



National University of Lesotho



Measurement and determinants of energy poverty in Lesotho

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Abstract

Energy poverty remains a significant barrier to sustainable development in Lesotho. This study assesses the prevalence of energy poverty and employs a multinomial logit model to analyse the determinants of energy poverty, using data from the Lesotho 2017 Household Energy Consumption Survey (HECS). The research study explores the impact of various socioeconomic and demographic factors on different categories of energy poverty during both summer and winter seasons. The statistical analysis was conducted using Gretl software, a robust, open-source tool specifically designed for econometric analysis. Gretl facilitated the multinomial logit model, enabling the identification of key socioeconomic and demographic factors influencing various categories of energy poverty. The analysis reveals seasonal variations in energy poverty, with a higher incidence of energy poverty during winter, highlighting the increased energy needs. The key determinants of energy poverty include household income, settlement type, education level and gender of the household head. Relatively higher income levels and urban or peri-urban households are less likely to experience energy poverty, while low-income and rural households face higher risks. The education of household heads has an impact on energy poverty but was found to be inconsistent across the summer and winter models. The summer model showed that higher education was protective against extreme energy poverty, while in the winter model, higher education showed a higher likelihood of transitioning from the non-energy poverty category to the transitional and moderate energy poverty categories. The study also highlights gender disparities, with female-headed households being more vulnerable to moderate energy poverty, particularly in summer. Based on these insights, the study provides policy recommendations aimed at enhancing energy access and reducing energy poverty, including targeted support for vulnerable groups, strengthening rural energy infrastructure and promoting educational initiatives on energy management. The findings offer valuable contributions to the ongoing policy discourse as Lesotho prepares to evaluate its national energy policy, presenting an opportunity to integrate these insights into future strategies.

Chapter 1: Introduction

1.1 Background

The consistent rise in per capita energy use globally, especially over the last century, underscores the profound relationship between energy consumption and the livelihood, wellbeing and prosperity of individuals and societies. This trend is closely linked to economic development, improvements in living standards and expansion of technology infrastructure. (Awan et al., 2022). According to the United States (US) Energy Information Administration (EIA), global per capita energy consumption has steadily increased. In the early 20th century, global per capita energy consumption was less than 20 gigajoules (GJ), significantly lower than the substantial values in recent decades, wherein 1980, the US alone was at 359 GJ (Smil, 2011). By the early 21st century, this figure had more than tripled, reflecting the substantial growth in energy demand alongside population growth (EIA, 2021). The World Bank data also indicates that global energy consumption has seen a significant rise, as depicted in Figure 1 which highlights the global energy consumption patterns from 1800 to 2022 (Our World in Data, 2023). This illustrates that as populations increase and people get richer, then the demand for energy across many countries increases.

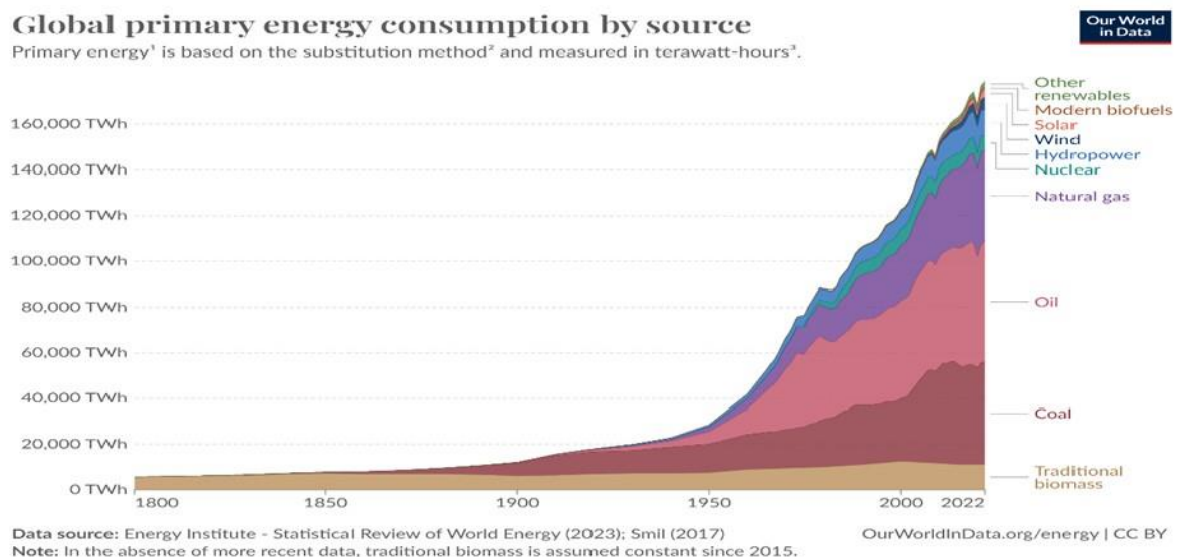


Figure 1: Global energy consumption adopted from (Our World in Data, 2023)

Over and above that, the seventh Sustainable Development Goal (SDG 7) of the United Nations aims to provide everyone with access to affordable, dependable and sustainable modern energy

by 2030 (Awan et al., 2022; Huang et al., 2022). However, as of 2021, it was estimated that 2.4 billion people globally still relied on solid fuels for cooking. These fuels are dangerous to both human health and the environment. Furthermore, 733 million people worldwide still lack access to electricity (Huang et al., 2022). Africa, especially sub-Saharan Africa, exhibits one of the highest levels of energy poverty globally. Despite rich renewable energy sources, a significant portion of the African population relies on traditional biomass for cooking as access to electricity is limited, especially in rural areas. The International Energy Agency (IEA) reported that in 2020, about 43% of the population in sub-Saharan Africa (SSA) lacked access to electricity, while the rural population had over 80% electricity deprivation (IEA, 2022). As of 2021, 66% of the households in SSA relied on traditional fuels to meet their energy demands. These households also face adverse health and environmental risks, with household-generated air pollution contributing to about 35.6% of premature deaths caused by lower respiratory tract infections in children under the age of 5 years and women aged 15-49 years respectively (Emodi et al., 2022).

Of the individual countries which face an extensive challenge of energy poverty within the SSA region, Nigeria, which has the largest population in Africa, has the highest number of residents that live in energy poverty. In 2021 approximately 38% of Nigeria's population lacked access to electricity which is a modern form of energy, and 75% of the families still relied on inefficient traditional biomass cooking methods (Emodi et al., 2022).

Lesotho faces similar challenges with limited access to clean and modern energy sources. A significant portion of the population relies on biomass for cooking and heating due to limited access to electricity, especially in rural areas. In 2018, households used 80% of the traditional fuels such as fuelwood, bushes, crop waste and animal manure for cooking and heating.

According to the World Bank, in 2021, Lesotho's electrification rate was reported to be 50.4% of the population (The World Bank, n.d.). It was also estimated that there was a 49.7% poverty rate in Lesotho, with the rural areas experiencing about 60.7%, which was likely to influence energy poverty (Mothala et al., 2022).

Lesotho has made efforts to improve energy access in recent years through various initiatives, including rural electrification programmes and exploring renewable energy options. The Lesotho Highlands Water Project (LHWP) is one of Lesotho's most significant hydropower and water export projects. Initially conceived in the 1980s, the project is a bilateral initiative

between Lesotho and South Africa, with a dual purpose of generating electricity for Lesotho and exporting water to South Africa's industrial heartland, Gauteng. The first phase, completed in 2003, included the construction of the Katse Dam and 'Muela Hydropower Plant, which generates approximately 72 MW of electricity for Lesotho. The second phase is currently under construction and is expected to inject an addition of approximately 90 MW to Lesotho's electricity Grid (Hitchcock, 2011; LHDA, 2024). The Ha Ramarothole Power plant project situated in the Mafeteng district is also a significant development for the country. The 30 MW solar plant was financed by the Exim Bank of China and is the first phase of the project, which is expected to be 70 MW upon completion (Hakeenah, 2023). The Lesotho Renewable Energy and Access Project (LREAP), funded by the World Bank, aims to increase access to electricity for rural households and institutions through off-grid solar systems (The World Bank, 2020). These initiatives have the potential to reduce energy poverty in Lesotho significantly.

Energy poverty, characterized by limited access to affordable and reliable energy services, is a multifaceted issue affecting millions of people globally, particularly in developing countries. The nexus between low income and economic status and energy poverty is critical as it directly impacts an individual's ability to access essential energy for cooking, heating and lighting (Awan et al., 2022). Low income and poor economic status are the primary drivers of energy poverty as they limit household choices to more affordable but often inefficient and polluting energy sources such as biomass, coal and kerosene. The high cost relative to income makes it difficult for these households to access cleaner energy sources such as electricity and gas, which are often expensive upfront and may require infrastructure that is not always available in remote areas (Pachauri et al., 2004). In many regions, especially remote rural areas, the lack of infrastructure, such as electricity grids, limits access to clean energy. The geographic and topographical challenges often increase the cost and complexity of extending infrastructure to these areas (Bazilian et al., 2012).

The unavailability of energy-efficient appliances and housing can also significantly impact energy poverty. Poorly insulated homes and inefficient cooking and heating devices lead to higher energy needs and costs (Halff et al., 2014). In addition, government policies and subsidies play a crucial role in energy access. Subsidies for fossil fuels deter the adoption of cleaner energy sources, while the targeted subsidies and investments in renewable energy and infrastructure can improve access to affordable energy (Guruswamy, 2011). Sociodemographic

factors such as age, education and household size also influence energy poverty. Large families may have higher energy needs, and older or less educated household heads may have less awareness of access to energy-efficient technologies and practices (Boardman, 2010).

In some contexts, cultural and social norms dictate energy use patterns, such as the preference for certain cooking fuels or practices, which can influence energy poverty (Rehfuess et al., 2014).

Energy poverty has a substantial negative influence on human health as well as human survival and societal development (Gafa & Egbendewe, 2021; Huang et al., 2022; Qurat-ul-Ann & Mirza, 2021). Solid fuels for cooking impact human health negatively, causing indoor air pollution and premature child deaths. In addition, firewood is harmful to the environment and contributes to deforestation in developing countries. Therefore, understanding the magnitude of energy poverty is important for a country as it reveals energy inequalities and helps in policy development for the improvement of lives, environmental protection and enabling the achievement of global development goals.

While universally acknowledged as a critical issue that affects sustainable development and human well-being, the concept of energy poverty lacks a universally accepted definition. This absence of consensus is caused by the multifaced nature of energy poverty, which encompasses a range of dimensions, including access, affordability, reliability and the quality of energy services amongst others. Boardman (1991) initially pointed to the importance of energy affordability, focusing on the proportion of household income spent on energy services. However, this income-based approach has been critiqued for its inadequacy in capturing the full spectrum of energy poverty, especially in developing countries where informal economies and non-monetary exchanges prevail (Pachauri et al., 2004).

The definition of energy poverty has been expanded by recent scholarly work to include the consideration of the quality and reliability of energy sources (Bazilian et al., 2012). This expansion indicates that access to energy may not be sufficient if the energy sources are unreliable or of poor quality, impacting health, education and economic activities. Although there is no consensus on defining energy poverty, this study adopts the definition by Rao et al.

(2022) which states that ‘energy poverty is the inability of families to have sufficient and affordable high-quality energy to survive and satisfy their development needs’, with the emphasis being on the lack of access to high-quality energy in developing countries.

1.2 Problem Statement

Lesotho’s dependence on traditional biomass, such as wood, coal, shrubs and animal manure for energy in rural areas leads to environmental degradation, poor health outcomes from indoor pollution and further entrenchment of gender inequalities, as women and children are often responsible for collecting fuel. With rural electrification rates stagnating and the rural population heavily reliant on polluting energy sources, Lesotho’s situation reflects a national crisis that exacerbates energy poverty, widens inequality and stymies progress towards achieving SDG 7. Furthermore, the country’s mountainous terrain presents logistical challenges to energy infrastructure development, complicating efforts to address the ruralurban divide in energy access (Thamae, 2018). Thus, the issue of energy poverty in Lesotho is a multifaceted problem that demands urgent, localized solutions to break the cycle of energy poverty and foster sustainable development.

Although there are different approaches of measuring energy poverty in the literature (Boardman, 1991; Pachauri et al., 2004; Bazilian et al., 2012; Rao et al., 2022), the quantification of energy poverty does not only shed light on the scale and depth of the issue but also directly contributes to the global effort of achieving SDG 7 set by the United Nations. Furthermore, the literature has highlighted that there is a complex interplay between energy poverty and its driving factors, such as socioeconomic status, demographic characteristics and government policies (Ozughalu & Ogwumike, 2019; Gafa & Egbendewe, 2021; Awan et al., 2022). Therefore, measuring energy poverty and examining its underlying determinants in Lesotho is important for developing targeted policy interventions that can address the challenges of reducing energy poverty.

Despite the abundance of renewable energy potential in Lesotho, around 50% of the population has access to power, with the majority of Basotho who live in the rural regions lagging in access to electricity the most (Mokeke & Thamae, 2021). In 2020, the poverty rate in Lesotho was at about 49.7% (Mpholo et al., 2020), thereby giving a glimpse of the financial well-being of the Basotho nation. In Lesotho, limited access to reliable, affordable and clean energy services exacerbates energy poverty. Despite some progress in electrification, close to half of the

population remains without consistent power. This situation hampers economic development efforts and affects health outcomes due to reliance on polluting energy sources such as wood and coal; it limits the opportunities for education and social advancement. This study aims to measure and identify the determinants of energy poverty in Lesotho, seeking pathways to enhance access to clean, affordable energy.

1.3 Research Questions

This study seeks to address the following research questions:

- i.* What is the level of energy poverty in Lesotho?
- ii.* What are the key determinants of household energy poverty in Lesotho?

1.4 Research Objectives

The main objectives of the study are as follows:

- i.* To identify the level of household energy poverty in Lesotho
- ii.* To determine the factors that influence the level of household energy poverty in Lesotho.

1.5 Justification

Research has been conducted globally and regionally on energy poverty and its determinants. However, existing research is often focused on broader regions or countries with characteristics that are different from those of Lesotho. For example, comprehensive studies often assess energy poverty in populous nations like India and China or across Europe, where the metrics and indicators used may not align well with the realities of small countries like Lesotho. Research like that of González-Eguino (2015) and Fizaine & Kahouli (2018) explores the multidimensional nature of energy poverty and provides frameworks for its measurement, but often with a focus on economies with different infrastructure challenges compared to Lesotho, where rural electrification is particularly constrained by geographical barriers. These studies emphasize the importance of using appropriate local indicators, as approaches tailored to more developed nations, that prioritize high energy consumption and fuel affordability, may not capture the access issues dominant in countries like Lesotho.

Similarly, a review by Siksnyte-Butkiene (2021) highlights the limitations of using single economic indicators to measure energy poverty, suggesting that more nuanced, multidimensional indices are needed. Yet, these indices are often applied at a regional level,

such as across the European Union, or in more industrialised developing countries, leaving a gap in research that specifically addresses the localized energy poverty contexts of smaller, less developed nations like Lesotho. This body of research suggests that although significant advances have been made in the measurement of energy poverty, these methodologies may not fully capture the unique challenges faced by Lesotho, particularly regarding rural access and the heavy reliance on biomass for energy. Investigating the specific determinants of energy poverty can inform targeted solutions.

This study aims to contribute to a more in-depth understanding of energy poverty dynamics in Lesotho and to identify the local socio-economic factors that contribute to the issue. The findings from this study can directly inform Lesotho's energy sector policies and strategies. By identifying the key drivers of energy poverty, policymakers can develop targeted interventions to improve energy access, affordability and, ultimately, the overall well-being of the population. This research study can also contribute to the global body of knowledge on energy poverty by providing insights and strategies that can be adopted and implemented in other contexts.

1.6 Organization of the Study

The rest of the study is organized as follows: Chapter 2 gives the context of the study. Chapter 3 reviews the literature on the measurement of energy poverty and its determinants. Chapter 4 presents the data and methodology used in this study. Chapter 5 gives the results of this study and discusses them. Chapter 6 provides the conclusion and policy recommendations of the study.

Chapter 2: Context

2.1 Introduction

This chapter provides the context for understanding the measurement and determinants of energy poverty in Lesotho. It is divided into two sections. Section 2.2 focuses on the country's background, which explores energy infrastructure and the socioeconomic factors that influence energy poverty and historical developments. Section 2.3 examines the country's background energy policies and major projects on energy access. The last section summarises the chapter.

2.2 Country Background

Lesotho, a landlocked country in Southern Africa, faces significant challenges in its energy sector, as evidenced by its heavy reliance on imported electricity at around 59% and solid biomass fuels for cooking and heating. The country's mountainous terrain exacerbates the difficulties of distributing and affording energy, particularly in the rural areas. These challenges are compounded by high poverty levels and limited domestic energy resource exploitation (EU, 2023; IEA, 2014).

Energy poverty in Lesotho is influenced by a variety of socio-economic factors. The key determinants may include income levels, employment rates and household size. Lower-income households often cannot afford modern energy services; they rely on biomass to meet their energy needs. This reliance on primitive energy sources has substantial health and environmental implications. For instance, biomass fuels are linked to respiratory infections, lung cancer and other serious health issues, particularly affecting women and children who are primarily responsible for cooking (Fullerton et al., 2008; Pachauri et al., 2004). Furthermore, the environmental degradation caused by deforestation for fuel contributes to broader ecological problems such as soil erosion and decreased biodiversity (Specht et al., 2015).

Before her independence in 1966, the country had minimal infrastructure development, including in the energy sector. The rugged mountainous terrain, low level of industrialization and a primarily agrarian economy meant there was little demand for extensive energy infrastructure. Energy needs were largely met by traditional biomass (wood and animal dung), especially in rural areas, a practice that persisted well into the post-independence period (SM. Law & AA. Eberhard, n.d.). The post-independence efforts focused on establishing connections to the South African grid were made due to a lack of investment in exploring domestic energy resources capable of large-scale electricity generation. This dependency on energy imports has

persisted, leaving Lesotho vulnerable to fluctuation in energy prices and supply reliability. The government's efforts in the 1980s and 1990s to increase rural electrification faced significant financial and logistical challenges, leading to slow progress (Tsikoane, 2010).

A notable development in Lesotho's energy sector came with the Lesotho Highlands Water Project, which began in the late 20th century. Although primarily aimed at water transfer to South Africa, the project included components for hydroelectric power generation (Wagner & Hein, 1998). However, the benefits of this hydroelectric power may have been limited in significantly reducing energy poverty within Lesotho, as the primary focus remains on exporting water to South Africa.

In recent years, there has been a shift towards exploring renewable energy solutions. Smallscale solar projects have been initiated to meet the energy needs, especially in rural and hard-to-reach areas. These projects are often supported by international donors and nongovernmental organizations but remain in the early stages of development (Taele et al., 2012). The Ha Ramarothole Solar Plant is also a significant step towards the country's goal of achieving energy self-sufficiency and reducing reliance on imports. The project, developed in two phases, has a planned capacity of 70 MW, making it one of the largest renewable energy initiatives in the country. Phase one of the project is currently operational, generating 30 MW. This phase involved the construction of photovoltaic (PV) installations and related infrastructure, such as a 132 kV substation and a 55 km transmission line to integrate the generated electricity into the national grid (Hakeenah, 2023).

Currently underway, the LREAP is a flagship initiative launched by the Government of Lesotho with financial and technical support from the World Bank. LREAP aims to improve access to clean, reliable, and affordable electricity in rural and underserved areas. LREAP focuses on deploying off-grid solar systems to rural households and public facilities, enhancing energy access in remote areas. The project supports the establishment of mini-grids powered by renewable energy, particularly solar, for concentrated communities. LREAP also promotes cleaner cooking solutions, reducing the use of harmful biomass. The project also invests in building local capacities, training technicians and energy services providers and establishing regulatory frameworks for renewable energy adoption. These efforts aim to ensure the long-term sustainability of rural electrification efforts (The World Bank, 2020).

2.3 Country Policies and Major Projects on Energy Access

Before the active energy policy of 2015-2025, Lesotho had drafted the Lesotho Renewable Energy Policy (LesREP) 2013. Although LesREP remained a draft and was never officially adopted as a national policy, it aimed to promote the development and utilization of renewable energy sources in Lesotho. The objectives of the policy were to enhance energy security, reduce greenhouse gas emissions and contribute to sustainable development. The policy targeted achieving 75% household electrification by 2030, primarily through renewable energy generation.

In contrast, the Lesotho Energy Policy 2015-2025 is a comprehensive framework designed to address various aspects of energy management and development in Lesotho. This policy outlines strategic directions aimed at enhancing energy security, promoting renewable energy, improving energy efficiency and ensuring sustainable and equitable access to energy for all the sectors of the economy. It emphasises stakeholder involvement, including the private sector, community groups and international partners, to achieve its objectives. In addition, it highlights the need for continuous capacity building and empowerment of stakeholders through education and training in energy-related issues.

Lesotho has undertaken several significant projects to improve energy access and reduce energy poverty. These projects demonstrate the country's commitment to enhancing energy access and achieving sustainable development goals. Lesotho actively combats energy poverty through the Universal Access Fund (UAF), an initiative administered by the Lesotho Electricity and Water Authority (LEWA). The UAF specifically targets underserved areas, particularly in the rural communities, to increase access to electricity services. For the 2021/22 financial year alone, the UAF demonstrably impacted lives by supporting electrification projects in various villages with a collective investment of M24,604,528 (LEWA, 2022). This significant funding has been instrumental in expanding the national grid and fostering socio-economic development in the targeted regions.

Between 2021 and 2022, LEWA also issued several licenses for electricity generation to promote renewable energy projects and to attract private sector participation in the energy sector. NEO 1 SPV for a 20MW solar PV generation project at Ha Ramarothole in the Mafeteng district and Onepower for the Ha Makebe Mini Grid solar PV pilot project are the beneficiaries of this initiative (LEWA, 2022). During the same period, LEWA developed and implemented

regulatory frameworks for mini-grids to ensure the sustainable expansion of electricity supply in remote areas where extending the national grid is not feasible. Sotho Mini-Grids SPV is a product of this initiative and covers areas such as Ketane, Tosing, Sebapala, Lebakeng, Raliemere, Sehonghong, Mashai, Matsoaing and Tlhanyaku (LEWA, 2022).

Recently, the Chinese Exim Bank opened a line of credit to finance the construction of a 70 MW solar power plant at Ha Ramarothole village in the Mafeteng district, Lesotho. The plant will be installed on a 220-hectare piece of land. The project is estimated to cost 70 MUSD and supplies 30MW of electricity to the national power grid in the first phase, followed by a 77 MUSD second phase with a 40MW capacity, which will be completed after the monitoring and evaluation of the first phase (Staff, 2020).

2.4 Summary

Understanding the context of energy poverty in Lesotho is essential for identifying effective intervention strategies. The country's unique landscape presents a complex challenge. The mountainous terrain hinders energy infrastructure extension, while limited investment in exploring domestic energy resource bases necessitates reliance on imported options. Furthermore, high poverty levels and the developing economy constrain affordability for many citizens (Mpholo et al., 2020).

Chapter 3: Literature Review

3.1 Introduction

This chapter reviews the existing literature on energy poverty measurement and its determinants for developing countries. Section 3.2 focuses on the theoretical literature, while section 3.3 focuses on the empirical literature. Finally, section 3.4 synthesises the literature.

3.2 Theoretical Literature

This section reviews various theoretical approaches to measuring energy poverty and understanding its determinants. Section 3.2.1 begins by examining the conceptual definition and measurement of energy poverty, while Section 3.2.2 discusses the theoretical link between energy poverty and its underlying factors.

3.2.1 Definition and Measurement of Energy Poverty

Energy poverty is characterised by a household's inability to access the necessary energy resources to heat its home, cook food and provide adequate lighting. Different authors and institutions have proposed various definitions emphasising the multifaceted nature of energy poverty. A common benchmark for energy poverty measurement, as noted by Rademaeker et al., (2016), is that households are considered energy-poor if they spend more than 10% of their income on energy services. According to González-Eguino (2015), energy poverty can be defined as the inability to attain adequate energy services for heating, cooling, lighting and appliance use. Day et al., (2016) argue that energy poverty should be seen as a deprivation of capabilities that modern energy services provide. These are services such as maintaining health, well-being and social participation. Saputri et al., (2024) defines energy poverty as the lack of affordability or access to basic energy services.

Various methods of measuring energy poverty are suggested throughout the literature, with specific merits and demerits in the discourse. They include the access-based approach, the engineering approach and the multidimensional assessment framework. The access-based approach is one such method and as was proposed by González-Eguino (2015) and expanded by Nathan & Hari (2020), it assesses whether households have physical access to modern energy resources such as electricity and or Liquefied Petroleum Gas (LPG) for cooking, lighting and heating. While this method effectively identifies the areas with infrastructural deficiencies, it may overlook the quality and reliability of the energy access, thus failing to account for intermittent supplies and fluctuations in voltage, frequent outages or insufficient electricity

power, for example, and these are common in underdeveloped regions and may render these services unusable for certain appliances or productive activities.

The engineering approach, on the other hand, calculates the minimum energy usage needed for the basic living standards, as discussed by González-Eguino (2015) and Nathan & Hari (2020). This method measures energy poverty based on the characteristics of various energy carriers such as fuel calorific value and the energy characteristics of the appliances such as size, efficiency, etc. However, critics argue that this method is sophisticated and requires interconnected data on home dwelling units, fuels and appliances for its computation. It is therefore complex to implement as detailed data on household characteristics would be required and often unavailable in developing countries.

Focusing on the financial aspect, the economic approach evaluates energy poverty by the proportion of income spent on energy. Households that spend more than 10% of their income on energy are often considered energy-poor (Ozughalu & Ogwumike, 2019). This method directly measures the financial impact of energy costs on households. It has, however, been critiqued for not considering the overall living costs across different regions, neglecting the fact that the cost of necessities such as food, housing and transport may vary significantly. The regional price variations are also overlooked in this approach. These variations may be brought about by factors such as access to energy resources, infrastructure costs and government policies and may potentially lead to the misclassifying of households in areas with high living costs but average energy prices (Herrero, 2017). It may also not accurately reflect energy quality.

Some scholarly debates emphasise the need for multidimensional assessment frameworks that integrate these methods to provide a holistic understanding of energy poverty. For example, Bouzarovski and Petrova (2015) suggest that single-dimension measurements fail to capture the dynamic and multi-scalar nature of energy poverty. They advocate for a Multidimensional Energy Poverty Index (MEPI). This more nuanced approach considers a range of indicators like access to electricity, type of energy used for cooking and heating, reliability and quality of energy supply e.t.c beyond mere energy consumption or expenditure. Maxim et al. (2016) discuss the regional variations in energy needs and costs, arguing for tailored approaches that consider local economic, environmental and social factors and calls for the Compound Energy Poverty Indicator (CEPI) approach. Similarly, Siksnylyte-Butkiene (2021) points out the

advantages of using a composite index that incorporates several indicators such as income, expenditure, energy price, energy consumption, household characteristics, dwelling type, comfort and access to energy, to reflect the complex realities of energy poverty more accurately. These multidimensional approaches are all critiqued for being data-intensive, which is commonly unavailable in developing countries and requires a sophisticated analysis, making it difficult to implement in resource-poor settings.

3.2.2 Determinants of Energy Poverty

Energy poverty is shaped by a range of interrelated factors including socio-economic status, energy performance of dwellings, homeownership and health conditions. These factors directly affect individuals' and households' ability to meet their energy needs (Qurat-ul-Ann & Mirza, 2021). According to Abbas et al. (2022), factors such as the age and education attainment of the household head, the size of the home, household expenses and employment status significantly determine the amount of energy required for daily tasks.

For instance, the theoretical literature on energy poverty emphasizes the crucial role played by the characteristics of the household head. Saputri et al., (2024) argue that the increasing age of the household head often leads to a reduced effort to utilize commercial energy, resulting in less expenditure on cleaner and commercial energy sources. Their opinion is that these factors lead people to not have immediate gains from better and more energy-efficient technologies and they would rather focus their efforts on other pressing issues. This pattern heightens the household's vulnerability to energy poverty (Qurat-ul-Ann & Mirza, 2021; Saputri et al., 2024). Conversely, a higher education level among household heads mitigates energy poverty. This is because educated individuals are more aware of the detrimental effects of indoor air pollution and are therefore more inclined to use cleaner energy solutions, additionally, education often opens up employment opportunities which further enhances economic stability and access to cleaner energy options (Qurat-ul-Ann & Mirza, 2021; Saputri et al., 2024).

The employment status of a household head is also a potential factor in household energy poverty. There exists a negative correlation between the likelihood of a household being energy-poor and the full-time employment status of the household head. The full-time employment status of a household head offers a consistent salary and a sense of financial security and such households can rely more on modern energy beyond the reasonable limits of consumption (Saputri et al., 2024).

Lower-income households are more likely to experience energy poverty due to limited financial resources to cover high energy bills (Saputri et al., 2024). Financial constraints often prevent low-income families from investing in energy-efficient appliances that reduce energy consumption thereby mitigating energy poverty. The energy efficiency of a dwelling also plays a crucial role in mitigating energy poverty. Homes with poor insulation, outdated heating and cooling systems and inefficient appliances consume significantly more energy to maintain comfortable temperatures and to perform essential tasks. This translates to higher energy bills, disproportionately affecting low-income households (IEA, 2023).

Larger dwelling sizes lead to higher and varied electricity demands. They normally have higher energy demand, thus exacerbating their vulnerability to energy poverty especially in households with limited financial resources (Saputri et al., 2024). Family size is another potential factor that affects household decisions about the kind and quantity of energy to use. Energy demand rises in proportion to the number of people living in a household; the more residences, the more the energy requirement rises. This can potentially promote energy poverty (Saputri et al., 2024).

Geographic variations and infrastructure factors such as proximity to fuel sources and access to urban markets also play a crucial role in shaping the demand for energy services and exacerbating energy poverty (Qurat-ul-Ann & Mirza, 2021).

3.3 Empirical Literature

Focusing on empirical studies in developing countries, this section analyses data-driven research and case studies that measure and evaluate the determinants of energy poverty. Section 3.3.1 focuses on unidimensional measures of energy poverty While section 3.3.2 focuses on multidimensional measures of energy poverty.

3.3.1 Studies Focusing on Unidimensional Measures of Energy Poverty

South African households are among the global south's energy-struck nations hence, Ismail & Khembo (2015) employed logistic regression and expenditure analysis to examine the factors that influence energy poverty here. Utilizing data from the 2012 wave of the National Income Dynamic Survey (NIDS), their measures of energy poverty, using the economic approach, was defined by the Department of Energy (DoE) of South Africa. This approach considers a household to be energy-poor if it spends 10% of or more of its income on energy facilities. This

economic approach is a unidimensional measure of energy poverty as it focuses solely on energy expenditure. The study found that higher expenditures on education and transportation exacerbate energy poverty while increased food spending has the opposite effect.

Ismail & Khembo (2015) further observed a significant reduction in energy poverty, with income rises linked to higher education levels. Their analysis highlighted racial disparities; African households face higher energy poverty rates compared to White, Asian/Indian and Colored households. In addition, larger households tend to be more energy-poor, those with more members were paradoxically less so. Notably, households connected to the national grid exhibited higher levels of energy poverty, highlighting the need for more affordable basic services, particularly in the rural areas. They recommended that addressing energy poverty in South Africa requires a multifaced approach that includes differential pricing, infrastructure expansion, promotion of renewable energy, improved data collection and education campaigns.

Nathan & Hari (2020) measured energy poverty using an access-based approach. This method departs from traditional economic or expenditure-based approaches; it focuses on whether households have access to modern energy services necessary for cooking and lighting. The study defined accessibility as the ability to utilise modern energy sources, such as LPG or electricity for cooking and lighting. This measure of energy poverty only focuses on the accessibility of modern energy resources and neglected issues such as affordability and quality. This study introduced a novel categorization method to assess energy poverty, grouping individuals into very poor, moderately poor, transitionally poor and not poor. The study used data from the 68th round of the National Sample Survey (NSS) to investigate the spatial distribution of energy poverty in urban areas across various Indian states and union territories. Their findings suggested a prevalent energy poverty among larger households, with the lack of modern lighting and cooking fuels as the primary determinants of energy poverty in metropolitan regions. This study proposes new measures for assessing the depth and severity of energy poverty. These are new measures which focus specifically on the energy-poor population and exclude the non-poor. They avoid the skewing results by a large share of nonpoor individuals. They identify the areas with high energy poverty severity to enable policymakers to target interventions more effectively.

Awan et al. (2022) used a double median approach which is derived from the economic or expenditure approach. It is an approach which was used by Ismail & Khembo, (2015) to

investigate energy poverty in Pakistan, analyzing data on eight Household Income and Expenditure Surveys (HIES) spanning from 1998 to 2019. According to this double median approach, a household is considered energy-poor if its energy expenditure is more than double the national median expenditure on energy. This method only focuses on the expenditure without referring to issues of access, reliability or quality which qualifying it as a unidimensional measure of energy poverty. Their study results indicated an increase in energy poverty over the surveyed period, with rural areas, female-headed households, low income and low educational levels as significant contributing factors. The study suggested several policy interventions to achieve Sustainable Development Goal 7 (affordable and clean energy) by 2030, an increase in access to clean energy, restructuring of energy tariffs, and introduction of gender-sensitive subsidies.

Gafa & Egbendewe, (2021) used various methods to measure energy poverty in Senegal, Togo. They used the physical threshold approach, the approach that measures energy poverty by comparing household energy consumption against a predefined minimum physical energy requirement needed to meet a basic energy need. They also used the demand-based approach, this method sets a threshold for energy consumption but focuses on the minimum level of energy required to meet the household needs. They further deployed the economic approach method and, finally, the income poverty line approach. These methods satisfy the criteria of being on the unidimensional measurements as each one of them focuses on a single dimension. Using the physical threshold approach, the study found that a significant proportion of households were energy-poor in Senegal. Similar findings were observed in Togo, with many households not meeting the minimum consumption requirements necessary for basic living standards.

On the demand-based approach, Gafa & Egbendewe, (2021) revealed that energy consumption levels increased with income in Senegal. However, many households remained below the defined energy poverty line. For Togo, the study also showed that a large portion of the population did not consume enough energy to meet its basic needs, reinforcing the physical threshold approach. According to the economic approach, the study found that in Senegal a significant number of households fell into this category. This observation indicated that energy costs were a substantial burden. In Togo, the method similarly identified high levels of energy poverty, with many households devoting a large portion of their income to energy expenses.

When utilising the income poverty line approach in Senegal, the study found that households whose residual income (income after energy expenditure) fell below the national poverty line were considered energy-poor and were substantial in number. A similar case was observed in Togo, showing a strong correlation between overall poverty and energy poverty. The study suggests that rural areas need targeted interventions to enhance access to modern energy, especially for disadvantaged groups such as female-headed households. It further suggests that policies should increase the affordability and accessibility of clean energy sources. At the same time, educational campaigns should raise awareness about the benefits and health risks associated with using traditional biomass fuels. Direct subsidies or financial assistance programmes could also assist.

Pachauri & Spreng, (2011) employed various approaches to measure energy poverty in [SubSaharan Africa where there were 64 estimates from 13 studies, South and Southeast Asia with 32 estimates from 14 studies and Latin America and the Caribbean with 7 estimates from 2 studies.]. They used the physical access approach, the economic approach and the income poverty line approach. These were unidimensional measures of energy poverty as they focused on one dimension of energy poverty at a time. The energy access-consumption matrix classifies households based on energy access and consumption, illustrating energy poverty levels across income groups. In India, between 1983/84 and 2004/05, the proportion of energy-poor households decreased from 38% to 8%, while households with electricity and possibly LPG increased significantly from 3.5% to 42%. The other approaches utilised in this study were all inconclusive as they did not meet the local conditions. These approaches are the Energy Development Index (EDI), the Energy Poverty Line and the Minimum End-Use Energy approach. The study found an overall pooled energy poverty of 49% which indicated that nearly half of the population in the sampled developing economies was considered energy poor.

3.3.2 Studies Focusing on Multidimensional Measures of Energy Poverty

Crentsil et al. (2019) assessed energy poverty in Ghana using cross-sectional data spanning from 2018 to 2014. The study measured energy poverty using the MEPI which follows the counting approach of multidimensional poverty measurement proposed by (Alkire & Foster, 2011). This approach involves two main steps which are identification and aggregation using five dimensions, namely lighting, cooking, heating, the services provided through household appliances and telecommunications and six indicators, namely electricity, modern cooking fuel,

indoor pollution, asset ownership, education, entertainment and telecommunications; that qualify it as a multidimensional measure. Their findings indicated a decrease in multidimensional energy poverty over the period, though both indices and intensity remained high. The study highlights energy poverty due to lack of access to modern cooking fuels and indoor pollution. Demographic factors like age, sex, education, wealth status and household head location contribute to this issue. It recommends intensifying LPG adoption campaigns, encouraging underserved groups, regular supply, addressing supply disparities, and increasing educational campaigns.

Gafa & Egbendewe (2021) also examined energy poverty in the rural areas of Senegal and Togo using MEPI which included four dimensions which are physical access and utilization, affordability, health and safety and convenience. It reveals that in Togo, the levels of rural energy poverty were higher compared to Senegal, reflecting the latter's relatively higher income levels. Their analysis highlighted the importance of enhancing female intra-household bargaining power and decision-making participation to improve energy outcomes in rural Togo.

Abbas et al. (2022) employed MEPI to explore the scope and depth of extreme energy poverty across various emerging nations. For this study, the MEPI considers five key dimensions, each with specific indicators. The dimensions include cooking as a dimension with the type of cooking fuel and indoor smoke as its indicator. Lighting, with electricity access as its indicator, telecommunication, with asset ownership as the indicator, entertainment or education, with possession of the concerned means as an indicator and household appliances, with ownership assets as the indicator. The study highlighted Afghanistan, Yemen, Nepal, India, Bangladesh and the Philippines as the countries particularly vulnerable to extreme multidimensional energy poverty. In Africa, the nations such as the D. R. Congo, Chad, Madagascar, Niger, Sierra Leone, Tanzania and Burundi were identified as the most affected. Their research also pinpointed the key socioeconomic determinants of household energy poverty, including the size and ownership status of homes, income level, marital status and geographical location. This study proposed a multi-faceted approach to tackling energy poverty, focusing on improving access to clean energy, affordability, education, and female empowerment and addressing regional disparities by expanding energy access, providing financial incentives, conducting education

and awareness campaigns, empowering women in energy decision making, provide support for education for women and girls design policies to address disparities.

3.4 Synthesis of the Literature

The literature review reveals energy poverty as a complex and multifaceted phenomenon with significant social, economic and environmental consequences. The unidimensional and multidimensional approaches serve as fundamental frameworks for analyzing energy poverty. While the unidimensional approach focuses on a single factor like physical access to energy, it often fails to capture the inference of energy quality, reliability and affordability. The multidimensional approach, conversely, considers these broader factors and offers a more holistic view of energy poverty but also tends to be data-intensive, thereby not making it a viable choice in this study due to its data-intensive nature.

The empirical studies in developing economies utilise both unidimensional and multidimensional frameworks to assess energy poverty across different geographical contexts. These studies highlight the varying impact of socioeconomic factors on energy access. Studies in SSA also revealed that rural areas are disproportionately affected by energy poverty due to infrastructure deficiencies and lower income levels. The literature suggests that generic policies may not effectively tackle energy poverty, highlighting the need for tailored interventions to specific areas. Although the current body of research on energy poverty offers a strong foundation, there is a crucial gap when it comes to understanding the specific situations in countries such as Lesotho. Thus by undertaking the measurement and determinants of energy poverty in Lesotho, this research study can significantly contribute to the body of literature by providing a more nuanced understanding of the issue within Lesotho and inform the development of targeted policies that effectively address the unique challenges of the country. It will achieve this by employing the multinomial logit regression method to assess the determinants of energy poverty in Lesotho.

Chapter 4: Methodology

4.1 Introduction

The chapter provides an overview of the data to be utilized in this study. It also explains the chosen methodology and the model specifications for data analysis. Section 4.2 describes the data used in this research study. Section 4.3 presents a model specification that gives an indepth

outline of the research approach that is used. Section 4.4 provides the estimating strategy, which gives clarity and rigour to the present study and lays the foundation for the subsequent empirical journey.

4.2 Tools for Analysis

In this study, Gnu Regression, Econometrics and Time-series Library (Gretl) was employed to conduct the statistical analysis, specifically for the multinomial logit model used to evaluate the determinants of energy poverty (gretl, n.d.). Gretl is a free open-source software package designed for econometric analysis and offers a range of features well-suited for this study's requirements. Its user-friendly interface and comprehensive set of econometric tools make it ideal for managing complex models and handling large datasets efficiently. Gretl allows for the estimation of multinomial logit models, which are critical in this study for modelling the likelihood of households falling into various categories of energy poverty based on multiple independent variables. The software's implementation of this technique provides accurate coefficient estimates and significance testing.

4.3 Data Description

The primary data used in this study is from the 2017 Household Energy Consumption Survey (HECS), which provides a depiction of energy consumption in Lesotho for 2017, focusing on household use of energy sources such as biomass, petroleum products, electricity, and solar photovoltaic systems. The main goal of the survey was to offer highly detailed information about the patterns of energy use in Lesotho homes for the summer and winter seasons. It was intended that this would be achieved by interviewing the same household in the two seasons, but unfortunately, this was not realised which led to different sample sizes for the summer and winter seasons, with the winter season having the bigger sample over the summer season. This poll was conducted across the country, in all the 10 districts of Lesotho. The stratified sampling method was conducted in two stages. Agroecological zones, including the lowlands, the foothills, the mountains and the Senqu River Valley, were used to choose the initial stratum. Urban, peri-urban and rural communities were used to define the second stratum (Mothala et al., 2022). A total of fifteen households were randomly selected in each enumeration area (EA) of the 2016 Population and Housing Census as the main primary sample units (PSU). A total of 2877 households were covered, with a response of 2664 households in the summer season and 2836 households in the winter season.

The summary of the demographic data from the survey is presented in Gender roles are determined by society, with women's labour being the primary source of fuel for the rural households (Dumga & Goswami, 2024). In Lesotho, the unspoken rules and expectations about how gender influences roles and responsibilities regarding fuel collection and consumption exist in households where females are generally expected to prepare food for their families and hot water for washing, with a slight discrepancy between rural and urban dwellers.

Table 1. The gender of the household head distribution is 62% and 38% for males and females, respectively, in the summer month and 50% for both males and females in the winter season. The average age of household heads was found to be 50 years in summer and a staggering 27 years for the winter season. The education level of the household head was found to vary from those who had none to those with only primary, high school and tertiary education levels. The distribution for the summer season was 2%, 64%, 29%, and 5%, respectively. For the winter season, the education level distribution was 19%, 50%, 28% and 3% for no education, primary, high school and tertiary education, respectively. In the summer season, 57% of the households were found to be in the low-income class, 34% of the households in the middle-income class, and 9% of the households were in the high-income class. For the winter season, 67% of the households were in the low-income class bracket, 30% were in the middle-income, and only 3% were in the high-income bracket. Thirty percent of the households received remittances in the summer season, while 22% received them in the winter season. In the summer season, 37% of households had electricity, and 22% had it in the winter season. Most settlements are in the rural areas making up 52% of the households of the total settlements in both the summer and the winter data. while urban settlements and peri-urban make up 38% and 10%, respectively, for both summer and winter seasons.

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Table 1: Demographic data

	Summer	Winter
Variables	Mean or Share	Mean or Share
Gender of household head		
Female	38%	50%
Male	62%	50%
Age of household head	50	27
Education level of household head		

None	14%	19%
Primary	53%	50%
High School	24%	28%
Tertiary	9%	3%
Number of housing units in household	2	2
Household income class		
Low	57%	59%
Middle	34%	32%
High	9%	9%
Households receiving remittances	30%	27%
Availability of electricity	37%	36%
Settlement type		
Rural	52%	52%
Urban	38%	38%
Peri-Urban	10%	10%

Source: own using Lesotho BOS 2017 HECS data

Table 2 shows the distribution of households by the main energy source and the settlement type of the household in both the summer and the winter seasons. Across many energy sources, we see slight variations in household numbers between summer and winter. Some energy sources are more predominant in one season than the other. For example, 32% of households using offgrid electricity are in urban areas, 27% in peri-urban and 41% in rural areas for the summer season against 31% in urban, 25% in peri-urban and 44% in rural areas for the winter season. Off-grid electricity usage is heavier in rural areas in both summer and winter, reflecting limited access to grid electricity in rural regions. In summer, 54% of grid electricity users are in the urban areas, 27% in peri-urban and 19%, while the distribution stays relatively stable in the winter with 54% in urban, 26% in peri-urban and 20% in rural areas. Urban households dominate grid electricity usage, consistently making up over 50%. This suggests strong electricity grid infrastructure in urban areas, while rural households have limited grid access, with only 19-20% relying on the grid in both seasons. The slight decrease in peri-urban areas usage during winter might reflect households shifting to other heating fuels like paraffin or biomass.

In summer, 72% of LPG users are urban, 16% are peri-urban, and 12% are rural, while in winter, there is a small decline in urban usage of 68%, while peri-urban 18% and rural 14%

usage increases. LPG is predominantly used in urban households, which likely reflects better access to infrastructure and better supply chains for this cleaner fuel. There is a small increase in rural and peri-urban LPG usage in winter, which might indicate efforts to use cleaner fuels for cooking or heating when the demand increases. During the summer and winter seasons, all biogas users are in rural areas. Biogas usage is exclusively rural, possibly because it relies on local organic material and small-scale production that is more viable in rural settings. Paraffin in the summer season had 41% of users in urban areas, 24% in peri-urban and 35% in rural against the winter season, experiencing a slight increase of 42% in urban and peri-urban with 26%, while rural usage decreased to 32%. Paraffin usage is relatively balanced across all settlement types but is the highest in urban areas. This suggests that even in urban settings, where grid electricity is widely available, some households rely on paraffin as an affordable alternative. The slight decrease in rural paraffin usage during winter might indicate a switch to more readily available traditional fuels such as biomass.

In the summer season, 60% of coal users are in urban areas, 20% in peri-urban and 20% in rural while urban usage decreases to 50% peri-urban increases to 25% and rural to 25%. Coal usage is generally low across all areas, but the highest percentage is in urban areas in summer. This might suggest industrial or other non-household usage or for those urban households using coal, it might be a low-cost alternative fuel. Biomass use is fairly distributed between both seasons, with 35% of users in urban, 32% in peri-urban and 33% in rural areas in summer and 40% users in urban, with peri-urban at 30% and 30% for rural in winter. Biomass is a widely used energy source, even in urban areas. This is notable because biomass is generally associated with rural or peri-urban settings. This could reflect urban household’s continued reliance on traditional fuels for certain purposes.

Table 2: Distribution of households by main source of energy and household settlement type

	Summer		Winter	
Source of	Settlement type	Total	Settlement type	Total

Energy	Urban %	Periurban %	Rural %	Number of Households	Urban %	Periurban %	Rural %	Number of Households
Electricity (Off-grid)	32	27	41	37	31	25	44	45
Electricity (Grid)	54	27	19	258	54	26	20	280
LPG	72	16	12	49	68	18	14	50
Biogas	0	0	100	1	0	0	100	2
Paraffin	41	24	35	123	42	26	32	130
Coal	60	20	20	5	50	25	25	4
Biomass	35	32	33	255	40	30	30	240
Other	31	22	47	32	34	20	46	35

Source: own using Lesotho BOS 2017 HECS data

Figure 2 **Error! Reference source not found.** and Figure 3 **Error! Reference source not found.** depict the predominant energy sources in summer for cooking and lighting in Lesotho. Notably, Liquefied Petroleum Gas (LPG) emerged as the leading energy source for cooking, capturing around 31.19% of distribution, followed by wood at about 27.47%. Other sources such as animal dung making 13.11%, electricity at 10.6%, straw/shrubs/grass at 8.20%, paraffin at 7.19%, and crop waste at 1.86% contributed less significantly, illustrating a diverse energy portfolio with varying levels of accessibility and usage.

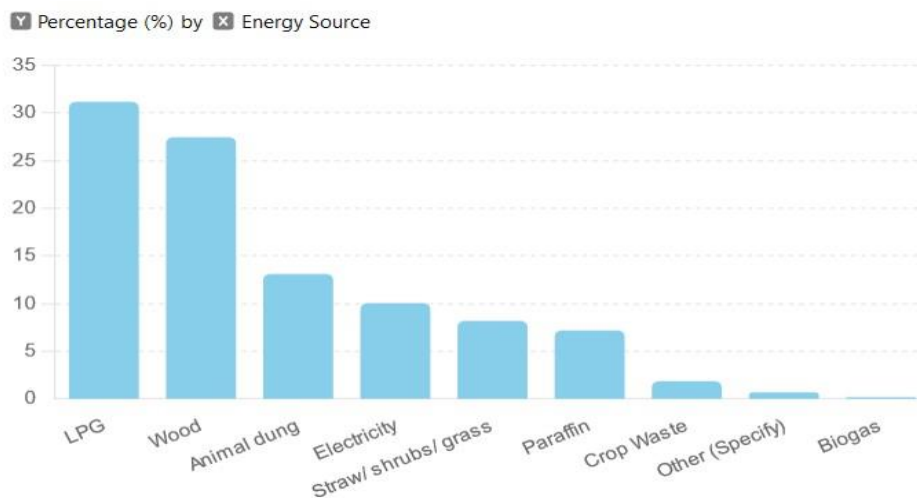


Figure 2: Summer Main Source of Energy for Cooking

Source: own using Lesotho BOS 2017 HECS data

Paraffin is the most utilized source for lighting, accounting for 49.12% and overshadowing grid electricity 37.12%. The minimal contributions from alternative sources, such as solar lanterns 2.16% and rechargeable battery lamps 0.75% highlight a significant reliance on traditional energy forms. This dependency underscores the challenges in transitioning to more sustainable energy solutions.

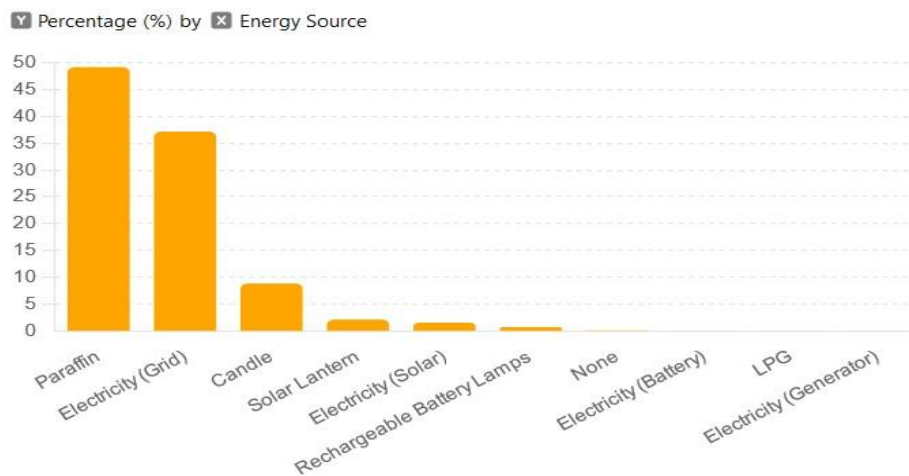


Figure 3: Summer Main Source of Energy for Lighting.

Source: own using Lesotho BOS 2017 HECS data

Figure 4 and Figure 5 depict the predominant energy sources in winter cooking and lighting in Lesotho. For cooking in winter, wood is found to be the predominant source of energy, accounting for 31.25% and LPG accounting for 29.95%. Animal dung and electricity account for 10.83 and 10.65 respectively. All the other sources make low contributions, with paraffin at 7.87%, straw/Shrubs/Grass at 5.94%, crop waste at 3.02% and biogas at 0.04%.

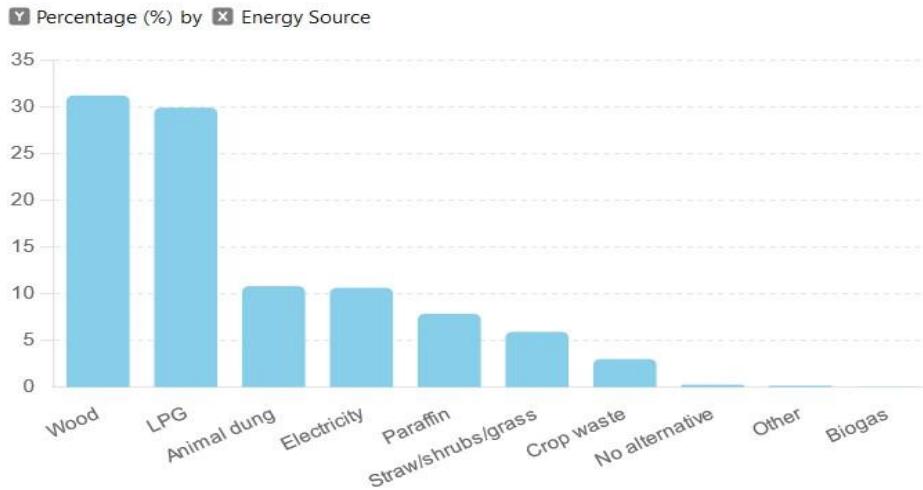


Figure 4: Winter Main Source of Energy for Cooking

Source: own using Lesotho BOS 2017 HECS data

For lighting, candles are the most utilized source, accounting for 49.44% and overshadowing grid electricity, which contributes 36.58%. The minimal contributions from alternative sources, such as solar lanterns 1.62% and rechargeable battery lamps 0.74% highlight a significant reliance on traditional energy forms. This dependency underscores the challenges in transitioning to more sustainable energy solutions.

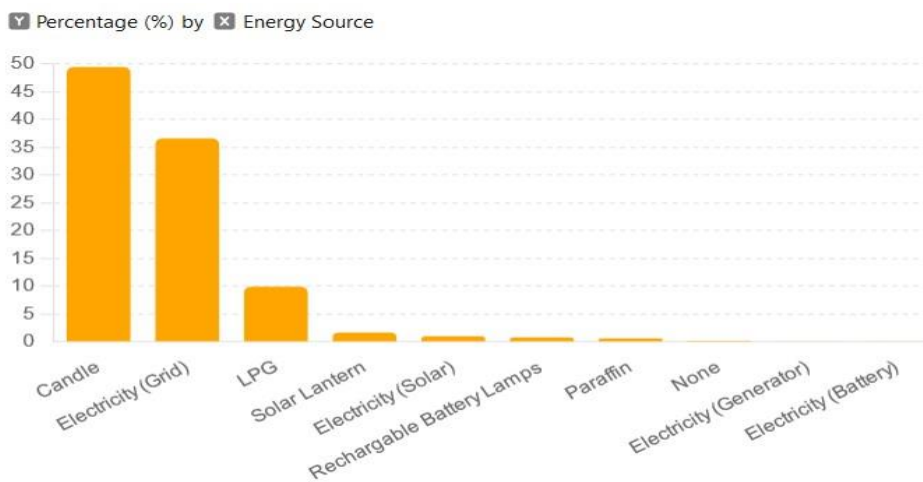


Figure 5: Winter Main Source of Energy for Lighting.

Source: own using Lesotho BOS 2017 HECS data

4.4 Energy Poverty Measurement

Following Nathan & Hari (2020), this study employs the access-based approach to measure energy poverty in Lesotho. This is primarily due to the type of data that was available to the researcher for the present study, which is the Lesotho BOS 2017 HECS dataset. In this approach, access to a desired energy service is a prerequisite to measuring energy poverty in the households. The access-based approach of measuring energy poverty is implemented in this study by calculating the number of people or households without access to modern forms of energy for cooking and lighting. Primary sources of energy for cooking include coke, coal, charcoal, firewood, LPG, biogas, animal dung cake, kerosene (paraffin), electricity and others, while lighting sources include kerosene (paraffin), oils, gas, candles and others. Modern cooking energy sources include LPG, electricity and biogas while modern lighting energy is primarily electricity. Inefficient fuels include coal, coke, charcoal, firewood, chips, dung cakes and kerosene.

Energy poverty is computed by dividing the energy-impooverished population into three groups: extreme energy poor, moderately energy poor and transitionally energy poor, to reduce the arbitrariness of the poverty line cutoff and discreteness. The first category of households is those that are not affected by energy poverty in all aspects and are termed energy non-poor. This refers to households that do not rely on any energy-inefficient fuels but only depend on modern energy fuels as the main energy sources. The first category of energy poverty is transitional energy poverty. A transitional energy-poor household uses modern fuels for cooking and lighting but also relies on inefficient fuels for certain purposes. The second category is moderate energy poverty. To meet this category, a household should rely on modern fuels for either cooking or lighting, but not both. The final category is extreme energy poverty. These households lack access to modern fuels as their primary source of energy for cooking and lighting.

4.5 Determinants of Energy Poverty: Model Specification and Estimation Strategy

The most utilized model for assessing determinants of energy poverty throughout the literature is the logistic regression model. In this model, energy poverty is the dependent variable, and there are six independent variables which have a direct impact either positively or negatively on the independent variable. The independent variables are the gender of the household head, age of the household head, education of the household head, household size, settlement type

and household income class. Therefore, the logistic model used in this study is specified as follows:

$$Y_i = \beta_0 + \beta_1 X_{1i} + \dots + \beta_k X_{ki} + u_i \quad \text{Equation 1}$$

where Y_i represents the dependent variable for household i , X_i represents all the explanatory variables (independent variables), β 's are the parameters of the model to be estimated, while u_i is an error term. The model Equation 1 **Error! Reference source not found.** can be estimated as a linear probability model (LPM) using the ordinary least squares method. However, the LPM on its own is insufficient for this study because of the nature of the dependent variable and its inability to limit the probabilities between 0 and 1. To counteract this limitation a more specialized model, logistic regression, which is a nonlinear model is more suited to capture the underlying patterns and correlations in the data to give more accurate estimates.

The conditional chance that $Y = 1$ or $Y = 0$ given X is described by a simple logistic regression model, which takes the following form:

$$\text{logit}(Y_i) = \ln \left(\frac{P}{1 - P} \right) = \beta_0 + \beta_1 X_{1i} + \dots + \beta_k X_{ki} + u_i \quad \text{Equation 2}$$

where $\text{logit}(Y_i)$ is the natural log (\ln) of the ratio of the probability of Y happening (i.e. a household is energy-poor), P , to the probability of Y not happening (i.e. a household is not energy-poor), $(1 - P)$.

Equation 2 **Error! Reference source not found.** is simple logit and is only applicable for dichotomous response variables, in situations where the dependent variable is categorical as in energy poverty, the multichotomous variable has discrete categories, requiring a change in log odds. The multinomial logit model is more suited for this scenario, and it is represented by Equation 3 **Error! Reference source not found.**,

$$\ln \left(\frac{\Pr(Y = m)}{\Pr(Y = n)} \right) = \sum_R (\beta_{mr} - \beta_{nr}) \quad \text{Equation 3}$$

$$X_r$$

$$r=0$$

where Y is the categorical outcome variable representing energy poverty status, m represents the energy poverty category of interest (e.g., transitional, moderate or extreme), n represents the base category (non-energy poverty), X_r represents the predictors or independent variables, while β_{mr} is the coefficient for the predictor X_r in category m and β_{nr} is the coefficient for the predictor X_r in category n .

4.6 Model Validation

To assess the adequacy of the model, the McFadden R^2 or Pseudo R^2 is utilized in this study to evaluate the model goodness of fit and is especially pertinent in the context of logistic regression. The McFadden R^2 is computed by comparing the probability of the tested model with the probability of a null model (a model without any predictors) and is given by,

$$R_{McFadden}^2 = 1 - \frac{\ln(Full)}{\ln(Null)} \quad \text{Equation 4}$$

where $\ln(Full)$ is the fitted multinomial logit model's maximum log-likelihood value and $\ln(Null)$ is the null model value or the value where all the coefficients are zero except for the intercept β_0 . For the goodness of fit, 0 is the worst fit, and 1 is the best fit. The value of Pseudo R^2 falls between these ranges. Nevertheless, the values of the Pseudo R^2 , in contrast to the traditional R^2 , in the range of 0.2 to 0.4 indicate a very strong fit for the models using cross-sectional data (Mothala et al., 2022). The chi-square statistic is also employed in addition to the McFadden R^2 to assess whether there is any significant association between the dependent and independent variables.

Chapter 5: Results and Discussions

5.1 Introduction

This chapter presents and analyses the study's findings as per the research objectives and Gretl is the main tool utilised. Section 5.2 presents the prevalence of energy poverty in the country. Section 5.3 presents the determinants of energy poverty and finally, Section 5.4 presents the discussion of the results.

5.2 Prevalence of Energy Poverty

This section provides the results on the prevalence of energy poverty in Lesotho. A comparison of energy poverty distribution between the summer and winter seasons in Lesotho is presented in Figure 6 with the emphasis being on the count of households in each energy poverty category. The non-energy poverty category shows a decrease in the number of households from summer to winter. The transitional energy poverty category, on the other hand, shows a significant increase during the winter season suggesting that more households fall into this category during the colder season. Moderate energy poverty group also increased in winter, indicating the worsening conditions for some households while the number of households in extreme energy poverty decreased in winter compared to summer presenting a seemingly counterintuitive observation.

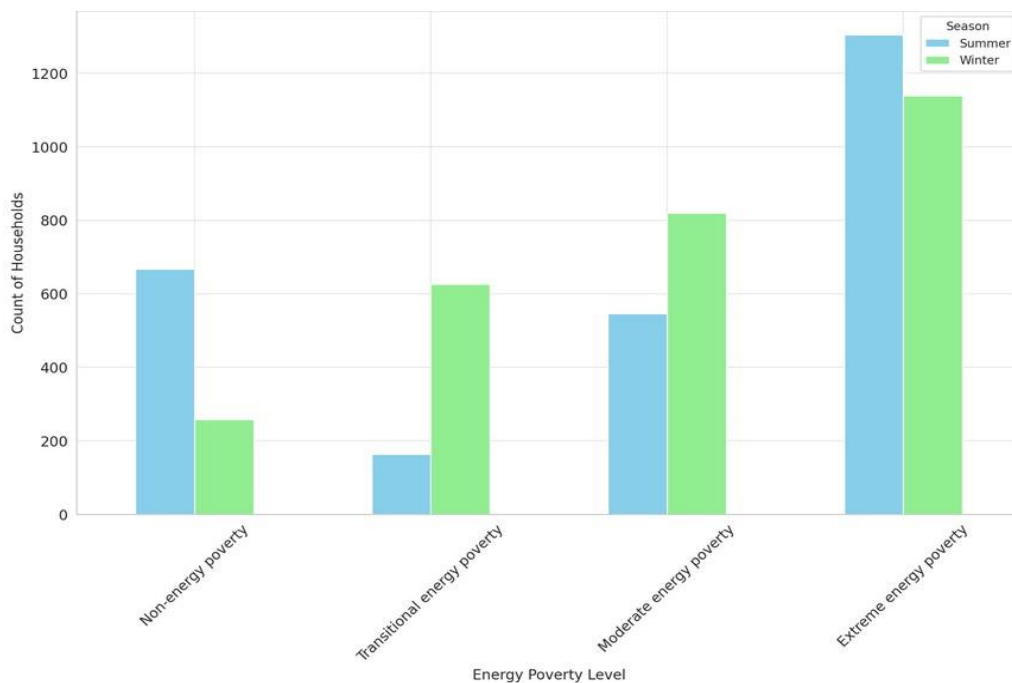


Figure 6: Energy poverty distribution between summer and winter.

Error! Reference source not found. Table 3 also presents a comparative analysis of energy poverty distribution across the summer and winter seasons, revealing a stark contrast in energy security. The sample sizes for the summer and winter seasons are slightly different with summer having a sample size of 2664 while the winter season had a sample size of 2836. The percentage of non-energy poor is significantly lower in the winter season at 9% compared to the summer season at 24.9%. The transitional energy poverty percentage is lower in summer at 6.1% compared to the winter at 22%. The moderate energy poverty percentage is lower for the summer season at 20.4% compared to 28.9% in winter. Extreme energy poverty percentage, on

the other hand, is higher for the summer season at 48.7% compared to 40% for the winter season.

For the summer season, male-headed households experience the highest percentages of energy poverty in all categories compared to female-headed households. Male-headed households have a 60.7% share in the extreme energy poverty category compared to 39.2% for female-headed households. For the winter season, a slight variation is observed, with female-headed households having marginally higher percentages of energy poverty in most categories except for the transitional energy poverty category where male-headed households still had a higher percentage.

In both seasons, rural settlements have the highest percentages of extremely energy-poor households at 82.7% for summer and 81.2% for winter. Urban areas have the highest percentages of non-energy-poor households in both seasons at 82.8% for summer and 77.7% for winter. On the education level energy poverty distribution, the households with their heads having primary education levels have the highest number of extreme energy poverty in both seasons at 64.3% for summer and 47.4% for winter. The households with the heads having tertiary education level, on the other hand, have the lowest number of extreme energy poverty in both seasons at 0% for summer and 3% for winter. On the energy poverty income class distribution, low-income households have the highest number of extremely energy-poor households in both seasons at 79.9% for summer and 25% for winter. High-income households have the lowest number of extremely energy-poor households in both seasons at 1% for summer and 0.4% for winter.

Table 3: Summary of energy poverty distribution

		Summer (Sample Size = 2664)				Winter (Sample Size = 2836)			
		Non-Energy poverty (663)	Transitional Energy poverty (164)	Moderate Energy Poverty (544)	Extreme Energy poverty (1293)	Non-Energy poor (256)	Transitional Energy poverty (626)	Moderate Energy Poverty (819)	Extreme Energy poverty (1135)
Energy poverty distribution		24.9%	6.1%	20.4%	48.7%	9.0%	22%	28.9%	40.0%
Energy poverty by gender of household head	Male	66.5%	67.1%	60.3%	60.7%	49.6%	52%	48.5%	49.0%
	Female	33.4%	32.9%	39.7%	39.2%	50.4%	47.9%	51.5%	51%
Energy poverty by settlement type	Urban	82.8%	69.5%	37.5%	10.3%	77.7%	77.5%	34.4%	11.0%
	Rural	9.8%	15.2%	47.2%	82.7%	10.5%	13.0%	54.7%	81.2%
	Peri-Urban	7.4%	15.2%	15.3%	7%	11.7%	9.58%	10.9%	7.8%
Energy poverty by education level of household head	Tertiary	12.2%	11.6%	0.6%	0.00%	1.2%	3.0%	4.2%	3.0%
	High school	40.9%	36%	27%	12.5%	23.4%	23.6%	29.1%	29.5%
	Primary	29.4%	31.7%	60.1%	64.3%	52.7%	53.8%	47.7%	47.4%
	None	0.9%	0.00%	0.6%	2.1%	22.3%	19.3%	18.6%	19.0%
Energy poverty by household income	High income	26.4%	26.2%	3.3%	1.0%	20.7%	13.9%	0.9%	0.4%
	Middle income	52.9%	53.7%	38.8%	19.1%	21.9%	28.8%	20.0%	7.8%

	Low income		20.7%	20.1%	57.9%	79.9%		14.1%	12.3%	30.3%	25.0%
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Source: own using Lesotho BOS 2017 HECS data

5.3 Determinants of Energy Poverty

The multinomial logit analysis was performed using Gretl to model the probability of different energy poverty levels based on socio-economic and demographic factors of a household.

Additionally, the software’s output, including coefficient estimates and marginal effects, provide insights into the relative importance of various determinants in explaining energy poverty. This section explores the primary factors contributing to energy poverty, including household income, education levels, gender of the household head and settlement type. Subsection 5.3.1 presents the model validation results while sub-section 5.3.2 presents the multinomial logit estimation results.

5.3.1 Model Validation Results

Model validation results are presented in Table 4. The statistical test of the summer model was a Chi-square (30) equal to 1428.04 and a p-value of 0, suggesting that the model was statistically significant and the predictors collectively explain variations in energy poverty categories significantly better than a model without these predictors. The statistical test of the winter model had a Chi-square (30) equal to 1560.69 and a p-value of 0, suggesting that the model was statistically significant, and the predictors collectively explain variations in energy poverty categories significantly better than a model without the predictors.

Table 4: Model Validation Results

	Summer	Winter
Metric	Value	Value
Depended on Variable	Energy Poverty Categorical	Energy Poverty Categorical
Number of Observations	2664	2836
Log-likelihood	-1929.171	-2836.9599
Akaike Information Criteria (AIC)	3924.342	5739.918
Correctly Predicted Cases	1417 (64.5%)	1558 (55%)
Likelihood Ratio Test	Chi-square (30) =1428.04	Chi-square (30) = 1560.69
P-value (Likelihood Ratio Test)	<0.0001	<0.0001

Source: own using Gretl software Multi Logit results

Both models are statistically significant, indicating that they fit the data well. However, the summer model has a better predictive accuracy of 64.5% versus the 55% of winter, suggesting that it may have captured the determinants of energy poverty better during that season.

5.3.2 Multinomial Logit Estimation Results

The multinomial logit model results are presented on Table 5 for the summer and winter seasons. The results were obtained with the aid of Gnu Regression, Econometric and Timeseries Library (Gretl) software package designed for econometric analysis. The results show the impact of the determinants of energy poverty on different energy poverty categories, namely energy poverty category 1, which is non-energy poverty; energy poverty category 2, which is transitional energy poverty; energy poverty category 3, which represents moderate energy poverty and energy poverty category 4 which is extreme energy poverty.

In both the winter and the summer seasons, category 1 was used as the base category in Gretl software and all the remaining categories were compared to it. During the summer season, first, the age of the household head was significant only in the moderate energy poverty category. Its coefficient was negative and significant at a 5% level. This implied that the households headed by older people were less likely to transition from non-energy poverty into moderate energy poverty. The variable for female-headed households was significant only in the moderate energy poverty category, with a positive coefficient that was significant at a 10% level. This indicates that female-headed households were more likely to transition from nonenergy poverty into moderate energy poverty compared to male-headed households.

Moreover, for the educational variable of the household head, the high school level was significant in the extreme energy poverty category, with a negative coefficient that was significant at 1%. This indicates that the households that are headed by members with a high school level education have a lower likelihood of transitioning from the non-energy poverty category into the extreme energy poverty category as opposed to the households headed by members with no education. However, tertiary education is significant only in the moderate energy poverty category, with a positive coefficient that is significant at a 10% level. This implies that households headed by members with a tertiary-level education are more likely to transition from non-energy poverty to moderate energy poverty than households headed by members with no education.

In addition, for the settlement type variable, peri-urban and urban settlements are significant in almost all the three energy poverty categories, with negative coefficients that were mostly significant at a 1% level. This indicated that the households from peri-urban and urban

settlements are generally less likely to transition from non-energy poverty category into other energy poverty categories as compared to the households from the rural

settlements. Furthermore, the variables for middle and high income levels and remittances received were all significant in the moderate energy and extreme energy poverty categories with negative coefficients which were significant at 1%. This indicated that the households in the middle and high-income levels and the ones receiving remittances were less likely to transition from non-energy poverty into either moderate or extreme energy poverty as opposed to the households in the low-income levels or the ones that did not receive remittances.

In the winter season, first the number of housing units was significant only in the moderate and extreme energy poverty categories, with positive coefficients that were significant at a 1% level. This indicated that the households with more housing units were more likely to transition from non-energy poverty into moderate and extreme energy poverty. Secondly, for the educational level variable, tertiary education was significant in the transitional energy poverty category, with a positive coefficient at a 10% significance level. This implies that the households headed by members with tertiary education are more likely to transition from the non-energy poverty category into the transitional energy poverty category. Thirdly, for the variables on settlement type and income levels, peri-urban and urban settlements as well as middle and high income levels were significant in the moderate and extreme energy poverty categories with negative coefficients at a 1% level. This indicated that the households in periurban and urban areas or with middle and high income levels are less likely to transition from non-energy poverty into moderate or extreme energy poverty as opposed to the households in the rural areas or with low income levels. Nevertheless, the variables on middle income level and remittances received are significant in the transitional energy poverty category, with positive coefficients at 5% and 10% significance levels, respectively. This implies that the households in the middle-income level or receiving remittances are more likely to transition from non-energy poverty into the transitional energy poverty as opposed to those that are in the low-income levels or which do not receive remittances.

Table 5: Multinomial Logit Results

Independent variable	Summer			Winter		
	Transitional energy poverty	Moderate energy poverty	Extreme energy poverty	Transitional energy poverty	Moderate energy poverty	Extreme energy poverty
Age of household head (years)	-0.003 (0.008)	-0.012** (0.005)	-0.008 (0.005)	0.001 (0.004)	0.0005 (0.004)	0.006 (0.004)
Number of housing units (number)	0.07 (0.05)	0.031 (0.036)	0.052 (0.036)	0.32 (0.21)	0.747*** (0.198)	0.905*** (0.198)
Female (Base: Male)	-0.023 (0.222)	0.158* (1.747)	0.27 (0.165)	-0.145 (0.15)	0.056 (0.157)	0.046 (0.164)
Primary education (Base: None)	22.529 (65613.6)	0.799 (0.674)	-0.753 (0.673)	0.157 (0.204)	-0.041 (0.216)	-0.145 (0.226)
High school education (Base: None)	22.399 (65613.6)	-0.221 (0.807)	-1.83*** (0.686)	0.152 (0.234)	0.1916 (0.2426)	0.072 (0.253)
Tertiary education (Base: None)	22.616 (65613.6)	1.004* (-1.899)	-23.889 (22001.4)	1.138* (0.649)	1.417** (0.657)	0.868 (0.678)
Peri-urban settlement (Base: Rural settlement)	0.316 (0.375)	-0.746*** (0.256)	-2.024*** (0.261)	-0.284 (0.32)	-1.4177*** (0.299)	-2.097*** (0.301)
Urban settlement (Base: Rural Settlement)	-0.53* (0.3)	-1.967*** (0.193)	-3.46*** (0.197)	0.005 (0.259)	-1.696*** (0.24)	-2.996*** (0.248)
Middle income (Base: >Low income)	0.067 (0.265)	-0.951*** (0.167)	-1.846*** (0.173)	0.395** (0.189)	-0.697*** (0.182)	-1.51*** (0.191)
High income (Base: Low income)	-0.063 (0.35)	-2.139*** (0.34)	-3.372*** (0.419)	0.089 (0.212)	-2.609*** (0.281)	-3.703*** (0.371)
Remittances Received: Yes (Base: No)	0.041 (0.25)	-0.351** (0.175)	-0.714*** (0.177)	0.378* (0.196)	-0.102 (0.198)	-0.258 (0.202)

Source: own using Gretl software Multinomial Logit results

Notes: ***, **, and * represent 1%, 5%, and 10% statistical significance levels, respectively; standard errors are in parenthesis.

The comparison shows that both models exhibit unique patterns possibly influenced by seasonal variations. The winter data highlights stronger socioeconomic disparities, particularly with harsher impacts on vulnerable populations. The summer model indicates a different set of dynamics possibly due to less harsh living conditions or different energy usage patterns.

5.4 Discussions

The study's findings offer significant insights into the dynamics of energy poverty in Lesotho, with a focus on how these are influenced by seasonal variations, household demographics, and socioeconomic factors. Using the multinomial logit model to compare energy poverty across summer and winter seasons provides a valuable understanding of seasonal fluctuations in energy access usage.

The seasonal variations in energy poverty, as presented in Figure 6, reinforce the notion that energy needs fluctuate with changes in weather conditions, consistent with the findings of Viggers (2022). The increase in transitional and moderate energy poverty during winter can be attributed to the additional energy demand for heating, which places a greater strain on household resources. In contrast, the observed decrease in extreme energy poverty during the winter season, though initially counterintuitive, may point to seasonal adaptation strategies such as reduced energy consumption in some areas or the use of alternative, possibly informal, energy sources that are not captured in the summer data. This could also suggest that households in extreme energy poverty during summer manage to secure more stable energy sources in winter, despite heightened energy needs.

The multinomial logit results, as outlined in Table 5, emphasize the significant role of household income, settlement type, and education in determining energy poverty. Households with higher incomes are consistently less likely to transition into energy poverty, supporting Pachauri et al.(2004), who argued that economic capability is strongly correlated with energy access. The protective effect of income underscores the need for targeted policies that improve income-generating opportunities for the poorest households, particularly in rural areas where energy poverty is most severe.

In addition to income, the impact of remittance on reducing energy poverty is more pronounced in summer. This seasonality in remittance effectiveness may be linked to the lower energy demands during warmer months or the timing of remittance inflows, which are more beneficial

when households are under pressure to meet higher energy costs. The seasonal variance in remittance effects suggests that while remittances are helpful, they are not sufficient to mitigate energy poverty in periods of high demand, such as winter, reinforcing the need for more robust support systems during critical seasons (Chakraborty, 2023).

The geographical disparities revealed by the data highlight the importance of settlement type in energy poverty outcomes. Households in urban and peri-urban areas are significantly less likely to fall into energy poverty, particularly in extreme and moderate categories. This finding underscores the infrastructure and accessibility advantages in more densely populated areas, where energy networks are better developed. It suggests that rural households, where energy poverty remains most acute, would benefit greatly from rural electrification programs and investments in off-grid energy solutions that are tailored to their specific needs. This aligns with global findings on rural energy access gaps (Clancy & Skutsch, 2003).

Education, particularly at the tertiary level, emerges as a complex determinant of energy poverty. While higher education generally reduces the likelihood of energy poverty, the surprising result that tertiary education correlates with an increased likelihood of moderate energy poverty in winter suggests a potential disconnect between educational attainment and economic stability in certain households. This may reflect a scenario where underemployment or income instability prevents these households from fully benefiting from their educational qualifications (Checchi, 2006). The findings imply that education alone may not be sufficient to protect against energy poverty and that other factors, such as employment opportunities and income stability, need to be addressed alongside educational improvements.

The study also reveals gender disparities in energy poverty, with female-headed households more vulnerable to moderate energy poverty, particularly in summer. This is in line with prior research showing that female-headed households often face greater socio-economic challenges, which limit their access to energy resources (Clancy & Skutsch, 2003). These challenges could be tied to gendered access to income, social safety nets and property rights, which disproportionately disadvantage women. Policies aiming to reduce energy poverty must consider these gender dynamics, ensuring that female-headed households receive targeted support to access reliable energy.

The number of housing units owned by a household was another determinant, particularly in winter, where it correlated positively with energy poverty categories. This could reflect the dispersion of household resources across multiple units diluting the financial resources available for energy consumption in the primary dwelling. Alternatively, it could indicate an added financial burden, where multiple properties require heating or lighting, straining the household's energy budget (Smith, 2000). These findings suggest that policies designed to mitigate energy poverty should account for complex household dynamics and resource allocation across multiple dwellings.

Chapter 6: Conclusions and Policy Recommendations

6.1 Conclusions

Measuring energy poverty and analyzing its determinants is crucial for understanding the underlying factors contributing to the persistent energy insecurities many households in developing economies face, thereby informing the policy interventions to improve energy access and reduce energy poverty. Thus, this study measured energy poverty using data from the 2017 HECS and utilized a logit model to assess the determinants of energy poverty in Lesotho, focusing on the primary sources of energy for cooking and lighting. The results reveal a diverse energy portfolio in Lesotho, with LPG being the predominant cooking energy source and paraffin leading for lighting. The analysis highlights significant seasonal variations in energy poverty, with winter exacerbating the issue due to increased energy needs for heating.

The multinomial logit model identified several key determinants of energy poverty. Higher levels of household income and urban or peri-urban settlements were consistently associated with less likelihood of falling into energy poverty across almost all the categories. Education level also played a crucial role, with higher education correlating with a lower likelihood of falling into energy poverty, though some discrepancies such as the positive effect of tertiary education on moderate energy poverty during winter were observed.

Furthermore, gender disparities were evident, with female-headed households more likely to experience moderate energy poverty in the summer months. Household size was a significant factor too. It indicates the potential resource strain across larger households. The study highlights the multifaceted nature of energy poverty influenced by economic, geographical, educational and gender-related factors in Lesotho. These findings provide a deeper understanding of energy poverty dynamics, offering valuable insights for the targeted policy interventions.

6.2 Policy recommendations

With the Lesotho Energy Policy up for evaluation, as it nears the end of its 2015-2025 cycle, there is a timely opportunity to integrate the findings from the study into the policy discourse. The targeted financial and social support programmes should be implemented, as female-headed households are more likely to fall into moderate energy poverty in the summer season. Such support may include the subsidies for the energy costs and access to affordable energy-efficient appliances and financial literacy programmes aimed at managing the energy

expenses. Furthermore, empowering women to make informed choices about energy consumption and resource management may be achieved by collaborating with Non-Governmental Organizations (NGOs) and community organisations to disseminate information on energysaving techniques and affordable technologies.

In addition, assistance programmes that are specifically tailored for younger household heads should be designed and implemented. They should focus on maintaining or improving their current energy status through energy efficiency upgrades and providing the targeted financial literacy to ensure energy security. Furthermore, educational initiatives and awareness campaigns focused on energy management for households with varying levels of education should be undertaken. Programmes aimed at enhancing energy literacy may be integrated into community education efforts, especially targeting those with lower education attainment.

Moreover, energy infrastructure and access in rural areas could be strengthened. While households in urban and peri-urban regions are less likely to experience energy poverty, rural households remain vulnerable. The targeted investments in improving energy efficiency and expanding access to reliable energy sources in rural areas are crucial. The policies may include incentives for rural households to adopt renewable energy sources and to invest in energyefficient technologies, thereby reducing the energy poverty gap between the rural and more urbanized areas. Additionally, income-sensitive policies that provide additional support for low-income households should be developed and implemented. These policies may include the increasing winter flow allowance subsidies for energy-efficient home improvements and progressive energy tariffs that reduce the burden on lower-income households while promoting conservation. Finally, the relevant policies should leverage the positive impact of remittances on reducing energy poverty by facilitating easier and cheaper remittance flows to vulnerable households. Financial institutions and policymakers should work to reduce the cost of sending remittances and provide education on how to use these funds effectively to improve energy security.

To have a wholesome and encompassing understanding of energy poverty and guide effective policy-making in Lesotho, further research can be undertaken on the impact of climate change on energy poverty. This research may aim at how climate change impacts energy needs and poverty in Lesotho, especially considering the country's vulnerability to extreme weather conditions. This strategy may include exploring the effects of the changing rainfall patterns,

temperature extremes and their influence on energy consumption and access. Another possible research area on this issue may be renewable energy adoption and its impact on energy poverty.

Future studies on energy poverty in Lesotho could benefit from a broader exploration of the barriers to adoption, cost-effectiveness and long-term benefits of renewable energy in both rural and urban areas. These studies would be critical for identifying the most efficient and sustainable energy solutions for communities with differing levels of access to resources and infrastructure. It is recommended that for future research a comparative study that examines Lesotho's energy poverty situation in relation to similar countries in the region would be valuable. Countries with similar geographic, economic and socio-political conditions could provide important insights into strategies that have been successful in improving energy access. Future research should also focus on understanding the economic, technical and social barriers that prevent widespread adoption of renewable energy technologies in both rural and urban areas. This could include studies on the affordability of renewable energy solutions, infrastructure challenges and cultural factors that may impact acceptance and use of new technologies. Future research should also explore the gender dynamics of energy poverty, investigating how men and women in both rural and urban areas experience energy deprivation and the specific challenges they face. Understanding these dynamics would inform more inclusive energy policies and interventions that address the unique needs of both genders.

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