it provides a definition coherent in different contexts, it is also built on a sound theoretical concept and which concurrently provides an understanding of well-being and energy poverty. However, they also highlight the methodological limitations – which include the challenge of defining the necessary capabilities at the primary and secondary level – making it a challenge to operationalize the concept.

The most recent approach to defining energy access was conceptualized by the Energy Sector Management Assistance Program (ESMAP). The foundation of this definition was built on defining and measuring access to energy in a way neutral of all technology, reflective of all of all interventions and ideal not only for households, but for communities and enterprises. ESMAP (2014: 2) defines energy access as "*the ability to obtain energy that is adequate, available when needed, reliable, of good quality, affordable, legal, convenient, healthy, and safe for all required energy applications across households, productive enterprises, and community institutions*".

2.1.2 A Critique of Energy Access Definitions

In the previous subsection, this study reviewed several definitions of energy poverty and it is evident that energy poverty is a multidimensional concept, following the diverse descriptions that have emerged from the different dimensions of energy access. It therefore comes as no surprise that until today, there is no clear consensus on what a standard definition of energy poverty should entail. However, what is clear is that, the goal of obtaining energy access needs to reach a consensus on whether to improve well-being or increase energy consumption – as this has a bearing on what constitutes basic energy needs of a household or an individual.

To begin with, it is fair to acknowledge that though physical availability of modern energy carriers is a precondition for access to modern energy services, it is not a sufficient condition to fully define energy poverty. The same can be said for the reliability and quality – a definition of energy poverty that often applies to the prevailing trend of load shedding and unplanned blackouts in developing countries. It is noted that reliability is rarely used as a standalone definition, but rather a dimension included in multidimensional frameworks. Yet again, its operationalization in multidimensional frameworks is often affected by data quality, which also has an impact on these measures.

Under the physical energy requirements, defining a minimum energy threshold in terms of energy use rests on a set of certain assumptions. Highly often, the assumption made on the efficiency and intensities of the appliances tends to be different in urban and rural areas. Urban dwellers tend to use more efficient and modern appliances when compared to rural households. On the other hand, the affordability approach presents an interesting definition of energy poverty – one that shows how expensive the market price of energy is, or how low household incomes are. Yet, this definition fails to account for non-monetary energy services such as wood or dung – which are often an important source of energy for the rural poor.

The fact that energy poverty can be defined from several dimensions is worth noting and in fact, offers support for a multidimensional approach in defining access. However, it is also important to note that multidimensional definitions such as that of Nussbaumer *et al.* (2012) only show whether households have access to a service, such as electricity, or to an appliance such as a fridge.

This study therefore accepts that energy poverty should be defined in terms of access to energy services for two reasons. Firstly, a service-based definition will provide a more holistic approach to energy poverty – also allowing for the identification of the service gap in South Africa. This definition requires understanding energy poverty from the energy services that households ought to experience towards a decent life such access to modern cooking fuel, or a fridge or television. This stands crucial for policy, especially when understanding the relationship between access to modern energy services and human development. Secondly, while other definitions have focused more on the supply-side, for policy, it is essential to understand the behaviour of demand side fundamentals.

2.2 Measuring Energy Poverty

Several efforts have been made towards measuring energy poverty from an international and national perspective. Most of these efforts have focused on energy poverty as a lack of physical access to modern energy services (Pachauri, 2011). From an international perspective, the IEA (2004; 2010) constructed the Energy Development Index (EDI) – a composite index combining three indicators (per capital commercial energy consumption, share of commercial energy of final energy use and the share of the population with access to electricity) of equal weighting. The EDI provides a basis for international comparison of the energy poverty status across countries. However, a drawback of the EDI can be traced through its inadequacy to capture the degree of the transition process to modern infrastructure (Bensch, 2013).

Furthermore, equal weighting, which is a product of high subjectivity, results in trade-offs on certain dimensions of energy poverty (Pachauri & Spreng, 2011).

At the national level, attempts have been made to measure energy poverty from an affordability perspective. The work of Boardman (1991) for the United Kingdom (UK), estimated an energy budget share index (also known as the Tenth-Percentile-Rule, TPR). The TPR defines affordability by the share of after-tax household income spent on energy services. Boardman (1991) states that a household would be considered energy poor if the proportion of household after-tax income spent on energy services exceeds 10 percent. If the share of household after-tax income spent on energy services falls below the predefined threshold of 10 percent, energy is affordable. With affordable energy services, households do not have to make trade-offs with other necessary household expenses to compensate for high-energy prices if they are matching to existing income levels. For example, lack of affordable energy services would prompt households to reduce the consumption of essential goods and services to compensating for the purchase of energy services sufficient for their basic energy needs

The method of using energy budget shares is often effective in most developed countries that have formalized energy markets and require a direct monetary payment for access to any form of energy services (Pachauri, 2011). This measure has gained international acceptance in countries like South Africa (DOE, 2009; 2013) and the United Kingdom (Schuessler, 2014). However, this measure may be problematic in developing countries with informal energy markets. Particularly in rural areas, this approach is contested because some households source their energy services (such as firewood or animal dung) without any direct monetary payment. It is likely that this measure would underestimate the share of energy poor people – whom in fact are supposed to be the target of policy on access to modern energy services. In addition, even in cases where a household does not incur a monetary cost for using firewood, there is an opportunity cost associated with collecting firewood for the time that could have been used for other economic activities.

Taking a further look at affordability, the work of Foster *et al.* (2000) in Guatemala focuses on the amount of energy used by households who are below the income poverty line. Therefore, households who are below the income poverty line and using a certain amount of energy would be considered as energy poor. Notable advantages of this measure over the TPR have been the estimation of a minimum quantity of energy required on a day-to-day basis.

Regardless, this measure still suffers the same deficiencies as the TPR – failure to account for non-monetary energy services (Pachauri & Spreng, 2011).

Based on the short-comings of previously discussed measures that focus on affordability, more recent attempts have focused on measuring energy poverty by also accounting for non-monetary costs of energy services used and the associated externalities that come with using traditional biomass. In their work on Pakistan, Mizra and Szirmai (2010) construct a composite index defined as the *Total Energy Inconvenience Threshold* (TEIT). The TEIT accounts for a shortfall in consumption (in comparison to some predefined minimum amount) and factors in the inconveniences associated with the use of different energy services at the household level. As such, a household is considered energy poor if it suffers inconveniences that exceed the TEIT. However, Pachauri and Spreng (2011) contend that this measure fails to account for the affordability of energy services and all direct costs related to it. Furthermore, they argue that this measure is often constrained with the lack of comprehensive survey data, which is mostly challenging to collect on a routine basis especially in developing countries.

Barnes, Shahidur and Hussain (2011) develop an income-invariant energy demand approach to energy poverty for Bangladesh. By estimating an energy poverty line based on estimates of final and end-use energy consumption, they set the energy poverty line to a level below which it is invariant to income. Therefore, consumption below this point allows only a certain amount of energy to be consumed. Essentially, this approach assumes that there exists some level of income where energy consumption remains constant. In other words, this level of income is the point which energy would no longer be responsive to changes in income. As such, consumption of energy services below this income threshold implies that households can only consume a certain minimum level of energy. While this may be applicable in the rural areas of developing countries, Pachauri and Spreng (2011) argue that this is unlikely to be the case in urban areas because households in urban areas are often associated with higher incomes relative to rural areas. Given that urban households can only use a certain amount of energy, it is unlikely that their income would be responsive to energy services and therefore, such a threshold becomes meaningless. Further, Pachauri and Spreng (2011) highlight that this measure accounts for the energy used and related efficiencies and therefore, it may be prone to classify houses with high traditional biomass usage as not being energy poor. It is clear that traditional biomass without a monetary cost will portray energy poor households as non-energy poor because their income may not be responsive demand for energy.

Motivated by the work of Amartya Sen and his prescribed foundation on the so-called capabilities approach, the Oxford Poverty & Human Development Initiative (OPHI) developed the *Multidimensional Energy Poverty Index* (MEPI) (Nussbaumer *et al.,* 2011). Sen (1999) reports that an intuitive understanding of poverty should be focused on evaluating the attainability of resources and the decisions made to use them in order to live a basic life. In the same regard, the construction of the MEPI borrows its conceptualization from the Multidimensional Poverty Index (MPI). MEPI introduces five dimensions and six indicators in its construction. A major criticism has been the fact that poor data quality and misspecification results in poor construction of the index.

Other attempts to measure energy poverty have originated from international non-governmental organizations such as Practical Action. In their work, Practical Action (2012) develop a metric and define energy poverty in terms of *Total Energy Access* (TEA). This metric focuses on capturing energy services that households want and need, while accounting for the minimum requirement for each service. However, it only focuses on the headcount ratio and treats the intensity of poverty as irrelevant, while at the same time, factoring in inter-personal inequality as a driver of energy poverty (Bensch, 2013). This means that although this measure identifies multidimensionally poor households, it does not differentiate between households deprived in a few dimensions and those deprived in all dimensions. The major concerns with this measure have mostly been around the availability of rich survey data.

A more recent development in energy access measurement was the Multi-Tier Framework (MTF) developed by ESMAP (2014). The MTF set out to redefine energy access away from the traditional binary count by introducing a multi-tier definition. A binary count defines access by two outcomes: either having access or not. The multi-tier aspect in this case considers not just having access, but the quality or degree of access. The MTF focuses on defining access as "*the ability to avail energy that is adequate, available when needed, reliable, of good quality, convenient, affordable, legal, healthy and safe for all required energy services*" (ESMAP, 2014: 2). For instance, electricity access is measured beyond having an electricity connection by incorporating other dimensions such whether electricity is affordable and reliable. In MTF, energy access is measured across five tiers ranging from Tier 0 (no access) to Tier 5 (the highest level of access) in a multi-tier matrix (ESMAP, 2014). An advantage to this measure is that multi-tier matrix, for example, allows for a country or region to create its own assumptions of what is considered as access. A major criticism about this metric is requires detailed and reliable data, which often, may not be easily accessible.

2.2.1 Practical Limitations and Choice of Metric

Above, this study reviewed several metrics of energy poverty and just like any other metric; its construction depends on the availability of data and in certain cases, detailed survey data. Notably, some metrics appear not to have the explanatory power of energy poverty in the context of South Africa. For instance, some of the metrics (such as TPR and TEIT) fail to account for non-monetary costs – such as firewood collected at no monetary value –, which are essentially an important aspect of energy poverty in rural areas. It is also acknowledgeable that some metrics such as the EDI capture less of energy access and more of the transition to modern energy infrastructure.

For the purpose of this study, focus will be on the TPR and the MEPI for a number of reasons. Firstly, there are several dimensions of energy poverty and the surveyed literature does not point to any one measure that incorporates all dimensions. This study takes interest in the dimension on affordability. This is measure using the energy-budget share. Like all measures, the TPR has been criticised for underestimating rural energy poverty. Secondly, one of the criticisms of MEPI is the lack of data to aid its full construction. However, the availability of data from the National Income Dynamic Study (NIDS) provides an opportunity to evaluate energy poverty from a multidimensional perspective. To the best of the author's knowledge, no study has used NIDS – the largest household survey in South Africa – to construct the MEPI.

2.3 Energy Poverty Metrics Employed in Previous Studies

In literature, several studies have emerged internationally and at national-level attempting to measure energy poverty using different definitions. However, the empirical literature surveyed in this study places focus on studies that define and operationalize energy poverty in terms of affordability and as a service based concept. More often, data on services and affordability tends to be accessible in household surveys, compared to data on consumption and reliability of energy services.

In the context of South Africa, an earlier study by Kohler, Rhodes and Vermaak (2009) estimates energy poverty by focusing on defining and measuring energy poverty through the dimension of affordability. Their study compares the energy budget shares and access-adjusted energy budget shares of energy poverty while allowing for varying levels of efficiencies and access to different fuel types in South Africa. They make use of household survey data from the 2008/2009 Department of Energy household survey. While assigning three thresholds using the Living Standard Measure (LMS) 1 to 3, they map all the South African provinces and show the spatial incidences of energy poverty. Their findings suggest that access-adjusted energy budget shares are more intuitive, robust and succinct in describing energy poverty. Although their results differ from the findings of the DOE (2009)[4], they identify that among electrified households, energy poverty rates are highest in Limpopo province (66%) and are lowest in Western Cape Province (20%). They also find that among non-electrified households, energy poverty rates are highest in Free State province (86%) and lowest in Western Cape Province (47%).

A more recent study by Ismail and Khembo (2015) estimates the drivers of energy poverty in South Africa using survey data for 2012 (wave 3) of the National Income Dynamics Study (NIDS). While making use of the 10 percent energy budget share as used by the Department of Energy (2013) in their estimates of energy poverty, Ismail and Khembo find that approximately 25 percent of households in South Africa are energy poor. They also find that energy poverty in South Africa is driven by several factors including demographics as well as individual socioeconomic factors (education level, race, married) and household characteristics (location, household size)

Using MEPI, energy poverty was first estimated in a study by Nussbaumer *et al.* (2011) under the OPHI for selected African countries[5] (excluding South Africa) using the Demographic and Health Survey (DHS). Their study measures two aspects of energy poverty: the incidence of energy poverty and the intensity of energy poverty. They however note that although estimating MEPI is robust and a more definitive measure of energy, the lack of detailed micro level data presents a limitation when using this measure.

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[4] 31 percent in the Eastern Cape and 54 percent spread across Limpopo, Mpumalanga and KwaZulu Natal.

[5] Angola, Benin, Burkina Faso, Cameroon, Congo Brazzaville, Congo DRC, Egypt, Ethiopia, Ghana, Guinea, Kenya, Lesotho, Madagascar, Malawi, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, Swaziland, Tanzania, Uganda, Zambia and Zimbabwe.

Recent trends in the literature have experienced increasing use of MEPI in measuring energy poverty. A study by Edoumiekumo*,* Tombofa and Karimo (2013) in Nigeria estimates the MEPI of the South-South Geopolitical Zone of Nigeria. Also in a different study, Edoumiekumo and Karimo (2014) use MEPI to estimate energy poverty of the Bayelsa State of Nigeria. At the national level, a study by Ogwumike and Ozughalu (2015) estimates energy poverty in Nigeria using the MEPI. These three studies have one thing in common – data paucity. Although the studies of Edoumiekumo *et al.* (2013) and Edoumiekumo *et al.* (2014) make use of detailed micro-level data to construct MEPIs fully for the South-South Geopolitical Zone of Nigeria and the Bayelsa state respectively, they lack detailed micro-level data to estimate the MEPI at the national-level. In the study by Ogwumike and Ozughalu (2015), they construct a national estimate of energy poverty using MEPI. However, the MEPI is not fully constructed due to a lack of data on three indicators (household appliance ownership, entertainment/education ownership and telecommunication means). Thus, MEPI is constructed using only the other three indicators (Modern cooking fuel, indoor pollution and electricity access). Other studies have been successful in constructing the MEPI fully. For instance, a study by Sher, Abbas and Awan (2014) constructs the MEPI and provides a national and provincial level analysis in Pakistan using survey data from the Pakistan Social & Living Standards Measure (PSLM) for 2007-2008. To the best of the author's knowledge, no study has estimated household energy poverty in South Africa using the MEPI.

While it is obvious that there exists various measures of energy poverty, very few known studies provide a critique of energy poverty metrics using a common dataset. However, a study by Bensch (2013), which is carried out for five sub-Saharan countries (Benin, Burkina Faso, Mozambique, Rwanda and Senegal), provides an empirical comparison of five metrics commonly used in the broad field of energy poverty measurement. Of the five, two of these metrics are unidimensional, and these are namely, the *Minimum Energy Consumption Threshold* and the *Income-Invariant Energy Demand Approach.* The other three metrics are multidimensional in nature particularly in the form of composite indices, which include the *Multidimensional Energy Poverty Index* (MEPI), *Correlation Sensitivity Energy Poverty Index* (CSEPI) and *Total Energy Access* (TEA). His major finding is that these metrics tend to perform differently in the context of identifying energy poor people, as well their overall sensitivity to changes in parameters of estimation and varying datasets. The empirical results show several drawbacks of *Income-Invariant Energy Demand Approach*, mostly to do with the underlying assumptions (such as elastic energy consumption among extremely poor people). Further, the CSEPI faces criticism because it fails to provide better policy guideline than the MEPI — which was the initial reason it was created. However, the *Minimum Energy Consumption Threshold,* MEPI and TEA seem to provide a much better and consistent measure of energy poverty in this study.

A recent study by Groh *et al.* (2016) employed the Multi-Tier Framework (MTF) using household survey data from rural Bangladesh to measure access to household electricity. Groh *et al.* contend that MTF captures several objectives such that it is more useful to evaluate several dimensions when measuring electricity access, than single composite index. The MTF is found to be robust in this study by testing the choice of attributes and thresholds assigned to each tier. The findings suggest that measuring access is vastly sensitive to changes in parameter values, availability of data and the use of different algorithms. They offer recommendations to the improvement of the MTF.

In summary, the various definitions of energy access and measures of energy poverty discussed throughout this literature review draw diverse meaning to the concept of energy poverty. From the reviewed literature, it is clear that no one measure can adequately demonstrate all dimensions of energy poverty, and therefore it is worth employing more than one measure. This is dependent on whether the data is available or resources permit to explore the different dimensions of energy poverty. Deciding which measure is appropriate depends on what one conceptualizes as energy poverty and how it all fits into the policy implications. This study aligns itself with two definitions of energy access. Firstly, this study aligns itself with the definition that lack of access to energy has to do with affordability of or the inability to pay for energy services. Of the surveyed literature, the energy-budget share proposed by Boardman (1991) is capable of depicting affordability. This measure is also of interest, as has been used by the South African Department of Energy (DOE, 2009; 2013). Secondly, this study aligns itself with the definition that the lack of energy access is a service-based phenomenon that is multifaceted and driven by the deprivation of different types of energy services. As indicated in the surveyed literature, the MEPI has proven to be a robust measure of energy poverty. However, the robustness of MEPI depends on how technically constructed the metric is, and the availability detailed micro-level data that is representative of the population of study. The MEPI has not been used to estimate energy poverty in South Africa. From the literature, it has also become clear that national estimates of energy poverty often trump subnational estimates. Therefore, decomposing household energy poverty estimates by the geographic, socioeconomic and temporal incidence using the two measures provides more insights to the problem. With the availability of detailed micro-level survey data from the National Income Dynamics Study, this study aims to fill this extant gap in the literature.

Chapter Three
Research Methodology

This chapter describes the research methodology that was employed in this study. A research methodology provides a description of the research activity, how to advance and measure progress at each stage, including what should be considered as a benchmark for success (Kallet, 2004). A key aspect of research is the selection of appropriate research methods that are proficient in accomplishing the focal aim of the study. Kumar (2011) defines research as a process of describing and exploring the unknown through a systematic, rigorous, valid and controlled process that establishes correlations and causations, which permit the prediction of certain outcomes under a given set of conditions.

The overriding aim of this study was to evaluate household energy poverty by systematically constructing these metrics using an identical form of survey data. This chapter therefore serves the following purposes. Firstly, it describes how the research was designed and how the data was collected. Secondly, it provides a systematic statistical description of how these data were analysed and interpreted, including how the sensitivity analysis was performed. Thirdly, it points out the limitations that were experienced when applying the chosen research methodology.

3.1 Research Design

This study followed a quantitative research approach. Creswell (1994: 38) defines quantitative research as a branch of research that describe phenomena through gathering numerical data which can be analysed by employing mathematically founded approaches with specific focus on statistics. This study adopted a combination of a descriptive and an evaluative research design. According to Selltiz, Wrightsman and Cook (1976: 44), a research design is "*the arrangement of conditions for collection and analysis of data in a manner that aims to combine relevance to the research purpose with economy in procedure*". A descriptive research design seeks to describe existing or uncover new features about individuals, a group or certain phenomena (Kothari, 2009: 37) while an evaluative research design requires finding out to what degree, a programme, practice, procedure or policy is working out (Polit & Hungler, 1999: 201). The research design therefore seeks to describe *how* the research problem can be addressed efficiently, with minimal effort, optimal time and minimised expenses (Kumar, 2011:41).

The descriptive and evaluative research designs were chosen based on two reasons. Firstly, a descriptive research design offered the opportunity to analyse survey data by focusing on the characteristics, socioeconomic and demographic dynamics of households in South Africa. For example, energy expenditure, electricity connections or household appliances by province, household income poverty status or household location. Secondly, the evaluative research design offered an opportunity to examine progress or effectiveness of a programme as well as compare the effectiveness of a process, for example establishing if policies on energy poverty in South Africa have been effective in reducing the number of energy poor households' over time. These research designs were selected to meet the objectives of the study, which were to: a) estimate national energy poverty; b) describe the geographic, socioeconomic and temporal incidence of household energy poverty by subgroups; and c) perform a sensitivity analysis the two measures of energy poverty. The design of this research is similar to that of Bensch (2013) in which, he makes an empirical comparison of household energy poverty indices for sub-Saharan countries.

3.2 Data Sources

Conducting descriptive and evaluative research requires using either secondary survey data or primary data originally collected through a survey. Kothari (2009) defines secondary data as data collected by another person besides the user while primary data is data originally collected. This study used secondary data in the form of household survey data, which was applied to quantitative methods in the form of survey data econometrics to construct, analyse and interpret these data.

These data were collected from the National Income Dynamics Study (NIDS) — the first ever nationally representative panel study in South Africa consisting of four waves of data covering the period 2008 to 2015. The Southern Africa Labour and Development Research Unit (SALDRU) at the University of Cape Town is responsible for the implementation of NIDS. The four waves of the NIDS[6] data were collected in 2008 (wave 1), 2010 to 2011 (wave 2), 2012 (wave 3) and 2014 to 2015 (wave 4) and are freely available in the public domain[7].

[6] See SALDRU (2015a; 2015b; 2015c; 2016) for data sources for all Waves.

[7] For more information on NIDS wave 1, 2, 3 and 4 datasets, see: http://www.nids.uct.ac.za/nids-data/data-access

Throughout these four waves, NIDS closely tracks and collects data from the lives of a specific group of South African individuals who are sampled from the population.

This study used data from two waves of NIDS: wave 1 (2008) and wave 4 (2014 to 2015) to allow for a sufficient period for cross-sectional comparative analysis and to note any significant changes in energy poverty during this period. Both waves were conducted over a period of 12 months. The wave 1 survey was conducted January 2008—December 2008 and consists of 28226 individuals and 7296 households. The wave 4 survey was conducted September 2014—August 2015 and consists of 42348 individuals and 11898 households. It is noted that although wave 4 includes more households and individuals, a system of cross-entropy and intertemporal standardisation was used in the creation of the NIDS. The logic behind this process is to ensure that repeated cross-sections have comparable samples over time. This is accounted for using post-stratified weights in NIDS, which not only ensure that the sample is representative of the population, but also comparable over time (NIDS, 2012)

The NIDS data contains comprehensive micro-level information about income and expenditure of households and individuals (children and adults), including detailed information on household characteristics as well as other socioeconomic and demographic factors. These data are collected through questionnaires such as the individual (adult and child) and household questionnaires. Often, the oldest female in the house completes the household questionnaire, but in her absence, a proxy questionnaire is used and an adult completes this with the capacity to respond to the household-level questions.

To ensure that all estimates are representative of the South African population, NIDS contains a set of post-stratified weights, which are used to equalize estimates from each individual or household to the true population. This effectively ensures that even with different sample sizes, both wave 1 and wave 4 data describe the population adequately and therefore, meet one of the conditions for comparability. Further, since data on financial assets[8], expenditure and liabilities were collected at different times in both waves, this study accounted for the effect of inflation on assets to ensure the second condition of comparability between the two waves was met. This was achieved by using the monthly Consumer Price Index (CPI) obtained from Statistics South Africa (Stats SA, 2014b) to inflate data from 2008 (wave 1) and

[8] In the context of this study, reference is made to financial assets such as total household after-tax income and total expenditure on energy services.

deflate data from 2014-2015 (wave 4) to the modal month of the Wave 4 interviews (November 2014) to allow for comparability.

Since part of the aim of this study was to describe the geographic, socioeconomic and temporal incidence of energy poverty in South Africa, selection of these datasets was motivated by the ability to track individuals in NIDS. The process of tracking and collecting data from the same individuals' over time provided an opportunity to evaluate household energy poverty in South Africa. This highlights an advantage of NIDS over more comprehensive domestic household surveys such as the General Household Survey (GHS) collected by Statistics South Africa[9], which does not track the same individuals. Calibration with other datasets was not possible in this study as NIDS is the only nationally representative panel study in South Africa. Therefore, a comparison with other dataset over time, would present the risk of differing results due to different weighting and sampling techniques.

Based on the discussion provided in Chapter 2, it was evident that creating measures of energy poverty (unidimensional or multidimensional) was a complex process and that required detailed micro-level information. The NIDS dataset provided detailed information on energy expenditure, and the type of fuel households used for cooking and heating. Further, the dataset contained information on the assets held by households (radio, mobile phone and so on), which were essential components in the process of constructing the MEPI. Additionally, the repeated cross-sections of the NIDS data ensured consistency of these metrics over time.

3.3 Data Analysis

After obtaining these data from SALDRU, the quantitative analysis performed in this study was done so using Stata (version 14). Stata is an integrated general-purpose statistical package capable of managing and analysing large-scale survey data[10]. However, before any analysis could be performed, these data were cleaned. Having observed the NIDS data alongside the questionnaires, this study followed a data cleaning process prescribed in the NIDS (2012) User

[9] See Statistics South Africa for more information on the General Household Survey. Available at: http://www.statssa.gov.za [Accessed: 2016, December 15].

[10] See available: http://www.stata.com/why-use-stata/ [Accessed: 2017, February 26].

Manual. This process required one to checking for missing values, extreme outliers[11], non-response to questions as well as refusal to respond to questions. For example, some respondents did not wish to disclose their household income for personal reasons. Missing data is a common issue in survey data collected from voluntary respondents. Studies by Daniels, Finn and Musundwa (2014), and Daniels and Augustine (2016) confirm this about NIDS data. It also should be noted that one house was dropped and considered an extreme outlier from the wave 4 sample because it had a monthly income of R50 million as after-tax. This does not necessarily affect the results, but would have had an effect on the household income distribution since the second highest value was 90 000. Dropping extreme outliers is compensated for by post-stratified weights as indicated in NIDS (2012). Further, this study adopted household as the unit of analysis over individuals because an individual is described as energy poor based on household achievements (Alkire & Santos, 2011). Moreover, using households as the unit of analysis for surveys has become a benchmark for international comparison, which have found collecting household-level data to be more reliable than individual-level data.

The remainder of this section describes a systematic statistical approach of how the data was analysed. In line with the main aim of the study, the analysis of the data was achieved through following three steps. Step 1 estimated household energy poverty at the national-level using the TPR and MEPI measures. Step 2 decomposed household energy poverty of the two measures by province, household income poverty status and household location. Step 3 validated the results in the study as obtained from the two measures by conducting a sensitivity analysis.

3.1.1 **Step 1:** Estimating National Energy Poverty

Step 1 of analysing these data shows the process adopted in this study to estimate national-level household energy poverty using the TPR and MEPI approaches. This subsection starts by showing how national-level estimates were calculated using the TPR and thereafter, shows how MEPI national-level estimates were calculated using the MEPI.

[11] In the context of this study, focus was on household after-tax income and household expenditure on energy services.

3.1.1.1 Estimating Energy Poverty using the TPR Approach

This study estimated energy poverty from a unidimensional perspective by making use of the Ten-Percentile-Rule (TPR) developed by Boardman (1991). The TPR classified a household as energy poor if a household spent more than 10 percent of their after-tax income on energy services (Boardman, 1991). Statistically, Equation 3.1 shows how national-level estimates of household energy poverty in South Africa were computed for 2008 (wave 1) and 2014-2015 (wave 4):

$$TPR = \sum_{i=1}^{n} \frac{\beta_i}{\alpha_i} \quad \textbf{(3.1)}$$

$$TPR = \begin{cases} 1, & if\ TPR > 0.1 \\ 0, & Otherwise \end{cases}$$

where β_i is the expenditure on energy sources[12] of household i and α_i is the total after-tax income of household i while $\frac{\beta_i}{\alpha_i}$ is the energy-income budget share and n is the total sample population. After obtaining these energy budget shares, a binary outcome was created showing whether a household was energy-poor or non-poor. An energy-poor household assumed a value of 1, having spent more than 10 percent of their household after-tax income on energy sources $(1,\quad if \quad TPR > 0.1)$. A non-energy poor household assumed a value 0, having spent less than 10 percent of its household after-tax income on energy sources $(0,\quad Otherwise)$. It is noted that since data on energy expenses and after-tax household income used was from 2008 and 2014-2015, making a comparative analysis of energy poverty over time would have been flawed if the effects of inflation for 2008 and 2014-2015 were not accounted for. As such, all these data were price-adjusted for inflation using the Consumer Price Index (CPI) from Statistics South Africa (Stats SA, 2014b) and expressed in 2014 Rands to ensure that all results were comparable between wave 1 (2008) and wave 4 (2014-2015).

[12] In NIDS, expenditure on energy sources entails expenditure on all forms of energy, including electricity.

3.1.1.2 Estimating Household Energy Poverty using the MEPI Approach

The Multidimensional Energy Poverty Index (MEPI) emerged from the research of Nussbaumer *et al.* (2011). The MEPI is an index that identifies energy poverty from more than just one dimension. It borrows from the literature on Multidimensional Poverty Index (MPI) – an index developed by Alkire and Foster (2007) that characterises poverty as a state of multiple deprivations

The construction of the MEPI was adapted from Nussbaumer *et al.* (2011) by considering five dimensions depicting basic energy services as a proxied by five indicators in Table 3.1. These dimensions are cooking, lighting, services from appliances, entertainment/education and communication. The indicators linked to these five dimensions are access to modern cooking fuel, electricity access, ownership of a household appliance, ownership of entertainment/education appliance and telecommunication means. In addition to the above-mentioned indicators, the weights associated with each indicator and deprivation cut-offs are also shown in Table 3.1. Note that the original construction of the MEPI by Nussbaumer *et al. l.* (2011)[13] included an additional indicator on the dimension on cooking depicting indoor pollution. This indicator was however excluded in this study due to data constraints in the NIDS[14] datasets. Additionally, Nussbaumer *et al.* (2011) only used a television or radio to depict the dimension on education/entertainment. Without adjusting the weights, this study added access to a computer as a joint indicator (with access to a radio and television) to better represent the dimension on entertainment/education.

A distinct feature of the MEPI, unlike the TPR, which uses a single energy poverty cut-off, is a dual cut-off approach when estimating energy poverty. Alkire and Foster (2011) state that a dual cut-off approach entails defining two thresholds in two steps. The first step requires defining a deprivation cut-off Z_i for each indicator X associated with household i so that, a household is held to be deprived in an indicator if the household's attainment in that indicator X_i is below the cut-off ($X_i < Z_i$). This study defined the deprivation cut-off Z_i by transforming indicators into a binary outcome X_i, which assumed a value of 0 if the household is not deprived in an indicator and 1, if the household is deprived in that indicator. For

[13] See Nussbaumer *et al.* (2011:9) for a Table on dimensions and variables with cut-offs for constructing the MEPI.

[14] The NIDS dataset does not ask a question on whether a household cooks in a house without a chimney or hood.

instance, a household without access to electricity would assume a value of 1 for that indicator and a value of 0 if it were not deprived in an indicator such as ownership of a household appliance. The same logic applies when determining deprivation cut-off for the other indicators.

Table 3.1: Dimensions and Variables with cut-offs for constructing the MEPI

Dimension	Indicator Weights in (Parenthesis)	Variable	Deprivation cut-off (Poor if…)
Cooking	Modern Cooking Fuel (0.4)	Type of Cooking	Use any fuel besides electricity, LPG, natural gas, or biogas.
Lighting	Electricity Access (0.2)	Has Access to Electricity	FALSE
Services from Appliances	Household Appliance Ownership (0.133)	Has a fridge	FALSE
Entertainment/ Education	Education/Entertainment Appliance Ownership (0.133)	Has a radio or television or computer	FALSE
Communication	Telecommunication means (0.133)	Has a mobile phone or landline phone	FALSE

Source: Nussbaumer *et al.* (2011) and Author's own adjustment of weight on modern cooking fuel

Table 3.1 also shows that each indicator was assigned a weight[15] based on its relative importance towards the associated dimension and its postulated impact on energy poverty. For instance, the indicator associated with the dimension on cooking (modern cooking fuel) was assigned a weight of 0.4, which was higher than the weight of 0.133 placed on whether a household had a fridge or not. The weights on each indicator sum up to 1[16] and this was calculated using Equation 3.2 from Alkire and Santos (2011):

$$\sum_{x=1}^{d} w_x = 1 \qquad \textbf{(3.2)}$$

where w_x is the weight w on each indicator x, d is the total number of indicators and the operation sums up to 1. A deprivation score was allocated to each household based on its

[15] Nussbaumer *et al.* (2011) indicates that creating weights for the MEPI involves value judgement and hence, weight may vary depending on the energy circumstances in anyone region, country or sector.

[16] The weights in Table 3.1 sum up to 1 = (0.4 + 0.2 + 0.133 + 0.133 + 0.133)

deprivation in the five indicators. This was calculated by obtaining the sum of the weighted number of deprivations such that the deprivation score for each household was between 0 and 1. An increase in the number of deprivations meant that the score would increase, but this score reached a maximum value of 1 if a household was deprived in all dimensions and a minimum value of 0 if a household was not deprived in any of the indicators. The deprivation score for each household was calculated using Equation 3.3 from Alkire and Santos (2011) as follows:

$$s_i = w_1X_1 + w_2X_2 + \ldots + w_dX_d \qquad \textbf{(3.3)}$$

where a household is considered to be deprived in indicator X if $X_i = 1$ and household is considered not deprived if $X_i = 0$, and the weight w_x allocated to each indicator sum to 1 as previously shown in Equation 3.2.

The second step of the dual cut-off approach defines an energy poverty cut-off k which shows the number of indicators a household i needs to be deprived of in order to be considered as energy poor from a multidimensional perspective. For a household to be considered as multidimensional energy poor, it required that a combination of its weighted indicators s_i to exceed the energy poverty cut-off k. For example, if a household were deprived of access to electricity and ownership of a household appliance without being deprived in the other indicators[17], this would mean that the combination of weighted indicators would be 0.333. In this study, an energy poverty cut-off *k* of 0.3 was adopted from Nussbaumer *et al.* (2011). In this example, it therefore means that a household with a weighted sum of deprivations s_i of 0.333 that exceeded the cut-off of 0.3 was considered as multidimensionally energy poor. The rationale for choosing 0.3 as the poverty cut-off was in line with the two justifications by Nussbaumer *et al.* (2011). First, a 0.3 cut-off identified a household at the very least, as multidimensionally energy poor if the household did not have access to modern cooking fuel and generated indoor pollution.[18] Due to the lack of data in NIDS on indoor

[17] The deprivation scores of the other indicators in which the household is not deprived are: Modern cooking fuel (0.4 * 0 = 0), Education/Entertainment appliance ownership (0.133 * 0 = 0) and Telecommunication means (0.133 * 0 = 0).

[18] Deprivation in these indicators amounts to a weighted deprivation score of 0.4, which is greater than the cut-off point of 0.3 – implying that a household is multidimensional energy poor.

pollution, particularly on whether a household cooks from an open fire and either has a hood or chimney, the indoor pollution variable was not included. Therefore, the weight on modern cooking fuels was re-weighted from 0.2 to 0.4. Second, a 0.3 cut-off identified a household as multidimensionally energy poor if it did not have both household and entertainment/education appliances, including telecommunication means.[19]

The previous example showed how a single household could be considered as multidimensionally energy poor. Estimating the degree of multidimensional energy poverty at the national-level becomes complex and requires estimating the national MEPI. The MEPI integrates two parts. The first element is the proportion of households from the total number of households in South Africa that are multidimensional energy poor. This proportion of multidimensionally energy poor households, also known as the multidimensional headcount ratio H of energy poverty, was calculated using Equation 3.4 from Alkire and Santos (2011) as follows:

$$H = \frac{q}{n} \qquad \textbf{(3.4)}$$

where q is the number of households considered as multidimensionally energy poor and n is the total sample population. The second element, denoted as A, is termed as the average intensity of energy poverty. The intensity, on average, describes the proportion of weighted deprivations that the poor face in South Africa. This was calculated using Equation 3.5 from Alkire and Santos (2011) as follows:

$$A = \frac{\sum_{i=1}^{n} s_i(k)}{q} \qquad \textbf{(3.5)}$$

where $s_i(k)$ represents the deprivation score of each household i. Although the multidimensional headcount ratio of energy poverty measures the proportion of households that are multidimensional energy poor, it does not provide information regarding whether a household is deprived in a few indicators or all the indicators. The product of the

[19] Deprivation in these indicators amounts to a weighted deprivation score of 0.399, which is greater than the cut-off point of 0.3 – implying that a household is multidimensional energy poor.

multidimensional headcount ratio H of energy poverty and the intensity A, creates the MEPI, which adjusts the headcount to the overall population as expressed in Equation 3.6 as follows:

$$MEPI = H * A \tag{3.6}$$

The MEPI is defined as the share of weighted deprivations that poor households experience in a society out of all possible deprivations that the society would have experienced (Alkire & Foster, 2007).

3.1.2 **Step 2:** Decomposing Energy Poverty by Subgroups

In Step 2 of the data analysis, this study shows how each metric (TPR and MEPI) was decomposed by 3 subgroups: province, household income poverty status and household location. When decomposing an energy poverty metric by subgroup, a simplistic way of understanding this process is to view a subgroup as a population. For example, when decomposing energy poverty by rural versus urban household location, the sum of energy poor households located in urban and rural areas should sum up to the national estimate of energy poor households. Therefore, decomposing by the three subgroups provided evidence for South Africa following consensus in the literature (Nussbaumer *et al.,* 2011; Bensch, 2013; Sher *et al.*, 2014) that national estimates tend to trump subnational estimates. As part of the objective of this study, this analysis described the geographic, socioeconomic and temporal incidence of household energy poverty.

3.1.2.1 Decomposition by Province

The first decomposition of energy poverty metrics (TPR and MEPI) performed in this study was done by province for each of the nine provinces of South Africa: Western Cape, Eastern Cape, Northern Cape, Mpumalanga, Limpopo, Gauteng, North West, KwaZulu Natal and Free State.

3.1.2.2 Decomposition by Household Income Poverty Status

The second decomposition of energy poverty metrics (TPR and MEPI) was performed by household income poverty status. A variable depicting household income poverty status was constructed using the household after-tax income variable in NIDS. This was done so by adapting individual income poverty lines from Budlender, Leibbrandt and Woolard (2015) who constructed a food poverty line (FPL), a lower bound poverty line (LBPL) and an upper bound poverty line (UBPL) using NIDS data.

Statistics South Africa (Stats SA, 2011) offers definitions for the FPL, LBPL and UBPL. The FPL is defined as a consumption level where individuals with an income below it are not able to buy enough food to afford them a sufficient diet. Any individuals below the FPL are therefore consuming inadequate calories for their sustenance, or have had to alter their consumption patterns away from those that would have been desired by low-income households. Individuals above the FPL but below the LBPL are able to afford certain non-food items, but requires that these individuals forgo food in place of purchasing these non-food items. Individuals above the UBPL are able to buy sufficient food and non-food items.

Budlender *et al.* (2015) estimated the FPL, LBPL and UBPL of R432, R669 and R1279 for January 2015, respectively. Note that these poverty lines by Budlender *et al.* are individual poverty lines and not household poverty lines. Since household was used as the unit of analysis, the total household income variable was divided by the household size to determine on average, the income attributable to each household member. This averaged income per person in each household was then compared against the income poverty lines to determine in which poverty line an individual falls or on average, a household. For example, a household with a total household income of R1000 and with five members in the household meant that the household had an average income of R200 for each individual. This implies that such a household would be classified as living below the FPL since each individual, on average has income below R432. In line with the year chosen (November 2014) for analysis of these data in this study, these poverty lines were adjusted for inflation to November 2014 using the Consumer Price Index (CPI)[20] from Statistics South Africa (Stats SA, 2014). This study chose to use poverty lines from Budlender *et al.* (2015) over poverty lines from Statistics South Africa (Stats SA, 2011) because evidence from Zizzamia *et al.* (2016) has shown that they are more robust, especially for the UBPL.

[20] Stats SA (2014) defines the Consumer Price Index (CPI) measurement of monthly changes in the prices of a range of consumer products.

3.1.2.3 Decomposition of TPR by Subgroup

The TPR was statistically decomposed for each of the groups (province, household income poverty status and household location) using Equation 3.7 from Boardman (1991) as follows:

$$TPR_g = \sum_{i=1}^{g} \frac{\beta_i}{\alpha_i} \qquad \textbf{(3.7)}$$

$$TPR_{subgroup} = \begin{cases} 1 & TPR > 0.1 \\ 0 & Otherwise \end{cases}$$

where TPR_g assumes the same interpretation as shown in Equation 3.1 but instead, over the total population of the subgroup g. In other words, the TPR for each of the three subgroups was estimated in the same manner as the country TPR, except only over the population of the subgroup. For example, decomposing the TPR by household location meant calculating a TPR for both urban households and rural households. It is noted that the TPR of all subgroups (urban and rural) still add up to the total country TPR.

Contribution of Subgroups to TPR

The contribution of each subgroup to the TPR was calculated using Equation 3.8 from Boardman (1991) as follows:

$$Contribution\ of\ g\ to\ TPR_{country} = \frac{TPR_g}{TPR_{country}} * 100 \qquad \textbf{(3.8)}$$

where TPR_g is the TPR of subgroup g and $TPR_{country}$ is the country TPR depicting country or national-level estimates of energy poverty. For example, the contribution of urban household energy poverty to $TPR_{country}$ was obtained through dividing the TPR of urban by the $TPR_{country}$.

3.1.2.4 Decomposition by Household Location

The third decomposition of energy poverty metrics (TPR and MEPI) performed was by household location. A variable on household location was constructed using NIDS data to classify households as either being located in a rural or urban area. The original variable in NIDS described three potential household locations: urban, rural and traditional. Due to the small sample size of traditional households, this was combined with rural households. It was logically sound to consider a household in a traditional setting or village as rural, particularly in the context of South Africa.

3.1.2.5 Decomposition of MEPI by Subgroup

The MEPI was statistically decomposed for each of the subgroups (province, household income poverty status and household location) as expressed in Equation 3.9 from Alkire and Santos (2011) as follows:

$$MEPI_{subgroup} = \frac{\sum_{i=1}^{g} s_i(k)}{g} \quad \textbf{(3.9)}$$

where $s_i(k)$ represents the deprivation score of each household i and g is the total number of households in the sample. Further, the multidimensional energy poverty headcount ratio was statistically decomposed for each of the three subgroups as expressed in Equation 3.10 from Alkire and Santos (2011):

$$H_{subgroup} = \frac{q_g}{n} \quad \textbf{(3.10)}$$

where q_g is the number of households considered as multidimensional energy poor in subgroup g and n is the total number of households in South Africa. The average intensity of multidimensional energy poverty was also statistically decomposed for each of the 3 subgroups using Equation 3.11 from Alkire and Santos (2011):

$$A_{subgroup} = \frac{\sum_{i=1}^{n} s_i(k)}{q_g} \quad \textbf{(3.11)}$$

where $s_i(k)$ represents the deprivation score of each household i and q represents the number of households considered as multidimensional poor in subgroup g while n is the total number of households in South Africa.

Contribution of Subgroups to MEPI and Headcount Ratio

The contribution of each subgroup to the MEPI was calculated using Equation 3.12 from Alkire and Santos (2011) as follows:

$$Contribution\ of\ g\ to\ MEPI = \frac{\frac{n_g}{n} MEPI_g}{MEPI_{country}} * 100 \qquad \textbf{(3.12)}$$

where n_g is the population of subgroup g and n is the total population while $MEPI_g$is the multidimensional poverty index of subgroup g and $MEPI_{country}$ is the overall national MEPI of the country. Further, the contribution of each of the three subgroups to the multidimensional headcount ratio of energy poverty was estimated using Equation 3.13 as follows:

$$Contribution\ of\ g\ to\ H = \frac{\frac{n_g}{n} H_g}{H_{country}} * 100 \qquad \textbf{(3.13)}$$

where n_g is the population of subgroup g and n is the total population while $H_g$is the multidimensional poverty index of subgroup g and $H_{country}$ is the national multidimensional energy poverty headcount ratio.

Contribution of indicators to MEPI

This study also calculated the contribution of each of the five indicators to the MEPI as expressed in Equation 3.14:

$$Contribution\ of\ x\ to\ MEPI = \frac{w_x H_x}{MEPI_{country}} * 100 \qquad \textbf{(3.14)}$$

where w_x is the weight of indicator x and H_x is the headcount of indicator x.

3.1.3 **Step 3:** Sensitivity Analysis

In Step 3, this study shows how the sensitivity analysis and robustness checks of the results were performed. This study acknowledges the implicit and explicit assumptions made in the methodology ideally with the energy poverty threshold for both the TPR and the dual deprivation cut-offs for the MEPI.

3.1.4.1 Stability of Rankings

To test for the stability in ranking of provinces in the subgroup decompositions (also used a proxy for the stability of all estimates), the energy poverty threshold of the TPR was varied from 7 percent, 10 and to 13 percent. The energy poverty cut-off k of the MEPI was also varied from 0.2, 0.3 and to 0.4. It should be noted that the variation in these thresholds was systematically done by considering a one-third variation in each measure. The same was done by multiplying this ratio by the TPR threshold of 10 percent, which allowed for a variation in the TPR threshold by 3 percent. After these MEPI cut-offs were estimated for each province, a ranking of the nine South African provinces by percentiles was constructed for both measures.

3.1.4.2 Spearman Rank Correlation Coefficient

The study utilized the Spearman rank correlation coefficient – a measure of the strength of the relationship between variables while ranking them (Pimentel, 2009). The logic behind this test was to identify if any changes in the rankings of provinces due to varying the threshold meant that the results were not robust. This was achieved by applying the Spearman correlation to each to ranking of provinces by each measure and by each wave of data.

3.2 Limitations of the Methodology

While the methodology has potential to explain energy poverty in South Africa from a unidimensional and multidimensional perspective, certain flaws were identified in this study. A lack of data particularly on whether households do or do not have a chimney or hood limited the construction of a variable depicting indoor household pollution in accordance with the original MEPI specification by Nussbaumer *et al.* (2011).

The weights assigned to the indicators of the MEPI are adopted from Nussbaumer *et al.* (2011) and are uneven, giving more importance to certain variables. While this is logically done, it makes interpretation slightly complex. Focusing on the TPR, this measure fails to account for asset deprivation – which is a critical aspect when defining energy poverty. However, neither does the MEPI take into account the relevance and importance of income in constructing a measure of energy poverty.

Chapter 4
Results and Discussion

As stated in Chapter 1, this study aimed to evaluate household energy poverty in South Africa through systematically constructing two metrics with an identical form of survey data. The unidimensional metric was operationalized by the energy-budget share, which is also known as "Tenth-Percentile Rule" (TPR) while the multidimensional metric was operationalized by the multidimensional energy poverty index (MEPI). This chapter starts with a presentation of the descriptive statistics of variables used to construct the TPR and MEPI metrics. This discussion is followed by a detailed presentation of results relating to the three objectives of the study. Results from the sensitivity analysis are then presented, leading into the final section of this chapter, which provides a detailed discussion of all the results presented in the study.

4.1 Descriptive Statistics

This section presents the descriptive statistics of some key variables used in the construction of the TPR and MEPI at household-level in South Africa using the NIDS datasets for 2008 (wave 1) and 2014-2015 (wave 4). As noted in Chapter 3, data from 2008 comprised of 7296 households while data from 2014-2015 comprised of 11898 households. These data were weighted using post-stratified weights in NIDS to ensure that all results were representative of the South African population. In line with conventional wisdom of econometric analysis (Gujarati, 2009; Asteriou & Hall, 2011), the computation of descriptive statistics for all key variables was done to provide understanding about the suitability of these data for the required analysis.

4.1.1 Descriptive Statistics of Variables used to Construct TPR

Table 4.1 presents the descriptive statistics of monthly household energy expenditure and monthly household income after-tax in South Africa for 2008 and 2014-2015 – the two variables required to construct the TPR. Table 4.1 shows the percentile distribution of monthly household expenditure on energy services and monthly household after-tax income, their minimum and maximum values, including some basic measures of central tendency such as the mean and median of the variables. The questions asked in NIDS to collect data on household after-tax income and energy expenditure presented in Table 6.1 in Appendix A.

Table 4.1: Descriptive Statistics of South African Monthly Household Energy Expenditure and Household After-Tax Income, 2008 and 2014-2015

Percentiles	Monthly Household Energy Expenditure[21]		Monthly Household After-Tax Income[22]	
	2008 Wave 1 (R)	2014-2015 Wave 4 (R)	2008 Wave 1 (R)	2014-2015 Wave 4 (R)
1%	3	3	222	314
5%	10	11	350	641
10%	15	15	629	964
25%	29	29	1257	1500
(Median) 50%	70	55	1776	2752
75%	146	149	3702	5000
90%	286	300	10000	10692
95%	419	400	26653	19355
99%	1232	877	88842	35126
Mean	142	117	7005	5024
Minimum	0	2	0	18
Maximum	3701	6022	419096	89758

Source: Authors' own calculations using NIDS data from SALDRU (2015a; 2016).

The average expenditure on household energy services in Table 4.1 was approximately R142 and R117 in 2008 and 2014-2015 while the median household spent R70 and R55 on household energy sources per month, respectively. However, some households at the lower end of the household energy expenditure distribution spent as low as R0 and R3 on energy sources a month in both 2008 and 2014-2015, respectively.

Evidently, some households on the upper end of the expenditure distribution, often described as the higher income households spent R3701 and R6022 on energy sources a month in 2008 and 2014-2015, respectively. Compared to the bottom end of the distribution, these figures are relatively high and could represent rich households whose energy usage are driven by a holistic set of determinants of energy consumption. Tewathia (2014) argues that these determinants include lifestyle choices, the use of complex and high energy consuming assets for heating, cooling and cooking, or other socioeconomic factors such as high household incomes and dwelling size.

[21] Note that monthly household energy expenditure represents household expenditure in the modal month (November 2014) of the survey interview but serves as proxy for monthly household energy expenditure.

[22] Note that monthly household after-tax income represents household after-tax income in the modal month (November 2014) of the survey interview but serves as proxy for monthly household after-tax income.

Table 4.1 also reports that the average household after-tax income in South Africa was approximately R7005 and R5024[23] in 2008 and 2014-2015 while the median household received a monthly after-tax income of R1776 and R2752, respectively. Taking the difference between the mean monthly household after-tax income and the median monthly household after-tax income provides a simplistic measure of central tendency that shows the basic level of household income inequality in South Africa. Observing that the difference is positive[24] in both 2008 and 2014-2015, this implies that income inequality is quite high among South African households and this is in line with the findings of Mbewe and Woolard (2016). Although worth mentioning, inequality is not the focus of this study, but conceivably, a factor that offers part of the explanation as to why households, particularly those at the lower end of the income distribution are lacking income or spend below optimal on energy services in South Africa.

To obtain understanding of average expenditure between low and high-income households, Table 4.2 presents the results of mean household expenditure on energy services by household after-tax income deciles in South Africa for 2008 and 2014-2015. The results show that average household energy expenditure increases as household income increases. This is evidenced by the rising average energy expenditure among households from bottom to top income deciles. Further, the results show that in 2008 and 2014-2015, households in the 10th income decile spent approximately 4 and 1.5 times[25] more on energy services, respectively, compared to households in the 1st income decile. It should be noted that the fluctuations in energy expenditure between household income deciles in Table 4.2 should be ignored. This is because energy expenditure is decomposed by income deciles and therefore, it would not be surprising if households in 8th income decile spent more on energy than those in the 9th income decile as seen in the Table. There has clearly been a reduction in the ratio of energy expenditure

[23] Note that one household with an after-tax income of R50 million and the highest in the sample was dropped from the 2014-2015 data as it was considered an extreme outlier note. Appendix B in Table 6.3 shows how the inclusion of this household increases the mean of the household after-income to R65760 compared to a mean of R5024 when the variable is dropped, as seen in Table 4.1. Exclusion of this household was to allow for a more even percentile distribution of household income in Table 4.1 and should be noted dropping is compensated by survey weights and therefore does not affect the measurement of energy poverty.

[24] A positive difference (R7005 – R1776 = R5229) in 2008 and in 2014-2015 (R5024 – R2752 = R2272).

[25] Energy expenditure ratio (10th decile: 1st decile). 2008 is (R373: R90 = 1:4.2) and 2014-2015 is (R152: R101 = 1:1.5).

between top and bottom income deciles between 2008 and 2014-2015. A reasonable explanation could be the increase in access to electricity, mostly to poor households, who are transitioning from non-monetary fuels (wood and animal dung) to prepaid grid electricity (Ismail & Khembo, 2015).

Table 4.2: Mean Household Expenditure on Energy Services by Deciles of Household After-Tax Income, 2008 and 2014-2015

Deciles of Household Income After-Tax	Mean Expenditure on Energy Services, 2008 wave 1 (R)	Mean Expenditure on Energy Services, 2014-2015 wave 4 (R)
1	90	10
2	94	73
3	81	108
4	111	11
5	103	104
6	112	107
7	111	130
8	108	134
9	141	126
10	373	152

Source: Authors' own calculations using NIDS data from SALDRU (2015a; 2016).

4.1.2 Describing Statistics of Variables used to Construct MEPI

Table 4.3 presents five indicators used to construct the MEPI and as a proxy for five dimensions of energy poverty. The indicators are: (1) access to modern cooking fuel; (2) electricity access (3) access to at least one fridge; (4) access to at least one radio, television or computer; (5) and access to a mobile or landline phone. Table 4.3 shows the proportion of South African households deprived or deprived in each of the five indicators. The questions asked in NIDS to collect these data are presented in Table 6.2 of Appendix A.

The results show that approximately 49 and 19 percent of households lacked access to modern cooking fuel in 2008 and 2014-2015, respectively. This shows a reduction in percentage of households deprived of modern cooking fuels between 2008 and 2014-2015. The results presented in Table 4.4 on the percentage distribution of South African households by main sources of cooking fuels provide an explanation for this. The results show that about 71 percent and 80 percent of households cooked using electricity from the mains in 2008 and

2014-2015, respectively. This indicates an increase in access to electricity, which is also considered as access to a modern cooking fuel.

Table 4.3: Degree of Deprivation in the five Indicators used to construct the MEPI, 2008 and 2014-2015

Dimension	Indicator	Proportion of households deprived (%)	
		Wave 1	Wave 4
Cooking	Modern Cooking Fuel	49	19
Lighting	Access to electricity	35	28
Household Appliance Ownership	Ownership of at least a fridge	54	35
Entertainment Appliance Ownership	Television or Radio or Computer	21	18
Telecommunication Means	Ownership of a mobile or landline phone	22	12

Source: Authors' own calculations using NIDS data from SALDRU (2015a; 2016).

Table 4.4: Percentage of South African Households' Main Sources of Energy for Cooking, 2008 and 2014-2015

Energy Sources for Cooking	2008, Wave 1 (%)	2014-2015, Wave 4 (%)
Electricity from mains	71.1	80.08
Electricity from generator	0.8	0.63
Gas	3.2	3.02
Paraffin	12.48	3.69
Wood	11.28	11.7
Coal	1.01	0.79
Animal dung	0.09	0.02
Solar energy	0	0.05
Other	0.04	0.02
Total	100	100

Source: Authors' own calculations using NIDS data from SALDRU (2015a; 2016).

Table 4.4 also shows a significant reduction in the use of paraffin from about 12 percent in 2008 to about 3 percent in 2014-2015. This is also supported by the reduction in deprivation of modern cooking fuel. In the case of wood, about 11 percent of households have used wood as a fuel for cooking in both 2008 and 2014-2015. However, very few households have used coal, animal dung and solar for their cooking needs both in 2008 and 2014-2015, showing not much of a difference over time. On the other hand, an insignificant number of households used solar energy for cooking purposes in 2008. In 2014-2015, about 0.5 percent of households were using solar for cooking, suggesting a slight increase in the uptake of renewable energy.

The second indicator (depicting the dimension of lighting) shows the extent of deprivation in access to electricity from mains[26]. The results indicate that 35 and 28 percent of South African households had no access to electricity in 2008 and 2014-2015, respectively. This shows a decrease in the number of deprived households over the period. A possible explanation lies in the increased access to electricity between 2008 and 2014-2015.

The third indicator (depicting the dimension on ownership of household appliances) shows the percentage distribution of households with at least one fridge in South Africa. The results show that about 54 percent of households did not have at least one fridge in 2008, but by 2014-2015, only 35 percent of households did not have at least one fridge. This shows a decrease in the percentage of households deprived of at least one fridge between 2008 and 2014-2015.

The fourth indicator (depicting the dimension on ownership of entertainment /education appliances) shows the percentage distribution of households with at least one radio/television/computer in South Africa. About 21 percent of households did not have at least one radio/television/computer in 2008 but by 2014-2015, only 18 percent of households did not have at least one radio. This shows a decrease in the percentage of households deprived of at least one radio between 2008 and 2014-2015.

The fifth indicator (depicting the dimension on telecommunication means) shows the percentage distribution of South African households with either a landline phone or at least one mobile phone. About 22 percent of households did not have at least a landline or mobile phone in 2008 and by 2014-2015, only about 12 percent of South African households did not have at least a landline or mobile phone. This shows a decrease in the percentage of households deprived of at least one cell phone or landline between 2008 and 2014-2015.

In summary, the five indicators above all show a reduction in deprivation between 2008 and 2014-2015. Of the five indicators, households were more deprived of access to a fridge, followed by access to modern cooking fuels in 2008. By 2014-2015, highly deprived of a fridge (relative to other indicators), followed by access to electricity. However remarkable,

[26] While it would be intuitive, data limitations in NIDS do not allow for further disaggregation of the lighting variable into different lighting sources.

deprivation in modern cooking fuels declined by more than a 100 percent between 2008 and 2014-2015. By intuitively observing these results, it should follow that multidimensional energy poverty reduced between 2008 and 2014-2015. The subsequent sections will show to what degree, multidimensional household energy poverty declined.

4.2 Estimates of National Energy Poverty

The first objective of this study was to estimate national-level household energy poverty for South Africa using unidimensional and multidimensional measures. This required estimating the TPR (unidimensional) and the MEPI (multidimensional) measure of energy poverty for 2008 and 2014-2015.

4.2.1 Tenth-Percentile Rule

Table 4.5 presents the results of energy poor household and non-energy poor households in South Africa for 2008 and 2014-2015. The results show that 21 and 13 percent of South African households lived in energy poverty in 2008 and 2014-2015, respectively. Over time, this shows a reduction in the percentage of households living in energy poverty in South Africa.

Table 4.5: Percentage of Energy Poor and Energy non-poor South African Households, 2008 and 2014-2015

State of energy poverty	Percentage of households	
	2008, Wave 1) (%)	2014-2015, Wave 4 (%)
Energy non-poor	79	87
Energy poor	21	13
Total	100	100

Source: Authors' own calculations using NIDS data from SALDRU (2015a; 2016).

Several things could account for the decline in household energy poverty using this measure. From a methodological standpoint, a decline in the household energy-budget share would support the claim of falling energy poverty over time. Falling household energy expenditure in South Africa would be because of increased access to electricity, accompanied with the use of Free Basic Electric (FBE) or moving away from expensive traditional fuels. This sort of a transition would be common among income-poor households.

4.2.2 Multidimensional Energy Poverty Index

Table 4.6 presents the results of the multidimensional headcount ratio of household energy poverty, average intensity of multidimensional energy poverty and the MEPI for South African households in 2008 and 2014-2015. The results show that 52 and 34 percent of households in South Africa were multidimensionally energy poor in 2008 and 2014-2015, respectively. This shows an overall reduction in the number of multidimensional poor households between 2008 and 2014-2015. However, the multidimensional energy poverty headcount only shows the number of households that are multidimensionally energy poor and does not distinguish whether a household is deprived in either some or all of the indicators.

Table 4.6: MEPI, Multidimensional Energy Poverty Headcount Ratio and Average Intensity of MEPI, 2008 and 2014-2015

Variable	**2008,** wave 1 **(%)**	**2014-2015,** wave 4 **(%)**
MEPI	37	19
Multidimensional Energy Poverty Headcount Ratio (H)	52	34
Average Intensity (A)	71	56

Source: Authors' own calculations using NIDS data from SALDRU (2015a; 2016).

The results also show that was 71 and 56 percent in 2008 and 2014-2015, respectively. This implies that multidimensionally energy poor household in South Africa, were on average deprived in 71 and 56 percent of the weighted indicators in 2008 and 2014-2015, respectively, which shows a decline in the average over time. Therefore, 15 percent[27] of the households that remained multidimensionally energy poor in 2014-2015 were on average deprived in fewer indicators than in 2008. The MEPI, which does not hold much intuitive explanation, except where comparison is made internationally still supports claims made using the results. The reduction in the MEPI from 2008 and 2014-2015 shows that multidimensional energy poverty among South African households reduced.

[27] The difference between average intensity in 2008 (76 percent) and average intensity in 2014-2015 (51 percent)

Consequently, since the TPR also measures the headcount of energy poor households, a comparison can be made with the multidimensional energy poverty headcount. The results show that on average, the multidimensional energy poverty headcount (see Table 4.6) identified more households (52 and 34 percent) as energy poor both in 2008 and 2014-2015, when compared to the TPR (21 and 13 percent) (see Table 4.5), respectively. Ismail and Khembo (2015) found that 25 percent of people in South Africa are energy poor (based on NIDS wave 3 data). This finding is slightly higher than the TPR estimates in this study, probably due to differences in data sets. Overall, the results from both the TPR and the multidimensional energy poverty headcount clearly show that the percentage of energy poor households has declined between 2008 and 2014-2015. However, the decline in energy poor households was higher using the TPR with a reduction by 38 percent[28] while the reduction from the multidimensional energy poverty headcount was 33[29] percent.

Having obtained insight into national-level multidimensional energy poverty of households in South Africa, Table 4.7 presents results of the contribution of each of the five indicators towards identifying households as multidimensionally poor.

Table 4.7: Dimensional Contribution to MEPI, 2008 and 2014-2015

Dimension	Indicator	2008, wave 1 (%)	2014-2015, wave 4 (%)
Cooking	Modern Cooking Fuel	53	40
Lighting	Electricity Access	19	27
Household Appliance Ownership	Fridge	15	18
Entertainment Appliance Ownership	Radio or Television or Computer	7	10
Telecommunication Means	Mobile or Landline	6	6
Total		100	100

Source: Authors' own calculations using NIDS data from SALDRU (2015a; 2016).

[28] $Reduction\ in\ TPR = \left(\frac{TPR2008 - TPR20142015}{TPR2008}\right) * 100 = \left(\frac{21-13}{21}\right) * 100 = 38\ Percent$

[29] $Reduction\ in\ MEPI = \left(\frac{MEPI2008 - MEPI20142015}{MEPI2008}\right) * 100 = \left(\frac{52-34}{52}\right) * 100 = 33\ Percent$

In addition, these contributions in Table 4.7 were computed based on the relative importance of the indicators determined by the assigned weights. These contributions all sum up to 100 percent for all indicators. The results show that deprivation in modern cooking fuels was the largest contributor to the MEPI in 2008 by more than half (53 percent). This implies that households in South Africa were more deprived of modern cooking fuel compared to other indicators. Although the contribution of modern cooking fuels to the MEPI fell to 40 percent by 2014-2015, it was still the largest contributor. It should however be cautiously interpreted that the increase in the contribution of other indicators to by 2014-2015 does not mean an increase (such as electricity access and ownership of a fridge) in deprivations by multidimensionally energy poor households. Rather, this is an adjustment factor of the contributions due to the substantial fall in the contribution of households deprived of modern cooking fuels between 2008 and 2014-2015.

4.3 Estimates of Energy Poverty by Subgroup

The second objective of this study was to describe the geographic, socioeconomic and temporal incidence of household energy poverty by subgroups. This objective also set to provide evidence following consensus in the literature that national estimates tend to disguise subnational estimates of household energy poverty. This was achieved by decomposing the TPR and the MEPI for 2008 and 2014-2015 by province, household income poverty status and household location. This objective assumed two parts and the one part focused on describing the geographic and temporal incidence of household energy poverty, which was accomplished by decomposing household energy poverty by province and household location. The other part focused on describing the socioeconomic and temporal incidence of household energy poverty and this was accomplished by decomposing household energy poverty by household income poverty status.

4.3.1 Decomposition of Energy Poverty by Province

The geographic and temporal incidence of household energy poverty was described by decomposing estimates of the TPR and MEPI by the nine South African provinces: Western Cape, Eastern Cape, Mpumalanga Northern Cape, Free State, KwaZulu Natal, North-West, Gauteng and Limpopo. In terms of the decompositions done using the TPR, this study estimated household energy poverty at the provincial-level and further estimated the contribution of energy poor households in each province to total number of energy poor households at the national-level in 2008 and 2015. In terms of the decompositions done using the MEPI, this study estimated: firstly, the MEPI at the provincial-level; secondly, the contribution by each dimension to the MEPI; and thirdly, the contribution of each indicator to the provincial MEPI.

4.3.1.1 TPR Decomposition by Province

Decomposing by TPR, Figure 4.1 presents the results of the percentage of energy poor households in the nine South African provinces in 2008 and 2014-2015. The results show that in 2008, household energy poverty was lowest in Western Cape Province with 10 percent, while it was highest in Limpopo with 34 percent. Other provinces displayed intermediate levels of household energy poverty in 2008. In 2014-2015, household energy poverty was again lowest in Western Cape (5 percent) and highest in Limpopo province (25 percent). On the other hand, other provinces displayed intermediate levels of household energy poverty in 2014-2015.

Although such comparisons are made, it should be acknowledged that policy effectiveness cannot be easily compared between or among the provinces, as population size of each province needs to be accounted for. For instance, a 10 percent reduction in energy poor households in a province with 20 energy poor households is not the same as a 10 percent reduction in a province with 50 energy poor households. By just observing at the percentage reduction in energy poor households, it is tempting to conclude that policy effect had the same impact. It would be right to only assume so if policy was focused on the percentage reduction rather than the headcount of energy poor households.

Overall, Figure 4.1 shows a reduction in household energy poverty in all provinces between 2008 and 2014-2015, except for Northern Cape indicating an increase from 15 percent in 2008 to 18 percent in 2014-2015. Evidence from Kohler *et al.* (2009) shows that the Northern Cape has been characterised by low incomes and high spending on one source of energy, charcoal.

After gaining understanding of household energy poverty at the provincial-level using the TPR, this study further provided evidence of which province had the highest number of energy poor households in relation to the total number of energy poor households in South

Africa. This was essential, especially for policymaking because knowing the percentage of energy poor households in a province does not necessarily indicate how severe energy poverty maybe be at the national-level. Figure 4.2 therefore presents the results of the contribution of provincial energy poor households to the overall proportion of energy poor households in South Africa in 2008 and 2014-2015.

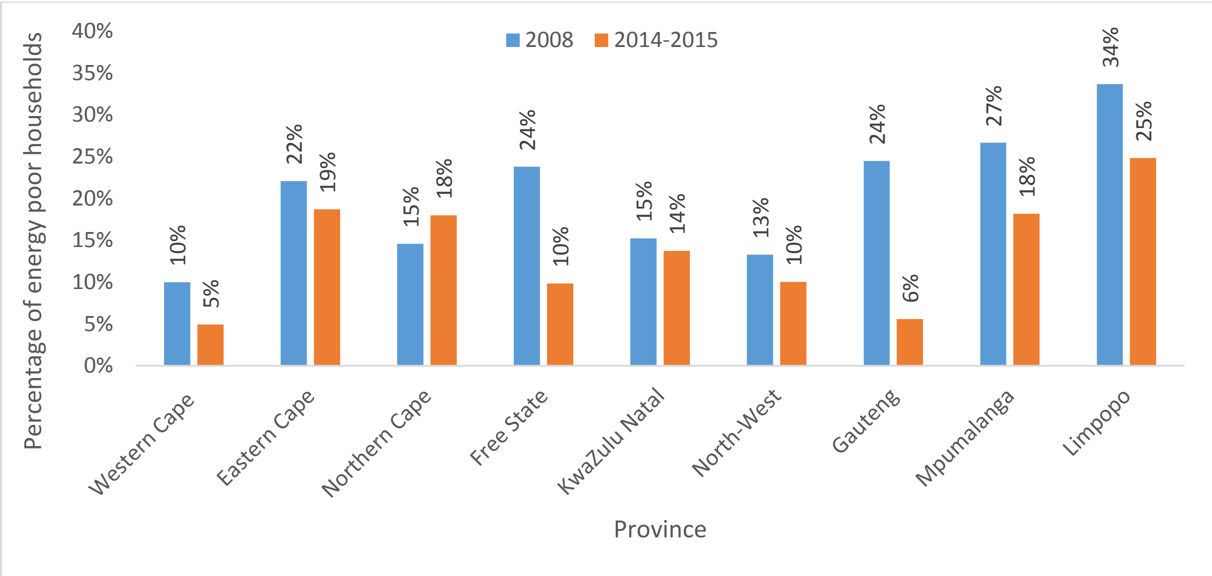

Figure 4.1: Percentage of Energy Poor Households by South African Provinces using the TPR, 2008 and 2014-2015. Source: Authors' own calculations using NIDS data from SALDRU (2015a; 2016).

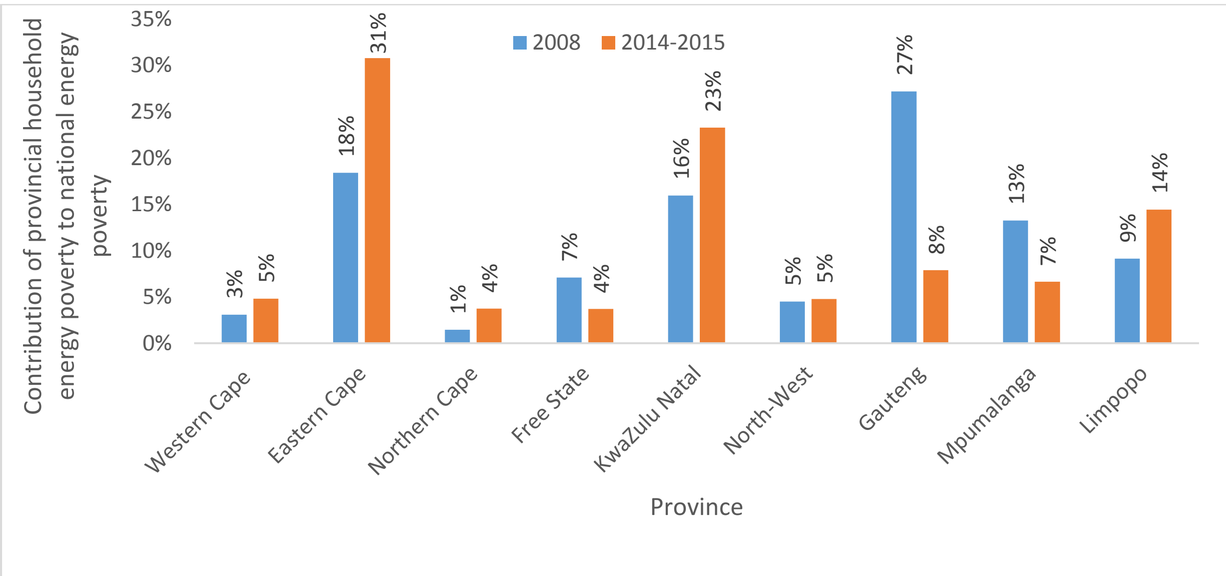

Figure 4.2: Province Contribution of Energy Poor Households to Total Number of Energy Poor Households in South Africa using the TPR, 2008 and 2014-2015. Source: Authors' own calculations using NIDS data from SALDRU (2015a; 2016).

The results show that in 2008, Northern Cape and Western Cape Province made the lowest contribution to the overall number of energy poor households with 1 percent and 3 percent, respectively. The highest contribution of energy poor households came from Eastern Cape and Gauteng with 18 and 27 percent, respectively. The other provinces displayed intermediate levels of household energy poverty. In 2014-2015, the lowest contribution of energy poor households came from Northern Cape Free State both with 4 percent while the highest contribution came from KwaZulu Natal and Eastern Cape provinces with 23 and with 31 percent, respectively.

By 2014-2015, Gauteng only made a contribution of 8 percent, supported by the fact that household energy poverty declined by 18 percent as seen in Figure 4.1. Yet, the reduction in the contribution to the total number of energy poor households in Gauteng was met with an adjustment factor and KwaZulu Natal (23 percent) and Eastern Cape (31 percent) contributed more towards total number of energy poor households in South Africa by 2014-2015. This does not mean an increase in the proportion of energy poor households. Rather, it means that by 2014-2015, most of the energy poor households in South Africa were from Eastern Cape.

4.3.1.2 MEPI Decomposition by Province

This section presents results from the decomposition of the multidimensional headcount ratio of energy poverty (Figure 4.3), average intensity of energy poverty (Figure 4.4) and the MEPI (Figure 4.5) by province for 2008 and the 2014-2015. Results from Figure 4.3 show that in 2008, the lowest percentage of multidimensionally energy poor households came from Western Cape with 8 percent and Northern Cape with 33 percent.

Results further show that the highest proportion of multidimensionally energy poor households came from Limpopo with 59 percent and Eastern Cape with 75 percent. The other provinces displayed intermediate levels of multidimensional household energy poverty. Overall, the result show that the number of multidimensionally energy poor households has declined in all provinces with the exception of Northern Cape, indicating an increase from 33 percent in 2008 to 36 percent in 2014-2015.

Further, results from Figure 4.4 show that in 2008, the average intensity of multidimensional energy poverty was lowest in Mpumalanga with 61 percent and Limpopo with 64 percent. This implies that in 2008, energy poor households were in Mpumalanga and

Limpopo were on average deprived of 61 and 64 percent of the weighted indicators, respectively. The highest average intensity came from Eastern Cape with 74 percent and from Western Cape, KwaZulu Natal and Gauteng each with 72 percent. The other provinces displayed intermediate average levels of intensity of multidimensional energy poverty. In 2014-2015, the average intensity of multidimensional energy poverty was lowest in Western Cape with 43 percent and Gauteng with 44 percent. The highest average intensity came from Northern Cape with 64 percent and from KwaZulu Natal with 65 percent. The other provinces displayed intermediate average levels of intensity of multidimensional energy poverty in 2014-2015. Overall, the result show that average intensity of multidimensional household energy poverty has declined in all provinces.

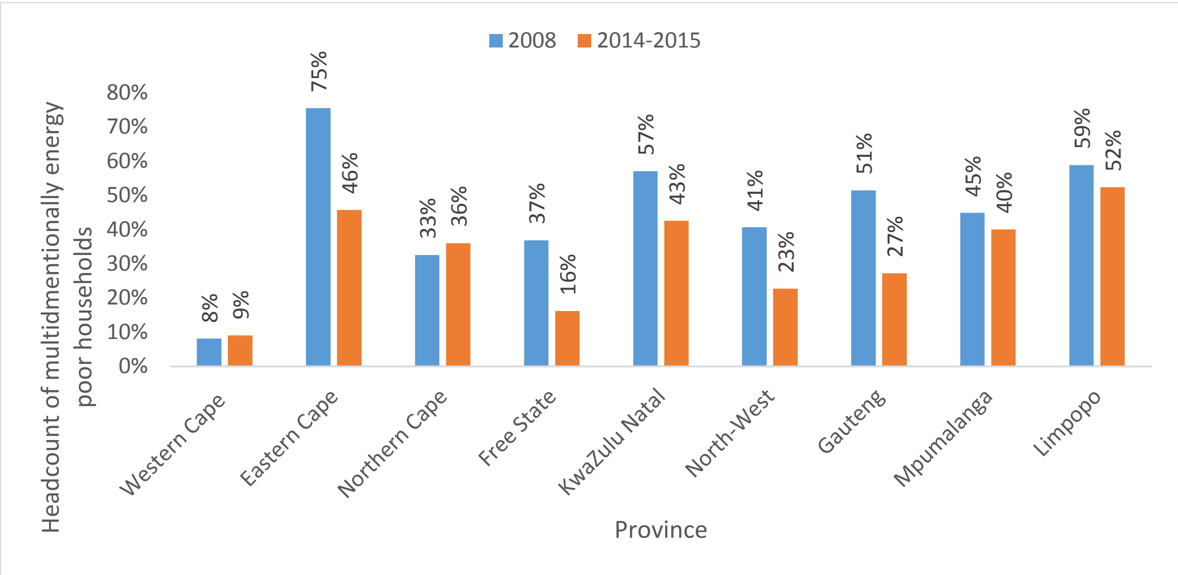

Figure 4.3: Headcount Ratio of Multidimensionally Energy Poor Households, 2008 and 2014-2015. Source: Authors' own calculations using NIDS data from SALDRU (2015a; 2016).

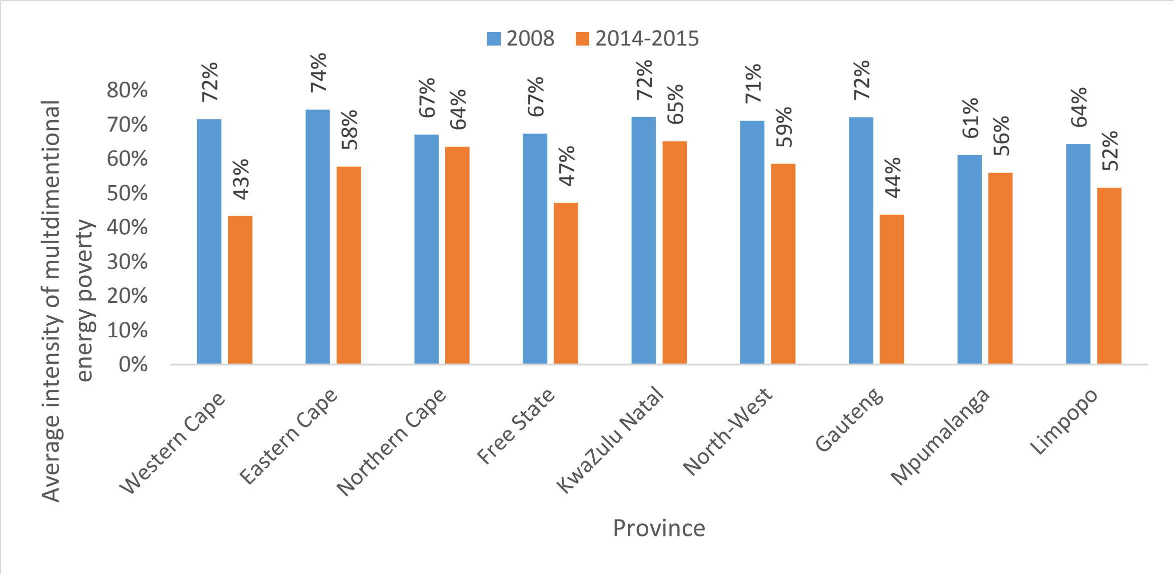

Figure 4.4. Average Intensity of Multidimensional Household Energy Poverty, 2008 and 2014-2015. Source: Authors' own calculations using NIDS data from SALDRU (2015a; 2016).

Subsequently, the provincial multidimensional household energy poverty headcount for 2008 and 2014-2015 can be compared with the TPR since they both capture the proportion of energy poor households at provincial-level. On average, the TPR (in Figure 4.1) and the multidimensional energy poverty headcount (in Figures 4.3) both show that the percentage of energy poor households has declined between 2008 and 2014-2015. There is also consensus between the two metrics that Northern Cape is an exception, and that the proportion of energy poor households has rather increased between 2008 and 2014-2015.

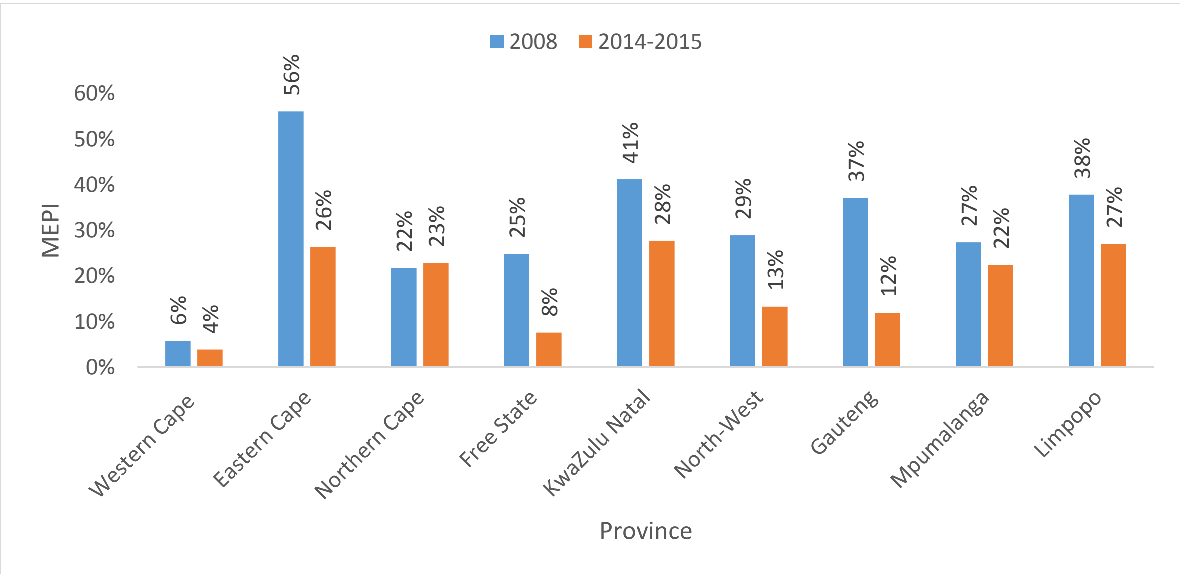

Figure 4.5: MEPI, 2008 and 2014-2015. Source: Authors' own calculations using NIDS data from SALDRU (2015a; 2016).

In 2008, the TPR (see Figure 4.1) identifies Limpopo as a province with the highest percentage (with 34 percent) of energy poor households while the multidimensional energy poverty headcount (see Figure 4.3) identifies the Eastern Cape (with 56 percent). However, in 2014-2015, both the TPR and multidimensional energy poverty headcount identify Limpopo as the province with the highest percentage of energy poor households with 25 and 27 percent, respectively. The multidimensional household energy poverty headcount shows in 2014-2015, Eastern Cape ranked second from Limpopo for having the highest percentage of energy poor households in South Africa. This highlights the basic fact that though these two measures are different conceptually, it shows that households conceivably energy poor by TPR standards might also be multidimensionally. Whether this is the case or not, is beyond the scope of this study.

The provincial multidimensional energy poverty headcount shows the degree of multidimensionally energy poor households in that province but does not show the level of poverty relative to other provinces. To show the level of poverty relative to other provinces, this is realized by considering the overall contribution of the provincial multidimensional energy poverty headcount to the national multidimensional energy poverty headcount. Table 4.8 presents the results of the provincial contribution to the multidimensional headcount ratio of household energy poverty and MEPI for 2008 and 2014-2015. These results confirm the fact that the high multidimensional headcount ratio of energy poverty identified for Eastern Cape in Figures 4.3 and 4.4 have a bearing for aggregate household energy poverty.

Table 4.8: Provincial Contribution to the Multidimensional Energy Poverty Headcount Ratio and MEPI, 2008 and 2014-2015

Province	**2008,** Wave 1			**2014-2015,** Wave 4		
	Headcount Ratio (%)	MEPI (%)	Intensity (%)	Headcount Ratio (%)	MEPI (%)	Intensity (%)
Western Cape	1	1	12	3	3	11
Eastern Cape	25	27	12	28	29	12
Northern Cape	1	1	12	3	3	11
Free State	5	4	9	2	2	11
KwaZulu Natal	25	25	12	26	30	13
North-West	6	6	12	4	4	11
Gauteng	23	24	12	15	12	9
Mpumalanga	9	8	10	6	6	11
Limpopo	6	5	10	12	11	10
Total	100	100	100	100	100	100

Source: Authors' own calculations using NIDS data from SALDRU (2015a; 2016).

Table 4.8 shows that the Eastern Cape and KwaZulu each contributed 25 percent to the total number of multidimensionally energy poor households in 2008, and 28 and 26 percent in 2014-2015, respectively. However interesting, these results imply that these two provinces had equal numbers of energy poor households in 2008 as seen through their equal contribution to the proportion of energy poor households nationally. Yet, the percentage of energy poor households within each province differed in 2008 as seen in Figure 4.3 with 75 percent for Eastern Cape and 59 percent for Limpopo. This is important in the analysis of household energy poverty and highlights the fact that different population sizes in each province will have different levels of household energy poverty within the province relatively compared to other provinces.

In other words, these estimates provide an opportunity for different policy responses. For example, a policy response looking to reduce energy poverty in South Africa could focus on where household energy poverty is high provincially (such as the Eastern Cape) or the province that has a highest number of energy poor households relative to the total number of households. This implies that although multidimensional energy poverty is higher within Eastern Cape (75 percent) compared to KwaZulu Natal (59 percent), Table 4.8 shows that both provinces have an equal contribution of the overall multidimensional headcount of energy poor households in South Africa. However, the intensity of multidimensional energy poverty is much higher in Eastern Cape.

This study has presented results of the multidimensional energy poverty headcount for each province and thereafter, the contribution provincial energy poverty to overall energy poverty in South Africa. For more focused policy intervention, it becomes more intuitive to analyse how the five indicators contributed to the value of the MEPI. Figures 4.6 and 4.7 present the results of the percentage contribution of each indicator to the overall provincial MEPI in 2008 and 2014-2015, respectively. It is noted that the contribution of these dimensions sum up to 100 percent in each province[30]. On average, the results show that in 2008, access to modern cooking fuels was the greatest contributor to the MEPI in each province followed by access to electricity. The least contributors were on average

[30] In each province, the percentage contribution of fuel, lighting, fridge, radio (which could also be television or computer) and phone to the provincial MEPI sum up to 100.

entertainment appliances (proxied by access to either a radio, television or computer) and phone (proxied by access to either mobile or landline phone).

The results in Figure 4.6 show on average, that lack of modern cooking fuel has been the highest contributor to the MEPI in all provinces in 2008. The lowest contribution of modern cooking fuel was in Western Cape Province with 47 percent while the highest was in Mpumalanga with 65 percent. All other indicators displayed intermediate levels of contribution in each province.

The results in Figure 4.7 show on average, a reduction in the deprivation towards access to modern cooking fuels in most provinces in 2014-2015 while electricity has assumed a greater contribution. It is noted that the increase in the contribution from access to electricity does not mean that households have become in this indicator. Rather, it simply means that policy interventions towards access modern cooking fuels has been effective, therefore becoming less important among the deprivations households have faced. A crucial aspect of these results shows how deprivations may differ between provinces. In policy intervention, a household deprived of appliances may require a different intervention strategy to a household deprived of modern cooking fuel.

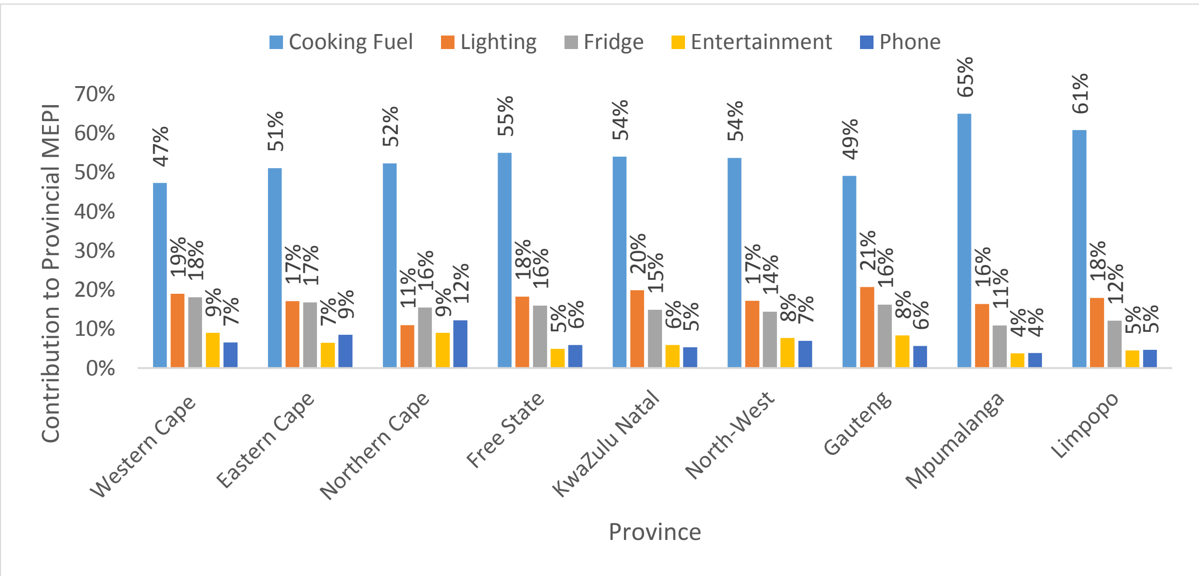

Figure 4.6: Percentage Contribution of each Dimension to the Individual Provincial MEPI, 2008. Source: Authors' own calculations using NIDS data from SALDRU (2015a).

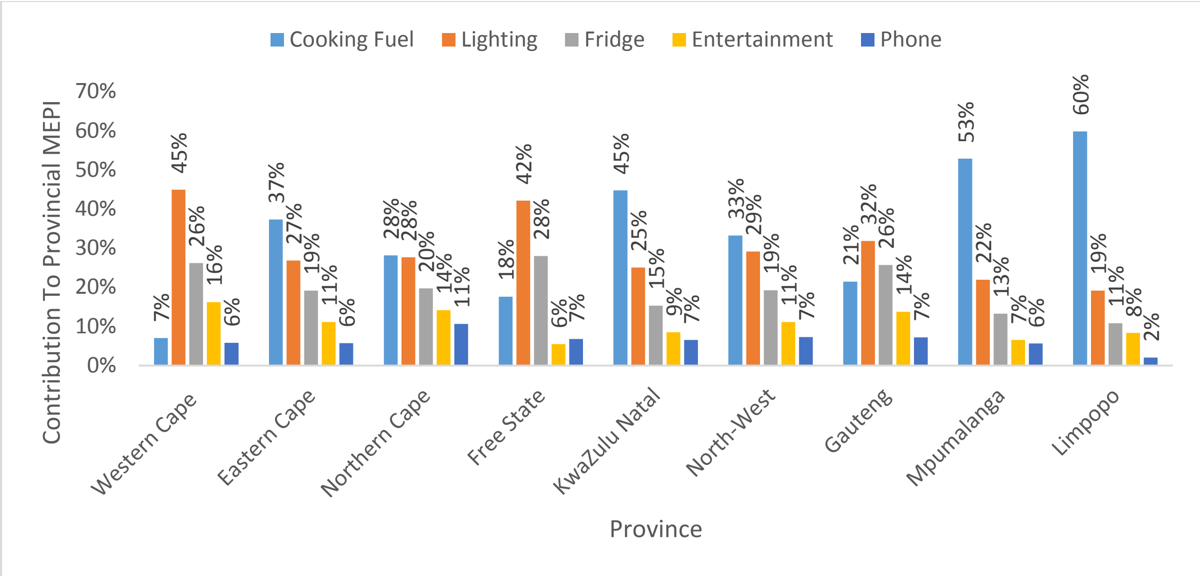

Figure 4.7: Percentage Contribution of each Dimension to the Individual Provincial MEPI, 2014-2015. Source: Authors' own calculations using NIDS data from SALDRU (2016).

4.3.2 Decomposition of Energy Poverty by Household Income Status

This section focused on describing the socioeconomic and temporal incidence of household energy poverty. This was achieved by decomposing the estimates of the TPR and MEPI by household income poverty status for 2008 and 2014-2015. Household income poverty status was used to proxy for the socioeconomic status and this variable was created using the household after-tax income variable in NIDS.

4.3.2.1 TPR Decomposition by Household Income Poverty Status

Decomposing by TPR, Figure 4.8 presents the results of the percentage of energy poor households by household income poverty status (FPL, LBPL, UBPL and non-income poor) for 2008 and 2014-2015. The results in Table 4.8 show that household energy poverty was highest among households who were on average living below the FPL. In 2008 and 2014-2015, 33 and 23 percent of energy poor households were living below the FPL, respectively. The results also show a declining number of energy poor households living below the FPL, LBPL, and UBPL, including those that non-income poor. In other word, these results seem to suggest that household energy poverty reduces as a household progress beyond each poverty — proposing an inverse relationship between household income and household energy poverty.

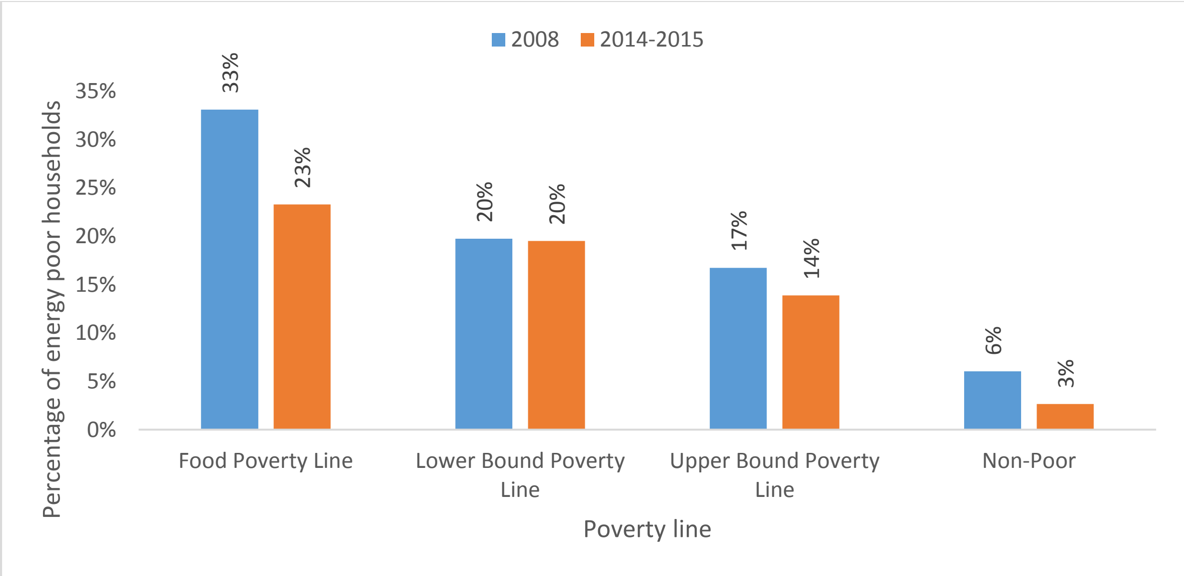

Figure 4.8: Percentage of Energy Poor Households by Household Income Poverty Status using the TPR, 2008 and 2014-2015. Source: Authors' own calculations using NIDS data from SALDRU (2015a; 2016).

Noteworthy, 6 and 3 percent of non-income poor households were however energy poor households. This presents a paradox because it would have been expected that high income earning households would not necessarily be energy poor. A reasonable explanation lies in one of the drawbacks of TPR. As highlighted in Chapter 2, the TPR tends to identify households spending above 10 percent of their income on energy services, though with the capability of paying for energy, as energy poor. Yet, one of the theoretical underpinning of the TPR is to show affordability, which can also be reflected in one's ability to pay. Alternatively, this could also suggest that either the UBPL might be low, or a household immediately above the UBPL are vulnerable to falling into the income poverty and/or energy poverty trap. An energy poverty trap depicts a situation in which people are in a vicious cycle of using unclean fuels due to deprivation in clean and affordable energy, which is accompanied by low incomes (IEA, 2015).

After gaining understanding of the level of household energy poverty by different income poverty lines using the TPR, this study further provided evidence of which income poverty lines contributed the highest number of energy poor households in relation to the total number of energy poor households in South Africa in 2008 and 2014-2015. This provides evidence of the severity of energy poverty among different measures or degrees of income poverty. Figure 4.9 presents the results of how energy poor households classified below the

FPL, LBPL, and UBPL or as non-income poor contribute to the total number of energy poor households in South in 2008 and 2014-2015.

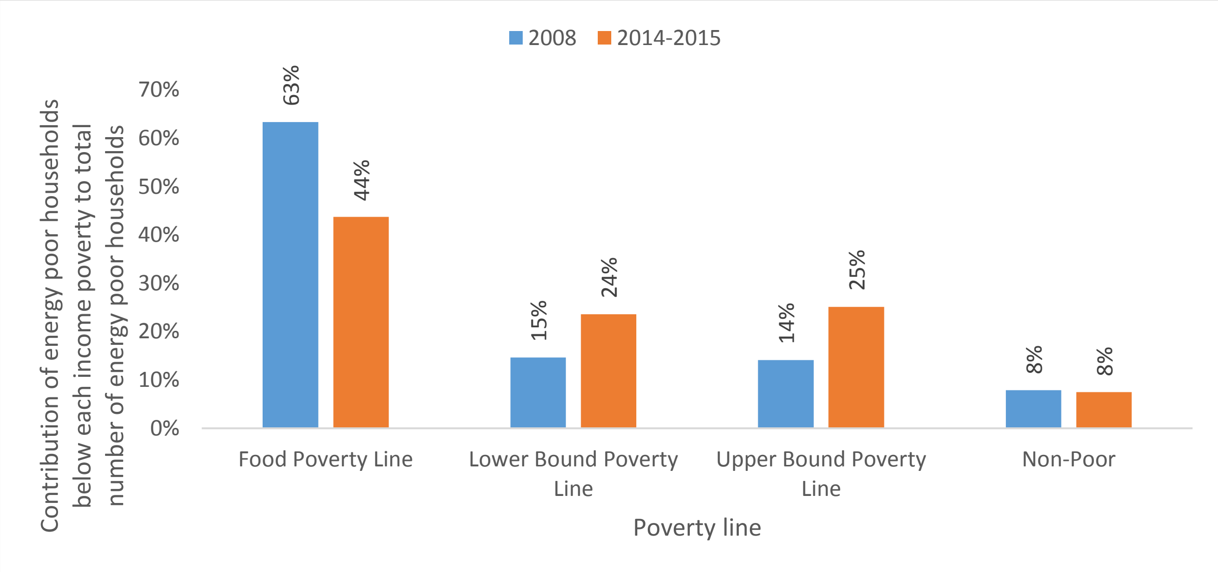

Figure 4.9: Proportion of Energy Poor Households by Income Poverty Status, 2008 and 2014-2015. Source: Authors' own calculations using NIDS data from SALDRU (2015a; 2016).

The results show that households living below the FPL made up most (63 Percent) of the energy poor households in South Africa. While there seems to be an increase in energy poor households living below the LBPL between 2008 and 2014-2015, a reasonable explanation could be because of a transition from the FPL to the LBPL. Similarly, the same logic would apply for the increase in the contribution of energy poor households for household living below the UBPL.

4.3.2.2 MEPI Decomposition by Household Income Poverty Status

This section presents results from the decomposition of the multidimensional headcount ratio of energy poverty (Figure 4.10), average intensity of energy poverty (Figure 4.11) and the MEPI (Figure 4.12) by household income poverty status for 2008 and the 2014-2015. Results from Figure 4.10 show that in 2008, the lowest percentage of multidimensionally energy poor households came from non-income poor households living above all the poverty lines with 34 percent while the highest came from households living below the FPL with 62 percent. The other households are displaying intermediate levels of household energy poverty by each income poverty line. In 2014-2015, the lowest percentage of multidimensionally energy poor households came from non-income poor households living above all the poverty lines with 22 percent while the highest came from energy poor households living below the FPL with 46 percent.

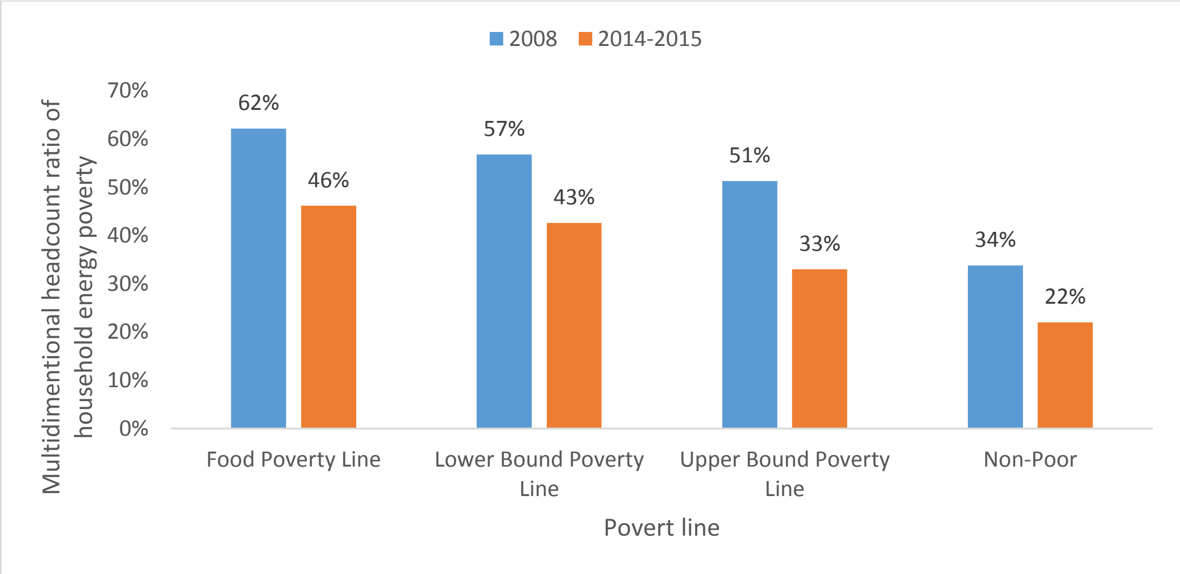

Figure 4.10: Multidimensional Energy Poverty Headcount Ratio, 2008 and 2014-2015. Source: Authors' own calculations using NIDS data from SALDRU (2015a).

Results from Figure 4.11 show that in 2008, the average intensity of multidimensional energy poverty was lowest among non-income poor households with 68 percent. This implies that in 2008, energy poor households who were also non-income poor were on average deprived of 68 percent of the weighted indicators. The highest average intensity came from energy poor households living below the FPL each with 72 percent. The other poverty lines displayed intermediate average levels of intensity of multidimensional energy poverty. In 2014-2015, the average intensity of multidimensional energy poverty was lowest among energy poor households who were also non-income poor with 47 percent. The highest average intensity came from energy poor households living below the FPL with 62 percent. The other provinces displayed intermediate average levels of intensity of multidimensional energy poverty in 2014-2015. Overall, the result show that average intensity of multidimensional household energy poverty has declined in all income poverty lines

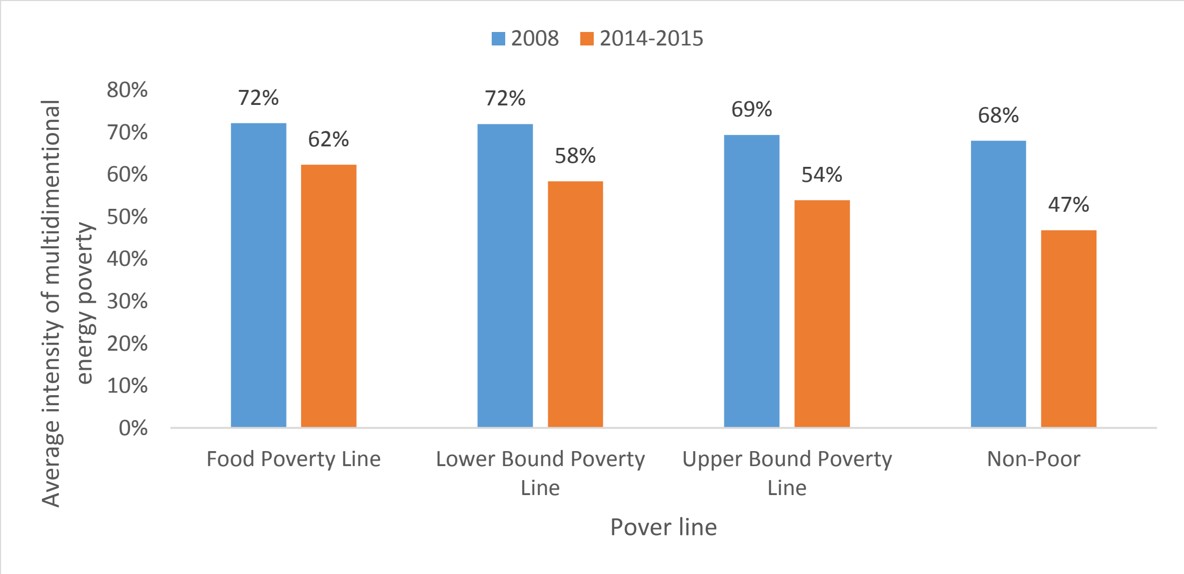

Figure 4.11: Average Intensity and MEPI by Household Income Poverty Status, 2008. Source: Authors' own calculations using NIDS data from SALDRU (2015a).

Further, results from Figure 4.12 show that in 2008, the MEPI was lowest for the energy poor households who were non-income poor with 23 percent. The highest MEPI came from energy poor households living below the FPL with 45 percent. The other provinces displayed intermediate levels of the MEPI in 2008. In 2014-2015, the MEPI was lowest (10 percent) for the energy poor households considered as non-income poor. The highest of MEPI (29 percent) came from energy poor households living below the FPL. The other provinces displayed intermediate levels of MEPI in 2014-2015. Overall, the result show a reduction in the MEPI in poverty lines.

Based on the results of the MEPI and TPR decomposed by household income poverty status, a comparison of the multidimensional energy poverty headcount and TPR for 2008 and 2014-2015 can be made. On average, the TPR (in Figure 4.8) and the multidimensional energy poverty headcount (in Figures 4.11) show that the percentage of energy poor households based on each of the poverty lines has declined between 2008 and 2014-2015. The results from the two measures also exhibit a pattern showing an inverse relationship between household income and household energy poverty both in 208 and 2014-2015.

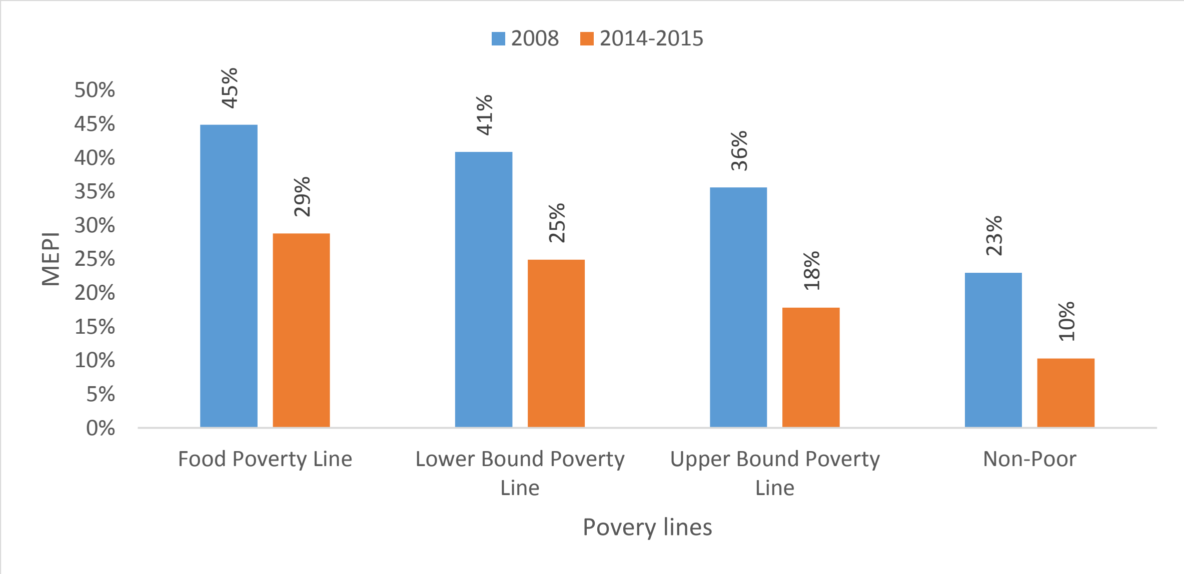

Figure 4.12: MEPI by Household Income Poverty Status, 2008. Source: Authors' own calculations using NIDS data from SALDRU (2015a).

After gaining understanding of the level of household energy poverty by different income poverty lines using the MEPI, this study further provided evidence of which income poverty lines contributed the highest number of energy poor households in relation to the total number of energy poor households in South Africa in 2008 and 2014-2015. This provides evidence of the severity of energy poverty among different measures or degrees of income poverty. This is achieved by estimating the contribution of energy poor households, classified below a certain poverty line, to the total number of multidimensional household energy poverty headcount and the MEPI. Table 4.9 presents the results of the contribution of energy poor household by each poverty line to the multidimensional headcount ratio of household energy poverty and MEPI for 2008 and 2014-2015.

The results in Table 4.9 confirm the fact that the high multidimensional household energy poverty headcount identified for households living below the FPL in Figure 4.10 have a bearing on the aggregate energy poverty. Table 4.9 shows that households living below the FPL contributed 47 percent to the total number of multidimensionally energy poor households in 2008 and 37 percent in 2014-2015. However interesting, these results show that energy poor households below the LBPL and UBPL, including those that are non-income poor had similar headcounts of between 17 and 18 percent. It should be noted that the rise in share contributions of other energy poor households living below the LBPL and the UBPL, including the non-income poor households in 2014-2015 does not mean an increase in multidimensionally energy poor households. Rather, this is an adjustment to the fall in the multidimensional headcount of households living below the FPL.

Table 4.9: Contribution by Household Income Poverty Status to Multidimensional Headcount Ratio, Average Intensity and MEPI, 2008 and 2014-2015

Poverty Line	2008, wave 1			2014-2015, wave 4		
	Headcount (%)	MEPI (%)	Intensity (%)	Headcount (%)	MEPI (%)	Intensity (%)
Food Poverty Line	47	48	26	37	41	28
Lower Bound Poverty Line	17	18	27	19	19	26
Upper Bound Poverty Line	18	17	24	22	21	25
Non-Poor	18	17	24	23	19	21
Total	100	100	100	100	100	100

Source: Authors' own calculations using NIDS data from SALDRU (2015a; 2016).

This study has presented results of the multidimensional energy poverty headcount for each poverty line and thereafter, the contribution of energy poor households below each poverty line to overall multidimensional household energy poverty in South Africa. With respect to policy interventions, it becomes more intuitive to analyse how the five indicators contribute to the value of the MEPI for each household income poverty status. Figures 4.13 and 4.14 present the results of the percentage contribution of each dimension to MEPI in 2008 and 2014-2015, respectively.

It is noted that the contribution of these dimensions sum up to 100 percent for each household income poverty status. On average, the results show that in 2008, access to modern cooking fuels was the greatest contributor to the MEPI for households below each poverty line, including those that were non-income poor. The least contributors were on average entertainment appliances and phone. Results in Figure 4.14 also show a reduction in the deprivation in modern cooking fuels among in each of the poverty lines while electricity has assumed a greater contribution.

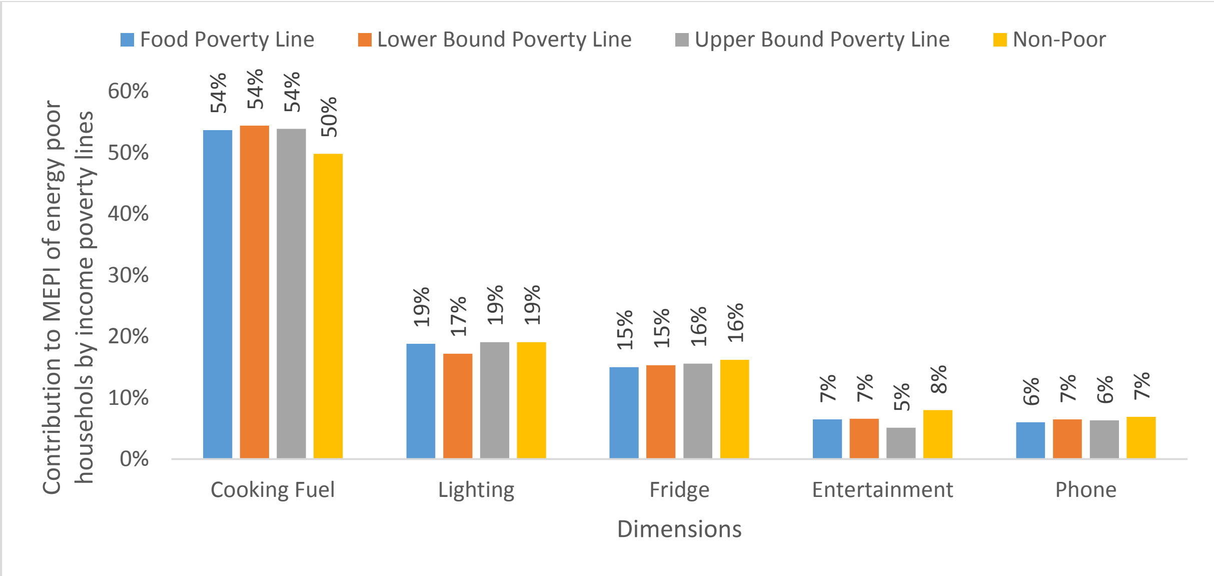

Figure 4.13: Percentage Contribution of Dimensions to MEPI by Household Income Poverty Status, 2008. Source: Authors' own calculations using NIDS data from SALDRU (2015a).

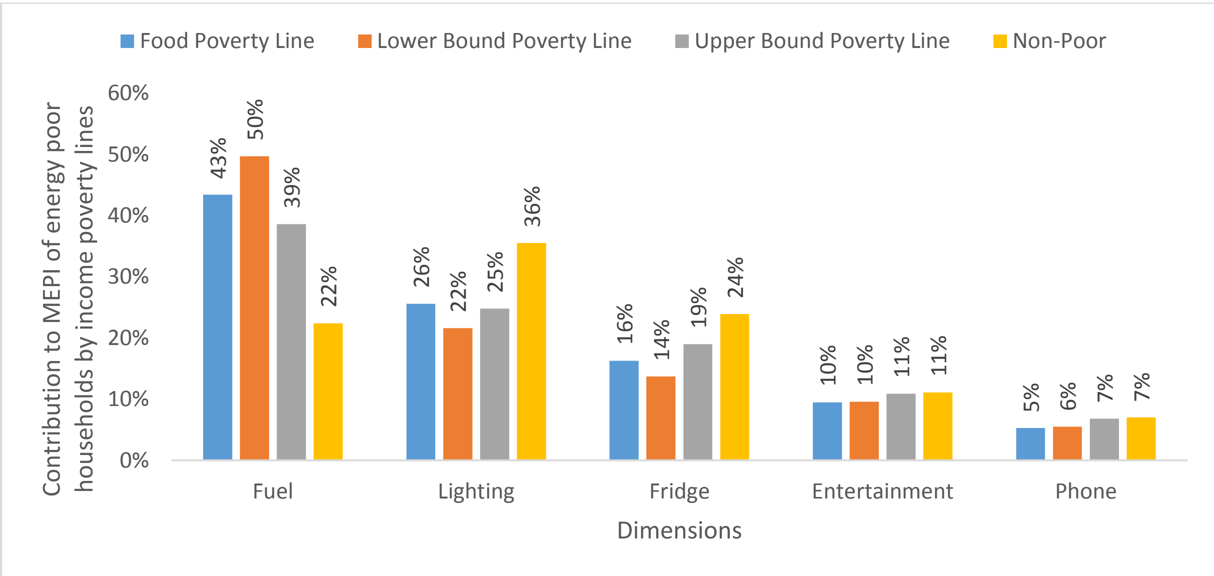

Figure 4.14: Percentage Contribution of Dimensions to MEPI by Household Income Poverty Status, 2014-2015. Source: Authors' own calculations using NIDS data from SALDRU (2016).

It is noted that the increase in the contribution from access to electricity does not mean that households have become more deprived in this indicator. Rather, it simply means that policy interventions towards access on modern cooking fuels has been effective, therefore becoming less of a concern relative to other deprivations energy poor households have faced. A crucial aspect of these results shows how deprivations may differ between the different income poverty statuses. In policy intervention, a household deprived of modern cooking fuel may require a different intervention strategy to household deprived access to electricity.

4.3.3 Decomposition of Energy Poverty by Household Location

The previous section described the geographic and temporal incidence of household energy poverty by province. This section provides a similar description however with a focus on household location. This is achieved by decomposing the estimates of the TPR and MEPI by household location. The household location variable is constructed for rural versus urban household location. In terms of the decompositions done using the TPR, this study estimates household energy poverty for rural and urban household locations and further estimates the contribution of both rural and urban energy poor households in to the total number of energy poor households at the national-level in 2008 and 2015. In terms of the decompositions done using the MEPI, this study estimated: firstly, the MEPI for urban and rural household locations; secondly, the contribution by each dimension to the MEPI; and thirdly, the contribution of each indicator to the urban and rural MEPI. Empirical evidence (Sustainable Energy Africa, 2014) suggests that energy poverty is not just rural phenomena but in fact, a phenomenon also pervasive among urban household – thereby giving rise to the term, "*urban energy poor*".

4.3.3.1 TPR Decomposition by Household Location

Decomposing by TPR, Figure 4.15 presents the results of the percentage of energy poor households decomposed by household location in 2008 and 2014-2015 by TPR. The results show that household energy poverty among rural households is higher than energy poverty among urban households in both 2008 and 2014-2015.

In 2008, 24 percent of households in rural areas lived in energy poverty while 18 percent of urban households were energy poor. In 2014-2015, 18 percent of households in rural areas lived in energy poverty while 8 percent of households in urban areas were energy poor. Overall, the results point to the fact energy poverty has reduced in both households located in rural and urban areas between 2008 and 2014-2015. However, the reduction was greater for households located in urban areas.

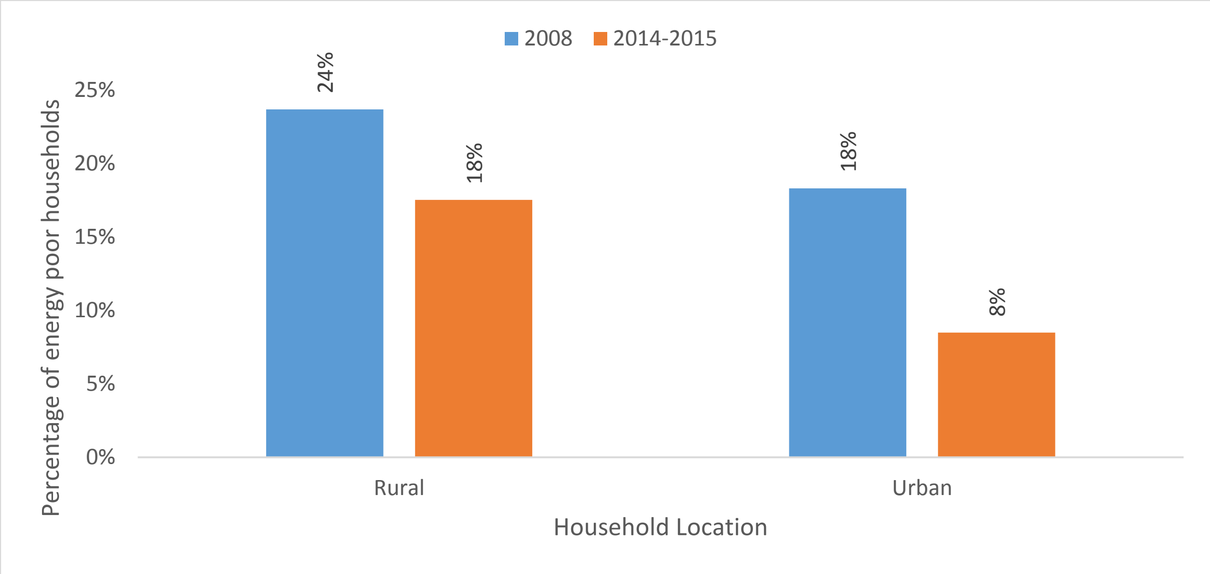

Figure 4.15: Percentage of Energy Poor Households by Household Location using the TPR, 2008 and 2014-2015. Source: Authors' own calculations using NIDS data from SALDRU (2015a; 2016).

It is noted from Figure 4.15 that neither do estimates of rural nor urban household energy poverty sufficiently show which of the two household locations has a greater number of energy poor households. An understanding of which household location has the highest number of energy poor households, rather than a percentage of poor households, has an impact for more focused and targeted policies to eradicate household energy poverty. Figure 4.16 presents the results of the contribution of energy poor rural and urban households to the overall proportion of energy poor households in South Africa in 2008 and 2014-2015.

In 2008, households located in a rural areas accounted for more than half (53 percent) of the energy poor households in South Africa while urban energy poor households account for 47 percent. By 2014-2015, the number of urban energy poor households declined in South Africa while numbers of energy poor households in rural areas increased. Note that this increase in the contribution of energy poor households does not mean that more households that are rural have become poor. It is a simple adjustment factor to declining urban household energy poverty.

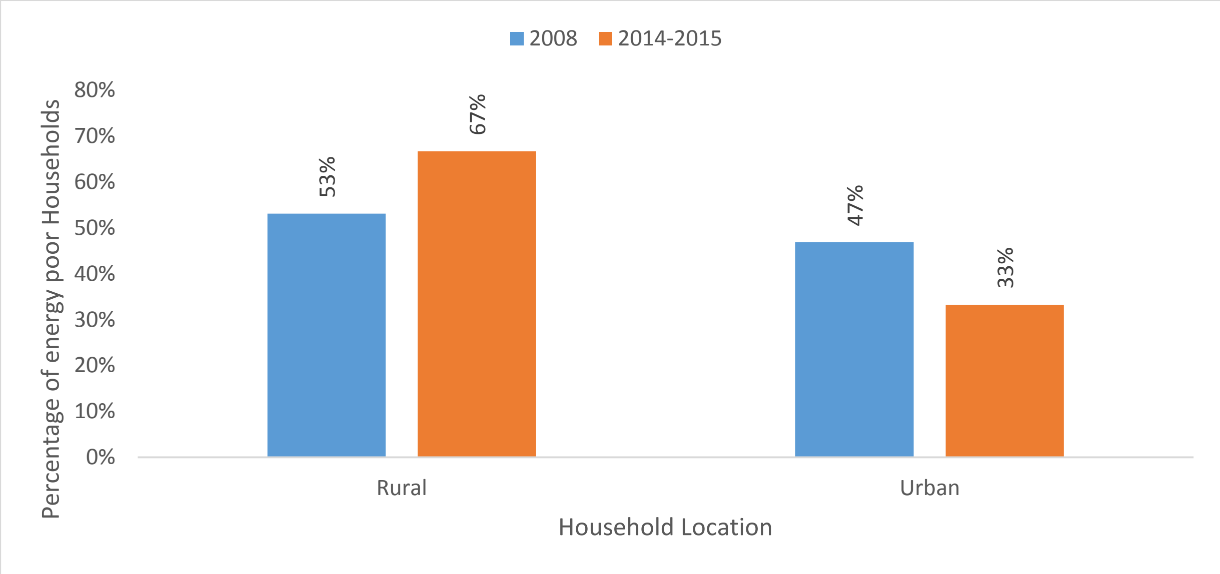

Figure 4.16: Percentage of Energy Poor Households by Household Location using the TPR, 2008 and 2014-2015. Source: Authors' own calculations using NIDS data from SALDRU (2015a; 2016).

4.3.3.2 MEPI Decomposition by Household Location

This section presents results from the decomposition of the multidimensional headcount ratio of energy poverty (Figure 4.17), average intensity of energy poverty (Figure 4.18) and the MEPI (Figure 4.19) by province for 2008 and the 2014-2015. Results from Figure 4.17 show that in 2008, the lowest proportion of multidimensionally energy poor households (36 percent) came from urban areas while the highest proportion (70 percent) came from rural areas. In 2014-2015, the lowest proportion of multidimensionally energy poor households (20 percent) came from urban areas while the highest proportion (36 percent) came from rural areas.

Results from Figure 4.18 show that in 2008, the average intensity of multidimensional energy poverty was lowest in urban areas with 70 percent while it was highest in rural areas with 72 percent. This implies that in 2008, energy poor households were in urban and rural areas were on average deprived of 70 and 72 percent of the weighted indicators, respectively. In 2014-2015, the average intensity of multidimensional energy poverty was lowest in urban areas with 48 percent while it was highest in rural areas with 60 percent. Overall, the result show that average intensity of multidimensional household energy poverty has declined in all provinces.

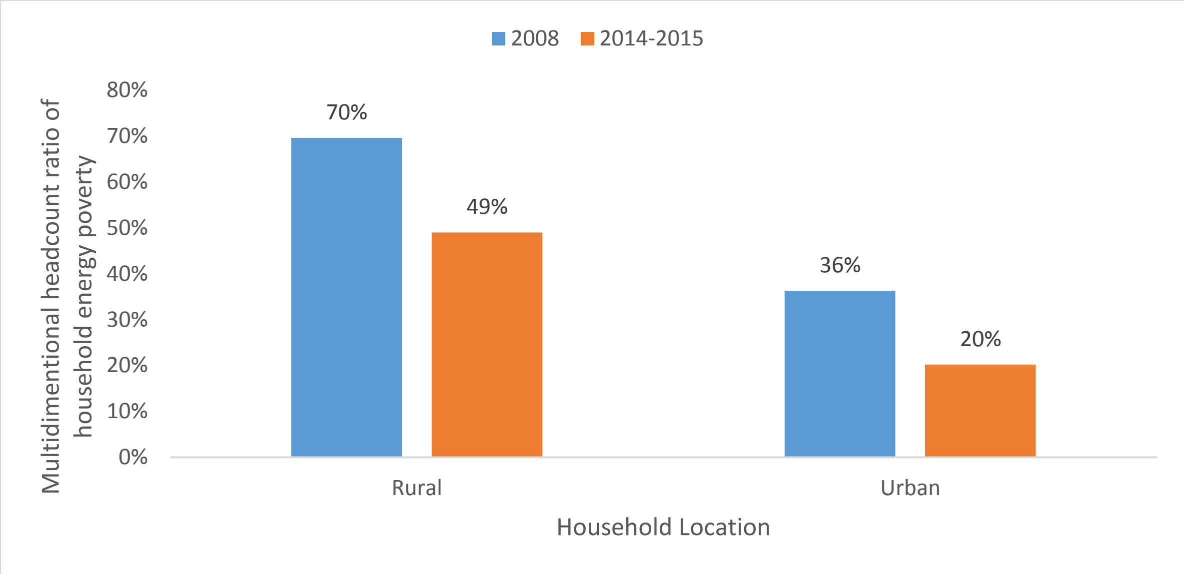

Figure 4.17: Multidimensional Energy Poverty Headcount Ratio, 2008 and 2014-2015. Source: Authors' own calculations using NIDS data from SALDRU (2015a).

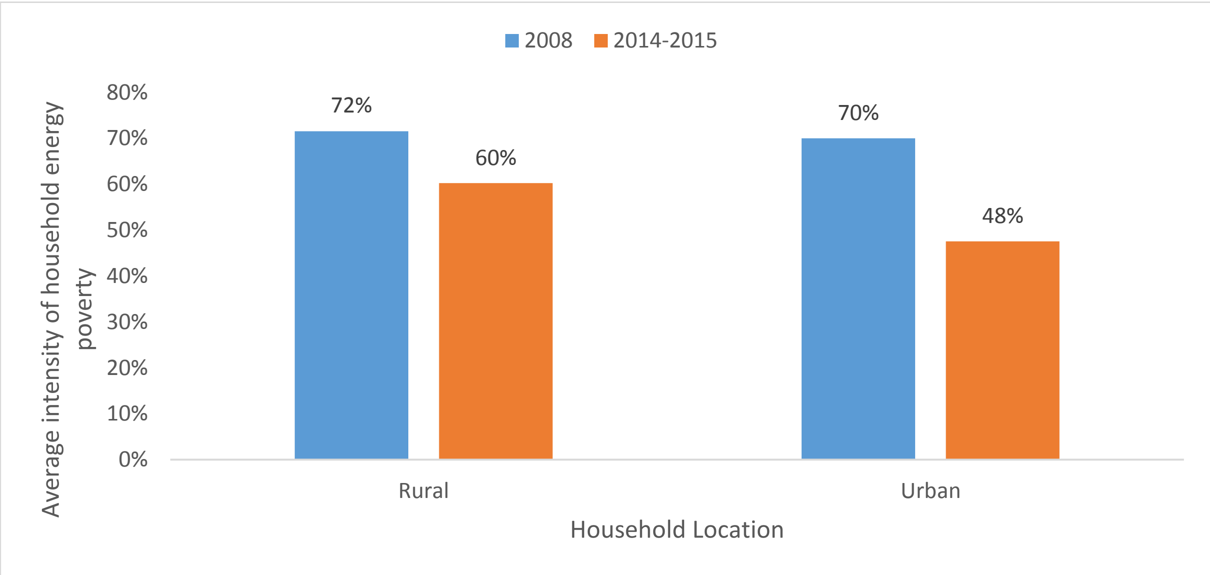

Figure 4.18: Average Intensity by Household Location, 2008. Source: Authors' own calculations using NIDS data from SALDRU (2015a).

Further, results from Figure 4.19 show that in 2008, the MEPI was lowest in urban areas with 25 percent and highest in rural areas with 50 percent. In 2014-2015, the MEPI was lowest in urban areas with 10 percent and highest in rural areas with 30 percent. Overall, the results show a reduction in the MEPI for both urban and rural areas.

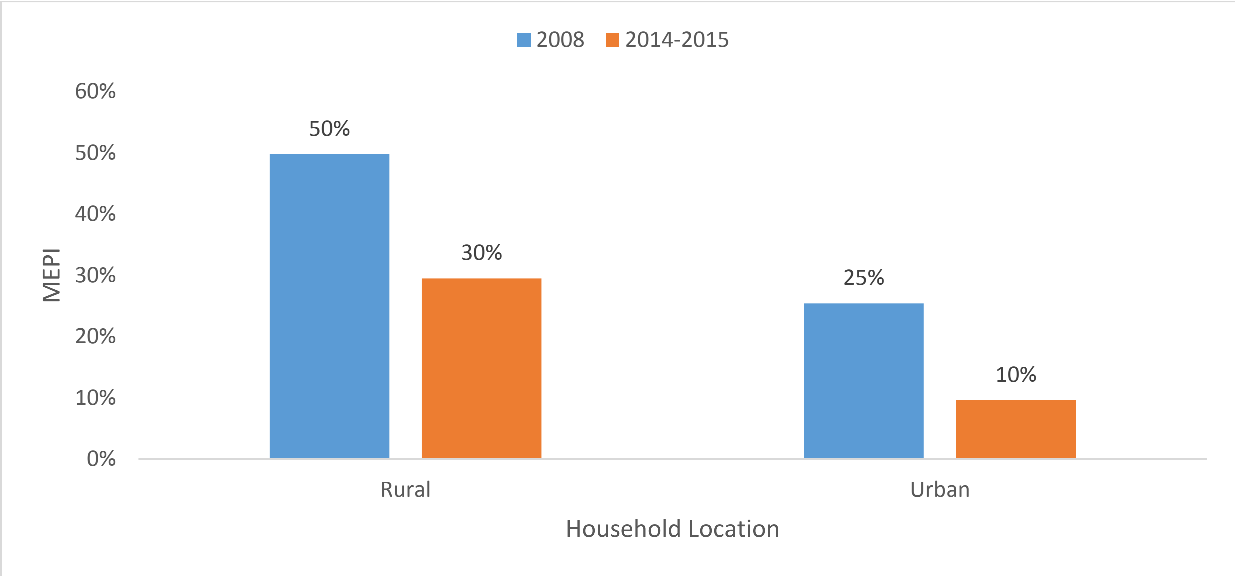

Figure 4.19: MEPI by Household Location, 2014-2015Source: Authors' own calculations using NIDS data from SALDRU (2015a; 2016).

Based on the results of the TPR and MEPI decomposed by household location, a comparison of the multidimensional energy poverty headcount and TPR for 2008 and 2014-2015 can be made. On average, both TPR (in Figure 4.15) and the multidimensional energy poverty headcount (in Figure 4.17) confirm that the percentage of energy poor households has declined between 2008 and 2014-2015 in both, households located in rural and urban areas.

After gaining insight into the levels of household energy poverty in rural and urban areas using the MEPI, this study further provides evidence of which household location (rural or urban energy) contributes the highest to the total number of energy poor households in South Africa in 2008 and 2014-2015. This is achieved by observing the contribution of urban and rural energy poverty to the total number of multidimensional household energy poverty headcount and the MEPI. Table 4.10 presents the results of the urban and rural contribution to the multidimensional headcount ratio of household energy poverty and MEPI for 2008 and 2014-2015. These results confirm the fact that the high multidimensional headcount ratio of energy poverty identified for rural and urban areas in Figure 4.17 have an impact on aggregate energy poverty. Table 4.10 shows that households located in rural areas contributed 62 percent to the total number of multidimensionally energy poor households in 2008, with 70 percent in 2014-2015.

Table 4.10: Contribution by Household Location to Headcount Ratio and MEPI to overall Estimates, 2008 and 2014-2015

Household Location	2008, Wave 1			2014-2015, Wave 4		
	Headcount Ratio (%)	MEPI (%)	Intensity (%)	Headcount Ratio (%)	MEPI (%)	Intensity (%)
Rural	62	63	51	70	74	55
Urban	38	37	49	30	26	45
Total	100	100		100	100	

Source: Authors' own calculations using NIDS data from SALDRU (2015a; 2016).

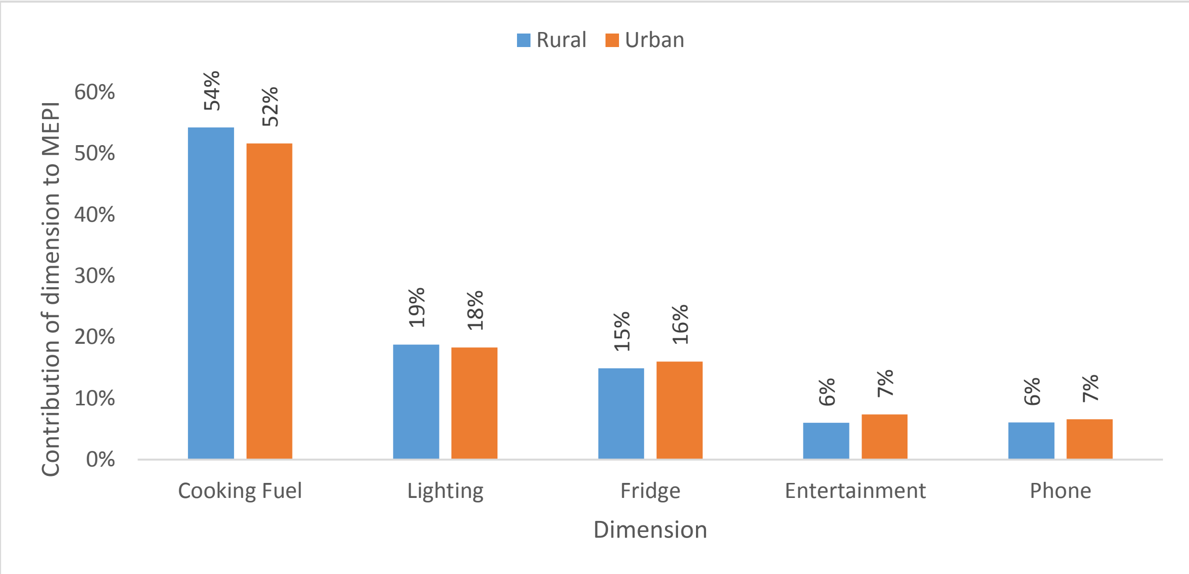

Figure 4.20: Percentage Contribution of Dimensions to MEPI by Household Location, 2008. Source: Authors' own calculations using NIDS data from SALDRU (2015a).

This study has presented results of the multidimensional energy poverty headcount for rural and urban areas and thereafter, the contribution of rural and urban household energy poverty to overall household energy poverty in South Africa. For more focused policy intervention, it becomes more intuitive to analyse how the five indicators contribute to the value of the MEPI. Figures 4.20 and 4.21 present the results of the percentage contribution of each dimension to the MEPI of households located in rural and urban in 2008 and 2014-2015, respectively. It is noted that the contribution of these dimensions sum up to 100 percent in each province[31]. On average, the results show that in 2008, access to modern cooking fuels was the greatest contributor to the MEPI.

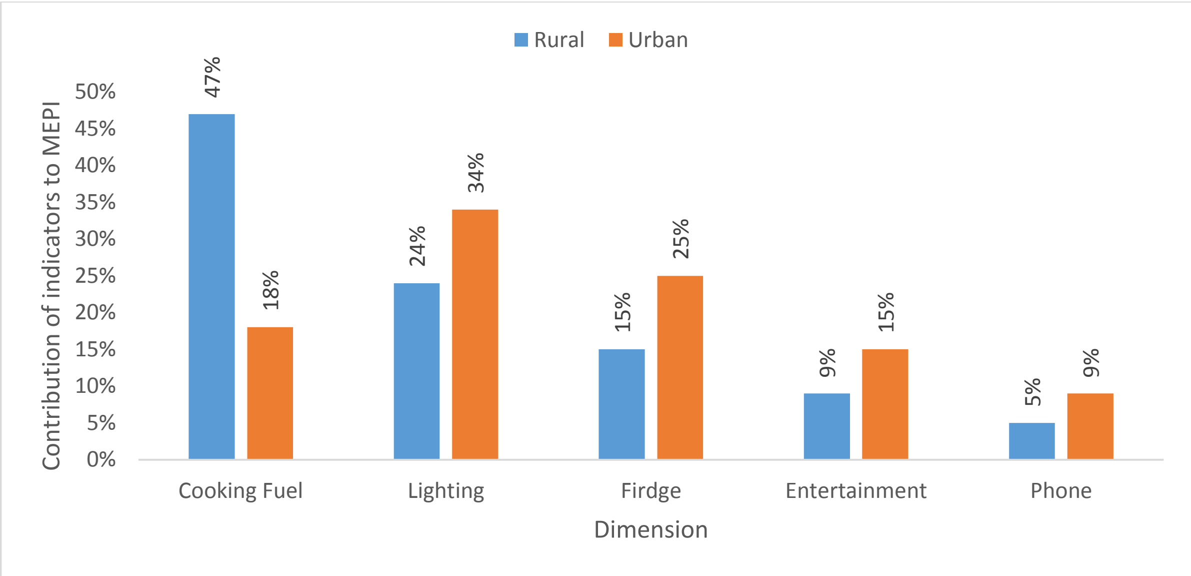

Figure 4.21: Percentage Contribution of Dimensions to MEPI by Household Location, 2014-2015. Source: Authors' own calculations using NIDS data from SALDRU (2016).

The results in Figure 4.21 show on average, a reduction in the deprivation towards access modern cooking fuels in households located in rural areas, with a greater reduction in those located in urban areas. It is noted that the increase in the contribution from access to electricity does not mean that households have become deprived in this indicator but rather, policy interventions towards access to modern cooking fuels has been effective. Therefore, deprivation in modern cooking fuel has become less important among the deprivations households faced. A crucial aspect of these results shows how deprivations may differ between energy poor households located either in rural or urban areas. Policy intervention would require that a household deprived of appliances be given a different intervention strategy to household deprived of modern cooking fuel.

4.4 Sensitivity Analysis

The methodology employed in this study made implicit and explicit assumptions potentially about the deprivation cut-offs for both the TPR and the MEPI. However, these deprivation

[31] In each province, the contribution of percentage contribution of fuel, lighting, fridge, radio/television/computer and phone to the provincial MEPI sum up to 100.

cut-off points are arbitrary and may induce uncertainty in the case of the MEPI if the ranking of decomposed subgroups is not stable. Similarly, the 10 percent energy-budget share requires testing against variations in increasing and decreasing the percentage share to points around the 10 percent loci to ensure the marginal effect is not significant.

4.4.1 Effect of varying the energy-budget share on Results from TPR

Tables 4.11 and 4.12 present the results of the effects of varying the energy-budget share threshold of the TPR for 2008 and 2014-2015, respectively. This study classifies provinces by percentiles based on the TPR with threshold values of 7, 10 and 13 percent in order to determine whether the analysis is robust or not.

Table 4.11: Effects of TPR Threshold Change on Distribution of South African Provinces by Percentiles, 2008

TPR Percentile	Energy-Budget Share Threshold		
	7 percent	10 percent	13 percent
0%	Western Cape	Western Cape	Western Cape
13%	Eastern Cape	Eastern Cape	Northern Cape
25%	Northern Cape	Northern Cape	Eastern Cape
38%	Mpumalanga	North-West	North-West
50%	North-West	Mpumalanga	Mpumalanga
63%	KwaZulu Natal	KwaZulu Natal	Gauteng
75%	Gauteng	Gauteng	KwaZulu Natal
88%	Free State	Free State	Free State
100%	Limpopo	Limpopo	Limpopo

Source: Authors' own calculations using NIDS data from SALDRU (2015a).

The results show that in Table 4.11, varying the threshold between 7 percent and 10 percent does not result in a change in the provincial rankings except for provinces such as Mpumalanga and North-West that switch at 10 percent. Aside from Eastern Cape, Northern Cape, Gauteng and KwaZulu Natal, all provinces maintain their rank when the threshold is varied form 10 percent to 13 percent. Further, results in Table 4.12 show that varying the threshold between 7 percent and 10 percent does not result in a change in the provincial rankings except in the case of Eastern Cape and Mpumalanga that switch. Aside from Eastern Cape, Northern Cape, KwaZulu Nata and Free State, all provinces maintain their rank when the threshold is varied form 10 percent to 13 percent.

Figures 19 and 20 present the results of the effects changing the TPR by 7 percent, 10 percent and 13 percent on household energy poverty levels for 2008 and 2014-2015. In 2008, results from Figure 19 showed a marginal change in household energy poverty levels when the TPR was varied by 7 percent, 10 percent and 13 percent. In 2014-2015, results from Figure 20 showed a marginal change in household energy poverty levels when the TPR was varied by 7 percent, 10 percent and 13 percent.

Table 4.12: Effects of TPR Threshold Change on Distribution of South African Provinces by Percentiles, 2014-2015

TPR Percentile	Energy-Budget Share Threshold		
	7 percent	**10 percent**	**13 percent**
0%	Western Cape	Western Cape	Western Cape
13%	Eastern Cape	Mpumalanga	Mpumalanga
25%	Mpumalanga	Eastern Cape	Northern Cape
38%	Northern Cape	Northern Cape	KwaZulu Natal
50%	KwaZulu Natal	KwaZulu Natal	Eastern Cape
63%	North-West	Free State	North-West
75%	Free State	North-West	Free State
88%	Northern Cape	Northern Cape	Northern Cape
100%	Limpopo	Limpopo	Limpopo

Source: Authors' own calculations using NIDS data from SALDRU (2016)

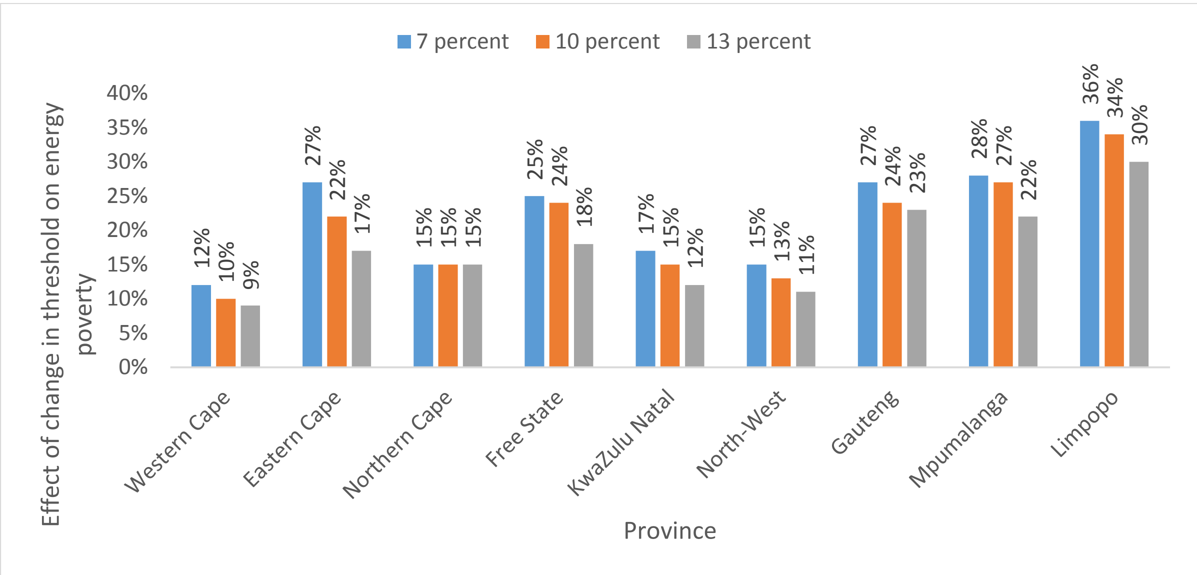

Figure 4.19: Effects of Energy Budget Share Cut-off Change on the TPR, 2008. Source: Authors' own calculations using NIDS data from SALDRU (2015a).

Tables 13 and 14 present the results from the Spearman rank correlation coefficients of the provincial rankings using the TPR for 2008 and 2014-2015, respectively. The results in Table 13 show a very strong correlation for all thresholds, suggesting that the ranking of provinces was stable in 2008. Further, the results in Table 14 show a very strong correlation for all thresholds, suggesting that the ranking of provinces was stable in 2014-2015.

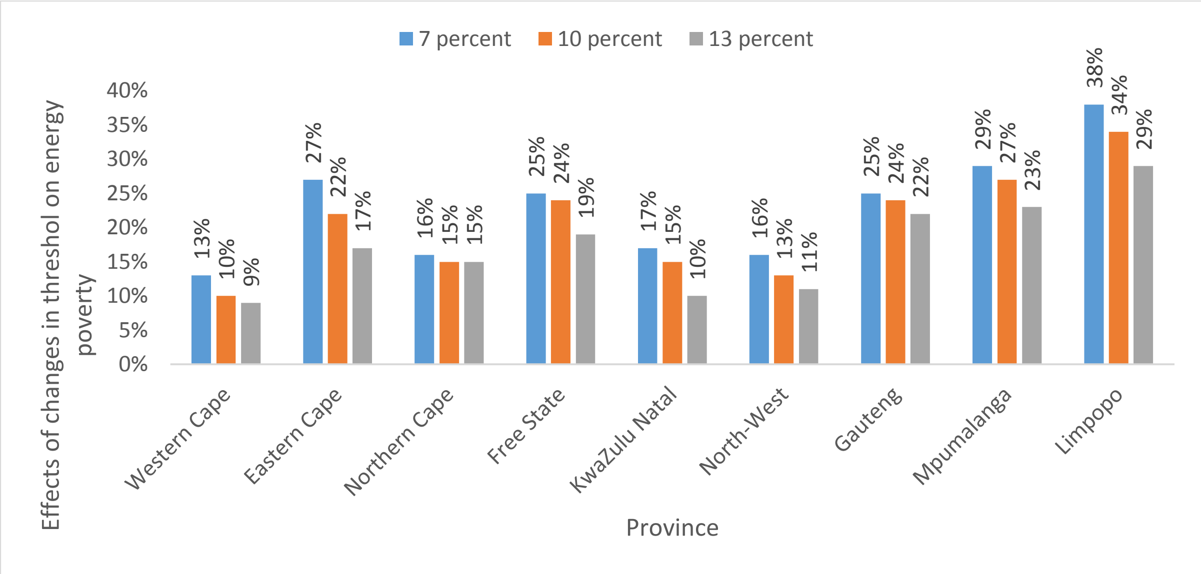

Figure 4.20: Effects of Energy Budget Share Cut-off Change on the TPR, 2014-2015. Source: Authors' own calculations using NIDS data from SALDRU (2016).

Table 4.13: Spearman Correlation in the Provincial Ranking after Varying the MEPI Deprivation Cut-off, 2008

Threshold	Spearman rank correlation coefficient		
	7 percent	10 percent	13 percent
7 percent	1.000		
10 percent	0.954	1.000	
13 percent	0.965	0.949	1.000

Source: Authors' own calculations using NIDS data from SALDRU (2015a).

Table 4.14: Spearman Correlation in the Provincial Ranking after Varying the MEPI Deprivation Cut-off, 2014-2015

Threshold	Spearman rank correlation coefficient		
	7 percent	10 percent	13 percent
7 percent	1.000		
10 percent	0.885	1.000	
13 percent	0.952	0.919	1.000

Source: Authors' own calculations using NIDS data from SALDRU (2016).

4.4.2 Effect of varying deprivation cut-off on Results from the MEPI

Tables 4.15 and 4.16 present the results of the effects of varying the deprivation cut-off *k* on the MEPI for 2008 and 2014-2015, respectively. This study classifies provinces by percentiles based on the MEPI and varies the cut-off by 0.2, 0.3 and 0.4 in order to determine whether the analysis is robust or not. The results show that in Table 4.15, varying the threshold between 0.2 percent and 0.4 does not result in a change in the provincial rankings except for provinces such as Free State and Northern Cape that switch. Aside from North-West and Mpumalanga, all provinces maintain their rank when the cut-off is varied from 0.3 to 0.4. Further, results in Table 4.16 show that varying the threshold 0.3 and 0.4 does not result in a change in all the provincial rankings. Similarly, the ranking of provinces is not changed when the cut-off is varied from 0.3 to 0.4.

Figures 21 and 22 present the results of the effects changing the MEPI by 0.2, 0.3 and 0.4 on household energy poverty levels for 2008 and 2014-2015. In 2008, results from Figure 21 showed a marginal change in household energy poverty levels when the MEPI was varied from 0.2, 0.3 and 0.4. Further, in 2014-2015, results from Figure 22 showed a marginal change in household energy poverty levels when the TPR was varied by 7 percent, 10 percent and 13 percent.

Table 4.15: Effect of MEPI Deprivation Cut-off (*k*) Change on Distribution of South African Provinces by Percentiles, 2008

MEPI Percentile	Distribution of Provinces		
	k =0.2	*k* =0.3	*k* =0.4
0%	Western Cape	Western Cape	Western Cape
13%	Free State	Northern Cape	Northern Cape
25%	Northern Cape	Free State	Free State
38%	North-West	North-West	Mpumalanga
50%	Mpumalanga	Mpumalanga	North-West
63%	Gauteng	Gauteng	Gauteng
75%	Limpopo	Limpopo	Limpopo
88%	KwaZulu Natal	KwaZulu Natal	KwaZulu Natal
100%	Eastern Cape	Eastern Cape	Eastern Cape

Source: Authors' own calculations using NIDS data from SALDRU (2015a).

Tables 17 and 18 present the results from the Spearman rank correlation coefficients of the provincial rankings using the TPR for 2008 and 2014-2015, respectively. The results in

Table 17 show a very strong correlation for all thresholds, suggesting that the ranking of provinces was stable in 2008. Further, the results in Table 14 show a very strong correlation for all thresholds, suggesting that the ranking of provinces was stable in 2014-2015.

Table 4.16: Effects of MEPI Deprivation Cut-off (*k*) Change on Distribution of South African Provinces by Percentiles, 2014-2015

MEPI Percentile	Distribution of Provinces		
	k =0.2	*k* =0.3	*k* =0.4
0%	Western Cape	Western Cape	Western Cape
13%	Free State	Free State	Free State
25%	Gauteng	Gauteng	Gauteng
38%	North-West	North-West	North-West
50%	Northern Cape	Northern Cape	Northern Cape
63%	Mpumalanga	Mpumalanga	Mpumalanga
75%	Limpopo	Limpopo	Limpopo
88%	KwaZulu Natal	KwaZulu Natal	Eastern Cape
100%	Eastern Cape	Eastern Cape	KwaZulu Natal

Source: Authors' own calculations using NIDS data from SALDRU (2015a).

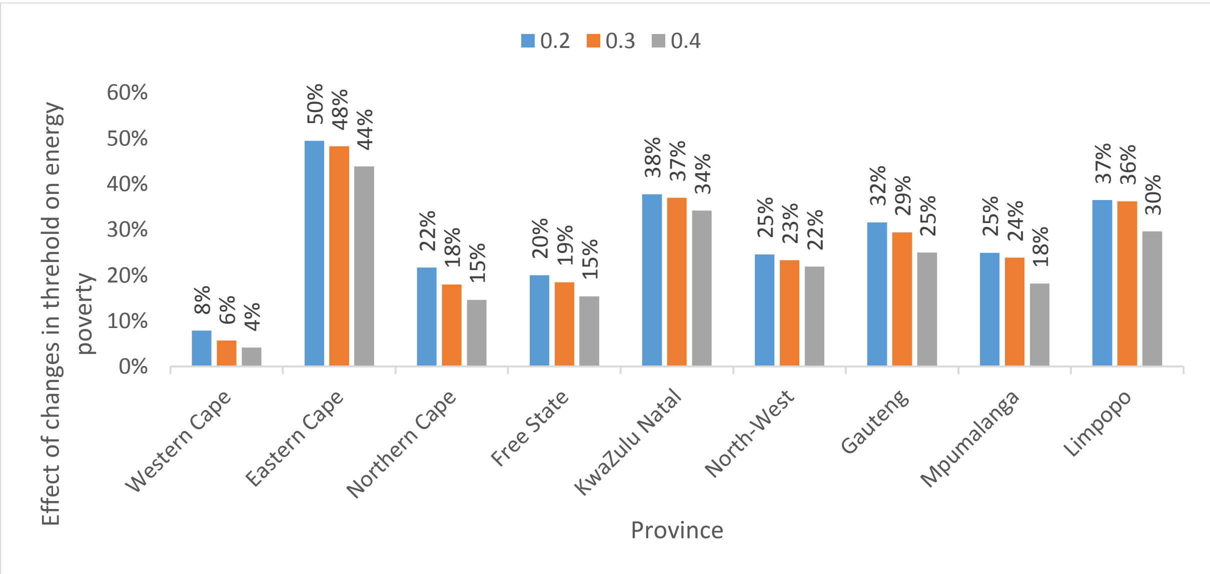

Figure 4.21: Effects of Deprivation Cut-off Change on the MEPI, 2008. Source: Authors' own calculations using NIDS data from SALDRU (2015a).

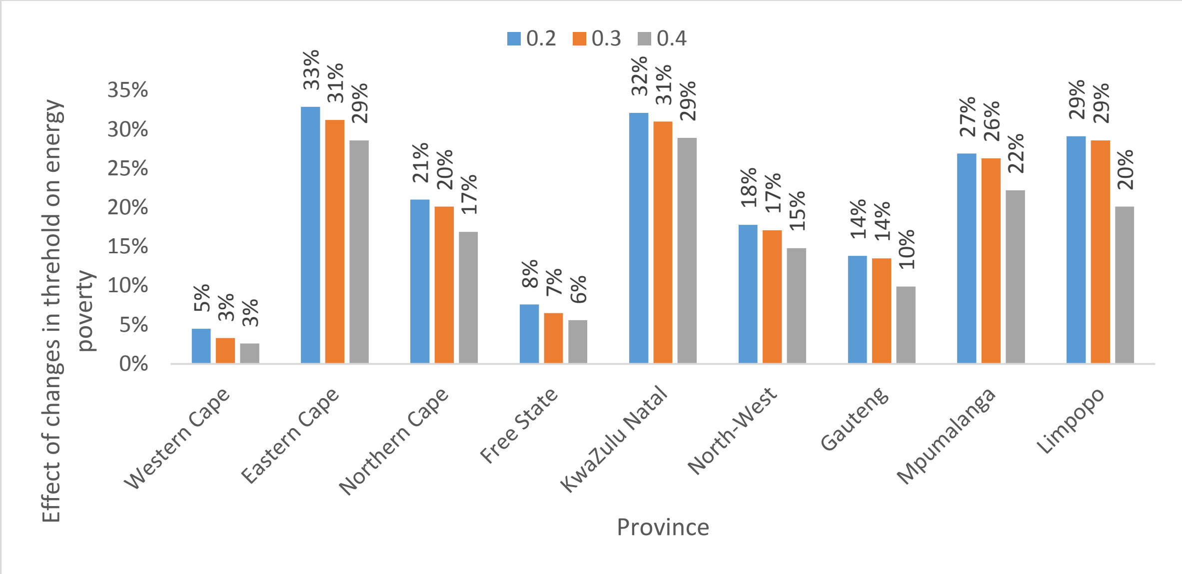

Figure 4.22: Effects of Deprivation Cut-off Change on the MEPI, 2014-2015. Source: Authors' own calculations using NIDS data from SALDRU (2016).

Table 4.17: Spearman Correlation in the Provincial Ranking after Varying the MEPI Deprivation Cut-off (*k*), for 2008 data.

k	Spearman rank correlation coefficient		
	k =0.2	*k* =0.3	*k* =0.4
0.2	1.000		
0.3	0.983	1.000	
0.4	0.967	0.983	1.000

Source: Authors' own calculations using NIDS data from SALDRU (2015a).

Table 4.18: Spearman Correlation in the Provincial Ranking after Varying the MEPI Deprivation Cut-off, 2014-2015

k	Spearman rank correlation coefficient		
	k =0.2	*k* =0.3	*k* =0.4
0.2	1.000		
0.3	0.988	1.000	
0.4	0.967	0.967	1.000

Source: Authors' own calculations using NIDS data from SALDRU (2016).

4.4 Discussion

As indicated in Chapter 2, there is no standard definition or measure of energy poverty. Measuring energy poverty with the existing measures depends on what aspect of energy poverty intends to be captured, given the country or region's demographic, economic and energy sector developments. Determining how the TPR and MEPI conceptually arrive at the household energy poverty estimates presented in this study begins with observing what the descriptive statistics highlight. From the onset, it becomes essential to understand what each metric actually captures. Above all, it does matter how these indicators fit into South Africa's unique developmental path, particularly with economic and energy sector developments, given South Africa's history of apartheid and the uneven geospatial developments in the energy sector. It is even more crucial to understand how each indictor captures energy poverty following previous, current and future energy policy, with particular focus on policies on energy poverty.

4.4.1 Household Energy Poverty

Estimates of national energy poverty using a measure of affordability (TPR) showed that energy poverty among South African households declined from 21 percent in 2008 to 13 percent in 2014-2015. Results from the MEPI also supported the claim of declining multidimensional household energy poverty in South Africa with evidence indicating a decline from 52 percent in 2008 to 34 percent 2014-2015. What appears obvious from these results is the higher percentage of energy poor households identified by the MEPI implies that more households are deprived of access to services compared to those identified by the TPR who do not have the ability to pay for energy services. Results from the MEPI also showed the intensity of multidimensional household energy poverty in South Africa. As reported in Table 4.6, the average intensity of multidimensionally energy poor households declined from 71 to 56 percent. This meant that 15 percent of the households that remained multidimensionally poor in 2014-2015 were on average deprived in fewer indicators than in 2008.

It remains unclear if estimates from the TPR or MEPI either underestimate or overestimate household energy poverty. This is because the two metrics explain different aspects of a complex multidimensional dimensional problem. However, some aspects of energy poverty can best be defined by analysing the descriptive statistics of how these two metrics were constructed. In terms of the TPR, the descriptive statistics in Table 4.1 showed that the median household in South Africa spent R70 and R55 on energy services in 2008 and 2014-2015 after receiving a median household after-tax income of R1776 and R2752, respectively. By calculating[32] whether the median household is energy poor using the TPR, the results show that the bottom half of the South African population spent 4 and 2 percent of their after-tax income on energy services in 2008 and 2014-2015, respectively. Therefore, if energy poverty were a problem deemed as common to income poor households, it would be expected that these households would be concentrated at the bottom end of the income distribution. However, if the results show that the bottom half of the population spend less than 10 percent of household income on energy services, it would not be surprising if the TPR failed to capture these households as non-energy poor. Using such a measure of energy poverty would therefore be prone to underestimate energy poverty as evidence showed that that the bottom half of South African households have very low incomes and are asset poor (Mbewe & Woolard, 2016).

From a developmental perspective, household income of the energy poor people has been increasing between 2008 and 2014-2015. From an energy poverty perspective, this has been noted through converging levels of energy expenditure between high-income households and low-income households. Table 4.2 showed that in 2008, households in the top income decile spent 4.5 times more on energy, compared to households in the bottom decile. By 2014-2015, top income households only spent 1.5 times more on energy services, compared to households in the bottom decile. A reasonable explanation to this could be the rising electricity price owing to inclining block tariffs that have seen greater proportional tariff increases for higher consumers (who tend to be rich).

Among the least income-earning households, the descriptive statistics of TPR also showed that some households spent nothing on energy services. A possible explanation lies in both – the actions of households with electricity – and those without electricity. For instance, a household with electricity, but yet, classified, as income poor may spend nothing on electricity and appear as energy non-poor off if their electricity consumption is within the Free-Basic Electricity (FBE). The FBE is a pro-poor South African government policy meant to

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[32] The ratio between household energy expenditure and household after-tax income. Therefore, median energy poverty was 4 percent $(70/1776 * 100\,percent)$ in 2008 and 2 percent in $(55/2752 * 100\,percent)$ in 2014-2015.

afford free electricity services to poor households with prepaid meters a predetermined threshold of kilowatt-hours consumed[33]. Evidence from Sustainable Energy Africa (2014) reports that 51 percent of income and asset poor households are still reliant on FBE. Therefore, high rates of electrification rates need not imply, particularly for low-income households, an improvement in welfare or reduction in energy poverty if the households cannot afford electricity services.

4.4.2 Subgroup Analysis of Household Energy Poverty

Empirical evidence has often suggested that national estimates tend to disguise subnational estimates of household energy poverty (Khandker, Barnes & Samad, 2010; Sustainable Energy Africa, 2014). Results in this study have added to the existing evidence by showing how national estimates in South Africa often mask estimates decomposed by the geographic, socioeconomic and temporal incidence of household energy poverty.

4.4.2.1 Provincial Energy Poverty Estimates

Focusing on the geographic and temporal incidence, the results of the provincial decomposition of the TPR and MEPI showed on average, higher estimates of household energy poverty compared to national estimates in 2008 and 2014-2015. Even among provinces, the results showed different levels of household energy poverty. For instance, the TPR showed that household energy poverty was much lower in Western Cape Province and higher in Eastern Cape and Limpopo provinces in 2008 and 2014-2015. Though results from the MEPI support this claim, what was also common among all multidimensionally energy poor households in each province was the similarity in the intensity of multidimensional energy poverty. The vast majority of multidimensionally poor households were on average, deprived of similar indicators. From the results of the MEPI, it is obvious that the lack of access to modern cooking fuels was the highest contributor to multidimensional energy poverty in 2008, followed by the lack of electricity by poor households. Lack of access to modern cooking fuels often leads to using inferior fuels, such as firewood. Not only does the continuance of such practices result in deforestation, but the use of such fuels also results in indoor pollution if the household does not have a chimney or hood. Women and children are often the first in line to suffer respiratory complications as result of exposure to hazardous smoke during cooking.

[33] Available: http://www.energy.gov.za/files/faqs/faqs_freebasic.html [Accessed: 2017, February 12].

Though the lingering problem for some provinces is the lack of access to electricity, provinces with the highest number of energy poor households such KwaZulu Natal are still burdened with lack of access to modern cooking fuels in 2014-2015. For policymaking, it is often crucial to have a sense of which deprivation is more pressing. For example, the policy intervention required for a province with a high number of energy poor households deprived of modern cooking fuels in 2014-2015 will differ from a province like Free State, which lacks electricity access.

This difference in national and provincial estimates in South Africa however has more to do with the country's unique history of apartheid, which has created a unique developmental path by economic opportunity, province or location. For instance, the timing of electricity rollout started post-1994 took different time horizons geographically. For instance, the pace at which wealthy provinces such as Western Cape were electrified was faster relative to provinces such as Limpopo and the Eastern Cape (Kholer *et al.*, 2009). There is consensus between the two measures proposing that in 2008, the KwaZulu Natal, Eastern Cape and Gauteng had the highest number of households living in energy poverty. While there was a reduction in overall number of households living in energy poverty by 2014-2015, both the TPR and MEPI show progress in KwaZulu Natal and Eastern Cape has been much slower.

4.4.2.2 Household Energy Poverty by Income Poverty Status

The growing literature on the link between energy poverty and actual poverty has often associated poverty as an income phenomenon (Khandker *et al.*, 2010). In other words, the energy poverty field of scholarship has also inherited the view that energy poverty is concentrated among income poor households. This study has provided evidence showing the severity of energy poverty among households living below the FPL of R430, the LBPL of R667, UBPL of R1275 and those that are non-income poor. Results from TPR and MEPI showed that household energy poverty is falling as household income rises. This would be evident in households transitioning from lower poverty lines (FPL) to higher poverty line (UBPL). In other words, energy poverty decreases as a households' ability to pay rises, which is noted through rising income. While the MEPI does not capture the concept of affordability, it sounds logical to lay the claim that rising income would serve as a proxy for ability to pay for services.

The results of both the TPR and MEPI showed that the majority of energy poor households, relative to the other poverty lines, also lived below the FPL. Using the TPR, about 33 and 23 percent of households that lived below the FPL were also energy poor in 2008 and 2014-2015, respectively. If average household income is below the FPL, this implies that a household does not have sufficient income to purchase food adequate for a balanced diet. It is only logical that these households are considered energy poor because they have very low household income to cater for the household size. It comes as no surprise that the majority of energy poor households are also income poor, especially in a country like South Africa with high income inequality and an associated Gini coefficient of 0.69 as evidenced by Finn and Leibbrandt (2013).

Interestingly, some of the non-income poor households happened to be energy poor. This presents a paradox and perhaps, one of the major shortcoming of the TPR as a measure of energy poverty. A reasonable explanation lies in the fact that while the TPR is meant to also proxy for the ability to pay, this measure tends to classify even high income households that are able to pay for energy services exceeding 10 percent of their income.

4.4.2.3 Household Energy Poverty by Household Location

This study further decomposed household energy poverty by household location (rural versus urban) to provide an additional description to the geographic and temporal incidence. The results provided evidence of how household energy poverty is not just a rural phenomenon but also one also pervasive among urban households. The TPR reported that rural and urban household energy poverty was 24 and 18 percent in 2008 and declined to 18 and 8 percent in 2014-2015, respectively. The reduction in urban energy poverty was higher than the reduction in rural poverty. In South Africa, urban household energy poverty was mostly as results of rapid urbanization that was experienced in the post-apartheid period. Evidence from the National Development Plan showed that 64 percent of South Africa's population is now residing in urban areas (NDP, 2010). However, while the system of apartheid opened a geographical formation of cities in low densely populated suburban areas, most of the poor households have emerged there with poor service delivery, a huge deterrent to human development.

The MEPI reported that in 2008, 36 percent of households located in urban areas where multidimensionally energy poor while 70 percent of households in rural areas where energy poor. By 2014-2015, only 20 percent of households in urban areas where energy poor while 36 percent of households in rural areas remained energy poor. Despite the notable difference between energy poverty in rural areas and urban areas in 2008, the intensity of energy poverty of households in rural areas (72 percent) compared to those in urban areas (70 percent) indicate that they were all deprived in not less than 70 percent of the weighted indicators. By 2014-2015, the intensity of energy poverty declined to 60 percent in rural areas and 48 percent in urban areas. The decline was higher in urban areas, suggesting that energy poor households where now deprived of less indicators compared to those in rural areas.

4.4.2.4 Sensitivity Analysis

The results from the sensitivity analysis showed that all estimates from the TPR and MEPI were robust in 2008 and 2014-2015. This was observed through how provinces ranked when the energy poverty threshold or cut-off was varied for both measures. The Spearman Rank Correlation Coefficient also confirmed that robustness of the marginal changes. The TPR gives lower estimates of energy poverty than the corresponding values obtained from the MEPI measure. There is negligible effect of varying the threshold values (within the studied range) of the TPR and k.

Chapter 5
Conclusions and Recommendations

The existing lack of access to reliable, affordable and modern energy services in developing countries is a hindrance to social and economic development. Energy poor households resort to using unclean energy sources such as firewood, paraffin and animal dung for their cooking, lighting and heating needs. Using such energy fuels causes indoor pollution and exposes people to health hazards. Women and children, who often spend most of their time in the kitchen, are at a higher risk of developing respiratory illnesses. Environmentally, using energy fuels such as firewood contributes to deforestation when households cut down trees to provide for their energy needs. Existing evidence shows that the most energy poor households are located in rural areas.

In South Africa, policy efforts to eradicate energy poverty have been implemented in the form of rural electrification programmes and the Free Basic Electricity programme. Like in most developing countries, it however remains problematic to identify adequately, energy poor households. With global efforts to obtain universal access to energy services by 2030, it is critical for countries to use effective measures for tracking and monitoring energy poverty. Recent trends in measuring energy poverty show a movement away from using unidimensional indicators to using multidimensional measures. Partly due to lack of data, very limited research had been applied in the South African context.

With access to data, this study aimed at evaluating household energy poverty in South Africa using unidimensional and multidimensional measures. These measures were applied to South African data from wave 1 (2008) and wave 4 (2014-2015) of the National Income Dynamic Study (NIDS). To realize this aim, it was required to arrive at some preconditioned objectives. Conceptualizing the meaning of energy poverty and how it is measured, assumed great importance in the review of the literature for this study. Linked to that effort, it was essential to motivate why this study defined and measured unidimensional household energy poverty using the energy-budget share (also known as the Tenth-Percentile Rule, TPR) as well as multidimensional household energy poverty using the multidimensional energy poverty index (MEPI). By means of the TPR measure, households were considered energy poor if more than 10 percent of after-tax income was spent on energy services. In the case of the MEPI, households were considered energy poor if the sum of weighted deprivations in the 5 indicators exceeded a cut-off *k* of 0.3.

In addition to estimating national household energy poverty using the two measures, it proved necessary to estimate and describe the geographic, socioeconomic and temporal incidence of household energy poverty through decomposing estimates by province, household income poverty status and household location (urban versus rural). The rationale for decomposing these estimates was to confirm the supposition that national estimates often disguise subnational estimates in South Africa. This chapter draws conclusions of this study and provides policy recommendations.

5.1 Conclusions

The legacy of Apartheid, which resulted in high income and wealth inequalities in South Africa between-race and within-race groups, created a unique development path for the country. In the context of energy poverty, evidence from this study showed that some households are still living in energy poverty – characterised through differences in household energy poverty estimates by province, household income poverty status and household location (rural or urban).

At national-level, this study found (using the TPR) that 21 percent of households in South Africa where energy poor in 2008 and by 2014-2015, only 13 percent of the households where energy poor. Results also showed (using the MEPI) that 52 percent of households were multidimensionally energy poor in 2008 and by 2014-2015, only 34 percent were multidimensionally energy poor. Further, this study also found that multidimensionally energy poor households in South Africa were on average deprived in 71 and 56 percent of the weighted indicators in 2008 and 2014-2015, respectively. The lack of access to modern cooking fuel was the main driver of multidimensional household energy poverty.

This study also described the geographic, socioeconomic and temporal incidence of household energy poverty. The findings confirmed that national estimates of household energy poverty mask subnational estimates by province, household income poverty status and household location. For instance, provincial estimates of energy poverty (using the TPR) were lowest (10 and 5percent) in Western Cape Province and highest (34 and 25 percent) in Limpopo province in 2008 and 2014-2015, respectively. This study found that (using the MEPI) provincial estimates of energy poverty were lowest (8 percent) in Western Cape Province and highest (75 percent) in Eastern Cape in 2008. In 2014-2014, provincial estimates of energy poverty were lowest (9 percent) in Western Cape Province and highest (52 percent) in Limpopo. This difference between energy poverty estimates was attributed to the unique developmental path each province had taken due to the role of apartheid. Obviously, more wealthy provinces like Western Cape had the opportunity of a more stable development path during apartheid, which explains the low level of household energy poverty.

Further, this study found an inverse relationship between household income poverty status and energy poverty – implying that rising household income reduces the possibility of being energy poor. Energy poor households from the TPR (33 and 23 percent) and MEPI (62 and 46 percent) also lived below the food poverty line R430. This meant that most of the energy poor households did not even have sufficient income to afford adequate food. This study found that some of the non-income poor households happened to be energy poor. A reasonable explanation was that although the TPR is meant to proxy for the ability to pay, this measure tends to classify even rich households with the ability to pay for energy services so long it exceeds 10 percent of their income.

In addition, findings of this study showed that estimates of both the TPR (24 and 18 percent) and the MEPI (70 and 49 percent) reported higher rates of energy poverty for households located in rural areas as compared to those in urban areas in both, 2008 and 2014-2015, respectively. However, this study identified that the estimates from the TPR, compared to the MEPI, are likely to be underestimated as evidence has previously shown that rural households often rely on non-monetary energy sources such as animal dung or firewood. As such, rural households would be expected to spend relatively small amounts of money on energy services. This study further found that, more households were identified as energy poor under the MEPI. This was attributable to the rapid urbanization that has been experienced in South Africa in the post-apartheid era. This era led to a formation of cities in low densely populated suburban areas – resulting in poor service delivery in these areas, including energy services.

In summary, this study has added the following to the existing literature on energy poverty. Firstly, while most of the studies in South Africa have relied on estimating energy poverty using unidimensional measures, this study has provided household estimates of energy poverty from a multidimensional perspective – making it the first study to construct the MEPI. Second, using the two measures, this study has provided evidence of how national estimates tend to disguise subnational estimates of energy poverty in South Africa, by decomposing household energy poverty estimates by province, household income poverty status and household location. Overall, household energy poverty has reduced in South Africa between 2008 and 2014-2015. It has been established that the TPR gives lower estimates of energy poverty than the corresponding values obtained from the MEPI measure. An explanation to this lies in the fact that, although these two measures capture different dimensions of energy poverty, estimates of the TPR are lower because many poor households spend little on energy services. Since they lack income, poor households end up rather using non-monetary energy sources such as firewood and animal dung. This effectively underestimates energy poverty, given that firewood and animal dung are not captured as a monetary expenditure on energy services. Finally, the sensitivity analysis performed for both measures of energy poverty has confirmed the robustness of the results in this study. Changes in the energy poverty threshold (TPR) or cut-off point (MEPI) marginally change the ranking of provinces.

5.2 Recommendations

The findings of this study highlight certain policy implications. It is therefore recommended that when choosing a measure of energy poverty, thorough understanding of the social and economic dynamics of the country is required. In the context of South Africa, where income and wealth inequalities are high, a measure capable of being decomposed offers more information for policy intervention. Additionally, understanding energy poverty should go beyond national estimates and focus on subnational estimates by wealth, income, location and province.

Future research should consider using more comprehensive datasets encompassing various indicators (such as consumption) of energy services to allow for the construction of several unidimensional and multidimensional measures of energy poverty. A more comprehensive dataset would give support for the estimation of more complex measures of energy poverty such the Multi-Tier Framework of ESMAP. Other futures works should consider exploring the determinants of energy poverty in the context of South Africa.

6. Appendices

Table 6.1: NIDS Questionnaire Extract for Questions used to construct the TPR for 2008 and 2014-2015

Survey Questions in NIDS Wave 1 and 4 Used to Construct the TPR

Amount Spent on Energy Sources

- How much was spent on electricity in the last 30 days? **Responses: (1) Amount (2) Refuse (3) Don't Know**
- How much was spent on other energy sources such as wood, paraffin, charcoal/coal, candles, gas, purchasing/charging batteries and diesel oil for generators in the last 30 days? **Responses: (1) Amount (2) Refuse (3) Don't Know**

Total Household Income After-Tax

- What was the total amount of income (after income tax) that this household received last month? **Responses: (1) Amount (2) Refuse (3) Don't Know**

Source: SALDRU (2016)

Table 6.2: NIDS Questionnaire Extract for Questions used to construct the MEPI for 2008 and 2014-2015

Survey Questions in NIDS Wave 1 and 4 Used to Construct MEPI Indicators

Modern Cooking Fuel

- What is the main source of cooking fuel for this household? **(Electricity from mains; Electricity from generator; Gas; Paraffin; Wood ;Coal ;Candles ;Animal Dung ;Solar Energy ;Other (specify) ;None ;Refuse)**

Electricity Access

- Does this household have electricity even if currently disconnected? **(Yes | No)**

Fridge

- Does the household own at least one fridge? **(Yes | No)**

Entertainment

- Does the household own at least one radio? **(Yes | No)**
  Does the household own at least one television? **(Yes | No)**
- Does the household own at least one computer? **(Yes | No**)

Phone

- Does the household own a mobile phone? **(Yes | No)**
- Does the household own at least one landline phone? **(Yes | Yes but disconnected | No)**

Source: SALDRU (2016)

Table: 6.3: Descriptive Statistics of South African Household After-Tax Income before Dropping Outlier as the Maximum, 2008 and 2014-2015

Percentiles	Monthly Household After-Tax Income 2014-2015 (Wave 4)
(%)	(R)
1%	315
5%	641
10%	964
25%	2753
(Median) 50%	5000
75%	5172
90%	10720
95%	19491
99%	36500
Mean	65760
Minimum	3
Maximum	50000000

Source: Authors' own calculations using NIDS data from SALDRU (2015a; 2016).

Table 6.4: Income Poverty Lines and Income Poverty Headcount Ratio adjusted to November 2014 Prices, 2008 and 2014-2015

Poverty Line	2008 Wave 1	2014-2015 Wave 4
Food Poverty Line (FPL)		
Rands	430	430
Headcount	40%	24%
Lower Bound Poverty Line (LBPL)		
Rands	667	667
Headcount	15%	16%
Upper Bound Poverty Line (UBPL)		
Rands	1275	1275
Headcount	18%	23%
Non-Poor		
Headcount	27%	37%

Source: Authors' own calculations using NIDS data from SALDRU (2015a; 2016).

References

Alkire, S. & Foster, J. 2007. Counting and multidimensional poverty measurement. *OPHI Working Paper No.* 7. Oxford Poverty and Human Development Initiative, University of Oxford. Available: http://www.ophi.org.uk/wp-content/uploads/ophiwp7.pdf. [Accessed: 2017, January 30].

Alkire, S. & Foster, J. 2011. Counting and multidimensional poverty measurement. *Journal of Public Economics* 95 (7): 476 487.

Alkire, S. & Santos, M.E. 2011. Training material for producing national human development reports. Available: http://www.ophi.org.uk/wp content/uploads/MPI_TrainingMaterial_23Nov2011.pdf [Accessed: 2016, December 5].

AGECC [Advisory Group on Energy and Climate Change, United Nations]. 2010. Energy for a sustainable future. New York.

Asteriou, D. & Hall, S.G. 2011. Applied Econometrics*: A Modern Approach.* Palgrave Macmillan, New York.

Barnes, D.F., Shahidur, R.K. & Hussain, A.S. 2011. Energy poverty in rural Bangladesh. *Energy Policy*. 39 (2): 894-904.

Bazilian, M., Nussbaumer, P., Cabraal, A., Centurelli, R. *et al.* 2010. Measuring energy access: Supporting a global target. Available: https://www.iaea.org/OurWork/ST/NE/Pess/assets/2010measuring-energy access.pdf [Accessed: 2016, May 18].

Budlender, J., Leibbrandt, M. & Woolard, I. 2015. South African poverty lines: a review and two new money-metric thresholds *A Southern Africa Labour and Development Research Unit Working Paper Number* 151. Cape Town: SALDRU, University of Cape Town.

Bensch, G. 2013. Inside the metrics–an empirical comparison of energy poverty indices for sub-Saharan countries. Ruhr Economic Paper No. 464.

Bhatia, M. & Angelou, N. 2014. *Capturing the Multi-Dimensionality of Energy Access.* World Bank, Washington, DC. Available: https://openknowledge.worldbank.org/handle/10986/18677 [Accessed: 2016, April 18].

Boardman, B. 1991. *Fuel Poverty. From Cold Homes to Affordable Warmth*. Belhaven Press: London.

Bouzarovski, S. & Petrova, S. 2015. A global perspective on domestic energy deprivation: Overcoming the energy poverty–fuel poverty binary. *Energy Research & Social Science*. 10 (2015) 31–40.

Bravo, V.G., Gallo Mendoza, J., Legisa, C.E. Suarez, I. & Zyngierman, I. 1979. Estudio Sobre Requerimientos Futuros No Convencionales de Energia en America. Report to the United Nations Development Program, 1979. Cited in Khandker, S.R., Barnes, D.F. & Samad, H.A. 2010. *Energy Poverty in Rural and Urban India: Are the Energy Poor Also Income Poor?* Policy *Research Working Paper No.* 5463.

Creswell, J.W. 1994. *Research Design: Qualitative & Quantitative Approaches*. London: SAGE Publications.

Day, R., Walker, G. & Simcock, N. 2016. Conceptualising energy use and energy poverty using a capabilities framework. *Energy Policy* 93 (2016): 255-264.

Daniels, R.C. & Augustine, T. 2016. The measurement and distribution of household wealth in South Africa using the National Income Dynamics Study (NIDS) Wave 4. Cape Town: SALDRU, University of Cape Town. *SALDRU Working Paper Numbe*r 183/ NIDS Discussion Paper 2016/10.

Daniels, R.C., Finn, A. & Musundwa, S. 2014. Wealth data quality in the National Income Dynamics Study Wave 2. Development Southern Africa. 31 (1): 31-50.

DOE [Department of Energy, Republic of South Africa]. 2003. *Annual Report, 2002/2003.*

DOE [Department of Energy, Republic of South Africa]. 2009. *Annual Report, 2008/2009.*

DOE [Department of Energy, Republic of South Africa]. 2013. *Annual Report, 2012/2013.*

DOE [Department of Energy, Republic of South Africa]. 2014. *Annual Report, 2013/2014*.

DOE [Department of Energy, Republic of South Africa]. 2015a. *Annual Report, 2014/2015*.

DOE [Department of Energy, Republic of South Africa]. 2015b. Sate of Renewable Energy in South Africa.

DECC [Department of Energy and Climate Change, British Government]. 2009. The UK fuel poverty strategy: 7th annual progress report 2009. London.

Edoumiekumo, S.G. & Karimo, T.M. 2014. Multidimensional energy poverty in Bayelsa State of Nigeria: Implications for sustainable development. *African Journal for Social Sciences*. 4 (1): 135-145.

Edoumiekumo, S.G., Tombofa, S.S. & Karimo, T.M. 2013. Multidimensional energy poverty in the South-South Geopolitical Zone of Nigeria. *Journal of Economics and Sustainable Development*. 4 (20): 96-103.

ESMAP [Energy Sector Management Assistance Program]. 2014. A New Multi-Tier approach to measuring energy access. Available: https://openknowledge.worldbank.org/bitstream/handle/10986/18677/886990BR0Live00Box385194B00PUBLIC0.pdf;sequence=4 [Accessed: 2017, February 11].

Falk, G., Herrmannm, F. & Schmid, G.B. 1983. Energy forms or energy carriers? *American Journal of Physics*. 51 (1983): 1074-1077.

Foster, V., Tre, J. & Wodon, Q. 2000. Energy prices, energy efficiency, and fuel poverty. Infrastructure reform and the poor in the Latin America Region, World Bank

Goldemberg, J., Johansson, T.B., Reddy, A.K.N. & Williams, R.H. 1985. Basic needs and much more with one kilowatt per capita. *Ambio*. 14: 190-200.

Gonzalez-Eguino, M. 2015. Energy poverty: An overview. *Renewable and Sustainable Energy Review*. 47 (2015): 377-385.

Government of India. 2005. National Electricity Policy. Ministry of Power, Government of India.

Groh, S., Pachauri, S. & Narasimha, R. 2016. What are we measuring? An empirical analysis of household electricity access metrics in rural Bangladesh. *Energy for Sustainable Development.* 30 (2016): 21–31.

Gujarati, D.N. & Porter, D.C. 2009. Basic econometrics. McGrawhill

IEA [International Energy Agency]. 2010. *World Energy Outlook 2010*. Paris: International Energy Agency.

IEA [International Energy Agency]. 2014. *World Energy Outlook 2014*. Paris: International Energy Agency.

IEA [International Energy Agency]. 2015. *World Energy Outlook 2015*. Paris: International Energy Agency.

IEA [International Energy Agency]. 2016. *World Energy Outlook 2016*. Paris: International Energy Agency.

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

Kallet, R.H. 2004. How to write the methods section of a research paper. *Respiratory Care.* 49 (2004): 1229-1232.

Khandker, S.R., Barnes, D.F. & Samad, H.A. 2010. *Energy Poverty in Rural and Urban India: Are the Energy Poor Also Income Poor? Policy Research Working Paper No.* 5463. Available: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1701524 [Accessed: 2016, May 20].

Kohler, M., Rhodes, B. & Vermaak, C. 2009. Developing an energy-based poverty line for South Africa. *Journal of Interdisciplinary Economics.*

Kothari, C.R. 2009. *Research Methodology: Methods & Techniques*. 2nd Revised Ed. New Age International Publishers: New Delhi.

Kateregga E. 2009. The welfare costs of electricity outages: A contingent valuation analysis of households in the suburbs of Kampala, Jinja and Entebbe. *Journal of Development and Agricultural Economics*. 1(1): 1-11.

Krugman, H. & Goldemberg, J. 1983. The energy cost of satisfying basic human needs. *Technological Forecast and Social Change*. 24: 45-60.

Mbewe, S. & Woolard, I. 2016. Cross-Sectional Features of Wealth Inequality in South Africa: Evidence from the National Income Dynamics Study. Cape Town: SALDRU, University of Cape Town. *SALDRU Working Paper* Number 185/ NIDS Discussion Paper 2016/12.

Mirza, B. & Szirmai, A. 2010. Towards a new measurement of energy poverty: a cross community analysis of rural Pakistan. *UNU-MERIT Working Paper* Series No. 024, United Nations University, Maastricht Economic and social Research and training centre on Innovation and Technology.

NIDS [National Income Dynamics Study]. 2012. National Income Dynamics Study Wave 2 User Manual.

Nussbaum, M.C. 2011. Creating capabilities: The human development approach. Harvard University Press, Cambridge MA.

Nussbaumer, P., Bazilian, M., Modi, V. & Yumkella, K.K. 2011. Measuring energy poverty: focusing on what matters. *OPHI Working Papers* 42, University of Oxford. Available: http://www.ophi.org.uk/measuring-energy-poverty-focusing-on-what matters/[Accessed: 2016, April 18].

Nussbaumer, P., Bazilian, M. & Modi, V. 2012. Measuring energy poverty: Focusing on what matters. *Renewable and Sustainable Energy Reviews*. 16 (2012): 231– 243.

OED [Oxford English Dictionary] Online. Oxford University Press, December 2016. Available: https://en.oxforddictionaries.com/definition/access [Accessed: 2017, February 1].

Ogwumike, F.O. & Ozughalu, U.M. 2015. Analysis of energy poverty and its implications for sustainable development. Environment and Development Economics. 21: 273-290.

Pimentel, R. 2009. Kendall's Tau and Spearman's Rho for Zero Inflated Data. (Ph.D. dissertation) Western Michigan University, Kalamazoo, Michigan (2009)

Pachauri, S. 2011. Reaching an international consensus on defining modern energy access. *Current Opinion in Environmental Sustainability*. 3 (2011): 235-240.

Pachauri, S. & Spreng, D. 2011. Measuring and monitoring energy poverty. *Energy Policy*. 39 (2011): 7497-7504.

Polit, D.F. & Hungler, B.P. 1999. *Nursing Research: Principles and Methods*. 6th. *Ed.* Philadelphia, Lippincott

Practical Action. 2012. Poor People's Energy Outlook 2012. Rugby Practical Action Publishing Ltd.

Kumar, R. 2011. *Research Methodology: A Step-by-Step Guide for Beginners*. 3rd.Ed. Singapore, Pearson Education.

Reddy, A. 2000. Energy and social issues. In: World Energy Council and UNEP, editors. Energy and the challenge of sustainability. New York.

Reddy, B.S. 2015 Access to modern energy services: An economic and policy framework. *Renewable and Sustainable Energy Reviews*. 47 (2015): 198-212.

Saisana, M. & Stefano, T. 2002. *State-of-the-art Report on Current Methodologies and Practices for Composite Indicator Development.* Available: http://www.eea.europa.eu/data- and maps/indicators/economic-water-productivity-of-irrigated/state-of-the-art-report [Accessed: 2016, May 18].

SALDRU [Southern Africa Labour and Development Research Unit]. 2015a. National Income Dynamics Study 2008, Wave 1 [dataset]. Version 6.1. Cape Town: Southern Africa Labour and Development Research Unit [producer]. Cape Town: DataFirst [distributor], 2015.

SALDRU [Southern Africa Labour and Development Research Unit]. 2016. National Income Dynamics Study 2014 - 2015, Wave 4 [dataset]. Version 1.1. Cape Town: Southern Africa Labour and Development Research Unit [producer], 2016. Cape Town: DataFirst [distributor], 2016. Pretoria: Department of Planning Monitoring and Evaluation [commissioner], 2014.

Schuessler, R. 2014. Energy poverty indicators: conceptual issues. ZEW Discussion Paper No. 14-037 Available: http://ftp.zew.de/pub/zew-docs/dp/dp14037.pdf [Accessed: 2016, May 15].

Sen, A. 1999. *Development as freedom*. Oxford University Press.

Sher, F., Abbas, A. & Awan, R.U. 2014. An investigation of Multidimensional Energy Poverty in Pakistan: A Province Level Analysis. I*nternational Journal of Energy Economics and Policy*. 4 (1): 65-75.

Sifo, A.T. 2009. Developing a framework for effective liquefied petroleum gas marketing and distribution in Nigeria. North-West University: South Africa.

Stats SA [Statistics South Africa]. 2011. Poverty trends in South Africa: An examination of absolute poverty between 2006 and 2011. Statistics South Africa. Available: http://beta2.statssa.gov.za/publications/Report-03-10-06/Report 03-10 06March2014.pdf [Accessed: 2017, February 26].

Stats SA [Statistics South Africa]. 2014a. *General Household Survey*. Available: http://www.statssa.gov.za/publications/P0318/P03182014.pdf [Accessed: 2016, May 14].

Stats SA [Statistics South Africa]. 2014b. Consumer Price Index: November 2014. (Statistical release P0141). Statistics South Africa.

Stern, D.I. 2004. Economic growth and energy. *Encyclopaedia of Energy*. 2 (2004): 35-51.

Selltiz, C., Wrightsman, L.S. & Cook, S.W. 1976. *Research methods in social relations*. New York: Holt, Rinehart and Winston

Sustainable Energy Africa. 2014. Tackling Urban Energy Poverty in South Africa. Report by Sustainable Energy Africa.

Tewathia. N. 2014. Determinants of the household electricity consumption: A case study of Delhi. *International Journal of Energy Economics and Policy*. 4 (3): 337—348

UNDP [United Nations Development Program]. 2005. Fact Sheet: Sustainable Energy Services – the Gender Dimension. UNDP, New York.

UNDP [United Nations Development Program]. 2010. *Human Development Report – The Real Wealth of Nations: Pathways to Human Development*. New York: United Nations Development Programme. Available: http://hdr.undp.org/sites/default/files/reports/270/hdr_2010_en_complete_reprint.pdf [Accessed: 2016, May 15].

UNDP, 2016. Sustainable Development Goals: Affordable and clean energy. Available: http://www.un.org/sustainabledevelopment/energy/ [Accessed: 2017, January 12].

Van der Kroon B., Brouwer, R. & van Beukering, P. 2013. The energy ladder: Theoretical Myth or empirical truth? Results from a meta-analysis. *Renewable and Sustainable Energy Reviews*. 20 (2013): 504–13.

Wittenberg, M. 2010. An introduction to maximum entropy and minimum cross-entropy estimation using Stata. *Stata Journal*. 10 (3): 315-330.

Zizzamia, R., Schotte, S., Leibbrandt, M. & Ranchhod, V. 2016. Vulnerability and the middle class in South Africa. Cape Town: SALDRU, University of Cape Town. *SALDRU Working Paper* Number 188/ NIDS Discussion Paper 2016/15.