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

Samson Mbewe
Energy Research Centre, University of Cape Town, South Africa

Abstract

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 evaluated 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 energy poverty cut-off point (k) was used for the MEPI. 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 between 2008 and 2014-2015, from 24 to 18 percent (using TPR) and from 70 to 49 percent (using MEPI). 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.

JEL Classification: C81, I32, O13

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1. Introduction

The ability to access energy services has become 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 is more severe 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).

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 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 prevalence of such trends would leave some households trapped in a vicious cycle of energy poverty by 2030 (IEA, 2010; IEA, 2015).

South Africa has realised household electrification rates of 85% through Eskom (the national energy utility supplier) and government supportive policies (DOE, 2015a). Despite 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), a majority of the 15 percent of energy poor households rely heavily on unclean energy sources (such as traditional biomass) for their cooking and heating needs (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).

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 these tools and metrics depends on how energy poverty is defined (Schuessler, 2014). Various definitions have emerged over the years, and yet to date, there is 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.

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1 For instance, electricity, kerosene, Liquid Petroleum gas [LPG], charcoal and biofuels.
2 SDG (Sustainable Development Goal) 7: Ensure universal access to affordable, reliable and modern energy services for all by 2030 (UNDP, 2016).
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 such as an energy poverty line or minimum energy required to live a basic daily life (Bazilian et al., 2010). While unidimensional indicators are straightforward and are easy to interpret, critics have argued that energy poverty is rather a multidimensional concept. In this respect, several multidimensional indicators, also 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).

Following the growing trend in tracking and monitoring energy poverty using multidimensional indicators, there is limited understanding of the geographical, socioeconomic and temporal incidence of energy poverty in South Africa, other than the rate of electrification. One critical factor hindering this process has been the lack of reliable and good quality detailed survey data (Nussbaumer et al., 2012). The downside of using the electrification rate as a measure of energy poverty is that it is a fairly simplistic and crude proxy to provide a sufficient understanding of the full extent of energy poverty.

In light of the above, this study aims to evaluate household energy poverty in South Africa by systematically constructing a unidimensional (Tenth-Percentile Rule) and multidimensional (Multidimensional Energy Poverty Index) measure of energy poverty. Using survey data from the National Income Dynamic Study (NIDS), this is achieved through estimating and describing the geographic, socioeconomic and temporal incidence of household energy poverty by subgroups in South Africa. To ensure robustness of the results, a sensitivity analysis of the two measures of energy poverty is performed. This study is henceforth organized as follows. Section two provides a review of the literature on conceptualization and measurement of energy poverty. Section three outlines the research methodology while Section four presents the results and the discussion. Section five draws conclusions and provides recommendations.

2. Literature Review

The definition of energy poverty is contested because of the lack of an internationally-accepted and internationally-adopted standard of how it should be defined and the dimensions required to develop
such a metric (IEA, 2016). Although some 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.

2.1 Conceptualising Energy Poverty and Access

2.1.1 Supply-Side Approaches

Some definitions have focused on defining energy poverty from a supply-side approach. Four common approaches have received a great deal of attention in the literature. The first approach focuses on the physical availability of modern energy fuels; including modern energy carriers as a single dimension of energy access. This definition views access in terms of the availability of modern energy fuels and carriers which help meet the basic cooking, heating and lighting needs of a household (IEA, 2010). However, this approach considers physical availability of energy as an indicator of improved level of service without accounting for challenges arising from poor quality or reliability (Mirza & Szirmai, 2010; Pachauri, 2011). As such, it may be problematic to rely only on this definition of energy access.

The second approach focuses on the physical energy requirements. This approach 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). However, estimating the minimum energy requirement is rather a technical process and often adopts a more engineering-like methodology based on certain assumptions. In cases where basic needs vary, due to varying socioeconomic factors such as age, gender, household composition or time period, among other factors, these assumptions would either underestimate or overestimate the minimum required energy of basic use (Pachauri, 2011).

The third supply-side approach defines access in terms of reliability of energy supply. 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 liquid petroleum gas (LPG), 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. As such there is no consensus on what constitutes as unreliable supply, which explains why there is limited research on this dimension.

The fourth approach defines energy access in terms of the deprivations people face. 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.

2.1.2 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.

2.1.3 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 viewed 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 five core categories of basic energy services, which include lighting, cooking and water heating, space heating, cooling as well as information and communication. When viewing energy poverty and access from a multidimensional perspective, service-based definitions 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.

Another 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 interventions and
deideal 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”.

Recently, Day et al. (2016) advanced the capabilities theory in an attempt to best define access
to energy. To achieve this, it had to be argued that defining 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 built on a sound theoretical concept which also 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.

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 a point at 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 (1999) 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 measure 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 that it requires detailed and reliable data, which often, may not be easily accessible.

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. 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 access to energy 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. The MEPI has not been used to estimate energy poverty in South Africa. 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.

### 3. Research Methodology

This study follows a quantitative research approach while adopting a combination of a descriptive and an evaluative research design. The descriptive research design describes existing and uncovers new features of household energy poverty (Kothari, 2009: 37) while the evaluative research design unearths the degree to which, energy poverty has changed overtime (Polit & Hungler, 1999: 201). These research designs were chosen based on two motives. Firstly, to afford the opportunity of analysing survey data by focusing on the characteristics, socioeconomic and demographic dynamics of household energy
poverty in South Africa. Secondly, to afford the opportunity to examine progress changes in energy poverty.

3.1 Data Sources

Waves 1 (2008) and 4 (2014–2015) of the National Income Dynamics Study (NIDS) are used in the construction of the TPR and MEPI. The logic behind using two-repeated cross-sections is to allow for a degree of comparability between the waves. NIDS closely tracks and collects data from the lives of a specific group of South African individuals who are sampled from the population. 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. 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.

All data are weighted using post-stratified weights to ensure representation of the entire South African population. Since data on financial assets, expenditure and liabilities were collected at different times in both waves, inflation is accounted for by adjusting prices using the monthly Consumer Price Index (CPI) obtained from Statistics South Africa (Stats SA, 2014b) to November 2014 (modal month of the wave 4 interviews).

3.2 Data Analysis

3.2.1 Estimating National Energy Poverty

The quantitative analysis started with an estimation of unidimensional energy poverty using the Ten-Percentile-Rule (TPR) developed by Boardman (1991) as shown in Equation 1:

$$ TPR = \sum_{i=1}^{n} \frac{\beta_i}{\alpha_i} $$

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

where $\beta_i$ is the expenditure on energy sources of household $i$ and $\alpha_i$ 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 number of
households in the sample population. 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, \( \text{if } \text{TPR} > 0.1 \)). 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, \( \text{Otherwise} \)).

The quantitative analysis proceeds with an estimation of the Multidimensional Energy Poverty Index (MEPI). The MEPI borrows from the literature on Multidimensional Poverty Index (MPI) – an index developed by Alkire and Foster (2007). The construction of the MEPI was adapted from Nussbaumer et al. (2011) by considering five dimensions (cooking, lighting, services from appliances, entertainment/education and communication) depicting basic energy services as a proxied by five indicators (cooking fuel, electricity access, ownership of a household appliance, ownership of entertainment/education appliance and telecommunication means) in Table 1.

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

The MEPI, unlike the TPR, uses 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. Table 1 also shows that each indicator was assigned a weight based on its relative importance towards the associated dimension.
and its postulated impact on energy poverty. The weights on each indicator sum up to 1 and this was calculated using Equation 2 from Alkire and Santos (2011):

$$\sum_{x=1}^{d} w_x = 1$$

(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 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 from Alkire and Santos (2011) as follows:

$$s_i = w_1X_1 + w_2X_2 + \ldots + w_dX_d$$

(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 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 \(k\). An energy poverty cut-off \(k\) of 0.3 was adopted from Nussbaumer et al. (2011).

Estimating the degree of multidimensional energy poverty requires integrating two elements. The first element is the proportion of multidimensionally energy poor from the total number of households (also known as the multidimensional headcount ratio \(H\)) is calculated using Equation 4 from Alkire and Santos (2011) as follows:

$$H = \frac{q}{n}$$

(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 and is calculated using Equation 5 from Alkire and Santos (2011) as follows:
\[ A = \frac{\sum_{i=1}^{n} s_i(k)}{q} \]  

(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 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 6 as follows:

\[ MEPI = H \times A \]  

(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).

### 3.2.2 Decomposing Energy Poverty by Subgroups

The second step of the quantitative analysis shows how each metric (TPR and MEPI) was decomposed by 3 subgroups: province, household income poverty status and household location. Decomposing energy poverty by subgroups provided evidence confirming findings from the literature (Nussbaumer et al., 2011; Bensch, 2013; Sher et al., 2014) that national estimates tend to trump subnational estimates.

The first decomposition of the poverty metrics performed was done by province for each of the nine provinces of South Africa (see Figure 1): Western Cape, Eastern Cape, Northern Cape, Mpumalanga, Limpopo, Gauteng, North West, KwaZulu Natal and Free State.

![Figure 1: Map of the nine South African provinces. Source: Reuters (2009)](image-url)
The second decomposition was performed by household income poverty status. This was achieved 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. 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 R430, R667 and R1275, respectively, adjusted to November 2014 prices.

The third decomposition was performed 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 theoretical underpinning to this analysis was meant to explain the concept if rural versus urban energy poverty.

3.2.2.1 Decomposition of TPR by Subgroup

The TPR was statistically decomposed for each of the subgroups (province, household income poverty status and household location) using Equation 7 from Boardman (1991) as follows:

\[ TPR_g = \sum_{i=1}^{g} \frac{\beta_i}{\alpha_i} \quad (7) \]

where \( TPR_g \) assumes the same interpretation as shown in Equation 1 but instead, over the total population of the subgroup \( g \).

3.2.2.2 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 9 from Alkire and Santos (2011) as follows:

\[ MEPI_{\text{subgroup}} = \frac{\sum_{i=1}^{g} s_i(k)}{g} \quad (9) \]

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 10 from Alkire and Santos (2011):
\[
H_{sub\,group} = \frac{q_g}{n}
\]

(10)

where \(q_g\) is the number of households considered as multidimensionally 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 11 from Alkire and Santos (2011):

\[
A_{sub\,group} = \frac{\sum_{i=1}^{n} s_i(k)}{q_g}
\]

(11)

where \(s_i(k)\) represents the deprivation score of each household \(i\) and \(q\) represents the number of households considered as multidimensionally poor in subgroup \(g\) while \(n\) is the total number of households in the sample population.

4. Results and Discussion

The presentation of the results commences with the descriptive statistics of key variables used to construct the TPR and MEPI, respectively. Table 2 presents key statistics used to construct the TPR while Table 3 presents key statistics used to construct the MEPI.


<table>
<thead>
<tr>
<th>Percentiles</th>
<th>Monthly Household Energy Expenditure</th>
<th>Monthly Household After-Tax Income</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2008 Wave 1 (R)</td>
<td>2008 Wave 1 (R)</td>
</tr>
<tr>
<td>1%</td>
<td>3</td>
<td>222</td>
</tr>
<tr>
<td>5%</td>
<td>10</td>
<td>350</td>
</tr>
<tr>
<td>10%</td>
<td>15</td>
<td>629</td>
</tr>
<tr>
<td>25%</td>
<td>29</td>
<td>1257</td>
</tr>
<tr>
<td>75%</td>
<td>146</td>
<td>1776</td>
</tr>
<tr>
<td>(Median) 50%</td>
<td>70</td>
<td>117</td>
</tr>
<tr>
<td>90%</td>
<td>286</td>
<td>229</td>
</tr>
<tr>
<td>95%</td>
<td>419</td>
<td>1257</td>
</tr>
<tr>
<td>99%</td>
<td>1232</td>
<td>1257</td>
</tr>
<tr>
<td>Mean</td>
<td>142</td>
<td>7005</td>
</tr>
<tr>
<td>Minimum</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Maximum</td>
<td>3701</td>
<td>419096</td>
</tr>
</tbody>
</table>

Source: Authors’ own calculations using NIDS data from SALDRU (2015a; 2016).
Table 3: Degree of Deprivation in the five Indicators used to construct the MEPI, 2008 and 2014-2015

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Indicator</th>
<th>Proportion of households deprived (percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Wave 1</td>
</tr>
<tr>
<td>Cooking</td>
<td>Modern Cooking Fuel</td>
<td>49</td>
</tr>
<tr>
<td>Lighting</td>
<td>Access to electricity</td>
<td>35</td>
</tr>
<tr>
<td>Household Appliance Ownership</td>
<td>Ownership of at least a fridge</td>
<td>54</td>
</tr>
<tr>
<td>Entertainment Appliance Ownership</td>
<td>Television or Radio or Computer</td>
<td>21</td>
</tr>
<tr>
<td>Telecommunication Means</td>
<td>Ownership of a mobile or landline phone</td>
<td>22</td>
</tr>
</tbody>
</table>

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

4.1 Estimates of National Energy Poverty

Table 4 presents the results of national estimates of households’ energy poverty in South Africa using the TPR. 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>
<thead>
<tr>
<th>State of energy poverty</th>
<th>Percentage of households</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy non-poor</td>
<td>79</td>
</tr>
<tr>
<td>Energy poor</td>
<td>21</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
</tr>
</tbody>
</table>

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

4.1.1 Multidimensional Energy Poverty Index

Table 5 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. 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 energy poor households between 2008 and 2014-2015. The average intensity indicates that on average, households were deprived in 71 and 56 percent of the weighted indicators in 2008 and 2014-2015, respectively.

<table>
<thead>
<tr>
<th>Variable</th>
<th>2008, wave 1 (percent)</th>
<th>2014-2015, wave 4 (percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEPI</td>
<td>37</td>
<td>19</td>
</tr>
<tr>
<td>Multidimensional Energy Poverty Headcount Ratio (H)</td>
<td>52</td>
<td>34</td>
</tr>
<tr>
<td>Average Intensity (A)</td>
<td>71</td>
<td>56</td>
</tr>
</tbody>
</table>

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

4.2 Estimates of Energy Poverty by Subgroup

4.2.1 Decomposition of Energy Poverty by Province

Figure 2 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 and highest in Limpopo with 34 percent. Other provinces displayed intermediate levels of household energy poverty. In 2014-2015, household energy poverty was again lowest in Western Cape (5 percent) and highest in Limpopo province (25 percent) with other provinces displaying intermediate levels of energy poverty.

Figure 2: 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).

Further, the results from the decomposition of the multidimensional headcount ratio of energy poverty (Figure 3), average intensity of energy poverty (Figure 4) and the MEPI (Figure 5) by province are presented for 2008 and the 2014-2015. Figure 3 shows that in 2008, the lowest percentage of multidimensionally energy poor households came from Western Cape with 8 percent followed by Northern Cape with 33 percent.
The results in Figure 3 show that the highest proportion of multidimensionally energy poor households came from Limpopo with 59 percent and Eastern Cape with 75 percent while other provinces displayed intermediate levels. Overall, the results show that the number of multidimensionally energy poor households has declined in all provinces with the exception of Western Cape and Northern Cape, indicating increases from 33 and 8 percent in 2008 to 9 and 36 percent in 2014-2015, respectively.

In Figure 4, results show that in 2008, the average intensity of multidimensional energy poverty was lowest in Mpumalanga with 61 percent followed by Limpopo with 64 percent. This implies that energy poor households 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 followed by Western Cape, KwaZulu Natal and Gauteng each with 72 percent. The other provinces displayed intermediate average levels of energy poverty intensity. 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 3: Headcount Ratio of Multidimensionally Energy Poor Households, 2008 and 2014-2015. Source: Authors’ own calculations using NIDS data from SALDRU (2015a; 2016).
4.2.2 Decomposition of Energy Poverty by Household Income Status

According to the TPR, Figure 6 presents the results of the percentage of energy poor households decomposed by household income poverty status for 2008 and 2014-2015. The results show that energy poverty was highest among households below the FPL and in 2008 and 2014-2015, 33 and 23 percent of energy poor households lived 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 are non-income poor between 2008 and 2014-2015. This seems to suggest that household energy poverty reduces as a household progress beyond each poverty. Worth noting, 6 and 3 percent of non-income poor households were however energy poor households. A reasonable explanation could be the TPR’s drawback in erroneously identifying energy non-poor households as energy poor.
Further, results from the household income poverty status decomposition of the multidimensional headcount ratio of energy poverty (Figure 7), average intensity of energy poverty (Figure 8) and the MEPI (Figure 9) are presented for 2008 and the 2014-2015. Results from Figure 7 show that in 2008, the lowest percentage of multidimensionally energy poor households came from non-income poor households with 34 percent while the highest came from households living below the FPL with 62 percent. In 2014-2015, the lowest percentage also came from non-income poor households with 22 percent while the highest came from energy poor households living below the FPL with 46 percent.

Results from Figure 8 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 also classified as 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. In 2014-2015, the average intensity of multidimensional energy poverty was lowest among energy poor households also classified as non-income poor with 47 percent. The highest average intensity came from energy poor households living below the FPL with 62 percent.

Figure 8: Average Intensity and MEPI by Household Income Poverty Status, 2008. Source: Authors’ own calculations using NIDS data from SALDRU (2015a).

Figure 9: MEPI by Household Income Poverty Status, 2008. Source: Authors’ own calculations using NIDS data from SALDRU (2015a).

4.2.3 Decomposition of Energy Poverty by Household Location

Figure 10 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 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.
Further, results from the household location decomposition of the multidimensional headcount ratio of energy poverty (Figure 11), average intensity of energy poverty (Figure 12) and the MEPI (Figure 13) are presented for 2008 and the 2014-2015. Results from Figure 10 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 12 show that in 2008, the average intensity of multidimensional energy poverty was lower in urban areas with 70 percent and higher in rural areas with 72 percent. This implies that in 2008, the energy poor households located 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.
Further, results from Figure 13 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.

4.3 Discussion

By measuring energy poverty through affordability, TPR estimates show 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 this claim of declining household energy poverty with evidence indicating a decline from 52 percent in 2008 to 34 percent 2014-2015. What appears obvious from these results is that 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 that the average intensity of multidimensionally energy poor households declined from 71 to 56 percent. This implies
that 15 percent of the households that remained multidimensionally poor in 2014-2015 were on average deprived in fewer indicators than in 2008.

Since these two metrics explain different aspects of a complex multidimensional problem, it remains unclear if TPR or MEPI estimates are either underestimated or overestimated. 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 A1 in Appendix A 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. The results show\(^3\) 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. Yet, the bottom half of the population spend less than 10 percent of household income on energy services and failure of the TPR to capture this is not surprising.

From a developmental perspective, household income of the energy poor people has risen 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 A1 in Appendix A 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 (see Appendix A) 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 electricity consuming households (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 if their electricity consumption is within the Free-Basic Electricity (FBE). The FBE is a pro-poor South African government policy meant to afford free electricity services to poor households with prepaid

\(^3\) The ratio between household energy expenditure and household after-tax income. Therefore, median energy poverty was 4 percent \((70/1776 \times 100 \text{ percent})\) in 2008 and 2 percent in \((55/2752 \times 100 \text{ percent})\) in 2014-2015.
meters a predetermined threshold of kilowatt-hours consumed\(^4\). 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.

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.

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 based on economic opportunity, provincial and household location. For instance, the timing of electricity rollout in the post-apartheid period 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.

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).

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 shortcomings 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.

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 were multidimensionally energy poor while 70 percent of households in rural areas were 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 were now deprived of less indicators compared to those in rural areas.

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 (see Appendix C) 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 (see Appendix B). 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.

5. Conclusions and Recommendations

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. This study aimed at evaluating household energy poverty in South Africa by systematically constructing two measures: a unidimensional (Tenth-Percentile Rule) and a multidimensional (Multidimensional Energy Poverty Index) measure of energy poverty. Using survey data from the National Income Dynamic Study (NIDS), this was achieved by describing the geographic, socioeconomic and temporal incidence of household energy poverty in South Africa. This study has added the following to the existing literature. Firstly, this study has provided household estimates of energy poverty from a multidimensional perspective – making it the first study to construct the MEPI for South Africa. Second, this study has provided better understanding of the geographic, socioeconomic and temporal incidence of energy poverty in South Africa. 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.
References


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](https://openknowledge.worldbank.org/bitstream/handle/10986/18677/886990BR0Live00Box385194B00PUBLIC0.pdf?sequence=4) [Accessed: 2017, February 11].


## Appendix A

**Table A1:** Mean Household Expenditure on Energy Services by Deciles of Household After-Tax Income, 2008 and 2014-2015

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>90</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>94</td>
<td>73</td>
</tr>
<tr>
<td>3</td>
<td>81</td>
<td>108</td>
</tr>
<tr>
<td>4</td>
<td>111</td>
<td>11</td>
</tr>
<tr>
<td>5</td>
<td>103</td>
<td>104</td>
</tr>
<tr>
<td>6</td>
<td>112</td>
<td>107</td>
</tr>
<tr>
<td>7</td>
<td>111</td>
<td>130</td>
</tr>
<tr>
<td>8</td>
<td>108</td>
<td>134</td>
</tr>
<tr>
<td>9</td>
<td>141</td>
<td>126</td>
</tr>
<tr>
<td>10</td>
<td>373</td>
<td>152</td>
</tr>
</tbody>
</table>

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

Table B1: Spearman Correlation in the Provincial Ranking after Varying the TPR Deprivation Cut-off, 2008

<table>
<thead>
<tr>
<th>Threshold</th>
<th>Spearman rank correlation coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7 percent</td>
</tr>
<tr>
<td>7 percent</td>
<td>1.000</td>
</tr>
<tr>
<td>10 percent</td>
<td>0.954</td>
</tr>
<tr>
<td>13 percent</td>
<td>0.965</td>
</tr>
</tbody>
</table>

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

Table B2: Spearman Correlation in the Provincial Ranking after Varying the TPR Deprivation Cut-off, 2014-2015

<table>
<thead>
<tr>
<th>Threshold</th>
<th>Spearman rank correlation coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7 percent</td>
</tr>
<tr>
<td>7 percent</td>
<td>1.000</td>
</tr>
<tr>
<td>10 percent</td>
<td>0.885</td>
</tr>
<tr>
<td>13 percent</td>
<td>0.952</td>
</tr>
</tbody>
</table>

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

Table B3: Spearman Correlation in the Provincial Ranking after Varying the MEPI Deprivation Cut-off ($k$), for 2008 data.

<table>
<thead>
<tr>
<th>$k$</th>
<th>Spearman rank correlation coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$k =0.2$</td>
</tr>
<tr>
<td>0.2</td>
<td>1.000</td>
</tr>
<tr>
<td>0.3</td>
<td>0.983</td>
</tr>
<tr>
<td>0.4</td>
<td>0.967</td>
</tr>
</tbody>
</table>

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

Table B4: Spearman Correlation in the Provincial Ranking after Varying the MEPI Deprivation Cut-off, 2014-2015

<table>
<thead>
<tr>
<th>$k$</th>
<th>Spearman rank correlation coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$k =0.2$</td>
</tr>
<tr>
<td>0.2</td>
<td>1.000</td>
</tr>
<tr>
<td>0.3</td>
<td>0.988</td>
</tr>
<tr>
<td>0.4</td>
<td>0.967</td>
</tr>
</tbody>
</table>

Source: Authors’ own calculations using NIDS data from SALDRU (2016).
## Appendix C

**Table C1:** Effects of TPR Threshold Change on Distribution of South African Provinces by Percentiles, 2008

<table>
<thead>
<tr>
<th>TPR Percentile</th>
<th>7 percent</th>
<th>10 percent</th>
<th>13 percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>Western Cape</td>
<td>Western Cape</td>
<td>Western Cape</td>
</tr>
<tr>
<td>13%</td>
<td>Eastern Cape</td>
<td>Eastern Cape</td>
<td>Northern Cape</td>
</tr>
<tr>
<td>25%</td>
<td>Northern Cape</td>
<td>Northern Cape</td>
<td>Eastern Cape</td>
</tr>
<tr>
<td>38%</td>
<td>Mpumalanga</td>
<td>North-West</td>
<td>North-West</td>
</tr>
<tr>
<td>50%</td>
<td>North-West</td>
<td>Mpumalanga</td>
<td>Mpumalanga</td>
</tr>
<tr>
<td>63%</td>
<td>KwaZulu Natal</td>
<td>KwaZulu Natal</td>
<td>Gauteng</td>
</tr>
<tr>
<td>75%</td>
<td>Gauteng</td>
<td>Free State</td>
<td>Free State</td>
</tr>
<tr>
<td>88%</td>
<td>Free State</td>
<td>North-West</td>
<td>Free State</td>
</tr>
<tr>
<td>100%</td>
<td>Limpopo</td>
<td>North-West</td>
<td>Limpopo</td>
</tr>
</tbody>
</table>

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

**Table C2:** Effects of TPR Threshold Change on Distribution of South African Provinces by Percentiles, 2014-2015

<table>
<thead>
<tr>
<th>TPR Percentile</th>
<th>7 percent</th>
<th>10 percent</th>
<th>13 percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>Western Cape</td>
<td>Western Cape</td>
<td>Western Cape</td>
</tr>
<tr>
<td>13%</td>
<td>Eastern Cape</td>
<td>Mpumalanga</td>
<td>Mpumalanga</td>
</tr>
<tr>
<td>25%</td>
<td>Mpumalanga</td>
<td>Eastern Cape</td>
<td>Northern Cape</td>
</tr>
<tr>
<td>38%</td>
<td>Northern Cape</td>
<td>Northern Cape</td>
<td>KwaZulu Natal</td>
</tr>
<tr>
<td>50%</td>
<td>KwaZulu Natal</td>
<td>KwaZulu Natal</td>
<td>Eastern Cape</td>
</tr>
<tr>
<td>63%</td>
<td>North-West</td>
<td>Free State</td>
<td>North-West</td>
</tr>
<tr>
<td>75%</td>
<td>Free State</td>
<td>North-West</td>
<td>Free State</td>
</tr>
<tr>
<td>88%</td>
<td>Northern Cape</td>
<td>Northern Cape</td>
<td>Northern Cape</td>
</tr>
<tr>
<td>100%</td>
<td>Limpopo</td>
<td>Limpopo</td>
<td>Limpopo</td>
</tr>
</tbody>
</table>

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

**Table C3:** Effect of MEPI Deprivation Cut-off ($k$) Change on Distribution of South African Provinces by Percentiles, 2008

<table>
<thead>
<tr>
<th>MEPI Percentile</th>
<th>$k = 0.2$</th>
<th>$k = 0.3$</th>
<th>$k = 0.4$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>Western Cape</td>
<td>Western Cape</td>
<td>Western Cape</td>
</tr>
<tr>
<td>13%</td>
<td>Free State</td>
<td>Northern Cape</td>
<td>Northern Cape</td>
</tr>
<tr>
<td>25%</td>
<td>Northern Cape</td>
<td>Free State</td>
<td>Free State</td>
</tr>
<tr>
<td>38%</td>
<td>North-West</td>
<td>North-West</td>
<td>Mpumalanga</td>
</tr>
<tr>
<td>50%</td>
<td>Mpumalanga</td>
<td>Mpumalanga</td>
<td>North-West</td>
</tr>
<tr>
<td>63%</td>
<td>Gauteng</td>
<td>Gauteng</td>
<td>Gauteng</td>
</tr>
<tr>
<td>75%</td>
<td>Limpopo</td>
<td>Limpopo</td>
<td>Limpopo</td>
</tr>
<tr>
<td>88%</td>
<td>KwaZulu Natal</td>
<td>KwaZulu Natal</td>
<td>KwaZulu Natal</td>
</tr>
<tr>
<td>100%</td>
<td>Eastern Cape</td>
<td>Eastern Cape</td>
<td>Eastern Cape</td>
</tr>
</tbody>
</table>

Source: Authors’ own calculations using NIDS data from SALDRU (2015a).
Table C4: Effects of MEPI Deprivation Cut-off ($k$) Change on Distribution of South African Provinces by Percentiles, 2014-2015

<table>
<thead>
<tr>
<th>MEPI Percentile</th>
<th>Distribution of Provinces</th>
<th>(k = 0.2)</th>
<th>(k = 0.3)</th>
<th>(k = 0.4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>Western Cape</td>
<td>Western Cape</td>
<td>Western Cape</td>
<td></td>
</tr>
<tr>
<td>13%</td>
<td>Free State</td>
<td>Free State</td>
<td>Free State</td>
<td></td>
</tr>
<tr>
<td>25%</td>
<td>Gauteng</td>
<td>Gauteng</td>
<td>Gauteng</td>
<td></td>
</tr>
<tr>
<td>38%</td>
<td>North-West</td>
<td>North-West</td>
<td>North-West</td>
<td></td>
</tr>
<tr>
<td>50%</td>
<td>Northern Cape</td>
<td>Northern Cape</td>
<td>Northern Cape</td>
<td></td>
</tr>
<tr>
<td>63%</td>
<td>Mpumalanga</td>
<td>Mpumalanga</td>
<td>Mpumalanga</td>
<td></td>
</tr>
<tr>
<td>75%</td>
<td>Limpopo</td>
<td>Limpopo</td>
<td>Limpopo</td>
<td></td>
</tr>
<tr>
<td>88%</td>
<td>KwaZulu Natal</td>
<td>KwaZulu Natal</td>
<td>Eastern Cape</td>
<td></td>
</tr>
<tr>
<td>100%</td>
<td>Eastern Cape</td>
<td>Eastern Cape</td>
<td>KwaZulu Natal</td>
<td></td>
</tr>
</tbody>
</table>

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