MULTIDIMENSIONAL MEASURE OF ENERGY POVERTY IN LESOTHO

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Abstract

This study employs the Alkire-Foster methodology to assess multidimensional energy poverty in Lesotho, using data from the Household Energy Consumption Survey in Lesotho. The investigation considers three dimensions, cooking, lighting, and water heating in constructing the multidimensional energy poverty index. In terms of the three dimensions, the overall findings indicate that at the national level, approximately 61% of the households experience multidimensional energy poverty. Upon decomposing the Multidimensional Energy Poverty Index (MEPI) by the settlement type, the results indicate that 83.50% of the households in rural areas are multidimensionally energy poor while 51.20% of the peri-urban households are deprived. In the urban areas, only 19% of the households experience energy poverty. In decomposing the MEPI by the gender of the household head, the results demonstrate that around 59.40% of female-headed households exhibit multidimensional energy poverty than their male-headed counterparts with 54.40%, with an average intensity of 91% of the weighted indicators. Decomposition by districts reveals that Butha-Buthe, Mokhotlong, Qacha, and Thaba-Tseka have over 80% of the multidimensionally poor households. Additionally, the study highlights the prevalence of traditional cooking fuels in rural areas, with minimal reliance on electricity. This pattern shifts with urbanization, where traditional fuel consumption decreases.

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1. Introduction

In the discussion about energy and the environment, the spotlight often falls on climate change, drawing considerable attention from researchers and policymakers alike (Gao et al., 2019; Li et al., 2019). However, amidst these discussions, the persistent challenge of ensuring access to electricity stands as a critical concern, particularly in the context of the developing world. Acknowledged not only as a fundamental human right but also as a catalyst for poverty alleviation, electricity access plays a foundational role in powering essential economic activities (González-Eguino, 2015). The absence of reliable access to electricity not only hampers economic development but also impedes the effective delivery of modern public services, including vital sectors such as education and healthcare, to their intended recipients.

The problem of energy poverty, which is defined as the lack of access to affordable, reliable, sustainable, and modern energy access to electricity, is presently receiving more attention in scientific circles, with an emphasis on understanding its different dimensions, spillover effects, and practical solutions. Energy poverty has become a widespread issue impacting households globally in the wake of the global financial crisis (Arpegis et al., 2022). For example, it was estimated that over 34 million Europeans could not afford adequate indoor thermal comfort in 2018. Furthermore, around 2.4 billion people globally do not have access to electricity or face limitations in connection to unreliable electricity grids (Sovacool et al., 2012). It is thus regarded as a phenomenon that raises social and economic concerns across the globe (Thomson et al., 2016).

Throughout history, the significance of energy as a crucial catalyst for economic activity, and consequently a fundamental element of growth, has been thoroughly elucidated (Olayele, 2015). The primary objective of the Sustainable Development Goal (SDG) 7 of the United Nations (UN) is to guarantee that everyone has equal access to cost-effective, sustainable, and reliable modern energy by 2030 (United Nations, 2021). Energy poverty in developing nations denotes the absence of access to modern energy sources necessary for modern energy services (Okushima, 2017). Energy poverty has been assessed using single-dimensional measures to determine the kinds of energy sources used in households. However, household energy poverty in developing countries can encompass multiple deprivations. Its impact extends across all territorial units, with rural and remote areas, in particular, facing significant disadvantages due to limited or no access to modern energy sources.

The World Energy Outlook (2020) published by the International Energy Agency (IEA) emphasizes that uncertainties resulting from the COVID-19 pandemic pose hazards to vulnerable people as well as obstacles to the progress of the clean energy transition. The COVID-19 pandemic's continuing effects highlight the larger effects of energy poverty on human welfare and climate change, which may postpone major energy investments and planned growth. Access to energy is vital for economic development and societal well-being. As highlighted by Sumiya, (2016), the delicate balance between energy poverty, prosperity, and livelihood may expand due to the significant role energy access plays in fostering overall societal and economic progress. Therefore, the World Energy Council (WEC) (2016) regards access to modern energy services as an essential societal entitlement, deeming it a crucial factor in the development of societies. Sher et al. (2014) similarly acknowledge it as the initial step in the development of any country.

According to the United Nations, more than 750 million people lacked access to modern electricity services in 2019, with sub-Saharan Africa (SSA) accounting for 75% of this total (United Nations, 2020). In severely impacted countries like South Sudan and Chad, 93% and 91% of the population, respectively, did not have electricity access in 2019 (World Bank, 2021a). The World Bank's 2019 World Development Indicators report that sub-Saharan Africa had the lowest average electricity access rate globally, at just 47%. Despite these challenges, there has been some progress: since 2000, approximately 145 million people gained access to electricity, particularly in countries like Nigeria, Ethiopia, South Africa, Ghana, Cameroon, and Mozambique.

Lesotho is a small mountainous kingdom landlocked by the Republic of South Africa (RSA) with a population of 2, 191,024 million and it covers an area of around 30, $355m^2$ according to the World Bank 2022. The socio-economic development of Lesotho is considered to be driven by electricity as a primary energy source. Lesotho is a member of the Southern African Development Community (SADC), which had severe electricity shortages in 2008 that led to load shedding. Local generation has been held steady at about 72 MW in the country even though power demand is still outpacing supply as highlighted by Lesotho Energy Report (2015-2025). Over 50% of Lesotho's electricity consumption was covered by imports by the end of 2013 while Lesotho associated herself with the goals of the United Nations Initiative on Sustainable Energy for All (SE4ALL).

Lesotho's energy sector is confronted with issues such as limited access to clean energy sources, dependence on imported fuels and power (which poses an energy security issue), and depleting forest resources. The government has set goals to raise access to electricity to 75 percent and the usage of renewable energy sources by 200 MW by 2020 in recognition that these obstacles are impeding the nation's progress. All licensed renewable energy generators, Independent Power Producers (IPPs), with a capacity of at least 500 kW are assured access to the transmission system at a set cost, according to the United States Agency for International Development (2021). However, due to large rural settlements in Lesotho, the cost of extending the grid to cover the entire nation is exorbitant, and the lack of access roads in rural areas makes it difficult for people to effectively make use of alternative clean energy options such as liquefied petroleum gas (LPG). As a result, biomass offers a convenient and reasonably priced source of energy for households (Mothala et al., 2022).

Lesotho's government formed the Rural Electrification Unit (REU) in 2004 to expand the electricity grid to rural areas previously not served by the national power monopoly, Lesotho Electricity Company (LEC). The REU was tasked with supplying energy to rural areas and locations more than 3.5 kilometers from the LEC's transmission and distribution network. Thus far Lesotho has been able to achieve 34% rural electrification and 77.7% urban electrification which signifies a wide gap in energy poverty in the two geographical areas.

While there exists some research on the effects of energy poverty on households in developing nations, there is a lack of studies that specifically measure multidimensional energy poverty in Lesotho. Notably, Mothala et al. (2022) conducted a study focusing on determinants of household energy consumption choices, but it did not specify the dimensions in which these households are energy poor which could highly influence their choice of energy in their daily activities. Thus, the study becomes crucial and adds to the existing literature as it aims to comprehensively measure energy poverty, considering various dimensions of accessibility. By adopting this approach, it becomes possible to gain a broader understanding of the nature and extent of energy deprivation in Lesotho.

The research provides a thorough analysis of energy poverty at national, district, and household levels within the country. This analysis of the extent and intensity of energy poverty can serve as a valuable resource for policymakers and social planners in improving access to clean energy sources. It facilitates the development of financial plans, legal frameworks, and policy plans aimed at those experiencing different forms of energy deprivation. It can be used to track the success and advancement of policies that are being implemented in line with SDGs, which may lead to changes in the creation and application of policies that are more closely aligned with the SDGs of the UN. Furthermore, carrying out a comprehensive multidimensional analysis of energy poverty aids in the creation of integrated, multisectoral policies that enable people who are experiencing many forms of energy deprivation to undergo social and economic reforms.

A commonly adopted method for measuring energy poverty is by affordability which calculates the percentage of household income spent on energy expenditures. In the context of energy affordability, a household is classified as deprived in this domain when the ratio of necessary energy expenses to total expenditure exceeds 10%. However, due to the availability of data in Lesotho, the current study focuses mainly on energy accessibility. Access, in this context, refers to the ability of households and businesses in a specific region to connect to established electricity sources, which is a grid-connected supply. The objectives of this work are threefold. First, the study assesses the extent of energy poverty in Lesotho within a multidimensional framework. Secondly, it examines the presence of sub-group differences in multidimensional energy poverty by decomposing the MEPI at the national level, by settlement type, district, and lastly by gender of the household head. The results indicate that female-headed households are multidimensionally poorer than male headed households. Furthermore, rural areas experience more severe energy poverty than peri-urban and urban areas. They further reveal that when MEPI is decomposed by the districts, Butha-Buthe, Mokhotlong, Qacha, and Thaba-Tseka over 80% of the households are multidimensionally poor.

The remaining sections of the study are divided as follows: Chapter 2 provides a background of the study, and chapter 3 reviews the existing literature on the measurement of energy poverty andits impacts. Chapter 4 is the data description of the study. Chapter 5 provides a detailed methodology description for the study, while chapter 6 provides results and discussions. Lastly, chapter 7 provides conclusions and highlights recommendations from the study.

2. Residential energy consumption in Lesotho

In the realm of consumer goods, energy consumption sets itself apart due to its classification as a fundamental necessity, as highlighted by Biermann & Welsch (2017). Its fulfillment is imperative for maintaining an acceptable quality of life. Moreover, modern energy services, such as electricity and liquefied petroleum gas, play a pivotal role in addressing a majority of basic human needs (Chakravarty & Tavoni, 2013). However, the consumption of energy adds to household expenditures, particularly in economically disadvantaged households, there may be a compromise between energy consumption and other essential purchases. These concerns form the foundation of SDG 7, which aims to "Ensure access to affordable, reliable, sustainable, and modern energy for all" (United Nations, 2021).

In 2015, approximately 72% of urban households were connected to the electricity grid in Lesotho, whereas only 5.5% of rural households had access to electricity (LEWA, 2017). Even in areas covered by the grid, not every household is connected to it. Moreover, households that are connected to the grid are often hesitant to utilize electricity extensively, as indicated by the observed decline in average household consumption (Mpholo et al., 2018). The study further highlights that a significant number of households in the nation experience poverty and face challenges in obtaining electricity. This is predominantly due to the spatial distribution of settlements which exacerbates this situation and mountainous terrain that limits infrastructural developments. Achieving nationwide grid extension seems to be economically unfeasible, and accessing alternative clean energy sources such as liquefied petroleum gas (LPG) poses difficulties in rural areas due to the shortage of access roads. Consequently, biomass emerges as a cost-effective and readily available energy source for households.

Households in Lesotho, particularly those situated in rural areas, predominantly rely on biomass, including fuel wood, agricultural residues, and dung. In contrast, other intermediate fuels such as coal and kerosene, as well as modern fuels like electricity and LPG, constitute a minor proportion of the overall domestic energy consumption. In regions where electricity is accessible, its primary usage is for lighting, TVs, and radios, rather than for cooking and heating (REU, 2017). This pattern is observed due to the prevalent perception among the majority of households that electricity and other cleaner energy sources, such as gas, solar, and batteries, are costlier than

traditional biomass fuels (Mpholo, 2018). Consequently, the perceived affordability of electricity, particularly in rural areas, emerges as a principal obstacle hindering greater adoption of electricity and other cleaner energy alternatives.

Due to the growing demand-supply gap and the deteriorating state of electricity transmission and distribution infrastructure, connecting every household to the national grid is not feasible. Hydropower emerges as a viable solution for generating electric power close to potential consumers, eliminating the need for expensive distribution costs in widely dispersed rural areas. Lesotho possesses substantial economically exploitable hydro potential, estimated at 450 MW for conventional hydropower systems and over 3000 MW for pumped storage schemes (Taele et al., 2012). However, only 75.25 MW of hydroelectric potential has been harnessed to date. The untapped potential amounts to 374.75 MW for conventional hydroelectricity.

The Lesotho Highlands Water Project (LHWP) is a multi-phased initiative between the governments of the Kingdom of Lesotho and the Republic of South Africa. It includes both water transfer and hydropower generation components, along with associated ancillary developments. The water transfer component involves constructing dams and tunnels in Lesotho to enhance water use from the Senqu (Orange) River and its tributaries by storing, regulating, diverting, and controlling the flow. This ensures the delivery of specified quantities of water to South Africa while utilizing the delivery system to generate hydroelectric power in Lesotho.

In light of hydropower being a viable solution for enhancing power generation, Lesotho has completed the feasibility study of Oxbow Hydropower Scheme which is phase 2 of the Polihali Dam Construction and is expected to enhance Lesotho's energy security by decreasing the country's reliance on electricity imports. The electricity produced at Oxbow is expected to contribute to the additional 40% of electricity that will be generated at ‘Muela Hydro electricity power, due to the increased water flow from Polihali Dam which is under construction.

The Lesotho energy mix comprises Biomass and hydropower. It will also incorporate solar whereby there is an ongoing construction of The 70 MW Ramarothole solar power project which runs in two phases. Phase I involved constructing a 30 MW solar generation facility over 18 months which was completed in 2023. Phase II will add 40 MW and is scheduled for completion in 2030. In Phase I, a 132 kV substation was built, and a 55 km transmission line was developed to carry electricity from Ha Ramarothole to Mazenod or Ha Mofoka for integration into the

national grid. Overall, since Lesotho has initiated power generation projects, it should leverage these efforts to attract investors who can help expand electricity distribution to underserved households, especially in rural areas where the challenging terrain has made it costly as shown in Lesotho Electricity Generating Company (LEGCO) 2023.

One problem identified in developing countries is that tariff prices hinder a lot of poor households from using modern energy for their daily activities. For example, the study by Sun & Lin (2013) highlighted that is of paramount importance, especially for low-income nations, to have a tariff reform that strikes a delicate balance between social stability, affordability, fairness, energy efficiency, and cost recovery, given that the majority of the population consists of individuals with limited financial means. This becomes even more critical considering that many electric utilities are constructed with public funding, creating an expectation that electricity should be accessible to all at an affordable price, catering to basic needs, at the very least (Hosier & Kipondya, 1993). This aspect holds particular significance in non-industrialized nations, such as Lesotho, where the bulk of energy consumption emanates from households. Table 1 highlights the percentage consumption by consumer category in Lesotho, revealing that domestic consumption tends to be slightly higher than industrial consumption, emphasizing the importance of ensuring equitable and economically viable electricity access.

Table 1 Consumption of energy by consumer category 2012-2017 (% of the households)

	2012/13	2013/14	2014/15	2015/16	2016/17
Domestic	34.6%	35.1%	34.4%	34.1%	33.1
General purpose	13.0%	12.9%	11.4%	11.4%	12.0
Commercial	18.0%	32.5%	19.7%	19.7%	19.1
Industrial	33.8%	19.1%	34.3%	34.6%	35.5
Street lighting	0.6%	0.5%	0.2%	0.2%	0.3

Source: Calculations by Mpholo et al. (2020)

The table shows the higher electricity consumption in the domestic consumer category compared to the industrial category, alongside elevated poverty levels, underscores the need for leveraging electricity for productive purposes to foster economic development. The emphasis on connecting to the electricity grid should extend beyond the advantages for domestic use. Redirecting energy usage towards productive purposes, rather than domestic consumption, can decrease the proportion of households experiencing energy poverty.

Mpholo et al. (2020) further emphasize that it can contribute to lowering production costs in established industries and simultaneously create new employment opportunities. Hence, following the energy ladder model, a rise in household income can prompt the adoption of cleaner, more convenient, and more efficient energy fuels like electricity and LPG (Masera et al., 2000). Conversely, the energy fuel-stacking model suggests that as income increases, households are not inclined to shift to cleaner energy fuels but rather tend to concurrently use multiple energy sources (Gould & Urpelainen, 2018).

3. Literature review

In this chapter, the research explores existing literature concerning the measurement of energy poverty.

3.1 Energy poverty measurement

There are several definitions of energy poverty (EP) in the literature. One definition states that households that do not have access to energy or cannot afford the energy necessary for essential needs such as lighting, water heating, space heating, and cooking are categorized as energy-poor (Ye et al., 2021), and such households can either be poor in affordability, or access, or both. Two methods have been used often in the literature to define affordability: the residual income method and the 10% indicator. In light of this, a household is said to be energy-poor in terms of affordability if it spends more than 10% of its income on energy costs (Welsch et al., 2017).

The residual methods concentrate on the remaining funds available for purchasing goods and services apart from energy. The after-fuel costs poverty (AFCP) indicator and low-income, high-costs (LIHC) indicator are two examples of these techniques. The AFCP has a drawback in that it identifies low-income households whose situation is exacerbated by high costs of energy. Consequently, regardless of their actual energy requirements, the AFCP could label practically all low-income homes as energy-poor. As a result, it might not be able to distinguish between energy and income poverty, as demonstrated by Legendre et al. (2015). On the other hand, the LIHC indicator operates under the assumption that households that are not considered poor in terms of income cannot be categorized as energy poor. However, it fails to account for vulnerable households that have been pushed into income poverty due to their high energy consumption expenses (Legendre et al., 2015).

3.2 International literature on energy poverty

The SDG7 established by the UN (2015), emphasizes the importance of making affordable and reliable energy accessible to all. Ensuring universal access to electricity, and clean cooking fuels, and promoting energy efficiency are critical factors in enhancing living conditions worldwide. According to the World Bank database, as of 2018, 89.6% of the global population had access to electricity. In contrast, only 59.34% had access to clean fuels and technologies for cooking in 2016. Energy availability has long been disregarded as a crucial development goal in the African context, even though it is essential to achieving other important objectives like improvements in health and education (El-Katiri, 2014). As a result, achieving universal access to electricity continues to be a challenge in the developing world, including many African nations.

Notably, North America and the European Union achieved 100% electricity access, while Sub-Saharan Africa lagged with only 47.7% of the population having the same access. Similarly, substantial variations exist in access to clean fuels and cooking technologies, with high percentages in the EU, North America, Middle East, and North Africa, but significantly lower rates in Sub-Saharan Africa (The World Bank Open Data, 2010). This data underscores the imperative to prioritize efforts towards augmenting the electrification rate in Africa. It emphasizes the need to invest in essential infrastructure that can extend access to electricity and cleaner cooking fuels to a larger population in the region. This strategic focus can enhance living standards, promote health, and improve overall welfare in the area.

Studies further underscore the severity of energy poverty in numerous developing countries (Hadri, 2000; Awaworyi et al., 2020). The definition of energy poverty, however, lacks universal consensus as the concept is dynamic and subject to ongoing debate (Hadri, 2000). Despite the conceptual challenges surrounding the definition of energy poverty, economists generally agree that it pertains to households' incapacity to fulfill basic energy requirements (Thomson et al., 2016). In simpler terms, individuals experiencing energy poverty primarily rely on traditional biomass for their energy needs, leading them to dedicate a significant portion of their time to gathering wood and dung to meet these basic requirements (González-Eguino, 2015).

According to EU guidelines on energy poverty, it combines factors like low income, substantial spending on energy relative to disposable income, and poor energy efficiency (Healy, 2017). This definition suggests a cause-and-effect relationship, where factors such as low income cause outcomes like energy deprivation. Essentially, it includes both the factors contributing to energy poverty (e.g., low income) and the effects (energy deprivation). The presence of these cause-and-effect elements has been proven to create ambiguity in the definitions and metrics used to conceptualize energy poverty in recent decades as highlighted in (Bardazzi et al., 2021). To address these challenges, especially in the Sub Saharan Africa (SSA) region where energy poverty still has alarming rates, in rural areas, there is a pressing need to measure energy poverty multidimensionally to fully unpack the level of deprivation by the households.

3.3 Energy poverty in developing countries

In the past, energy poverty has been assessed using single-dimensional measures to determine the kinds of energy sources used in households. For instance, researchers like Karimu (2015), Mensah & Adu, (2015), and Akpalu et al. (2011), have focused on investigating the types of energy for cooking chosen by households in Ghana. However, household energy poverty in developing countries can encompass multiple deprivations, occurring simultaneously in terms of both energy availability and affordability. Therefore, it is crucial to adopt a composite indicator that considers these combined aspects to effectively measure and understand the extent of energy poverty. Considering recent advancements in measuring multidimensional poverty, an increasing number of studies have begun to evaluate energy poverty using multidimensional frameworks. Nussbaumer et al. (2012) introduced a Multidimensional Energy Poverty Index (MEPI) inspired by the counting approach to measuring multidimensional poverty, as proposed by Alkire et al., (2011a, b). This innovative index, MEPI, assesses both the occurrence and severity of multidimensional energy poverty.

The study by Crentsil et al. (2019) draws from the theoretical underlying of the capability approach to households' energy use analysis to study energy poverty within the multidimensional framework. It further highlights that fuel use and household energy demand play an essential role in the wellbeing of the households and that the drawbacks of a household's lack of energy resources coupled with energy demand are, by nature, multidimensional. This approach is important in measuring sources of household energy deprivations and energy poverty determinants, as it is proven as a better assessment method in developing countries. It is further applauded by its ability to measure households' energy poverty beyond a unidimensional metric, for example, the type of energy resources consumed, the amount spent on energy resources, or services to a multidimensional framework that encompasses the quality of life and energy services of an indicator.

Energy poverty in developed economies mostly relates to affordability issues, while in poor countries, the situation is more complex and involves issues with both affordability and accessibility. International organizations have recently emphasized a concept that prioritizes accessibility. IEA (2010) notes, for example, that a large proportion of households in developing nations do not have access to modern energy sources for basic purposes like lighting, heating, and cooking. According to Barnes et al. (2011), energy poverty is more severe in Bangladesh (58%) than income poverty (45%). Comparable studies have been carried out in Nigeria (Ogwumike & Ozughalu, 2015), Pakistan Sher et al. (2014), and African nations (Nussbaumer et al., 2012).

Existing research has extensively explored the nexus between energy poverty and health and education in developing nations, as evidenced by studies such as those conducted by Apergis et al. (2022) and Sule et al. (2022). Additionally, Ye et al. (2018) investigated the factors influencing household electricity consumption in South Africa, while Mothala et al. (2022) delved into the determinants of household energy fuel choices in Lesotho. The study specifically focused on cooking and water heating energy fuel choice for Lesotho. However, the study did not take into account determinants of fuel choice for lighting which is also a crucial energy service in developing countries. This may lead to policymakers relying on limited analysis. Despite these efforts in Sub-Saharan Africa, there remains a notable research gap, particularly in the context of Lesotho, where no comprehensive study has addressed the multidimensional aspects of energy

poverty among households. This gap motivates the current study, seeking to address this unexplored aspect in the context of Lesotho's energy landscape.

In contrast to these prior investigations, this study investigates energy poverty in Lesotho using a multidimensional framework. As outlined by Wiley (2013), concerns and challenges remain, such as how to best define and quantify energy services, which dimensions to prioritize, and how to set threshold levels in ways that assist in attaining desirable development results. The data employed in our study is therefore prone to subjective perceptions of individual energy situations, and these perceptions might widely vary and can lead to inconsistent and subjective data on energy poverty dimensions. For example, within certain households, individuals might refrain from utilizing specific energy sources not due to a lack of access or affordability, but rather owing to their inherent personal norms and preferences. As exemplified in the REU (2017) study, households abundant in cow dung may persist in using biomass, even when connected to the grid.

The current study analyzes multidimensional energy poverty in the country as a whole and subsequently decomposes the MEPI based settlement type, by the gender of the household head and lastly by the districts. The proposed method contributes to existing literature and solves the outlined limitations by identifying specific dimensions contributing to energy poverty, policymakers can design more targeted and effective interventions. Gafa and Egbendewe (2021) assessed energy poverty in Senegal and Togo across multiple dimensions. Results showed higher prevalence in rural Togo, attributed to lower per capita income and limited access to modern energy. Key factors influencing energy poverty included household income, fertility, and fuel type. Consequently, these outcomes serve as a compelling motivation for the present study, particularly in the context of Lesotho to look at energy poverty in more than one dimension, thereby providing insights into the extent of energy deprivation.

4. Data

This research utilizes the 2017/2018 Household Energy Consumption Survey (HECS) sourced from the Bureau of Statistics in Lesotho due to its ability to offer comprehensive insights into energy usage among end users, primarily households. HECS not only provides a more detailed overview of household energy consumption but also captures a broader range of data on household income compared to the budget survey. This additional information is integral to the core objectives of the study.

The principal aim of this survey was to acquire data on the energy consumption of households in Lesotho in two phases, phase 1(July) and Phase 2 (November). The survey sought to gather quantitative information on energy consumption across various sources and investigate diverse energy usage patterns, and it used a phase 2 survey. The household energy consumption questionnaire encompasses demographic data and household energy usage. It comprises fourteen sections, which entail information about household identification and demographics, while the remaining sections focus on various aspects of energy end uses. These include details such as the type of biomass used, characteristics of its usage, connection to the electricity grid, type of energy for cooking, consumption patterns, water heating practices, and the source of energy for lighting.

It further captures information on households' including details on household income, household-level characteristics, and access to electricity across the country. The target population consists of approximately 50,000 households based on the 2006 household census. To ensure representative sampling, the population was divided into strata, which were defined by combining demographic size, geographical areas, and altimetric areas of enumeration areas. Within each stratum, a random selection process is employed to choose 15 households. A stratified sample comprising 2,877 households was interviewed by enumerators in their respective homes achieving a response rate of 93%.

It is worth noting that while the HECS is reliable data to use in this analysis, it is still subject to the following limitation, respondents may not accurately recall their energy consumption details or may provide incorrect information about the types of energy sources they use for lighting, cooking, and heating. It is also subject to self-reporting errors where there may be inaccuracies in self-reported data due to misunderstandings of survey questions or intentional misreporting. This is particularly relevant when detailing specific energy sources and consumption patterns. Energy consumption patterns vary significantly by season, especially for heating and cooling. A survey conducted in one season might not capture the full range of household energy use. Furthermore, missing data on specific energy sources that households use for lighting, cooking, and heating can lead to gaps in the analysis. Hence the research recognizes these limitations.

During the data cleaning process, it was observed that some variables provided more information than others. Notably, all demographic variables were complete, whereas the housing status variable had instances of missing values. To preserve valuable data and acknowledge the unique and significant information contributed by each variable, the study chose not to eliminate variables with missing information. As a result, 2683 observations were utilized for this analysis despite the presence of missing values.

The survey gathers information on demographic characteristics, encompassing details about household members such as their names, gender distribution (total women, total men, andchildren), age, and highest education level attained by the household head. It also includes housing characteristics, covering aspects like household ownership of units and the number of units owned.

Furthermore, economic characteristics were captured, which involved recording the range of monthly household income and whether they received remittances or any transfers monthly. Income in this case was captured using ranges and not specific numerical values where the low-income category is households earning between M0-M999 per month (equivalent to 1 USD = M17) in 2017br. Additionally, those falling within the range of M1,000-M4,999 were categorized as middle income, while the remaining were categorized as high-income earners with a monthly income of M5,000 and above as also highlighted in (Mothala et al., 2022).

Various settlement types display specific characteristics and demographic profiles. The inclusion of all settlement types in the study ensures a representative sample of the entire population, enhancing the accuracy of generalizations and conclusions drawn from the research. The research uses three settlement types urban, peri-urban, and rural of the country. All the settlement types captured by the survey are used in this analysis as they provide a comprehensive approach that enables the study to draw holistic insights into the interconnectedness of different regions within Lesotho.

This study uses four educational levels: primary, secondary, tertiary, and 'none' as a category. According to the data, forms 1 to 5 are secondary education in this setting, while standards 1 to 7 comprise primary education. Post-secondary certifications, vocational and technical certificates, and degrees ranging from honors to doctorates are all considered tertiary education. These distinctions are used to determine the greatest degree of education attained, offering a thorough grasp of the level of education in Lesotho and possibly bearing on policy decisions. “None” in this case corresponds to the households who do not hold any level of education.

Table 2 Descriptive statistics

Variable	Mean (%) or share	SD	Min	Max
Age of household head	49.53	17.11	14	99
Gender				
Male	62.47	0.48	0	1
Household Size	4.09	2.44	1	15
Ownership Status of the house				
Government housing	1.03	0.17	0	1
Private housing	22.50	0.19	0	1
Household housing	76.07	0.43	0	1
Education level of household head				
Primary	52.68	1.60	0	1
Secondary	23.94	1.04	0	1
Tertiary	8.39	0.71	0	1
None	13.05	0.46	0	1
Settlement type				
Urban	37.46	0.48	0	1
Peri-urban	9.32	0.29	0	1
Rural	53.22	0.50	0	1
Income				
Low income	57.21	1.01	0	1
Middle income	33.53	0.74	0	1
High income	9.29	0.46	0	1
Grid connection				
Connected to the grid	36.90	0.48	0	1

Table 2 represents the information from the 2017 Household Energy Consumption Survey in Lesotho. The variables of interest are selected such as the head of the house gender and age. As indicated, the mean age of the household head is 50 years. The gender distribution among household heads was 38% females and 62% males. The data shows that on average, 63% of the households are without connection to the grid while only 37% of them are connected. The findings also revealed that 57% of the participants belonged to the low-income class, earning between M0 and M999 per month (1 USD ≈ M17). Additionally, 34% were categorized as middle-income (M1,000–M4,999), while the remaining 9% fell into the high-income class (M5,000 and above). The data shows that on average every household consists of 4 members, and the highest qualification that most of the household heads were able to acquire is secondary with 24% while fewer households' heads have attended tertiary. In Lesotho, it is observed that the majority of houses (76%) are owned by households, followed by 23% in private ownership, and a mere 1% owned by the government.

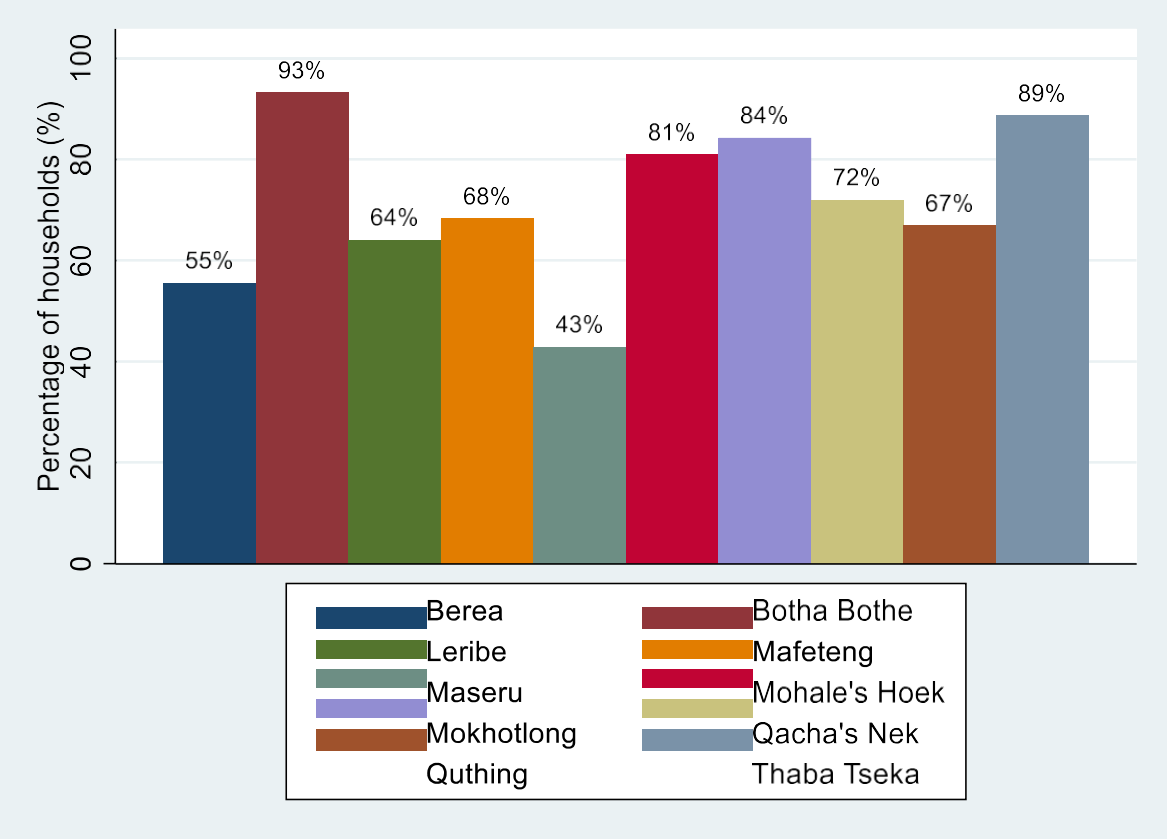

Figure 1 Percentage of households without grid connection, by District

Figure 1 illustrates the percentage of households that are not connected to the grid across various districts. On average, 55% of Berea's households face energy poverty, contrasting with a higher deprivation rate of 93% in Butha Buthe. Leribe reports 64% energy poverty, whereas Mafeteng exhibits 68% of households without grid access. Maseru stands out with a lower percentage, at 43%, making it the least energy-poor district in Lesotho. Conversely, Mohale's Hoek records 81% without a grid connection, while Mokhotlong is at 84%. Qacha's Nek experiences 72% deprivation, Quthing follows with 67%, and Thabatseka ranks as the second-highest district, with 88.6% of households lacking grid connectivity.

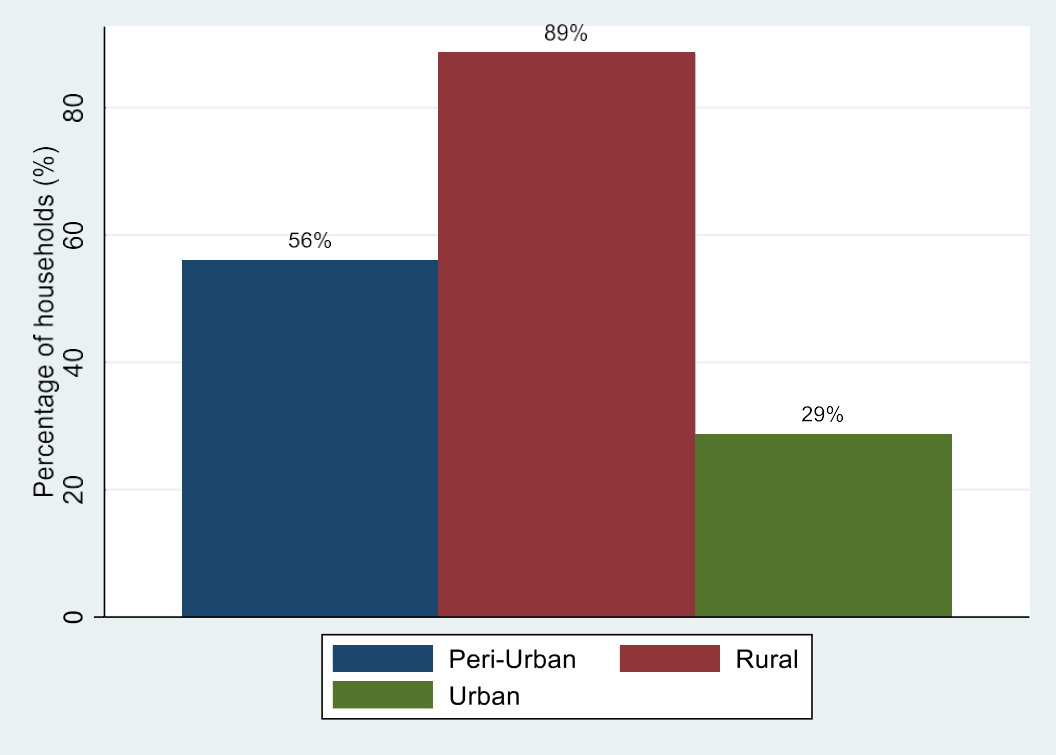

Figure 2 Percentage of households without grid connection, by Settlement type

Figure 2 depicts grid connection among households based on their settlement type. On average, 56% of peri-urban households lack grid connectivity, while a notably higher 89% of rural households are not connected, marking it as the sole settlement type with significantly elevated rates of deprivation. In contrast, only 29% of urban households lack grid connection, showcasing significantly lower levels of energy poverty compared to rural and peri-urban areas.

5. Methodology

5.1. Constructing a multidimensional energy poverty index

Table 3 Multidimensional energy poverty measure

Dimensions	Indicators (Weights)	Deprived if
Cooking	Clean fuels for cooking (0.5)	If the households mainly used any fuel besides solar energy, electricity, and gas.
Lighting	Clean fuels for lighting (0.3)	If the households mainly used any fuel besides solar energy, electricity, and gas.
Water heating	Clean fuels for water heating (0.2)	If the households mainly used any fuel besides solar energy, electricity, and gas.

In constructing the Multidimensional Energy Poverty Index (MEPI), the study employs the Alkire-Foster (AF) method (Alkire et al., 2011). The MEPI incorporates binary indicators related to clean energy usage for water heating, lighting, and cooking. In the framework of the Alkire-Foster methodology, weights can be assigned in an equal or unequal manner, depending on the relative significance of each indicator. Higher weights are indicative of greater importance. Consistent with other developing countries, this study will assign weights to the accessibility component (Zhang et al., 2019) which is an essential aspect of achieving the goals outlined in Sustainable Development Goals 7 (SDG).

Additionally, the study will assign weights to the binary indicators related to all dimensions. Specifically, higher weights will be assigned to cooking (0.5) and lighting (0.3), while lower weights will be assigned to water heating (0.2), emphasizing the relatively greater importance of the former indicators. Access to clean lighting is considered an essential human necessity, as its absence is known to have adverse effects on the education of adults and children as well as women's health (Sovacool, 2012). Consequently, the focus is placed on these indicators, with

appropriate weighting assigned to highlight their significance. The weight of each indicator sums up to 1 as indicated in Alkire & Santos (2011):

$$\sum_{j=1}^{d} w_j = 1 \qquad (1)$$

Where d denotes the total number of dimensions while w_j is the weight of each dimension d which sums up to 1.

The deprivation score for each household is determined using three dimensions. This study computes the deprivation score by adding up the weighted number of deprivations experienced by each household, resulting in a value ranging from 0 to 1. A score of 1 indicates that the household is deprived in all dimensions, while a score of 0 signifies the absence of deprivation. The composite index c_i for household i is calculated as the sum of the products of the weights w_j and corresponding indicator values I_{ij}. The method for calculating the household deprivation score (count), as outlined by Alkire and Santos (2011), is as follows:

$$c_i = \sum_{j=1}^{d} w_j \, . \, I_{ij} \qquad (2)$$

Where a household i is considered to be deprived in indicator j if

$$I_{ij} = 1$$

and

$$I_{ij} = 0$$

otherwise.

Secondly, households can be classified as energy poor if they surpass a predetermined threshold or poverty cut-off, denoted as k. Specifically, if the weighted deprivation counts c_i of household i exceeds the threshold, it is considered energy poor. In this study, two energy poverty cut-offs are proposed, following the suggestions of Alkire et al. (2014). Accordingly, a household is categorized as energy poor if it experiences deprivation in at least one-third of the weighted dimensions ($k \geq 0.33$).

The headcount ratio will be calculated to measure the proportion of households that are energy poor which is specified as follows by Alkire and Santos (2011):

$$H = \frac{q}{n} \tag{3}$$

where q is the number of multidimensional energy-poor households, and n is the total number of households. According to AF methodology, MEPI is the product of H and A (average intensity) which is the number of dimensions for which households are poor where A is specified as follows by Alkire et al. (2011):

$$A = \frac{\sum_{i=1}^{n} c_i(k)}{q} \tag{4}$$

where each household's deprivation score is represented as $c_i(k)$.

While the multidimensional headcount ratio of energy poverty gives us the proportion of households experiencing multidimensional energy poverty, it lacks information about the extent of deprivation in individual indicators. To overcome this limitation, the MEPI is computed by multiplying the multidimensional headcount ratio H of energy poor households by its intensity A. This approach allows for adjustments to the headcount based on the overall population, as expressed in the provided equation:

$$MEPI = H * A \tag{5}$$

6. Results

6.1. Energy usage patterns for Lesotho

This section is an overview of the descriptive statistics for essential variables employed in formulating the multidimensional measure of energy poverty. The data is presented by the settlement type of the households in Lesotho. As detailed in Chapter 4, the dataset encompasses 2683 households.

Table 4 Energy usage patterns for Lesotho households (% of the households)

	Electricity	Gas	Solar	Wood	Animal Dung	Crop wastes	paraffin	Straw shrubs	Candle
Urban N=1005									
Cooking	23.48	56.22	-	3.68	2.93	0.70	12.14	0.90	-
Lighting	71.64	-	0.80	-	-	-	23.38	-	3.68
Water heating	49.05	27.66	-	2.99	2.19	0.80	15.92	0.90	-
Peri-Urban N=250									
Cooking	6.40	38.00	-	30.80	6.40	1.20	10.00	6.40	-
Lighting	46.80	0	1.60	-	-	-	43.60	-	7.60
Water heating	16.40	23.60	0.80	30.40	6.40	1.60	11.60	8.80	-
Rural N=1428									
Cooking	1.26	12.74	-	43.63	21.85	2.80	3.22	13.66	-
Lighting	11.24	-	6.18	-	-	-	68.40	-	12.78
Water heating	4.00	7.93	-	40.28	20.91	3.72	6.32	15.72	-
Total N= 2683									
Cooking									
Lighting	10.06	31.39	-	27.47	13.12	1.86	7.19	8.20	-
Water	37.26	0.04	3.73	-	-	-	49.20	-	8.88
heating	22.05	16.90	-	25.37	12.54	2.43	10.41	9.51	-

Source: Author's computation.

When summarizing the energy pattern used by household settlement types, it is discovered that in urban areas, 23.48% of households use electricity as their energy source for cooking, while only 6.40% of the peri-urban use electricity. The rural area is one settlement type with only 1.26% of households using clean energy for cooking. Under the traditional source of energy the results show that in the urban areas, 3.68% of the households use wood, while 2.93% use animal dung. 0.7% of the households in the urban areas use crop wastes while 12.14% of them use paraffin.

In peri-urban, 6.40% of households use electricity for cooking, while 38% use gas. Households use the traditional source of energy in peri-urban which is paraffin, 10% of wood, 6.40% use animal dung, and lastly, 1.20% use crop wastes and 6.40% of shrubs. In rural areas only 1.26% use electricity for cooking. 7.93% of the households use gas for water heating, 21.85% use animal dung for cooking, 2.80% use crop wastes, and 16.66% use straw shrubs. Furthermore, 68.40% of the households use paraffin for lighting, while 12.78% use candles. On the other hand, 6.18% of the households use solar for lighting.

For water heating, households in rural areas use unclean energy, whereby 40.28% of them use wood, 3.72% use crop wastes, and 15.72% use shrubs. All in all, it is realized that the rural areas use unclean energy sources for cooking, lighting, and water heating which are mostly wood with 43.63%, paraffin 68.40% used for lighting while 12.78% use candles and lastly, and 40.28% use wood for water heating. In urban areas, more households use clean energy sources for cooking, and lighting, which is electricity and gas while peri-urban use wood mostly for cooking and water heating with 30.80% and 30.40% respectively.

The data presented in the table reveals that, at the national level, 10% of households utilize electricity for cooking, 37.26% for lighting, and 22.05% for water heating. Additionally, 31.39% of households rely on gas for cooking, and 16.90% use it for water heating. In Lesotho, solar power is predominantly employed for lighting, accounting for 3.76% of households. Wood is a prevalent choice for cooking in Lesotho, with 27.47% of households opting for it, and 25.37% using it for water heating. Nationally, paraffin is primarily used for lighting. The table also indicates that traditional fuels, such as fuelwood, shrubs, crop waste, and animal dung, significantly contribute to cooking practices in Lesotho, particularly in rural areas compared to other settlement types nationwide.

6.2. Multidimensional energy poverty estimates

Table 5 Multidimensional energy poverty estimates (% of the households)

	Peri-urban	Rural	Urban	Total
Deprivation in clean energy for Cooking	54.30	51.50	53.30	52.00
Deprivation in clean energy for Lighting	24.40	27.70	25.10	27.10
Deprivation in clean energy for water heating	21.30	20.80	21.60	20.90
MEPI (H*A)	51.20	83.50	19.00	56.30
Multidimensional Energy Poverty Headcount Ratio (H)	60.80	89.50	22.80	61.70
Average Intensity (A)	84.21	93.30	83.30	91.10

Table 5 represents the MEPI, average intensity, and multidimensional energy poverty headcount ratio for Lesotho in 2017. The results indicate that 61.70% of the households in Lesotho were multidimensionally energy poor in 2017/2018. However, the multidimensional energy poverty only shows the number of households that are multidimensionally energy poor and thus fails to indicate whether these households are deprived in some or all the indicators. The average intensity of energy poverty of the households is 91.10%, indicating that multidimensionally poor energy households in Lesotho were on average deprived in 91.10% of the weighted indicators. The MEPI is the product of the headcount ratio and average intensity and is computed to overcome the limitation of the multidimensional headcount ratio which lacks information on the extent of deprivation by the households. Therefore, 56.3% of the households are energy poor in multiple dimensions after adjusting the headcount ratio to account for the intensity of the deprivation suffered.

When decomposing energy poverty by settlement type, the results indicate that peri-urban households are more deprived of clean energy for water heating at 21.30%, lighting at 24.40%, and cooking at 54.30%. In rural areas, 51.50% of households are deprived of clean energy for cooking. 27.70% of the households are deprived of lighting while water heating energy deprived households constitute 20.80%. In urban areas, it is realized that 53.30% of the households are deprived of clean energy for cooking with approximately 25.10% in lighting and 21.60% in water heating. Furthermore, results indicate that in peri-urban 60.80% of the households are multidimensionally energy poor while in rural areas there is 89.50% of them, in urban only 22.80% of the households are multidimensionally energy poor. The intensity of energy poverty is higher in the rural areas with 93.30%, 83.30% in urban, and 83.30% in peri-urban.

Table 6 Decomposition of MEPI by gender of household head (% of the households)

Variable	Female	Male
MEPI (H*A)	59.40	54.40
Multidimensional Energy Poverty Headcount Ratio (H)	65	59.80
Average Intensity (A)	91	90.96

When it comes to the gender of the households it is realized that males are mostly head of the households in Lesotho and are 90.96% deprived in all weighted indicators, while females experience an intensity of 91%. 54.40% of the male headed households are multidimensionally energy poor while approximately 59.40% of the female-headed households are multidimensionally poor.

Table 7 Decomposition of MEPI at district level (% of the households)

	Berea	Butha Buthe	Leribe	Mafeteng	Maseru	Mohales's Hoek	Mokhotlong	Qacha	Quthing	Thaba-Tseka
MEPI (H*A)	50.70	77.50	60.40	58.90	36.60	70.40	76.60	77.60	55.40	81.30
Multidimensional Headcount ratio (H)	56.50	83.60	66.30	64.30	41.90	75.80	80.30	85.40	58.30	87.40
Average Intensity (A)	89.70	92.70	91.10	91.60	87.35	92.88	94.65	90.87	95.02	93.02

The table presents the outcomes of the decomposition analysis conducted on the multidimensional headcount ratio, average intensity, and Multidimensional Energy Poverty Index (MEPI) across various districts of Lesotho during 2017/2018. According to the results depicted in Table 8, the Maseru district exhibited the lowest percentage of multidimensionally energy poor households at 36.60%. Conversely, Thaba-Tseka recorded the highest proportion of multidimensionally energy poor households at 81.30%, followed by Qacha at 77.60%, Butha-Buthe at 77.75%, and Mokhotong at 76%. Other districts exhibited varying levels of multidimensional energy poverty, with Quthing district demonstrating the highest number of multidimensionally energy poor households and Maseru district the lowest at 36.60%.

Additionally, the data from Table 7 reveals that the Maseru district had the lowest average intensity of multidimensional energy poverty, with a deprivation of 87.35% in weighted indicators. This was succeeded by the Berea district with an average intensity of 89.73%. Conversely, Quthing district recorded the highest average intensity at 95.02%, followed by Mokhotlong at 94.65%, Thaba-Tseka at 93.02%, Mohale's Hoek at 92.88%, and Butha-Buthe at 92.70%. Berea district reported an average intensity of 89.73%, Leribe 91.10%, Mafeteng 91.60%, and Qacha district with 90.87% of their weighted indicators. This underscores the significant impact of geographical location on the energy poverty experienced by households in Lesotho.

6.3. Energy poor and income poor

Table 8 Headcount ratio of energy poor by income (% of the households)

Income groups	Energy poor	Energy non-poor
Less than M300	91.21	8.76
M300- M500	80.17	19.83
M500- M999	77.86	22.14
M1000- M1999	56.60	43.40
M2000- M4999	32.71	67.29
M5000- M9999	18.07	81.93
M10000- M29999	6.67	93.33
M30000- and above	0	100

According to the Lesotho poverty mapping report (2018), the Cost of Basic Needs (CBNs) estimated monthly poverty lines for the year 2017/2018 include a food poverty line, indicating the monetary value of a minimum consumer basket (Maloti (M) 352.39 per household per month). Additionally, there is a lower bound estimate for the poverty line at M 572.41 per household per month, and an upper bound estimate set at M648.88 per household per month, all denominated in 2017 prices.

The table helps in answering the most common question that relates to energy poverty; are income poor households also energy poor? It illustrates the income groups of households in Lesotho, from the household's energy consumption survey of 2017/2018 and the percentage of households who are energy-poor and non-poor accordingly. In this case, energy poverty is measured by the percentage of households who are connected to the grid as highlighted in This is further indicated

in the study by Hammond (2010) who indicated that electricity access can be defined as physical availability or access to the grid.

The results show that 80% of the households that earn M300 to M500 are energy-poor. 77.86% of energy poor households earn M500- M999. 56.60% are clean energy poor and earn M1000- M1999. As income increases, the percentage of households that are energy poor decreases from approximately 33% with income of M2000- M4999 to 6% energy poor that earn M30000- and above. This shows a negative relationship between energy poverty and income. This further shows that lower income groups are likely to also be energy-poor. However, this is not the case with higher income groups, where more income leads to more households being connected to the grid. For households that earn M10000- M29999, 93.33% of them are connected to the grid. For income exceeding M30000, all the households are connected to the grid. From the analysis, it is shown that households with income less than CBNs are mostly energy-poor. This is in line with the energy ladder model which states that as income increases, households switch to clean energy sources for their daily activities.

6.4. Discussions

The research examined the multidimensional energy poverty of households in Lesotho. The results revealed that rural areas predominantly rely on unclean energy sources for cooking, lighting, and water heating. Clean energy usage is found to be merely 10% of the households using electricity for cooking, 37% use it for lighting while 22% use it for water heating. 31.39% of the households use gas for cooking while 16.90% use it for water heating. Lighting disparities exist among the three settlement types, with 68.40% of rural households using paraffin 12.78% relying on candles, and in urban approximately 72% using electricity. This underscores the distinct energy source preferences across settlements. Location-based variations are evident across all dimensions of energy poverty. Furthermore, the scarcity of clean energy sources in rural households may be attributed to a lower rate of grid connectivity, as indicated in section 4 of the study. Additionally, it was highlighted that the challenging terrain of the country could contribute to the expense of affording grid connection (Mothala et al, 2021).

The study further decomposes the MEPI by gender of the household head, and lastly by the districtsof Lesotho. At the national level, findings reveal that 61% of households in Lesotho face energy poverty. Moreover, the average intensity of energy poverty highlights that, on average, energy-deprived households in Lesotho are lacking in 91.10% of the weighted indicators.

The decomposition of MEPI across different settlement types reveals distinct patterns. Urban areas exhibit the lowest levels of energy poverty, with an average of 22.80%, and only 19% of households experiencing multidimensional energy poverty. In contrast, peri-urban areas have a significantly higher multidimensional energy poverty rate of 51.20%. Rural areas demonstrate thehighest MEPI at 83.50%, with an average intensity of 93.30% in weighted indicators. This disparity may be attributed to the absence of grid connectivity in rural regions due to geographical challenges. Additionally, a contributing factor to the exacerbation of clean energy access deprivation rates in Lesotho is the observation that rural households connected to the grid primarilyuse electricity for lighting, radio, and television, neglecting its potential for cooking and water heating purposes (REU, 2017). Such usage patterns may lead to diminished returns on investment for the country or discourage government initiatives aimed at improving infrastructure in these underserved areas.

In decomposing the gender of the household head, the findings reveal that among female-headed households, 65% experience multidimensional energy poverty, whereas for male-headed households, this figure is slightly lower at 59.80%. The average intensity of energy poverty is 91.40% for female-headed households and 90.96% for male-headed households, as measured by weighted indicators. These results are unexpected because, in Table 2, the majority of households in Lesotho are headed by males. One might anticipate a higher degree of energy poverty among these households given their larger representation in the population compared to female-headed households.

Contrary to expectations, female-headed households exhibit a higher degree of multidimensional energy poverty compared to male-headed households, with percentages of 59.40% and 54.4%, respectively. This might be the case because, in Lesotho, there exists a social norm where men are typically recognized as the head of the household. These are households that have both a man and

a woman present, while female headed households are those headed by widows or unmarried women with limited sources of income. Consequently, households led by women tend to experience higher levels of poverty compared to those led by men, a trend evidenced by the findings of this study. This is in congruence with Thabane (2015).

These results resonate with previous research findings which underscore the disproportionate burden of energy poverty experienced by women. This phenomenon is attributed to women's traditional roles as primary caretakers responsible for household energy provision, often leading to time-consuming tasks such as collecting firewood over long distances. Notably, the impact of energy poverty appears more pronounced in female-headed households, which constitute approximately 37.9% of households in South Africa, compared to their male-headed counterparts, (Nwosu & Ndinda 2018).

The study further provides the incidence of geographic energy poverty by decomposing the MEPI in the ten districts of Lesotho. It provides evidence of which districts had the highest number of energy poor households in relation to the total number of energy poor households in Lesotho. This is crucial in policy making because knowing the percentage of energy poor households per district does not necessarily indicate how severe energy poverty is at the national level. The results indicated that Maseru experiences the lowest rate of multidimensional energy poverty. This could be due to it being the capital city where developments are first implemented and there is a higher rate of grid connected households.

Table 8 illustrates that both districts, Butha-Buthe and Qacha, exhibit an equal MEPI of 77%. Despite this parity in MEPI, the headcount ratios differ between the two districts, standing at 83.6% for Butha-Buthe and 85.40% for Qacha. This variance underscores the nuanced nature of energy poverty within households across districts. Consequently, these findings underscore the necessity for tailored policy responses. For instance, focusing on districts with a higher headcount ratio of energy poverty, such as Qacha, Thaba-Tseka, Mokhotlong, and Butha-Buthe, could be a strategic approach for Lesotho.

When examining the relationship between monthly incomes and energy poverty among households, the findings indicate a clear correlation: higher-earning households tend to experience

less energy poverty. This trend is exemplified in Table 5.4.1, where 91.21% of energy-poor households earn less than M300, while none of the households earning a monthly income of M30,000 and above face energy poverty. This aligns with the study by Mothala et. al (2022) who discovered that one of the main determinants of energy fuel consumption choice in Lesotho is the household income. Similar results which clarify that household demand for energy services does increase with income are shown in (Gelo et al., 2023). This underscores the notion that as household income increases, there is a shift towards adopting clean energy sources.

A multidimensional assessment of energy poverty proves useful in situations like these because it offers insights into the extent of deprivation across the dimensions. Unlike a uni-dimensional assessment, which only offers a general overview of energy poverty, a multidimensional approach allows for a detailed understanding of deprivation levels within each dimension. This granularity is essential for policymakers to effectively target areas with the most severe deprivation when addressing household energy poverty in Lesotho.

6.5. Sensitivity analysis

It is widely recognized that in the Alkire-Foster (AF) method, the outcome can be influenced by factors such as weights, cut-offs, and the threshold for accessibility deprivation. Consequently, the study performs a series of tests to examine how changes in these key parameters will impact the multidimensional estimates.

Next, we allocate equal weights of 0.33 to the indicators when forming the multidimensional measure. Upon doing this, we observe that the Multidimensional Energy Poverty Index (MEPI) experiences minimal change, as the intensities decrease with a small magnitude from 56.30% in Table 5 to 55.30% in Table 9, despite the small change in rates of the headcounts from 61.70% to 59.60% in table 9. For rural areas, it decreases from 89.50% to 88% in Table 9, and lastly, for urban areas, it decreases from 22.28% in Table 5 to 20.70% in Table 9.

Table 9 Energy poverty estimates with equal weights for indicators (% of households)

Variable	Peri-urban	Rural	Urban	Total
MEPI (H*A)	48.50	82.80	18.20	55.30
Multidimensional Headcount ratio (H)	54.80	88	20.70	59.60
Average Intensity(A)	88	94	87.92	92.80

In conclusion, the findings suggest that adjustments to the weights of the indicators and the cut-off (k=0.5) values do not result in substantial changes to the MEPI. Consequently, the MEPI demonstrates robustness to variations in the critical parameters employed in constructing this multidimensional index.

7. Conclusion

The study constructed a multidimensional measure in investigating energy poverty in Lesotho using the Household Energy Consumption Survey of 2017/2018 for cooking, lighting, and water heating. The results indicate that access to electricity, which is measured by access or connection to the grid in this case differs across settlement types. In the peri-urban, 56% of the households are not connected to the grid. In the rural areas, 88.6% are deprived of grid connection while only 28.7% of the households are not connected to the grid. This signifies that there are higher rural and urban disparities in energy access in Lesotho which are dependent on the settlement types. The results are also similar to the study in Bangladesh which experiences deprivation in energy access in the rural areas by 58% (Barnes et al, 2010) while 30% of the rural households in South Africa are energy poor while 11% of urban households do not experience energy poverty (Ye et al., 2023). This could be the case in that these households may not have enough means to afford the grid connection services.

When energy poverty is measured by dimensions, the results show that 58.55% of the households do not use clean energy for cooking, that is, they utilize wood, paraffin, and shrubs. For lighting, 58.08% of the households use unclean energy such as candles, paraffin, and kerosene. Lastly, for water heating, 60.26% of households use unclean energy. When MEPI is decomposed by the gender of the head of the household, results show that approximately 59.40% of female-headed households are multidimensionally poorer than male-headed households with an average intensity of 91% of the weighted indicators. Results further indicate that in rural settings, traditional fuels for cooking are widely adopted, while the use of electricity remains minimal. The prevalence of traditional fuel consumption diminishes with increasing urbanization.

In the decomposition of the MEPI by districts, Maseru demonstrated the smallest share of households experiencing multidimensional energy poverty, standing at 36.60%. In contrast,Thaba-Tseka showcased the highest prevalence of multidimensional energy poverty amongst the households at 81.30%, followed by Qacha at 77.60%, Butha-Buthe at 77.75%, and Mokhotlong at 76%. Other districts exhibited varying degrees of multidimensional energy poverty, with Quthing district registering the highest count of multidimensionally energy poor households, while Maseru district had the lowest percentage at 36.60%.

Studies indicates that rural households are particularly vulnerable, with about 82% of the rural population in sub-Saharan Africa relying on traditional firewood stoves, kerosene lanterns, and candles for cooking and lighting (IEA, 2010; Mohammed et al., 2013; WHO, 2016; World Bank, 2019). For instance, in Nigeria, the most populous country and largest economy in Africa, over 40% of the population (87.4 million people) lacks access to electricity. As a result, approximately 58% of the population uses kerosene for lighting, and 57% rely on firewood for cooking. Overall, only 10% of the population has access to clean cooking technology. A similar situation exists in Lesotho, where only a small percentage of the population has access to clean energy.

A study by Nduka (2021) uses a Contingent Valuation method to assess the willingness to pay (WTP) of rural households and found a strong preference for sustainable energy (energy transition). Lesotho could explore this option, and given its smaller population compared to Nigeria, it may be easier to conduct a cost-benefit analysis to determine viability. Since many people in rural areas have limited incomes, an installment payment plan could be implemented to facilitate the transition. Policymakers should mandate microfinance banks to provide interest-free loans to rural residents to help them adopt sustainable energy solutions.

One limitation of this study is the lack of exact household income and energy expenditure data which restricted the study to focus on one dimension of energy poverty which is accessibility and not others, such as affordability. However, in light of the study's findings, additional research can be done to examine the determinants of energy poverty, in order to further investigate the key drivers that affect energy poverty in Lesotho.

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