Energy Poverty in Zambia

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1 Introduction

Of the estimated 3.01 million households in Zambia, in 2015, only 35.8% and 16.1% utilised clean energy fuels for their lighting and cooking services respectively[1] (CSO, 2016). Usage and access to clean energy is essential for economic growth, human development and more generally poverty reduction. This notwithstanding, access has remained low in many developing countries. For instance, 1.1 billion of the total global population do not have access to electricity, of which majority are found in Asia, Africa and Oceania (United Nations, 2016). Furthermore, the majority of this population is found in rural areas.

Given the centrality of energy to people's everyday life, governments worldwide have devised different policies and mechanisms to enhance the use of clean energy. Limited access and use of clean energy is mainly thought of as an issue of affordability (Barnes and Floor, 1996; Pachauri et al., 2004; Rosnes and Vennemo, 2012; Murtaza and Faridi, 2014; Ismail and Khembo, 2015; GRZ, 2017; Venkateswaran et al., 2018; Kyprianou et al., 2019; Oum, 2019; Yan et al., 2019). Hence, the subsidy policies being implemented in many countries. On the one hand, it has been observed that lack of access to clean energy is a sign of poverty; while on the other hand, access to clean energy helps in the alleviation of poverty (Pachauri et al., 2004; Nussbaumer et al., 2011; Okwanya and Abah, 2018). However, in some cases, access to clean energy is hampered by both the price of the energy (i.e. an affordability issue) and by availability of infrastructure to deliver the required energy. Thus, in such situations, some governments have had to borrow to facilitate the development and expansion of energy infrastructure; on top of subsidising the use of clean energy.

This notwithstanding, the lack of use of clean energy at household level is not well understood. For instance, it is thought that if a household is classified as income poor, then it will not be able to use electricity (Pachauri et al., 2004; Murtaza and Faridi, 2014). And in such cases, some governments opt to implement subsidy policies. While this approach has proved useful for some households, it is not an effective approach of delivering clean energy to the people who need it the most. There is, therefore, great need to identify aspects that determine whether a household would have access to clean energy and let alone use it. This knowledge would be critical in designing policies that hope to increase utilisation of clean energy fuels. As such, this paper sought to understand energy poverty among households in Zambia. Energy poverty is a concept concerned with lack of access and use of modern energy fuels.

[1] In this paper, clean energy fuels focus on the end-user side. As such, a clean energy fuel is that which leads to, among others, minimal indoor air pollution (in the residential sector). Electricity and gas are considered clean while charcoal, wood, coal and other crop residuals are considered dirty and unsafe fuels.

1.1 Energy use in Zambia

Clean energy usage in Zambia, is not very different from the general picture of sub-Saharan Africa, where only 35% and 13% of the total population (of one billion people) had access to electricity and used clean energy for their cooking service respectively (United Nations, 2016). Lack of access and utilisation of clean energy is largely driven by two factors: affordability and availability (Tembo, 2018). However, the energy use in Zambia is not well researched and understood.

At household level, energy services can be grouped into three: cooking; lighting; and refrigeration, heating, cooling and others. Cooking service is required and met in all households while the other two services are secondary services, that is, they may not always be met. Further, because the penetration of cooking is 100%, households use some form of energy fuel to meet their cooking needs. Since the 1960s to date, the three main cooking fuels in Zambia are firewood, charcoal and electricity. However, there have been reported cases of minimal use of coal ($< 0.1\%$), kerosene ($< 0.1\%$) and other ($\approx 0.1\%$), which for all intents and purposes could be re-classified as 'other' (CSO, 2012, 2016). Figure 1 below shows the break-down of households use of different fuels to meet their cooking service by location (rural and urban) in 2015.

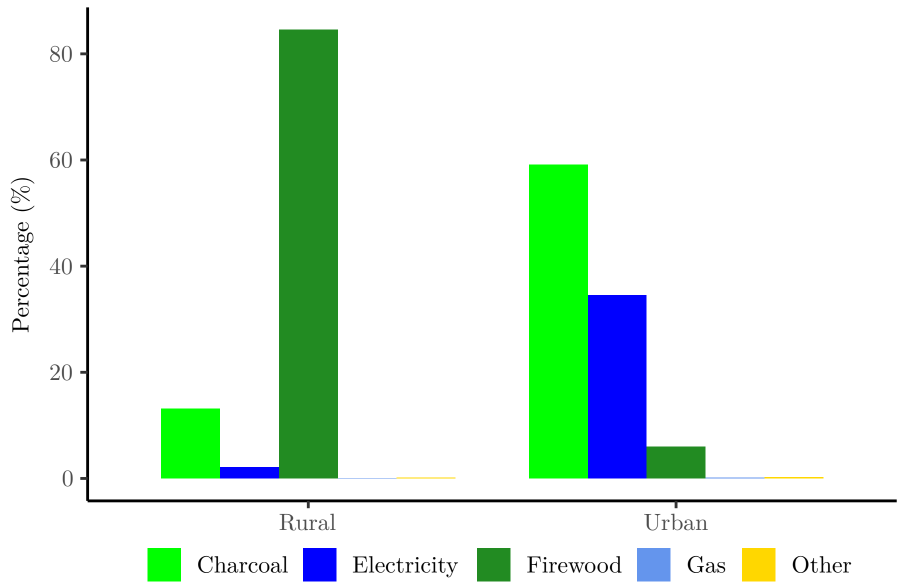

Figure 1: Cooking fuel usage patterns

In 2015, the four main fuels for households' lighting service were dry-cell torch (45.7%), electricity (31.2%), candles (10.6%) and solar power (4.6%) (CSO, 2016). However, because lighting service is not a primary energy need, it implies that these lighting fuels are not used on a daily basis. This was confirmed with some households reporting that they do not use any fuel for their lighting (CSO, 2012, 2016). Figure 2 below shows the break-down of households use of different fuels to meet their lighting service by location (rural and urban).[2] It can be seen from the Figure that rural areas have the least penetration of clean energy for lighting service (electricity at 3.7% and solar at 7.4%); with 2.4% of households reporting that they used no energy fuel to meet their lighting services.

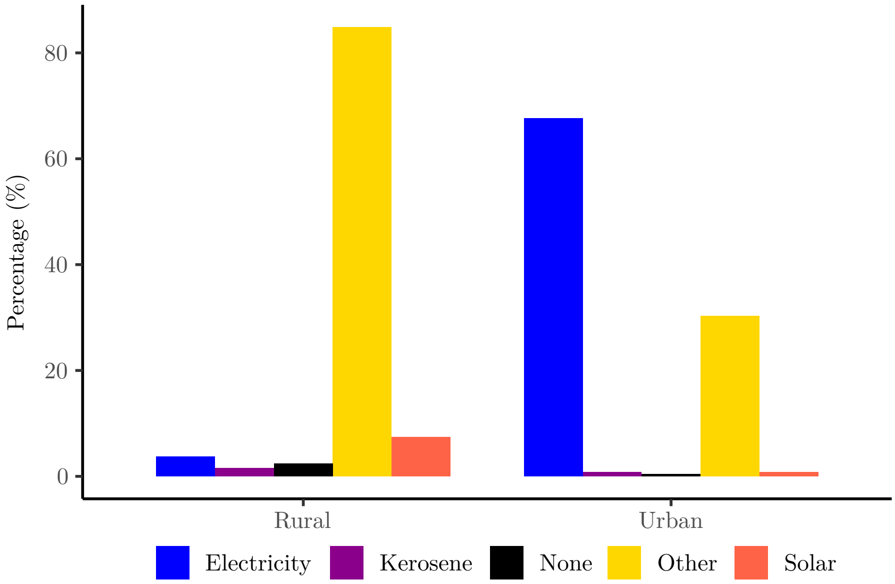

Figure 2: Lighting usage patterns

Compared to 2010, there were more households (by percentage share) using cleaner fuels in 2015 for their lighting needs; indicating improvements in utilisation of clean energy for lighting service among Zambian households. However, the reverse was true for cooking: there were fewer households using clean energy for cooking in 2015 compared to 2010. This reversal, as we will show in Section 4, is more of a result of lack of availability than affordability. Furthermore, the break-down of use of clean energy and access to electricity[3] for households' energy needs show the unevenness of development in the country.

Despite these energy challenges (low access to the grid and utilisation of clean energy among households), there has been limited research in understanding this issue, particularly in Zambia. Most literature (Barnes and Floor, 1996; Rosnes and Vennemo, 2012; GRZ, 2017) that looked at this issue simply advanced an argument of affordability. They argue that poor households cannot afford to use clean energy. Among other things, such a conclusion could falsely inform policy on the need to subsidise energy use (among poor households).

[2]'Other' in this Figure is made up of all possible fuels that are not electricity, kerosene, and solar. Some of these fuels are candles and dry-cell torches.

[3]In 2015, only 4.4% of rural households had access to the grid while 67.3% of urban household had access (CSO, 2016)

However, CSO (2005) show that, in 2004, while 46% and 13% of the population were classified as non-poor in urban and rural areas respectively, the penetration of electricity for lighting service was 47.6% in urban and 3.1% rural areas.[4] This challenges the narrative of affordability; because this (the statistic as given in CSO (2005)) implies that poor households in urban areas can afford electricity while non-poor households in rural areas cannot. Thus, in order to better inform policy, this study looks, in detail, at the interaction between income poverty and energy poverty. This is critical for policy design, as some households that can afford to use electricity (in rural areas) do not, because electricity infrastructure is not available.

Furthermore, at policy level, the Government recognises the key role that energy plays in human development and in the economy. As such, the Seventh National Development Plan (7NDP) outlines efforts that should be undertaken to expand and enhance the energy system, and also increase access to clean energy[5]. These energy targets (of the 7NDP) are in line with Goal 7 of the Sustainable Development Goals (SDGs), which elaborates the central role that energy plays in achieving many SDGs. This importance notwithstanding, it is essential that policy is informed by evidence; which this paper seeks to provide.

1.2 Study objective and research questions

Despite energy being central to human development and economic growth, there is limited understanding of the extent of energy poverty, particularly in developing countries. The common use of access rate as a measure of energy poverty says little about the nature of energy poverty enablers. For instance, lack of access to clean energy is assumed to be linked to income poverty. In other words, it is usually assumed that the income poor are also energy poor. Such an assumption implicitly means that clean energy is available but poor households cannot use it because it is not affordable; an assertion that is not correct as shown in Living Conditions Monitoring Survey reports (CSO, 2005, 2016). These Living Conditions Monitoring Survey (LCMS) reports show that there are Extremely poor households that have access and use electricity while some non-poor households do not have access to electricity. There is, therefore, need to understand energy poverty among Zambian households; so that policy actions can be tailored to address it.

The main objective of this study is to characterise energy poverty among Zambian households. Factors such as social-economic and geographical location characteristics of a household are considered in the study. To achieve this objective, the following specific questions are answered:

[4]Similarly, CSO (2016) also shows that, in 2015, even though there were 80.7% and 28.8% of non-poor households in urban and rural areas respectively, households' access to the electricity grid was 67.3% and 4.4% in urban and rural areas.

[5]While clean energy encompasses both supply (production) and demand (consumption), in this study, clean energy only refers to consumption: the energy forms that end-users consume to meet their needs.

1. Which household characteristics best predicate energy poverty?
2. How severe and widespread is energy poverty among households in Zambia?
3. What are the policy implications of using Multidimensional Energy Poverty Index (MEPI) and income poverty when assessing energy poverty in Zambia?

2 Literature review

The concept of energy poverty focuses on issues of lack of access and use of modern fuels. A person or household is considered energy poor if they do not have access nor use modern energy fuels to meet their energy services (Pachauri et al., 2004; Bhide and Monroy, 2011; Li et al., 2014). These modern forms of energy include electricity, LPG, natural gas and biogas; the other forms of energy are traditional fuels which include firewood, charcoal and primary coal (as an end-use fuel).

However, while having access and using modern energy fuels is desirable, a household can still be regarded as energy poor if its use of these modern fuels does not meet a specific criterion. For instance, Pachauri et al. (2004) would classify a household that consumes electricity for cooking purposes as energy poor if the cooking service are not fully delivered by electricity. Similarly, Nussbaumer et al. (2011) would classify a household that uses clean energy to meet their lighting and other energy services but uses firewood or charcoal for cooking as energy poor, because cooking deprivation weight is greater than energy poverty cut-off level. As such Nussbaumer et al. (2011) would not regard studies such as Venkateswaran et al. (2018) as research that focuses on solving energy poverty in its totality, because this study (Venkateswaran et al., 2018) mainly looks at lighting service. This highlights the complexity of energy poverty.

Literature (Pachauri et al., 2004; Murtaza and Faridi, 2014; Ismail and Khembo, 2015; Venkateswaran et al., 2018; Kyprianou et al., 2019; Oum, 2019; Yan et al., 2019) generally supports the narrative that when a household is classified as income poor, it is also energy poor. This narrative generally holds in countries where clean modern energy forms are available to all, save for their ability to purchase and use those energy forms. For instance, Kyprianou et al. (2019) found that in the European Union (EU), high energy costs, poor energy building performance and low income was a common thread among the energy poor. Low income directly affects the ability of a household to purchase clean energy and also to rent out a building that has a good energy performance.

However, in a country such as Zambia which does not have sufficient supply of clean modern energy forms, characterisation of energy poverty is more complex. In similar lines, Ismail and Khembo (2015) found that beyond income, factors such as race, education level, household and dwelling size, location of the household and access to electricity are important when explaining energy poverty in South African households.

Oum (2019), which studied the impacts of energy poverty on education and health in Lao PDR, also found that alongside increasing household income, there is a need for deliberate policies that focused on making clean energy forms available. The impacts of energy poverty are far reaching, hence the need for concerted efforts to eradicate it. Different studies show how energy poverty affects people's well-being in various ways: from health to education to gender inequality to lack of political participation (Pachauri et al., 2004; Bhide and Monroy, 2011; Murtaza and Faridi, 2014; Ismail and Khembo, 2015; Gillard et al., 2017; Oum, 2019; Razmjoo et al., 2019).

Similar to energy poverty, which has been described above in the context of use and access to modern energy, there is another phenomenon called fuel poverty. Fuel poverty is mainly described in the context of a household failing to use a particular fuel to meet their energy needs. This is largely an issue of affordability. In the same line, almost all studies that focus on the impact of tariff adjustment on households' welfare advance an affordability argument, with a strong inclination to fuel poverty. These studies also usually assume that clean energy is available for use save for the high tariff. As Barnes and Floor (1996), Bhide and Monroy (2011) and Ismail and Khembo (2015) argue, when households fail to use clean energy form on the basis of price, then fall back on traditional biomass (charcoal and firewood) which are relatively cheaper. However, these studies have not paid particular attention to households that are energy poor because of lack of availability of clean energy forms rather than affordability.

Most studies that focus on fuel poverty are focused on cold climate developed and developing countries (Li et al., 2014; Bouzarovski and Petrova, 2015; Wang et al., 2015; Day et al., 2016). For all intents and purposes, this paper considers fuel poverty as a subset of energy poverty. However, the interaction between energy poverty and fuel poverty as usually studied and presented as shown in Figure 3 below. On a global scale, households in Group A can be thought of as those in warm climates such as Central & South America, sub-Saharan Africa and central Asia. While those in Group B are households in developing countries, who have cold climate such as those in northern rural China, Nepal and India, and finally those in Group C are those in cold climates in developed countries such as the UK and Ireland (Li et al., 2014).

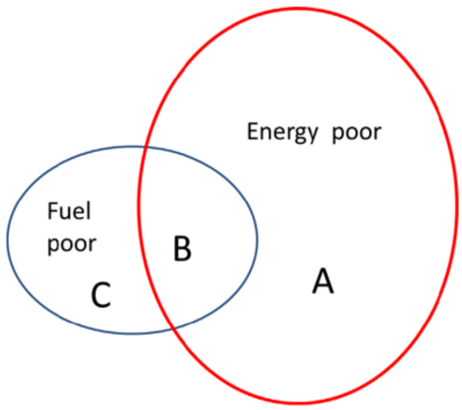

Figure 3: Interaction between energy and fuel poverty (Li et al., 2014)

Different approaches of how energy poverty is measured are given in Pachauri et al. (2004), Nussbaumer et al. (2011), Li et al. (2014), Ismail and Khembo (2015), Culver (2017) and Herrero (2017). As Culver (2017) notes, the choice of which measuring approach to use depends on what aspects of energy poverty are being studied. This choice is always a trade-off between simplicity, comprehensiveness and accuracy. Further, because this paper intends to get a deeper understanding of the energy poverty phenomenon among Zambian households, the MEPI proposed by Nussbaumer et al. (2011) was considered sufficient. The MEPI approach is able to capture subtle aspects of deprivation of use and access to modern energy forms by considering energy types used to meet different energy services.

3 Methodology

This study makes extensive use of CSO's 2010 and 2015 LCMS datasets. The authors have access to CSO's disaggregated 2010 and 2015 LCMS datasets that enables a detailed characterisation of energy poverty at household level. These datasets capture 19,397 and 12,251 randomly selected households in 2010 and 2015 LCMS datasets respectively, and are representative at provincial and national level. The datasets also come with sample weights; this makes generalisation of findings easy. More detailed description of these datasets can be found in CSO (2012) and CSO (2016).

The review of literature focused on identifying the main threads in energy poverty discourse and methods used in quantifying energy poverty. Literature show different ways in which a household can be classified as energy poor, that is, not using clean energy to meet some or all of their energy demands. The approaches range from a single indicator (such as electrification rate) to composite indices such as MEPI, Energy for Development Index (EDI) and Human Development Index (HDI).

Based on this review, an approach that best captures Zambia's energy specifics was adopted: the MEPI. This approach (described and defined further below) focuses on comprehensiveness, simplicity of estimation, easiness of interpretation of energy poverty and suitability based on the available dataset. However, like all other indicators of energy poverty, the MEPI, does not take into account other confounding factors (such as type of material a house is made out of) that could lead to a household not being about to access and use clean energy fuels. To best handle these confounding factors, they could be treated as axes of analyses (like the way we treated location and income in this paper). This was not done, as it was not the focus of this paper.

Nussbaumer et al. (2011) summaries the main advantages of the MEPI approach as follows: Firstly, it focuses on energy services and is based on data related to energy deprivations, as opposed to derived variables from other proxies. Secondly, it captures both the incidence (number of energy poor people) as well as the intensity (how energy poor they are). And thirdly, its flexible decomposability. This enhances a wide range of analyses focusing on sub-groups, such as wealth classes and rural-urban splits.

The description and definition of the Multidimensional Energy Poverty Index (MEPI) methodology given below is adapted from Nussbaumer et al. (2011) and Nussbaumer et al. (2012). The MEPI approach grew out of a multi-year effort and collaboration of the Oxford Poverty and Human Development Initiative (OPHI) and the United Nations Development Programme (UNDP). Some of the major literature that create the foundation of this technique are Alkire and Foster (2008), Alkire et al. (2010) and Alkire and Foster (2011). All this literature is inspired by Sen (1999) contribution to the debate on deprivation and capabilities. As such the MEPI has a strong focus on deprivation of clean and safe energy services.

The $MEPI$ is the product of the share of households identified as energy poor (a head-count ratio) and the average intensity of deprivation of the energy poor. Putting it more simply, it captures both the incidence energy poverty (number of energy poor households, defined in Equation 2 below) and the intensity of that poverty (how energy poor these households are, defined in Equation 3 below). This level of detail is important as it enables analysis at a disaggregated level. Further, since the method focuses on individuals (as described in Nussbaumer et al. (2011) and Nussbaumer et al. (2012)) but the CSO's datasets report energy characteristics at household level, the number of individuals affected by deprivation of energy clean and safe energy services could be calculated, if desired, by considering the household size of those households identified as energy poor.

The formal definition of the $MEPI$ is given below:

$$MEPI = H \times A \tag{1}$$

where,
$MEPI$ is the measure of energy poverty in a type of energy service across households,
H is the proportion of households considered energy poor, and
A is the intensity of the multi-dimensional energy poverty among those households.

Let $Y = [y_{ij}]$ represent the matrix of achievements for i households across j variables. $y_{ij} > 0$ denotes a household's i achievement in the variable j. Therefore, each row vector $y_i = (y_{i1}, y_{i2}, \ldots, y_{id})$ represents a household's i achievements in the different energy service variables, and each column vector $y_j = (y_{1j}, y_{2j}, \ldots, y_{nj})$ gives the distribution of achievements in the variable j across individuals.

This approach thus facilitates for uneven weighting of indicators (energy services), if desired. A weighting vector w is composed of the elements w_j corresponding to the weight that is applied to the variable j. With the summation of w_j being equal to 1 (i.e. $\sum_{j=1}^{d} w_j = 1$). For the sensitivity analysis, and by means of capturing uncertainty associated with the assigned weights, probabilistic functions can be applied to the respective weights.[6]

With z_j as the deprivation cut-off in variable j, all households deprived in any variables can then be identified. Let $g = [g_{ij}]$ be the deprivation matrix whose typical element g_{ij} is defined by $g_{ij} = w_j$ when $y_{ij} < z_j$, and $g_{ij} = 0$ when $y_{ij} \geq z_j$. In the case of the $MEPI$, the element of the achievement matrix being strictly non-numeric in nature, the cut-off is defined as a set of conditions to be met. The entry ij of the matrix is equivalent to the variable weight w_j when a household i is deprived in variable j, and zero when the household is not deprived. A column vector c of deprivation counts, where the ith entry $c_i = \sum_{j=1}^{d} g_{ij}$ represents the sum of weighted deprivations suffered by household i.

The multi-dimensionally energy poor are identified by defining a cut-off $k > 0$ and applying it across the column vector, and consider a household as energy poor if their weighted deprivation count c_i exceed k. Therefore, $c_i(k)$ is set to zero when $c_i \leq k$ and equals c_i when $c_i > k$. Thus, $c(k)$ represents the censored vector of deprivation counts, and it is different to c in that it counts zero deprivation for those not identified as multi-dimensionally energy poor.

[6]The applied function could take the assigned deterministic weight as a mean of a respective distribution function and/or with a set standard deviation.

Finally, the Headcount ratio H is computed, which is the proportion of households that are considered energy poor. With q as the number of energy poor households (where $c_i > k$) and n the total number of households, then H, which represents the incidence of multidimensional energy poverty is then defined as,

$$H = \frac{q}{n} \tag{2}$$

The average of the weighted deprivation counts $c_i(k)$ represents the intensity of multi-dimensional energy poverty A. More formally, A is calculated as

$$A = \sum_{i=1}^{n} \frac{c_i(k)}{q} \tag{3}$$

In this paper, to capture the set of energy deprivations that may affect a household, the MEPI approach considers dimensions of energy poverty: cooking, lighting, appliance ownership and entertainment. The dimensions are then weighted as shown in Table 1 below.[7] This Table also gives a description of each of these dimensions.

Table 1: Dimensions and respective variables, including relative weights (adapted from Nussbaumer et al. (2011))

Dimension/ Indicator	Variable	Deprivation (poor if ...)
Cooking	Uses modern cooking fuel? (0.2)	false
	Does cooking fuel cause in-door pollution? (0.2)	true
Lighting	Uses electricity or solar for lighting? (0.2)	false
Services provided by household appliance	Owns a fridge or refrigerator or washing machine? (0.2)	false
Entertainment	Has a computer or television? (0.2)	false

[7] On the whole, the issue of energy poverty cut-off and weights of indicators, like in all indices, remain a hotly debated issue. As such, sub-section 4.2 is focus on the same.

You will note from the Table that the cooking dimension, has two distinct components: the cooking fuel and the in-door pollution of the fuel.[8] Further, if a household uses a clean fuel for cooking, then it will not suffer from in-door pollution as a result of using that fuel. Therefore, in this study, we combined the weights of cooking fuel and in-door pollution, for simplicity. That said, this makes the cooking dimension the most important dimension in energy poverty. To illustrate, it implies that if a household is deprived of clean cooking fuel, chances that it is energy poor increase significantly. However, as described in the MEPI approach (described in the preceding paragraphs above), a household can only be classified as energy poor if the combined deprivation (in the mentioned dimensions) exceeds a pre-defined cut-off (k). In this study, the initial cut-off was set to 0.3.[9]

After estimating energy poverty (using the MEPI), an analysis that compares energy poverty and income poverty, as defined in the 2015 LCMS report (CSO, 2016), helps answer the second research question. Through this analysis two main questions were addressed: 1. Does income poverty imply energy poverty? 2. Does increase in clean energy (in this particular case, electricity) tariff lead to increase in energy poverty? Finally, based on the findings of research questions, policy recommendations are given.

The LCMS datasets were analysed using R (R Core Team, 2018). For research reproducibility and replicability[10], the R code has been shared on github[11]. However, the datasets were not shared to github because ZIPAR did not have permission from CSO to do so.

4 Results and Discussion

4.1 Quantifying energy poverty

The MEPI for national and provincial (sub-national) level were calculated by setting the multidimensional energy poverty cut-off, k, to 0.3. This means that all households that do not use electricity, LPG or other gas[12] for their cooking services are energy poor, as the cooking dimension is weighted at 0.4 (because 0.4 is greater than 0.3 the cut-off).

[8]From literature and those utilised in Zambia, a clean fuel can be any of the following, electricity, LPG, natural gas and biogas. These fuels are also thought not to cause any meaningful in-door pollution.

[9]This impact of varying this cut-off k on MEPI is discussed in sub-section 4.2 below.

[10]The importance of making research reproducible and replicable has been presented by Leek and Peng (2015)

[11]https://github.com/BTembo/energypoverty_zambia

[12]Note: Of the listed cooking fuels (in LCMS questionnaires), only electricity and LPG (other gases included) are clean fuels.

The Zambia's national MEPI were estimated at 0.79 and 0.74 for 2010 and 2015 respectively.[13] This estimation is consistent with the finding of Nussbaumer et al. (2011), which was estimated at 0.74 using the Demographic and Health Surveys dateset (ICF, 2011).[14] Table 2 below gives the MEPI at provincial level, which shows significant differences between Provinces.

Table 2: MEPI at provincial level in 2010 and 2015

Province	2010 LCMS	2015 LCMS
Central	0.827	0.798
Copperbelt	0.596	0.585
Eastern	0.934	0.894
Luapula	0.934	0.935
Lusaka	0.456	0.453
Muchinga	0.920	0.850
North-Western	0.894	0.885
Northern	0.941	0.898
Southern	0.824	0.773
Western	0.934	0.925

Table 2 shows that multidimensional energy poverty reduced in all provinces between 2010 and 2015 except for Luapula, which increased by a small margin. Further, in 2015, energy poverty was highest in the same Province: Luapula. In both 2010 and 2015, Lusaka and the Copperbelt provinces had the lowest energy poverty. The study found that even though the headcount ratio of energy poverty increases in four Provinces (Copperbelt, Eastern, Lusaka and Northern), as shown in Figure 4 below, the intensity of energy poverty reduced in all provinces except in Luapula province between 2010 and 2015. This indicates progress in reducing energy poverty.

[13]See Appendix A Tables 9 to 13 for the break-down of access to the grid, cooking, lighting, entertainment and appliance ownership factors used in the MEPI calculation.

[14]Furthermore, a sense check was done to reproduce the results (such as access rate, percentage of households using electricity for their cooking and lighting services) of both the LCMS reports.

This progress notwithstanding, the provision of clean energy, particularly for cooking, remains low. For cooking, the available clean fuels are electricity and LPG (other clean gases included). Penetration of LPG remains painfully low at 0.1% (in 2015),[15] while electricity stood at 16% (of which Lusaka, Copperbelt, Southern and Central province have the highest access to the grid and also usage). Thus, to make a meaningful and sustained progress in reducing headcount incidence of energy poverty (and the overall MEPI), there is need to invest in new energy infrastructure. In Zambia, while there have been increased reports of stand-alone solar solutions, grid extension remains the most important means of reducing energy poverty (as estimated using MEPI), as it can be used for cooking, among other energy services. In addition, LPG and natural gas infrastructure and supply chains which can be used as clean cooking fuel are currently under-developed in Zambia.

In 2015, among households that had access to the grid in Zambia, only 51% reported using electricity for cooking, a reduction from 77% in 2010. Nonetheless, access to the grid increased from 21.9% in 2010 to 31.4% in 2015 (CSO, 2012, 2016). Later in this section, we present an analysis of energy versus income poverty. In that analysis, alongside with the implication of the households having access to the grid, we show that while many households can afford to use electricity for their energy services such as cooking and lighting, they do not because they do not have access to clean fuels (such as electricity), among other reasons.

Furthermore, if Zambia is to develop a strategy of increasing usage of natural gas and LPG as a cooking fuel (as was proposed in Ghana (MOP, 2016)), all the natural gas and LPG requirements would need to be imported as there are no reported occurrences of neither natural gas nor crude oil in the country. This would imply significant increase in Zambia's energy import bill, something that the Government is looking to reduce by developing the local bio-fuel industry. However, either way, for energy poverty to reduce, there is need for massive investments in new energy infrastructure.[16]

Reduction in the intensity of energy poverty (an indication of how poor the energy poor are) is attributed to two main factors: increased penetration of solar stand-alone solutions and increased use of electricity for other energy services such as refrigeration, lighting and entertainment (other than cooking). As mentioned above, if a cost effective and sustainable solution for cooking is found, coupled with an increased penetration of solar solutions, energy poverty could be reduced significantly. That said, we should emphasise that having clean lighting only reduces the intensity of energy poverty and not the incidence of energy poverty. This is because lighting service make up only a small

[15] A respective of INDENI informed the Conference, during the Energy Week hosted by the Ministry of Energy in June 2019, that INDENI does not have the capacity to meet the current demand of LPG.

[16] There are a number of projects aimed at reducing deforesting through usage of energy efficient cook stoves. These efforts, however, do not lead to reduction in energy poverty, as charcoal is not a clean fuel.

portion of a household's energy requirement.

To interpret Table 2 in light of Figure 4 below, while Eastern and Northern provinces had identical MEPI in 2015, the energy poor in Northern province experienced a more intense form of energy poverty. This is because even though more households in Northern province (in 2015) had access to the grid, households in Eastern province utilise their access to the grid more than the households in Northern province.

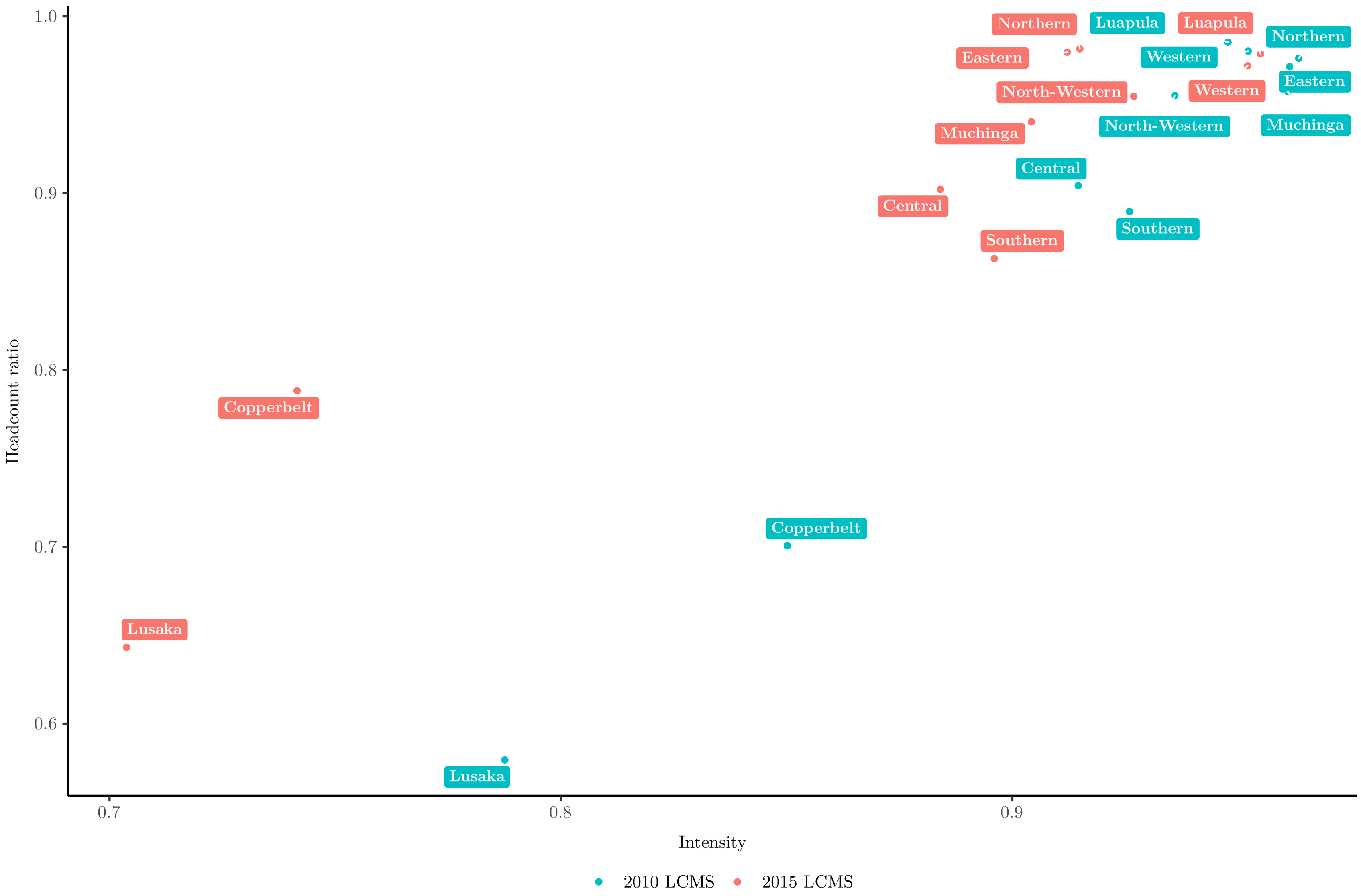

Figure 4: 2010 and 2015 Headcount ratio vs. intensity of energy poverty at provincial level

4.2 Sensitivity analysis on MEPI

The MEPI, like many other such composite indices, mainly suffers from the uncertainty in the choice of indicators, the weights of these indicators (i.e. the importance of these indicators) and availability of data. In this analysis, reliable and validated datasets from CSO were available. This data comprehensively captures the headcount ratio of energy poverty, such as access to the grid, use of electricity for lighting and cooking. The choice of indicators used in this paper is consistent with Nussbaumer et al. (2011), save for the 'Communication' indicator which was not included because we know that in Zambia, ownership of a phone is not correlated to owning a clean energy battery charging equipment nor having access to clean energy, at household level. Thus, the initial weights of indicators are adjusted (to take into consideration the omission of the 'Communication' indicator), but are in line with Nussbaumer et al. (2011) and Awan et al. (2013). This notwithstanding, cut-off and weights of indicators remain a controversial issue.

In this sensitivity analysis, specific attention is given to weights of indicators and cut-off.[17] A summary of the varied weights is given in Table 8 below (in Appendix A). To account for the impact that this variance in weights has on the headcount incidence, intensity and MEPI, a total of 1,500 simulations were done using a random uniform distribution function.

Figure 5 below shows the impact of varying weights of indicators and cut-off k on headcount incidence, intensity and MEPI. The relative ratios[18] show that varying cut-off has the most effect on the headcount incidences of energy poverty, while varying weights has a wide and considerable effect on both the intensity and MEPI. This Figure highlights that varying weights has a more significant impact on the MEPI than varying the cut-off (k). This implies that in energy poverty discourse, care must be taken in the assignment of weights since it has a greater impact on the magnitude of energy poverty experienced by households.

[17] Initial weights of indicator and cut-off are given in Table 1 above

[18] The relative ratios for varying indicators' weights was calculated by dividing the outputs of varied weights with outputs of initial weights (the cut-off was kept constant), while relative ratios of varying cut-off was calculated by dividing the outputs of varied cut-off with the outputs of varied weights.

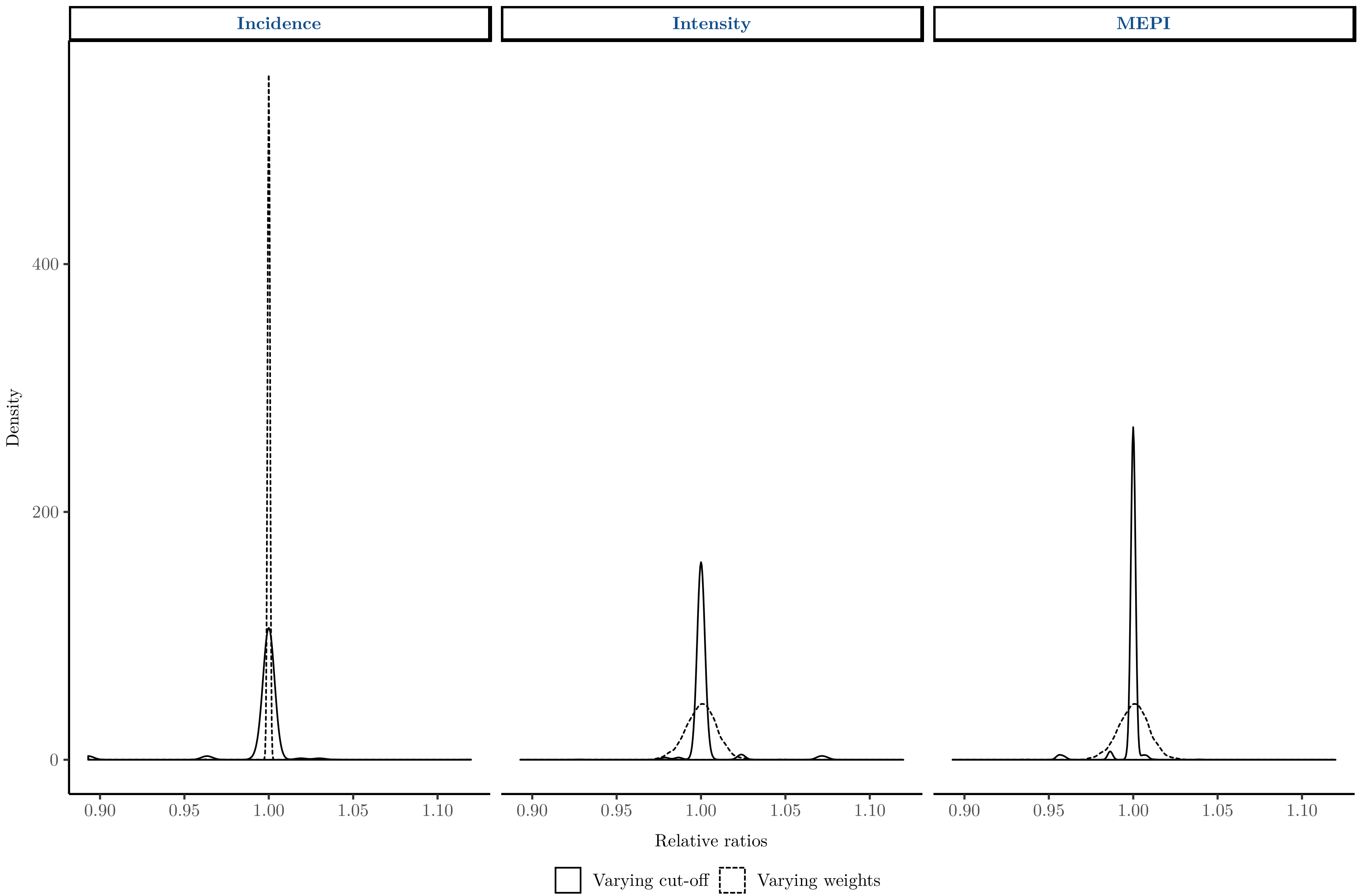

Figure 5: Relative ratios of the impacts of varying the cut-off and weights

4.3 Income poverty versus energy poverty analysis

Of the 3.01 million households in 2015, 57.0% are from rural areas, with the rest from urban areas. Tables 3, 4, 5, 6 and 7 below give a breakdown of households in Zambia by location and poverty categories, on the status of energy access and use.

In 2015, income poverty[19] at national level is estimated at 54.4% of the total population (CSO, 2016), this estimate is a sum of both Extremely Poor and Moderately Poor categories as defined by CSO. At household level, income poverty is estimated at 49%. This means that, on average, poor households (Extremely Poor and Moderately Poor) have more household members than Non-poor households. Table 3 below gives a breakdown of income poverty at household level by location. It can be seen that income poverty is more pronounced in rural areas, with 71.3% of household classified as poor while only 20.3% of urban households are classified as poor. This means that 7 out of every 10 households in rural areas are income poor.

Table 3: Share (in %) of households by poverty status in 2015

Poverty status	Rural	Urban
Extremely Poor	54.9	10.0
Moderately Poor	16.4	9.25
Non-Poor	28.8	80.7

Table 4 below shows the share of households that were connected to the national grid in 2015.[20] It can be seen that location of a household has a significant influence on whether a household is connected to the grid or not compared to the poverty status of a household. This assertion can be inferred from this Table, as the share of households connected to the grid under Extremely Poor category in urban areas is larger than the share of households under the Moderately Poor category in rural areas. Similarly, the share of Moderately Poor households in urban areas is larger than the share of Non-Poor households in rural areas that are connected to the grid. This is expected as urban areas are more densely populated and therefore are easier to electrify, but Table 4 also highlights an important point that income poverty does not always mean lack of access to clean energy. Secondly, it highlights the need for infrastructure development in rural areas, where access to the grid stands at 4.4%.

[19] According to CSO, a person is classified as poor when their measure of income (i.e. consumption expenditure) falls below a pre-determined absolute poverty line.

[20] Note that percentage share in Tables 4-7 are calculated based on each poverty status and each location. For instance, in Table 4, the value of 79.2% under Non-Poor (row) and Urban (column) means that of all households considered Non-Poor in Urban areas, 79.2% have access to the grid.

Table 4: Share (in %) of households that had access to the grid in 2015

	Have grid access	
Poverty status	Rural	Urban
Extremely Poor	0.66	9.5
Moderately Poor	1.8	29.0
Non-Poor	12.9	79.20

Tables 5 and 6 below show electricity usage among households that have access to the grid. Table 5 bring out two striking differences between urban and rural household usage patterns. It shows that urban households who have access to the grid almost always use electricity for their lighting regardless of the economic status. Such a finding is particularly important in light of the discourse around the issue of electricity affordability. If electricity usage was driven by affordability, the Extremely Poor households in urban areas would not have been using electricity to a near 100%; and also, households across poverty status categories could have had similar usage patterns. This, however, is not the case, Non-Poor households in rural areas who have access to the grid have a lower usage pattern than all categories in the urban areas. Table 5 also shows unusually low usage of electricity for lighting among rural households. It is not yet clear why this could be the case.

Table 5: Share (in %) of households that used electricity for lighting in 2015

	Use elec. for lighting	
Poverty status	Rural	Urban
Extremely Poor	37.7	97.5
Moderately Poor	73.0	99.5
Non-Poor	87.6	99.5

Table 6 below shows the usage of electricity for cooking service among households that are connected to the grid. This usage pattern is what would be expected across poverty status, where the usage patterns of rural Non-Poor households have the similar patterns as the Non-Poor households in urban areas. Similar to Table 5, this Table highlights that electricity usage patterns among households is not only driven by affordability. For instance, some Extremely Poor households in the urban areas can afford to use electricity while within the urban areas some Non-Poor households are not using electricity for cooking. A plausible explanation could be that the quality and reliability that the grid delivers to some households cannot reliably support cooking services. These plausible reasons however are not analysed in the paper, it is something that needs to be studied using appropriate methods, such as the World Bank's Multi-Tier Framework (MTF) approach[21].

Table 6: Share (in %) of households that used electricity for cooking in 2015

	Use elec. for cooking	
Poverty status	Rural	Urban
Extremely Poor	8.79	15.5
Moderately Poor	22.9	16.4
Non-Poor	51.4	52.6

Finally, Table 7 shows the overall state of energy poverty (MEPI) in Zambia in 2015, which shows skewness of rural households being energy poor regardless of their income poverty status. This is the evidence of the impact that location plays in the energy poverty discourse. As mentioned above, access to clean cooking is the main determinant of whether a household could be classified as energy poor or not. This emphasises the need for the provision of clean fuels for cooking if energy poverty is to be reduced.[22]

Table 7: Share (in %) of households that are not energy poor in 2015

	Not energy poor	
Poverty status	Rural	Urban
Extremely Poor	0.01	1.33
Moderately Poor	0.34	3.33
Non-Poor	5.56	37.0

In this energy poverty versus income poverty analysis, we have shown that income poverty does not mean a household cannot afford to use electricity (a clean fuel) for their energy services. Thus, when a household is connected to the grid, usage of electricity is driven by many other factors other than affordability. Furthermore, we also highlighted that the location of a household plays a significant role as to whether a household has access to the grid or not; urban areas have better and more developed infrastructure than rural areas. Therefore, a deliberate strategy and policy of reducing energy poverty in Zambia should

[21]Details for Multi-Tier Framework approach can be found in Bhatia and Angelou (2015)

[22]The values in Table 7 can be estimated using Tables 4 and 6; the slight differences can be explained by the access to clean fuels for cooking has been treated (see Section 3 above for how the treatment was done).

be developed other than solely focusing on reducing income poverty with the hope that energy poverty would be reduced too. The underlying dynamics of energy poverty and income poverty are different and require focused strategies and policies. This is truer for a country like Zambia where availability of clean fuels is not available to all.

4.4 Discussion summary

In literature, we found much of the results created a strong link between income poverty and energy poverty. This literature advanced an affordability argument. It is, for instance, argued that when a household is income poor, then it is energy poor, and is also vulnerable to energy price shocks. While this might be true in some countries, it is not so for Zambia.

In Zambia, being income poor does not imply energy poverty. Actually, as shown in the analysis above, there are households that are classified as Extremely Poor (income wise) but are not energy poor. Furthermore, we have households that are Non-poor (income wise) that are energy poor. The characteristic of energy poverty in Zambia is complex. One of the factors that complicates the characteristic is the clean energy availability factor, among other possible confounding household characteristics.

For instance, there are households that can afford to access and use grid electricity but do not have access to the grid because of lack of infrastructure. These types of households are pre-predominately located in rural areas. Therefore, to ensure that energy poverty is reduced, there is need for more investment in energy infrastructure than the usual approach of subsidising energy consumption. In the current state of the Zambian energy market (for commercial fuels), subsidies would have little effect on the reducing energy poverty. Actually, energy subsidies may just benefit those who are able to bear the full cost of the energy price and not those whom it is intended for: the actual poor.

Our paper analysed energy poverty in the context of both affordability and availability. We showed in Tables 5 (above) that in 2015, affordability did not play a significant role in influencing which household is classified energy poor, especially in urban areas. The results are not conclusive for rural areas, as the percentage use of electricity for lighting among households with access to the grid is varied. More work and analysis need to be done to identify the cause for these differences highlighted in Table 5 above.

Throughout the analysis presented in the sub-sections above, the main source of energy poverty seems to be more of an availability issue than affordability. Hence our argument that to effectively reduce energy poverty among Zambia households, there is a need for investment in energy infrastructure. This infrastructure should be able to deliver clean fuel for cooking services; it can be electricity, LPG, natural gas or bio-gas. Energy subsides, particularly without investing in supply infrastructure, we argue will not lead to reduction of energy poverty among Zambian households.

5 Concluding remarks

This paper sought to characterise energy poverty among Zambian households. While there are many household factors that could be used to characterise energy poverty, this paper focused on income, location and access to the grid. We conclude that location and access to the grid are better predictors of the energy poverty status of a household in Zambia than income. This finding presents a major departure from the usual narrative of the impact of income. The finding implies that the Zambian government should focus on policies that would close the gaps that result from difference in location and also on policies that would increase access to the grid. We argue that energy subsidies are not an efficient solution to making clean energy more affordable.

We found that energy poverty is wide spread in Zambia, particularly among Provinces that have a significant portion of rural areas. Lusaka and Copperbelt provinces have the least incidences of energy poverty with Luapula, Eastern and Northern having the most incidences of energy poverty. Similarly, households in Lusaka and Copperbelt provinces experience the least severe form of energy poverty while households in North-Western, Luapula and Western provinces experiences a more intense form of energy poverty. Overall, both the incidence and intensity of energy poverty decreased between 2010 and 2015. An indication of progress in the right direction. However, policies that could effectively address these two aspects are different but at the core of this policy package should be energy infrastructure.

By using the MEPI or access to the grid rates, this paper highlights one major policy implication, the need for increased investments in energy infrastructure instead of energy subsidies. Energy subsidies have for long time been thought as a good mechanism for improving the poorer households' energy status. However, we have shown that in Zambia, lack of availability of clean energy and access to clean energy infrastructure is more of an issue than how affordable the clean energy is. Therefore, in order to meaningfully reduce energy poverty, the Government must invest in clean energy supply infrastructure than subsidise consumption of clean energy in Zambia.

For future work, there is need to check how best other household characteristics can be used to predict energy poverty in Zambia. One such analysis would be testing if a household headed by a female is more likely to be energy poor than that headed by a male, all things held constant. This analysis could feed into the energy access project of the World Bank that subsidises female headed households to be connected to the grid in Zambia. Beyond the need to check for evidence in certain policy directions, these types of analyses would help improve characterisation of future energy demand among households in countries like Zambia. This is of great importance because Tembo (2018) also found that uncertainty in energy demand has a significant impact on both investment capital cost of an energy system and also on tariffs.

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A Appendix for Section 4

Table 8: Variance of indicators and cut-off weight

Indicator	Weight	Var. range	Distribution
Clean cooking	0.4	±25%	Random uniform
Clean lighting	0.2	±25%	Random uniform
Appl. ownership	0.2	±25%	Random uniform
Entertainment	0.2	±25%	Random uniform
Cut-off (k)	0.3	±25%	Random uniform

Table 9: Summary share (in %) for households without access to the electricity grid

Province	2010 LCMS	2015 LCMS
Central	85.7	80.4
Copperbelt	55.2	42.0
Eastern	94.7	92.2
Luapula	95.4	93.5
Lusaka	39.3	29.4
Muchinga	92.1	82.9
North-Western	91.1	86.1
Northern	94.6	91.1
Southern	82.9	75.4
Western	96.0	94.0

Table 10: Summary share (in %) for households without clean cooking fuels

Province	2010 LCMS	2015 LCMS
Central	90.3	89.8
Copperbelt	69.0	78.6
Eastern	97.0	97.9
Luapula	98.5	97.9
Lusaka	56.0	63.3
Muchinga	95.6	94.0
North-Western	95.5	95.3
Northern	97.5	98.2
Southern	88.4	86.0
Western	98.0	97.1

Table 11: Summary share (in %) for households without clean lighting fuels

Province	2010 LCMS	2015 LCMS
Central	83.2	75.4
Copperbelt	54.9	40.9
Eastern	90.7	83.5
Luapula	93.4	89.5
Lusaka	38.5	27.8
Muchinga	89.6	75.8
North-Western	87.4	81.5
Northern	90.0	86.2
Southern	78.5	69.6
Western	88.2	87.8

Table 12: Summary share (in %) for households without electrical appliances

Province	2010 LCMS	2015 LCMS
Central	82.6	79.6
Copperbelt	64.3	57.6
Eastern	95.6	88.4
Luapula	85.5	94.1
Lusaka	54.4	50.9
Muchinga	93.4	87.9
North-Western	84.9	89.0
Northern	96.4	82.3
Southern	85.6	79.0
Western	94.0	93.5

Table 13: Summary share (in %) for households without entertainment

Province	2010 LCMS	2015 LCMS
Central	69.5	66.2
Copperbelt	46.2	38.1
Eastern	87.2	79.2
Luapula	91.2	88.2
Lusaka	33.4	26.4
Muchinga	86.8	75.0
North-Western	85.0	81.8
Northern	89.3	84.3
Southern	73.7	67.4
Western	88.9	87.5

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