National University of Lesotho

Determinants of choice of household energy use in Lesotho

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Abstract

With the need to achieve Sustainable Development Goals, modern clean household energy choice forms the basis for heeding this call. In developing countries, most of the population lives in rural areas and is characterized by high dependence on polluting biomass for cooking and heating while they rely predominantly on paraffin and candles for lighting. Women and children in developing countries spend an appreciable amount of time collecting the biomass, hence unable to carry out other development activities. The use of modern technologies such as solar home systems for lighting could help pupils study at night with adequate light and with no adverse effects on their health. Nevertheless, the determinants of household energy choice have not been studied in many developing countries including Lesotho, despite the potential benefits of such a study. This study uses the data collected by Lesotho's Bureau of Statistics through a national household energy consumption survey of 2017, to develop a multinomial logistic regression to identify and analyze the determinants of the choice of household energy use. The results indicate that income, as predicted by the energy ladder model is statistically significant for the choice of clean energy fuels. But other socio-economic factors such as gender, education, household size, and settlement type also play an important role in the choice of clean energy choice. The role of gender in the choice of fuels used within a household is generally statistically insignificant. There is not a clear distinction of preference, on the choice of fuel, between male-headed households versus female-headed households. An increase in the

education level of the household head is statistically significant in choosing cleaner fuels. This suggests that public policies should have a strong focus on improving formal and informal education to increase awareness of clean energy fuels and their benefits. Household size is negative and statistically significant for the choice of clean fuels over traditional fuels. Large households have enough labour that is required for the collection of traditional fuels. In rural settlements, electricity is hardly used for either cooking or water heating, it is used only for lighting. This suggests that policies, for economic reasons, should not focus on extending the grid to the rural areas but to promote domestic systems and micro-grids that provide enough electricity for lighting and household entertainment.

Chapter 1: Introduction

1.1 Background

Understanding household choice is essential to formulating effective clean energy and climate change policies. It is reported that greenhouse gas (GHG) emissions from household energy consumption have a share of 72% of the total world's GHG emissions (Dubois *et al*., 2019). This is due to a large number of people, around 2.7 billion, that rely on biomass to meet some of their basic household energy needs (Rahut *et al*., 2016). With the Paris agreement aiming at curbing temperature increase to 1.5 °C above pre-industrial levels, closer attention to the household energy choice is required. Household energy consumption does not only degrade the environment but it also impacts the health of people within those households. The use of clean energy fuels has the potential to avoid unnecessary deaths that result from indoor pollution. Poor households are more susceptible to illness that results from indoor air pollution as cleaner energy fuels are usually associated with higher costs. It is therefore important that factors that influence household energy choice are explored to formulate sustainable development policies.

Fuel choice may sometimes be restricted to affordability and accessibility only. Although these may be the most obvious determinants of choice from the surface, deep underlying factors such as age, social norms, and education can influence the choice of energy within a household (Amoah, 2019a; Trac, 2011; Uhunamure et al., 2017a). For instance, old age comes with limited strength and as such, an individual may prefer less labour intensive energy sources. On the other hand, a fuel choice may be based on the preferred taste of food and how they were cooked. Those with higher education are more likely to be aware of the environmental impacts of fuels such as biomass and may be inclined towards the use of clean energy fuels. Issues of convenience and opportunity cost are also critical in energy choices. For example, some energy sources may be chosen based on the proximity of a fuel source relative to the household or because the time used for collecting wood can better be used for other productive uses. These result in a wide pattern of energy uses across different households or settlement types.

There are a lot of studies that examine patterns of fuel use and determinants of the choice of fuel in developing and emerging market economies such as China, India, Bhutan (Ekholm *et al.*, 2010; Rahut *et al.*, 2014; Sehjpal *et al.*, 2014; Hou *et al.*, 2017; Malakar, 2018; Acharya and Marhold, 2019; Zou and Luo, 2019) and sub-Saharan Africa (Pundo and Fraser, 2006; Hiemstra-van der Horst and Hovorka, 2008; Arthur *et al.*, 2010; Onoja and Idoko, 2012; Bamiro and Ogunjobi, 2015; Nlom and Karimov, 2015; Uhunamure *et al.*, 2017; Guta, 2018). Although there is a consensus that households do not switch to cleaner fuels due to an increase in income, there is ambiguity on other socioeconomic factors for the choice of energy to be used within a household. For instance, Rahut *et al.* (2014) report that in Bhutan, the gender of the household head is important in the choice of energy for cooking. They report that femaleheaded households prefer electricity over firewood. Further, they show that age and education are very critical and positively influence the choice of cleaner energy fuels relative to biomass. On the contrary, Bamiro and Ogunjobi (2015) report that in Ogun State, Nigeria gender, age, and education are not important in the choice of energy use within a household. Nlom and Karimov (2015) show that age is critical but negatively influences the choice of clean energy fuel in Northern Cameroon, but this the opposite of what Rahut *et al.* (2014) found. But both studies agree that education is positive and important in the choice of energy fuel within a household. The difference in the findings represents a gap in the literature relative to the country that is considered. Determinants seem to differ by country or region. To the best of the author's knowledge, this will be the first study in Lesotho that critically assesses the determinants of energy choice within households.

In Lesotho, the residential sector consumes around 80% of all the solid fuels in the country (Letete *et al.*, 2019). The use of these fuels has negative health implications as they cause indoor air pollution. Moreover, the excessive use of firewood negatively impacts the environment as it causes deforestation. The dependence on these types of fuels can sometimes be associated with ease of access and affordability (Rahut *et al.*, 2014; Nlom and Karimov, 2015; Hou *et al.*, 2017). The World Bank states that the poverty rate in Lesotho is around 49.7% and as high as 60.7% in the rural areas as of 2017 (World Bank, 2019). Moreover, the country has an electrification rate of around 41% (LEWA, 2018b), while the rural areas have an electrification access rate of around 5% in 2015 (Mpholo *et al*., 2018). These statistics show that the majority of people in the country are poor and there is a lack of access to electricity. The topography of the country makes the situation worse as the country is largely mountainous. Grid extension to cover the whole country is economically prohibitive while access to other clean energy resources like liquefied petroleum gas (LPG) is also a challenge in the rural areas because of the lack of access roads in these settlements. Therefore, biomass provides an affordable and easily accessible source of energy within a household.

1.2 Problem Statement

Through its energy policy (MEM, 2015), the Government of Lesotho (GoL) has put forth a framework for achieving sustainable energy for all within the country by the year 2025. The framework puts much emphasis on the adoption of clean and renewable energy sources. To achieve this, an investment plan was formulated (DoE, 2017). Within the investment plan, it has been identified that low electrification rates, dependence on imported fuels, and deforestation are core challenges in the energy sector, and hinder economic development. As part of strategic development, the energy sector is envisioned to play a critical role by developing electricity networks and expanding electricity access to households, among other things. Without a clear understanding of what factors are involved in the choice of a certain energy fuel over another within a household, the adoption of clean fuels may never be realized. For example, the national electrification rate has been increasing in the past two decades, but average household electricity consumption has declined by over 60% in the same period (Mpholo *et al.*, 2020). This shows that electricity access does not necessarily translate into electricity adoption within a household, instead, it is likely that increase in electrification rates may result in an increase in electricity tariffs in an effort to recover investment costs of extending the grid.

Understanding the determinants of the choice of energy use in households will, therefore, be crucial in formulating strategies that will help to implement the energy policy. The literature on the determinants of energy use within a household is ambiguous, showing that what applies in another country is not necessarily the case in a different country, irrespective of economic development. Therefore, policies can only be effective when the determinants of the choice of energy fuel for a specific country are known. Designing and implementing a one-size-fits-all policy can have limited success if certain important factors associated with energy choices are not considered. A critical assessment of determinants of energy choice within a household is therefore crucial.

1.3 Research questions and objectives

This study seeks to answer the following main research question: What are the determinants of the choice of household energy use in Lesotho?

This question is addressed by answering the following sub-questions in the context of household in rural, peri-urban and urban settlements, as well as Lesotho as a whole:

- What are the determinants of the choice of fuel for cooking?
- What are the determinants of the choice of fuel for water heating?
- What are the determinants of the choice of fuel for lighting?

The main objective of the research emanating from main the research question is as follows to assess the determinants of the choice of energy use in Lesotho. In order to effectively achieve this objective, it is being broken into specific objectives as follows:

- To assess the determinants of the choice of cooking fuel in households in rural, periurban, and urban settlements as well as Lesotho.
- To assess the determinants of the choice of water heating fuel in households within the study settlement types.
- To assess the determinants of the choice of lighting fuel in households within the study settlement types.

1.4 Justification

Although a lot of research has been done on the determinants of the choice of household energy use, such a study has never been done in Lesotho, at least to the best of the author's knowledge. Moreover, studies that have addressed this subject in Sub-Saharan Africa have concentrated on specific settlement types within a country, mostly rural, without comparison with other settlement types of the same country. This would give an overall view of the determinants of fuel choice within that country and how they vary with settlement type. It is important to divide a country into settlement types as access to resources and socio-economic characteristics normally differ with settlement types. Unlike those previous studies, this study assesses the determinants of the choice of household energy use by first considering the country as a whole, then disaggregating the determinants with settlement types as rural, urban and peri-urban. This will aid in energy policy design and implementation because it will be easier to tell whether a policy must target a certain settlement type or whether it should cover the whole country. The resulting policies and strategies will be better targeted and therefore more fruitful as they will be relevant to the different settlement types.

1.5 Organization of the study

The rest of the dissertation is organized as follows: Chapter 2: give the energy landscape in Lesotho while Chapter 3: gives the literature on the theories of energy fuel choice as well as empirical evidence on the theories. Chapter 4: describes the data used in this study and goes further to specify the model adopted in meeting the objectives of the study. Chapter 5: provides the results of the model and their discussions. The last chapter concludes the study, gives recommendations for policy implementation and suggests actions of further research.

Chapter 2: Energy context of Lesotho

2.1 Country background and policies

Lesotho is a country in Southern Africa, which is completely landlocked by its sole neighbour, South Africa. The country is sometimes referred to as the kingdom in the sky due to its lowest point of elevation being at 1400 m above sea level and the highest point is at 3482 m (LESMET, 2020). It is divided into four agro-ecological zones; mountains, foothills, lowlands, and Senqu valley. The climate is characterised by relatively warm summer temperatures that can go as high as 20 °C in the highlands and 32 °C in the lowlands. Winters have temperatures ranging from -6 °C to 5 °C in the lowlands and reaching as low as -10 °C in the highlands (LESMET, 2020). In terms of economy, Lesotho is classified as a lower-middle-income class country by the World Bank (World Bank, 2019). The poverty rate, as shown in Figure 1, is estimated at around 49.7%, with the rural population being the poorest at a poverty rate of 60.7% recorded in 2017. The country has been experiencing low growth in the economy due to substandard agriculture and lack of physical structure coupled with underdeveloped institutions (Ministry of Development Planning, 2012). The poverty rate has decreased from 56.6% in 2002 as a result of a transition from an economy highly dependent on subsistence agriculture and remittances to one that is based on manufacturing and services (MEM, 2017). With the rural population constituting around 44% as reported by Mpholo *et al.* (2018), the poverty rate is exacerbated by the fact that the rural population is in hard to reach scattered settlements with a population density of 72.3 inhabitants per square kilometre, making services delivery extremely economically prohibitive (MEM, 2017).

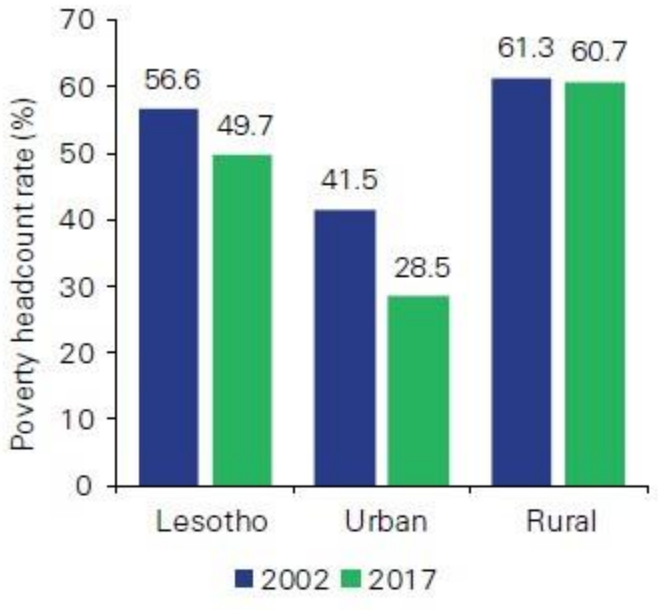


Figure 1: National poverty rate, 2002 - 2017 (World Bank, 2019)

Access to electrification is around 41% for the whole country (LEWA, 2018b), with urban electrification at 76% while the rural electrification was estimated at around 5% (M. Mpholo *et al*., 2018). Because of the mountainous terrain and sparsely populated settlements in the rural areas, grid extension is not economically attractive. Thus, achieving universal access would require off-grid technologies. But with the current off-grid electrification policy and an estimated annual population growth rate of 1.04%, universal access might be met after over 30 years (Fernandez, 2018). The current fiscal policy sets an annual budget of 150 million Maloti (M150 million) for national electrification. This is divided into 80% for grid electrification and 20% for off-grid electrification, therefore leaving only M30 million for off-grid electrification. The current effort is not going to achieve the set goals of the national energy policy of the country which runs from 2015 to 2025. The national energy policy stipulates: "Energy shall be universally accessible and affordable in a sustainable manner, with a minimal negative impact on the environment." (MEM, 2015). With five years remaining before its time comes to an end in 2025, it is hardly easy to see how universal access is to be achieved. In fact, the policy itself does not provide any specific timelines or projections for when anything will be achieved, which makes it harder for monitoring and evaluation. Moreover, every policy statement strategy ends with the words "Develop specific principles for the policy statement", indicating that strategies must be developed to reach the objectives of the policy.

Given that the country has no known reserves of fossil fuels, renewable energy would go a long way towards universal access. Technically, Lesotho has an enormous potential of renewable energy resources, with a solar potential estimated at 188 MW (DoE, 2017) for small-scale power plants to large scale. The solar resource is considered to be good with an average of 300 days of sunshine and insolation levels ranging between 5.25 – 5.53 kWh/m^2/year (MEMWA, 2013). The potential for wind power and hydropower is estimated at 2077 MW and 14000 MW, respectively, with average wind speeds between 3.7 – 4.7 m/s/year at a hub height of 10 m. Furthermore, the prices of these technologies have been declining over the past decade due to the improvement in the technologies and the renewable energy industry becoming more competitive (REN21, 2019). Prices of solar modules have fallen by around 87% and 92% while prices of wind turbines have fallen by approximately 44% to 78% (IRENA, 2020). The declining prices mean that renewable power generation is now competitive with conventional power generation such as power from coal. For a country that is mountainous and with scattered settlements, distributed generation in renewable energy would be ideal. To take advantage of the falling prices and limited electrification through distributed power generation, a robust renewable energy policy is required. But to date the only renewable energy policy document, in Lesotho, remains a draft since 2013 (MEMWA, 2013). The policy, if adopted and implemented would be a tool that could be used to work towards universal access and energy security.

In compliance with the United Nations Framework on Climate Change Convention (UNFCCC), Lesotho has compiled its nationally determined contributions (NDCs) towards the global efforts aimed at climate change mitigation and adaptation (LMS, 2017). LMS (2017) states that if the business-as-usual approach is followed, the greenhouse gas emissions from the energy sector will only rise and suggests that a different path that entails low-carbon energy technologies be followed. The efforts required include; energy efficiency measures, investment in renewable energy, and adoption of clean energy such as improved cook-stoves. However, the greatest drawback of the NDCs is that they depend on the implementation of the Lesotho Energy Policy 2015 – 2025 and the Draft Renewable Energy Policy 2013, among other policy documents. The energy policy does not provide how the policy objectives are to be implemented and monitored while some of the targets such as an increase in electricity generation have not been quantified. Moreover, the renewable energy policy document is still a draft and has not been adopted as a policy document that can be used to achieve any objectives. It, therefore, makes it hard to see how, if at all, the NDCs will be achieved.

As it stands, the energy security of the country is highly compromised because it relies on imported electricity from South Africa and Mozambique. This makes Lesotho susceptible to electricity prices that may increase or decrease without the country's consent. To hedge against fluctuating prices, the country will need to seriously invest in renewable energy to meet its demand. The country recorded a peak of 177.31 MW in 2018 while the national power resources have a capacity of around 74.7 MW (LEWA, 2019a). But the bulk producer of the power, 'Muela Hydropower Power Station, has a capacity of 72 MW but hardly operates at full capacity. Although this generation deficit seems like an opportunity for independent power producers, the fact that the renewable policy has not been implemented means that access to the grid is still a major challenge. The draft document of the renewable energy policy (MEMWA, 2013) specifies that electricity generators that are grid-connected and below a maximum rating of 500 kW for self-generation would be granted net-metering, where the customer would only pay for the net energy consumed and be paid for any surplus that has been fed into the grid. This incentive would scale up investment in self-generation systems are hence increase the share of renewable energy in the country's energy mix while also promoting energy security. Furthermore, electricity generators above 500 kW would be allowed access to the grid and offered a feed-in-tariff price scheme. This initiative would attract independent power producers (IPP) and consequently increase electricity generation. An increase in players in the electricity supply sector would generate competition, which would likely drive down electricity prices for consumers. But as was mentioned earlier, the policy has not been adopted and none of the discussed benefits can be realised without such a policy being adopted.

2.2 Household energy choices in Lesotho

Lesotho is a mountainous country with a population of around 2.1 million (BoS, 2019). The population is mostly concentrated in rural areas with rural population accounting for around 76% of the total (BoS, 2013). This population is sparsely scattered over 83% of the country (M. Mpholo *et al*., 2018). Because of the scattered settlements and the mountainous topography, extending the electrical grid network to these places is economically challenging. Therefore, around 90% of the population in these rural areas is reliant on biomass for cooking and heating. Other sources of energy for households in Lesotho include; electricity, liquefied petroleum gas (LPG), paraffin, and biogas. Of these energy sources, LPG has been reported to be prevalent in urban areas, accounting for 49.2% of penetration in cooking. Electricity is hardly used in the rural areas, and these areas are characterised by low access rates of around 5% as compared to the urban areas with electrification rates of 72% (M. Mpholo *et al.*, 2018).

Even for those connected to the grid, the average electricity consumption has been declining, showing that electricity has been sparingly used. This is illustrated in Figure 2. The number of customers being connected to the grid increases yearly by almost a factor of 10 between 2000 and 2017, with an average of 14000 customers per annum (LEWA, 2018b). But, despite these efforts in access to electricity, the average electricity consumption in the past two decades has decreased by around 60%. It can be inferred from the graph in Figure 2 that electricity has not completely replaced some of the energy needs within the household but has only diversified the energy mix. In fact, it has been reported by the Department of Energy (DoE, 2018) that electricity is used mostly for lighting as opposed to cooking or heating. The resulting overall consumption share of electricity in Lesotho does not exceed 5% including all other economic sectors (DoE, 2018). Paraffin is on the other hand mostly preferred for cooking, heating, and lighting.

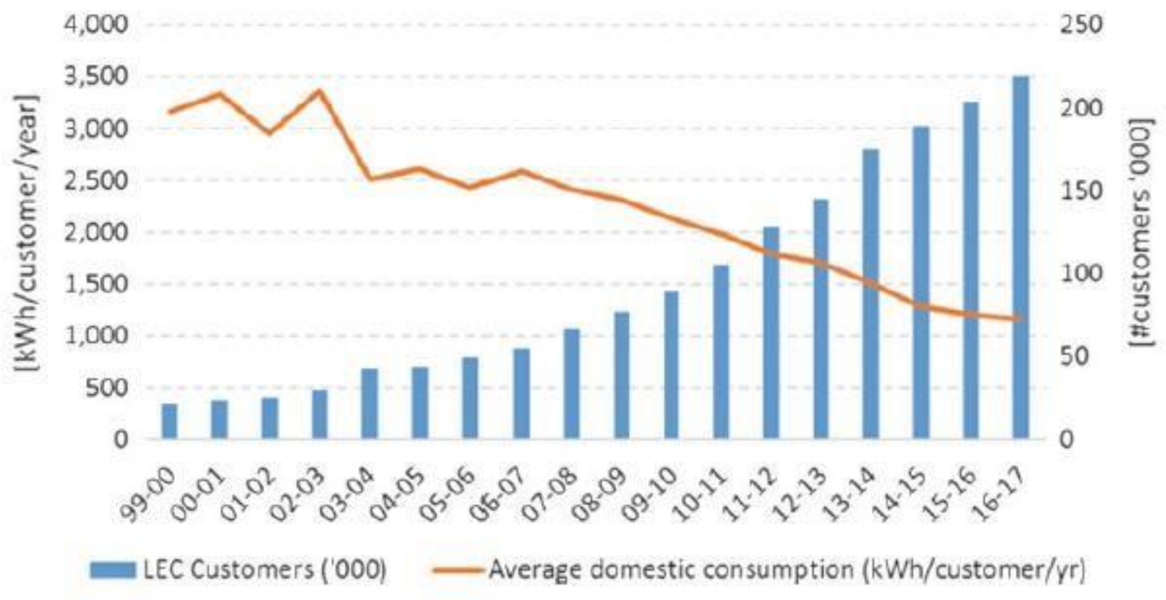
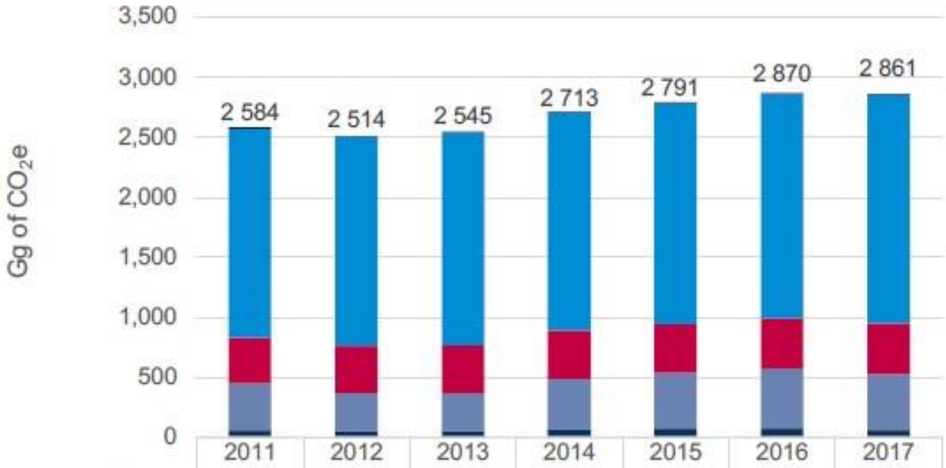


Figure 2: Customers connected to the grid and average electricity consumption. Adapted from (LEWA, 2018)

These sources of energy have adverse effects on household members, affecting women disproportionately as compared to men. Women are mainly responsible for the collection of wood. The continued collection of firewood has resulted in depleted forests and has therefore resulted in travelling a radius of around 4-6 km just to collect firewood (Taele *et al.*, 2007).

Because of the over-reliance on traditional sources of energy for cooking and heating, there been have concerns about their impact on the environment as well. Firstly, there is a concern on the continued deforestation due to the use of firewood, with increased fear that consumption has exceeded the supply, in the context of sustainable development (Letete *et al*., 2019). Furthermore, trees are being cut for the production of charcoal which is still used for cooking or space heating. Trees play an important role in climate change mitigation by absorbing the CO_2, which is responsible for the greenhouse effect. They also help to stop soil erosion as they have the ability to trap protective topsoil from being washed away by the heavy summer rains (Taele *et al*., 2007). Secondly, the use of animal dung and crop waste has negative impacts on agriculture. Animal dung and crop waster provide nutrients for the soil when they decompose and their use as energy sources deprives the soil of essential nutrients. This, in turn, exacerbates the problem of poverty. But most importantly, the use of biomass results in indoor pollution. In fact, according to a recent GHG inventory in the country, the residential sector has been found to be the most polluting sector in the country, with emissions from this sector contributing 65.3% in 2016 (Letete *et al*., 2019). The burning of traditional fuels, which are mainly solid fuels results in the emission of harmful air pollutants. These emissions are a result of incomplete combustion from open fires that are normally prevalent in a rural household. Combustion efficiency from open fires, for example, is in the order of 13-18% for fuelwood as reported by Malla and Timilsina (2014). The comparisons of GHG emissions per economic sector are shown in Figure 3. This should be a national concern considering that the residential sector is never listed under the National Accounts as providing anything towards economic development.



	2011	2012	2013	2014	2015	2016	2017
1A4c Agriculture, Forestry & fishing	9.85	8.94	9.04	11.62	12.46	12.95	9.99
1A4b Residential	1741.71	1741.85	1766.65	1806.58	1831.71	1866.01	1900.86
1A4a Commercial / Institutional	384.67	390.92	397.23	403.54	409.84	416.15	422.46
1A3b Road Transport	390.50	319.31	318.33	422.40	463.18	497.40	465.89
1A3a Civil Aviation	0.15	0.43	0.81	0.61	0.67	0.58	0.95
1A2 Manufacturing Industries and Construction	56.73	52.23	53.41	68.30	73.52	76.83	61.01

Figure 3: GHG emissions by sector 2011-2017 (Letete et al., 2019)

Chapter 3: Literature Review

3.1 Introduction

The total energy consumption in households of developing countries has a penetration of 15-25% of total primary energy consumption and the per capita energy consumption is nine times less than in developed countries (Bamiro and Ogunjobi, 2015). As a country develops and per capita income increases, the total consumption of energy within a household normally increases. Furthermore, the increase in income and consumption may also be expected to go along with the shift from traditional fuels such as biomass to clean modern sources of energy such as liquefied petroleum gas (LPG) and electricity. However, this may not always be the case as fuel choice sometimes depends on its availability, which may influence prices, and social and cultural norms depending on the intent for which the fuel is to be used (Sehjpal *et al.*, 2014). These factors are region-specific and therefore important in policy formulation.

The rest of this chapter is structured as follows: Section 3.2 gives the theory behind energy transitions in developing countries and it is followed by Section 3.3, which outlines common factors that influence household energy choice. Section 3.4 concludes the chapter with synthesis from the literature.

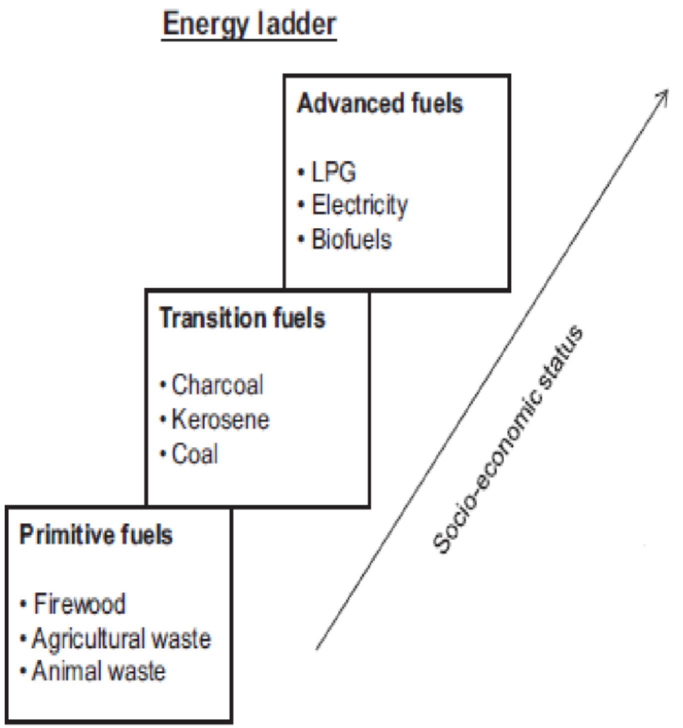
3.2 Household energy transitions in developing countries

3.2.1 Energy Ladder

The energy ladder model stipulates that an increase in income will see a transition from primitive sources of energy such as biomass to cleaner and more convenient modern sources of energy such as LPG and electricity (Nansaior *et al.*, 2011; Trac, 2011; van der Kroon *et al.*, 2013). The transition in fuel or energy source is expected to unfold as shown in Figure 4 and the choice of fuel use is expected to be as shown in Figure 5. At the bottom of the energy ladder lies the primitive and 'dirty' fuels, with fuels becoming more clean, efficient, and modern when moving up the ladder. The movement up the energy ladder is linear (Kowsari and Zerriffi, 2011; van der Kroon *et al.*, 2013; Nlom and Karimov, 2015). What this model assumes is that there will be a total transition from one fuel to another, abandoning the primitive fuel as the household moves up the energy ladder (van der Kroon *et al*., 2013).

The model is strongly based on the correlation between modern fuels and household income (Kowsari and Zerriffi, 2011; van der Kroon *et al*., 2013). At the base of the model lies almost free energy sources or those that may require very limited income such as fuelwood. These sources result in enormous indoor pollution and are associated with very poor households (van der Kroon *et al*., 2013). However, as household income increases, traditional fuels are abandoned completely and a switch to better fuels in the second level is reached. The fuels in the second level are called 'transitional fuels' (Nlom and Karimov, 2015), perhaps to signify that a household has transitioned from primitive fuels and is heading towards advanced fuels. As income increases further, households are able to afford costly appliances that use electricity and LPG.

The very assumption that forms the basis of the energy ladder model is also its weakness. It assumes that all fuels are available and that the only barrier for using clean, modern fuel is household income (Kowsari and Zerriffi, 2011). It is argued by Trac (2011), van der Kroon *et al.* (2013), and Masera *et al.* (2000) that it ignores other patterns and factors that may drive the choice of a certain fuel regardless of the economic status of the household. In a study in Bhutan, Rahut *et al.* (2014) assert that income is a very important driver for choosing a fuel for lighting but the influence of income on the choice of fuel for cooking and heating leaves matters open. In Caoxiu, China, it is has been reported that the area has had electricity access at least since 1980 yet some meals are still cooked using firewood (Trac, 2011). This is despite electricity being perceived to be cheap and reliable within the communities. This could be influenced by culture as quick meals such as noodles are cooked using electricity and slow-cooked meat is prepared using firewood. Similar cases were reported in Thailand (Nansaior *et al*., 2011) and Mexico (Masera *et al*., 2000). There does not seem to be a complete fuel substitution across the reported households, but instead households using multiple fuels for the same purpose depending on their preferences. This leads to the concept of fuel stacking.



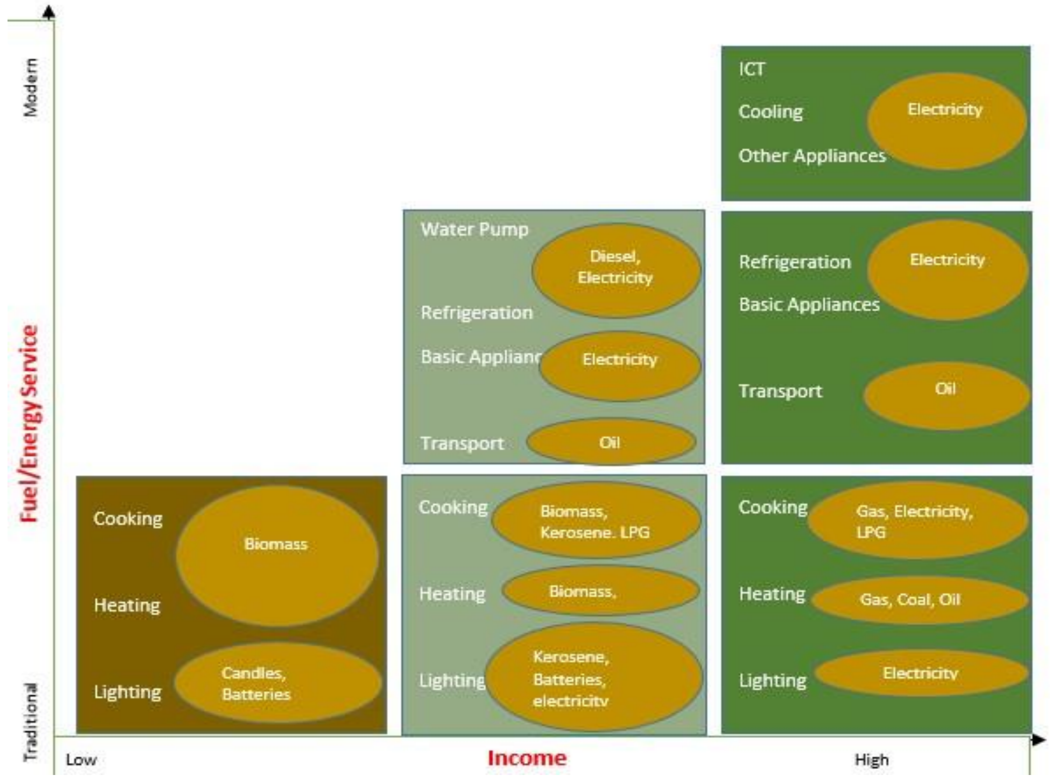


Figure 4: Fuel transition in an energy ladder model Figure 5: Fuel choice in an energy ladder model (adopted from Trac, 2011) (adopted from van der Kroon et al., 2013)

3.2.2 Fuel Stacking

From their study in rural Mexico, Masera *et al.* (2000) claim that the notion of fuel switching is in actual fact fuel stacking. They argue that the complete transition to modern cooking fuels has proved a daunting task due to economic, social, and cultural dynamics that are interlinked. In fuel stacking, increased household income results with the adoption of new fuels but these serve as partial as opposed to perfect substitutes of the traditional fuels (van der Kroon *et al*., 2013). An important point made in fuel stacking is that the transition to cleaner fuels is not a one-way street but one that allows households to go back and forth between fuels when such a need arises. In essence, the increase in income only increases the available fuel options for the household (Kowsari and Zerriffi, 2011; Masera *et al*., 2000). This is better illustrated graphically as shown in Figure 6. In fact, there are cases such as Maun in Botswana (Hiemstra-van der Horst and Hovorka, 2008) and Caoxiu, China (Trac, 2011) where even the lower-income classes have access to cleaner fuels but still use them both even though Figure 6 does not depict this. But this is really without assuming that the energy pattern use across the different income classes is identical.

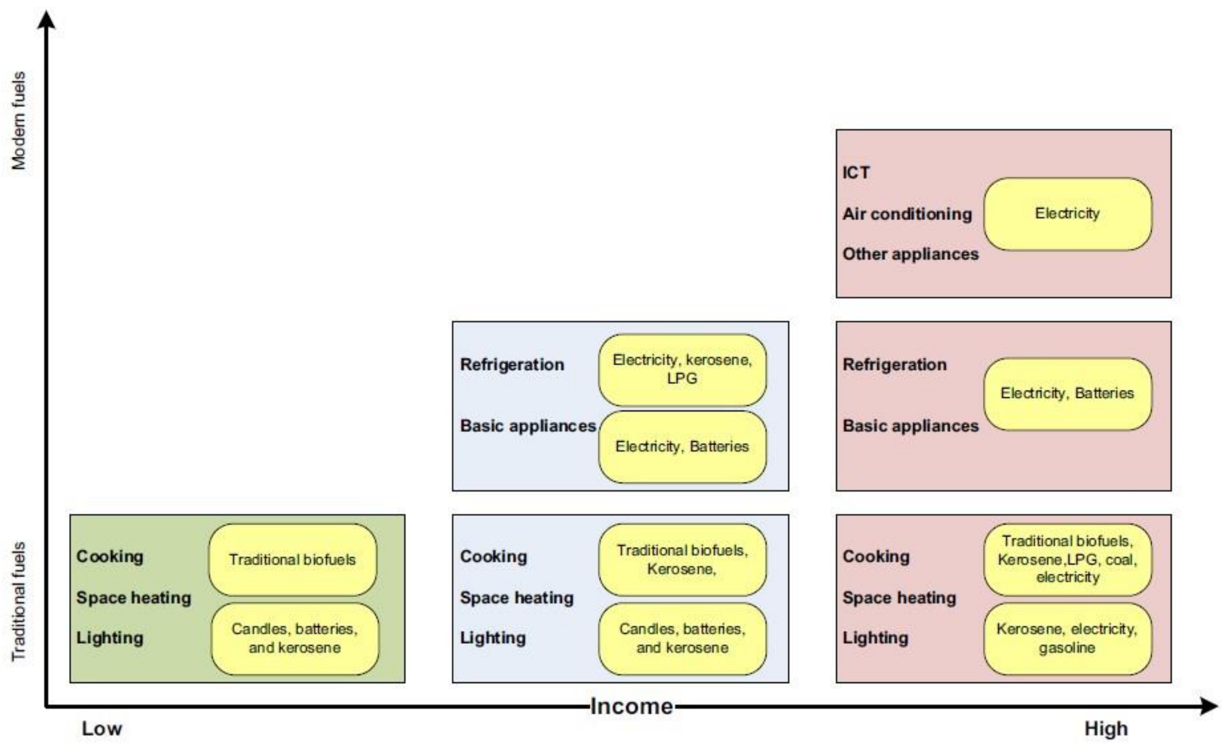


Figure 6: Fuel stacking (adopted from Kowsari and Zerriffi, 2011)

3.3 Factors determining household energy choice

The energy transition according to the energy ladder model discussed earlier is solely based on household income. But as it has been shown, not all situations show a direct correlation between energy transitions and household income, instead, some households tend to stack fuels as income increases. The factors that drive households to consume a certain fuel are very diverse, ranging from endogenous (Ekholm *et al.*, 2010; Couture, Garcia and Reynaud, 2012; Rahut *et al.*, 2014; Sehjpal *et al.*, 2014; Bamiro and Ogunjobi, 2015; Nlom and Karimov, 2015) to exogenous (Hiemstra-van der Horst and Hovorka, 2008; Jingchao and Kotani, 2012; Kowsari and Zerriffi, 2011; Özcan *et al*., 2013). Endogenous factors are those that are dependent on the household itself, that is, those that describe the characteristics of the household, while exogenous factors are those that are external and are not related in any way to the household.

3.3.1 Endogenous factors

Moving away from income as the sole driver, social and cultural factors play very important roles in determining the choice of energy. Gender of the household head, for instance, has been found to be very important. In a study by Rahut *et al*. (2014) in Bhutan, employing multinomial logit to analyse determinants of energy source for lighting, heating and cooking, it was found that households with females as the heads were more likely to adopt cleaner fuels. This is probably because most cooking is done by females in most countries and a female is more likely to move towards fuels that are not very labour intensive (Behera et al., 2015a). There is also an element of the opportunity cost of collecting traditional fuels. It is likely that modern energy fuels may be more appealing to a female household head so that more time can be spent on other activities that may be income generating or simply having more time for the family. In Northern Cameroon, Nlom and Karimov (2015) analyse the determinants of fuel choice using ordered probit and logit models, with the models yielding similar results. The types of fuels considered are firewood, kerosene and LPG and are ordered based on comfort, ease of use and efficiency from 1, 2 and 3, respectively. The results of the study show that the level of education of the household head was the most important factor above everything else in influencing the choice of fuel. It is generally perceived that people with higher education levels are more aware of the health-related issues of using unclean energy sources. Sehjpal *et al*. (2014) employ a binary logit model that assumes that a household in rural India chooses between traditional and modern cooking energy fuel. They assert that since higher education levels usually result in more formal forms of employment, the time spent on collecting fuelwood may be reduced and hence influence the choice of fuel; affirming that education is indeed significant. Furthermore, education has been found to be effective not only when it is held by the head of the household but also by other family members. The evidence is given by a case in India, where the increased adoption of compact fluorescent light (CFL) bulbs was attributed to what the children had been taught in school (Sehjpal *et al.*, 2014).

The collection of traditional fuels can be time-consuming and varies with the available amount. This would put a burden on a household of old people due to physical constraints. Therefore age is an important determinant of fuel choice within a household (Pundo and Fraser, 2006). Pundo and Frase (2006) reached this conclusion by employing a multinomial logit model to analyse the determinants of household cooking fuel choice in Kisumu, Kenya. Behera *et al*. (2015) employ a multivariate probit model to show that in South Asia (Nepal, India, and Bangladesh) senior household heads prefer the use of fuelwood only if it is collected within the yard, confirming the physical constraints. But it is worth noting that Nlom and Karimov (2015) argue that the older the senior household head, the less likely a transition from biomass will occur. The reason being that old people are resistant to change. However, since the distance travelled when collecting wood was not mentioned, it is debatable that given the physical constraints associated with old age, one would still lean towards biomass than modern fuels. Behera *et al*. (2015) find that households with many children are more likely to stick with biomass as children seem to provide adequate labour for collection of biomass, but on the contrary, Rahut *et al*. (2014) reports that a household with many children under 15 years are more likely to adopt electricity and LPG, most probably because of the perception that they are still young to participate in biomass collection. An important observation from these differences in findings is that the choice of fuel is location-specific as these determinants are found in different countries on different continents.

There are other factors that are influenced by cultural norms and some just convenience. For instance, in Caoxiu, China, almost every household uses an electric rice cooker for cooking rice, and yet the same household prefers to cook meat using firewood (Trac, 2011). This could probably be because of taste and how the meat is perceived to taste when cooked using firewood. Similarly, in Jaracuaro, Mexico, it is reported that tortillas are perceived to taste better when cooked on a clay comal atop open fire as compared to cooking them over an LPG flame (Masera *et al*., 2000).

Moreover, the LPG stove does not provide a large enough surface area to cook many tortillas at once relative to the traditional clay comal. The latter point shows that the issue of convenience and time plays a very important role in the selection of the fuel. The endogenous factors that influence the choice of a fuel described in this section do not provide an exhaustive list of all possible factors, as some are unique to a household and others are unique to a region.

3.3.2 Exogenous factors

The choice of a certain fuel may not be influenced by the household at all. Macroeconomic factors and national policies may play an important role, for example. The choice of government to subsidize or put a tax on a certain fuel may have an impact on the household decision of using that fuel (Hou *et al.*, 2017). In India, Heltberg (2004) reports that households were reluctant to choose LPG over kerosene because there was a subsidy for kerosene for households without access to electricity. This subsidy was from the public distribution systems (PDS), and it was lost once LPG was used within a household. LPG is cleaner than kerosene, but the government of India had made kerosene more attractive than LPG hence the choice of fuel was almost towards kerosene because of that fiscal policy. But on a more general note, both LPG and kerosene, whether subsidized or not are susceptible to market price fluctuations of crude oil. In Sri Lanka, the national energy policy states that the basic energy needs will be met at the lowest possible cost to the economy (Wickramasinghe, 2011). This means that the poor are likely to suffer more from price hikes as the policy does not offer any form of shielding. In pursuit of energy security, households in Sri Lanka have therefore shown to prefer firewood instead of petroleum fuels. To add on this, Bamiro and Ogunjobi (2015) use a multinomial logit to analyse determinants of fuel choice in Ogun State, Nigeria and they found that increase in paraffin prices makes it less likely for households to adopt paraffin as their main fuel over other solid fuels. By employing the same multinomial logit approach, Sehjpal *et al.* (2014) confirms that prices of LPG and paraffin influence a decision by a household to choose a fuel as most households have a budget constrained. Over and above the fuel prices, Ekholm *et al.* (2010), in a study in India, develop a MESSAGE-Access model to argue that paraffin and LPG stoves have higher investment costs which may be prohibitive for low income households.

Household energy choice depends on demand and supply, as is the case with any commodity. The reliability of supply can have serious implications on energy security. Households will tend to rely or choose the most easily available source of fuel to meet the basic energy needs. This is affirmed by a study in Pakistan, through descriptive statistics, where respondents showed that the limited use of gas was attributed to limited supply despite the preference of gas over biomass (Jan et al., 2012a). Hou *et al.* (2017), using linear regression, highlight that fuel accessibility is a crucial factor in choosing a certain fuel in China, particularly in the rural areas. Fuel accessibility is characterised by distance to market and transportation infrastructure. Rahut *et al.* (2014), Amoah (2019), Hou *et al.* (2017) and Behera *et al.* (2015) all show that households that are located closer to the market are more likely to choose clean fuels relative to households that are located far away from the market. Energy choice may also be dependent on how easier it is to get to the market. Most developing countries are characterized by underdeveloped road infrastructure (Schlag and Zuzarte, 2008). This makes it harder to reach the markets for supply of clean energy fuels. In fact, Jingchao and Kotani (2012), through the use of tobit model in rural Beijing, show that geographical locations play an important role in energy choice. They show that rural areas can be hard to reach because of underdeveloped road infrastructure, hence limiting access to modern fuels but at the same time, the rural areas provide ample biomass. The challenges highlighted above influence a household's energy fuel choice, influencing household that have biomass in abundance less likely to choose clean energy fuels (Wijayatunga and Attalage, 2003).

The geographical location makes some place not only hard to reach by road, especially the rural areas, but also hard to reach by electricity grid. Households in urban areas are more likely to have access to electricity and therefore are more likely to move up the energy ladder (Sehjpal *et al*., 2014). Rahut *et al.* (2014), through multinomial logit, show that household with access to electricity are more likely to choose electricity for cooking than households without access to electricity. These studies show that access to electricity plays a vital role in the choice of household energy fuel. However, it is important to note that an electricity network may be within reach to a household yet the household may not be connected to the grid. Connection to the grid requires a substantial investment in terms of connection fees and the appliances to be used. Institutional barriers such as lack of access to credit, especial for low income households, mean that some households may be willing to choose electricity as the primary energy fuel yet be constrained financially (Guta, 2018).

3.4 Synthesis from literature

The reviewed literature provides empirical evidence of fuel stacking theory as the prevailing theory associated with household energy choice. The literature shows that as much as the income of households plays a critical role in the household energy choice as predicted by the energy ladder model, other socio-economic and demographic factors play a very important role too. Thus the energy ladder model as the basis for fuel transition has greatly been criticized. But an important observation from the literature is that there is ambiguity in the results obtained. The determinants of household energy choice do not have similar impacts for different countries or regions. Even for countries with relatively the same economic development, some of the determinants of household energy choice are found to be statistically significant in other countries while the same determinants are not significant in some countries. This means that any country that has not been analysed in this context could have new contributions to this field of research. Thus, this has been identified as the gap that analysing the determinants of household energy choice in Lesotho could help to fill. In terms of methodological approach, the most common approaches that have been identified are logit and probit models. These models yield similar results as some of the studies have gone on to compare the results from each model and the choice of one over the other is based on preference not necessarily superiority.

Chapter 4: Data description and model specification

4.1 Introduction

This chapter provides the methodology that was followed in this research. The first part of the chapter provides a synopsis of data collection procedures and uses descriptive statistics to summarize what the whole data entails. In the second part, a linear econometric model that describes fuel choice as a binary response regression model is presented. The output of this model is estimated using the logit regression in the third section of this chapter.

This chapter is structured as follows: Section 4.2 describes the data used in the study and Section 4.3 provides the model specification and how the model was tested for adequacy.

4.2 Data description

The data used in this study comes from the Household Energy Consumption Survey 2017 (HECS) conducted by the Lesotho Bureau of Statistics. The data available for this study were collected in the summer months, October to December. Even though the data was collected in the summer months, the findings from the study will apply for all seasons as only the primary energy choice is considered, alternatives are not considered for a household, which could otherwise depend on seasons. Furthermore, the study does not consider the quantity of each fuel used, which would likely differ with seasons. The primary purpose of the survey was to provide very specific information pertaining to the patterns of energy use within households in Lesotho. This was a national survey, covering all ten districts of Lesotho. A two-stage stratified sampling technique was used. The first strata were selected using agro-ecological zones: lowlands, foothills, mountains, and Senqu River Valley. The second strata were selected based on settlements: urban, peri-urban, and rural. By using the enumeration area (EA) of the Population and Housing Census 2016 as primary sample units (PSU), a total of fifteen households were randomly sampled in each EA. A total number of 2877 household with a response rate of 93% was covered. This sample size compares very well with other studies such as one in Cameroon reported by Nlom and Karimov (2015), with a sample size of 2,860 households for a population that is around 10 times that of Lesotho (BoS, 2019; Cameroon Data Portal, 2019).

All the respondents in the survey were heads of households. The Bureau of Statistics in Lesotho defines household head as any member of the household who is regarded by other members of the household as such due to his/her role within the household or because he/she is a chief breadwinner and such a person is held responsible for maintenance of the household (BoS, 2011). According to Table 1, the average age of the household head was 50 years, while the gender distribution was 38% females and 62% males. The most prevalent education level was primary education with a share of 53% while those with no education at all accounted for 14%. The respondents with high school and tertiary education accounted for 24% and 9%, respectively. The average household size was recorded as 4 persons per household. It was found that 57% of the respondents fell under the low-income class category (between M0 – M999 per month), 34% made the middle-income class (M1000 – M4999) and the rest was high-income class (M5000 and above). Some respondents, 30%, indicated that they received remittances, irrespective of whether they earned income or not. Using a similar classification as in the income classes, 87% fell in the low category while 12% and 1% made the middle and high category classes, respectively. Most of the respondents were from rural areas, accounting for 53% while peri-urban and urban accounted for 9% and 37%, respectively. The penetration of electricity was found to be only 37%.

Table 1: Summary of statistics for demographic variables

Variables	**Mean or %Share**
Gender of household head	
Female	38%
Male	62%
Age of household head	50
Education level of household head	
None	14%
Primary	53%
High School	24%
Tertiary	9%
Household size	4
Household income class	

Low	57%
Middle	34%
High	9%
Households receiving remittances	30%
Availability of electricity	37%
Settlement type	
Rural	53%
Urban	37%
Peri-Urban	9%

The choice of cooking fuels is predominantly traditional fuels, with an overall share of 50.3% as is shown in Figure 7. These types of fuels are mostly used in rural areas, as compared to other settlement types. The penetration of traditional fuels for cooking in rural areas is in excess of 80% while that of electricity is as low as 1.3%. As was noted earlier, these can lead to deforestation and unwanted indoor pollution. Choice of traditional fuels decreases with increasing urbanization as it is observed from Figure 7. The share of traditional fuels is as low as 7% in urban areas. Cleaner fuels such as electricity and LPG are mostly preferred in the urban areas, with LPG constituting 56.6% of the cooking fuels used in the urban areas, with the second most prevalent cooking fuel being electricity at 23.6% penetration. The urban areas also represent a higher penetration of paraffin relative to other settlement types at 12%. The peri-urban areas lie between the urban areas and rural areas in terms of the choice of each fuel for cooking. They consume around 44.1%, 6.5%, and 38.5% of traditional fuels, electricity, and LPG, respectively for cooking. Biogas is hardly used in Lesotho, with an overall penetration of 0.2%. Other sources of cooking fuels, such as torn clothes and plastics, constitute around 1.3% of the overall cooking fuel consumption.

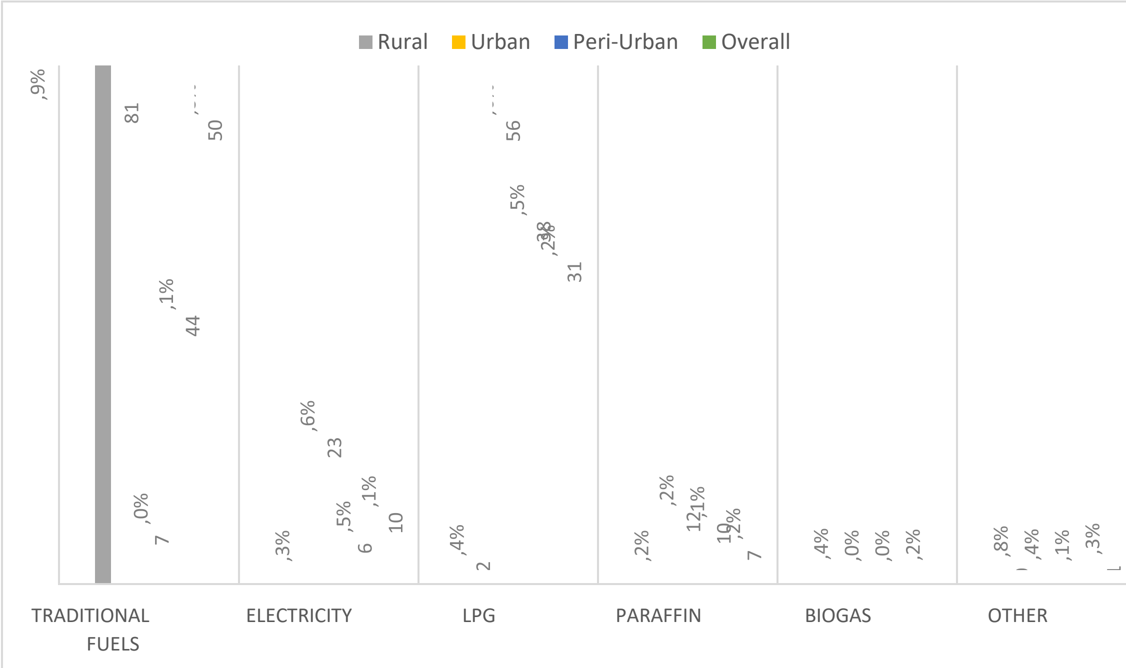


Figure 7: Distribution of cooking fuels in Lesotho

Different energy mixes for the purpose of water heating are observed in different settlement types. The different energy mixes by region are shown in Figure 8. The most widely preferred water heating fuel in Lesotho is traditional fuels, with an overall share of 51.0%. It is followed by electricity with a share of 23.0%, LPG with a share of 15%, and finally paraffin at 11.0%. The use of traditional fuels in predominantly prevalent in rural areas, where they make up a massive 81.0% share of the total water heating fuel mix. The least fuel used for water heating in the rural settlements is electricity, making just 4% of the energy mix. Electricity is mostly preferred in the urban areas, making up 49.1% of the water heating fuel mix in urban settlements. It is followed by the use of LPG at 27.7% and then paraffin at 15.0%. The use of traditional fuels for water heating in urban settlements is restricted to just under 7.0%. The urban areas produce a pattern of energy choice for water heating that would be preferable for sustainability and environmental impact. The most efficient fuel is the one with the greatest share in the energy mix and the least efficient has the least share of the energy mix. The peri-urban settlements rely very much on traditional fuel, making up a total share of 62.0%, followed by electricity at 22.0% and then paraffin at 15.0%.

Biogas and coal have a net share of zero per cent in all settlement types for purposes of water heating.

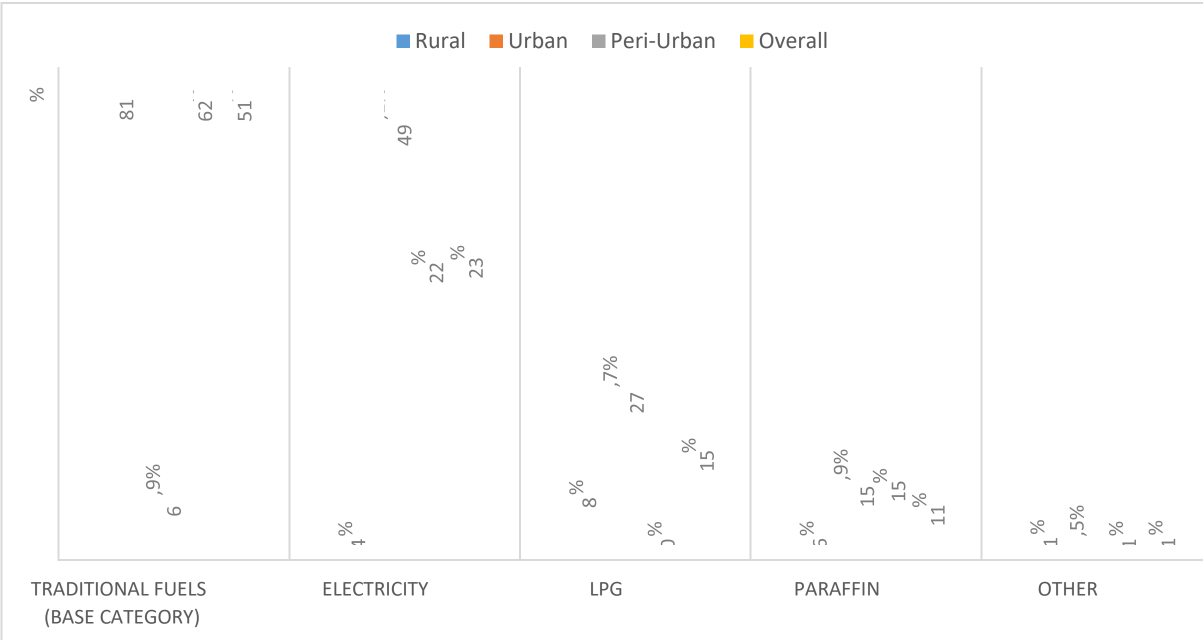


Figure 8: Distribution of water heating fuels in Lesotho

The fuel mix for lighting varies greatly by settlement type as shown in Figure 9. In the urban areas, the most widely used source of fuel for lighting is electricity, with a penetration of 68.5% in the settlement type. The use of electricity is followed by paraffin at around 27.0%. Candles, rechargeable battery lamps, and solar products (Solar PV electricity and solar lanterns) constitute around only 5%. On the other hand, the rural settlements are highly reliant on paraffin for lighting, with the share of paraffin making 68.4% of the energy mix for lighting. Candles make up around 12.8% of the energy mix. Electricity constitutes only 13.9%, while solar products combined with rechargeable battery lamps make roughly 5% of the energy mix. In the peri-urban areas, the share of electricity is almost equal to that of paraffin with each fuel contributing 46.7% and 43.6%, respectively. Candles and solar products make up the rest. Overall, the most preferred or the most widely used source of fuel in Lesotho is paraffin, with a net share of 51.0%, followed by electricity at 38.8%. Solar products only make up around 2.2% of the fuel mix.

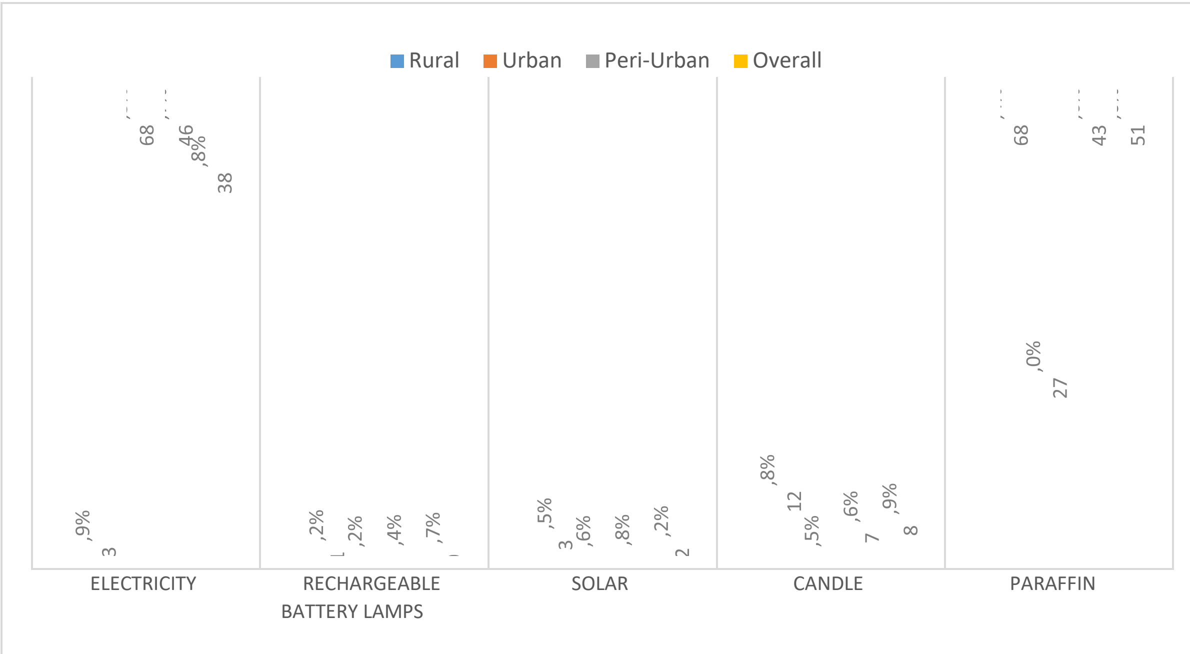


Figure 9: Distribution of lighting fuels in Lesotho

4.3 Model Specification

Subsequent to the models used in the literature, a multinomial logit model has been chosen to analyse household fuel choice in Lesotho. Although some authors like Nlom and Karimov (2015) use both logit and probit models, they yield similar results, and the choice as to which one to use over the two is arbitrary (Brooks, 2008). Since the dependent variable, household fuel choice, is categorical, and it is not ordered in any logical, a multinomial logit model has been adopted. Furthermore, the adoption is based on the fact that some independent variables are continuous, dichotomous or categorical. Employing a multinomial logit offers the flexibility of estimating all logits simultaneously without requiring the independent variables to be statistically independent, while also ensuring independence of irrelevant alternatives, that is, the choice of one alternative over the second alternative is unaffected by the presence or absence of the third alternative that is not chosen (Rahut *et al.*, 2014). Although property of independence of irrelevant alternatives may be regarded as a limitation of the multinomial model, it is important in this study because it is assumed that there are no perfect substitutes between fuels that can be chosen within a household.

To specify this model, a linear probability model (LPM) with a dichotomous response variable is first considered. This model is expressed mathematically as shown in Equation (1),

$$Y = \beta_0 + \beta_1 X \tag{1}$$

where *Y* is the probability response that can either be 1 or 0, depending on whether the event occurs or not. *X* is the independent variable and β_0 and β_1 would be the intercept and slope, respectively, of the linear regression curve. The LPM gives the conditional probability that $Y = 1$, that is the event occurs, given the value of *X* or $Pr(Y=1 \mid X)$ (Gujarati, 2004).

As was explained earlier, the greatest flaw of the energy ladder theory is the assumption that fuel choice depends on income and there are hardly any other factors or biases in the decision-making process. The fuel stacking theory builds upon the energy ladder theory by allowing for other factors to partake in the decision-making process and allowing biases. From this, therefore, the mathematical specification can be described as in Equation (2),

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n + u \tag{2}$$

In this form, the dependent variable depends on a given number of regressors and another parameter *u*. This parameter is referred to as the error term or random variable. Its inclusion is important because the fuel stacking theory acknowledges that there are just too many factors that influence the choice of fuel and these may not all be captured in the data or may be a result of intrinsic behaviour. However, if the right-hand side of Equation (2) approaches infinity or negative infinity, the probability can have a value that is either greater than 1 or less than 0, respectively (Gujarati and Porter, 2009). This violates the basic rules of probability. To ensure that the probability is maintained within the boundaries of 0 and 1, an activation function is used to transform the LPM. This is done by adding an exponential function as shown in Equation (3),

$$P = \frac{\exp\left(\beta_0 + \beta_1 X_1 + \beta_3 X_2 + \cdots + \beta_n X_n + u\right)}{\left(\beta_0 + \beta_1 X_1 + \beta_3 X_2 + \cdots + \beta_n X_n + u\right) + 1} \exp \tag{3}$$

Equation (3) can be re-written as shown in Equation (4),

$$\text{Ln}\left(\frac{P}{1-P}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n + u \qquad (4)$$

Equation (4) is known as a logit model. Since *P* is the probability of the dependent variable being 1, it follows that *(1-P)* will be the probability that the dependent variable is 0. This, therefore, implies that the ratio *P/(1-P)* gives the *odds* of the dependent variable being 1. Thus the left-hand side of the equation gives the log of odds, commonly referred to as the logit (Gujarati and Porter, 2009). An important feature of Equation (4) is that although *P* is non-linear in *X*, the logit is linear in *X*. This is in contrast to the LPM where the *P* increases linearly with *X*. Furthermore, even though *P* is bounded between 0 and 1, as it changes from 0 to 1 the logit is not necessarily bounded and goes from -∞ to ∞. A positive logit implies that when the regressors increase, the odds that the dependent variable equals 1 increase, while a negative logit simply implies that an increase in the value of regressors decreases the odds of the dependent variable being 1.

Equation (4) represents a logit regression for a dichotomous response variable. In a practical situation, a household would have to make a choice among many fuel alternatives for a particular use such as cooking. In this case, the response variable becomes a multichotomous variable, that is it has discrete categories that are more than two. The log odds have to change to represent the probability of choosing fuel *m* over fuel *n* where there are multiple choices. Therefore, Equation (4) can be re-written as in Equation (5),

$$\text{Ln}\left(\frac{\Pr(Y=m)}{\Pr(Y=n)}\right) = \sum_{r=0}^{R} (\beta_{mr} - \beta_{nr}) X_r \qquad (5)$$

In this form, the right-hand side of Equation (5) or the log odds of choosing fuel *m* over the choice of fuel *n* are independent of other choices. This property is called the independence of irrelevant alternatives. It means that the probability of choosing fuel *m* over fuel *n* is unaffected by the presence or absence of another fuel *k*.

The multinomial logit model specified in Equation (5) is estimated in R software. For the first part of the model, the base category is chosen as traditional fuels. The likelihood of a transition from traditional fuels to modern fuels for cooking purposes given certain independent variables is explored. Furthermore, traditional fuels are at the base of the energy ladder and it is informative to explore what variables constitute moving up the energy ladder. The independent variables: gender of household head, education level of household head, household income, household receiving remittances, availability of electricity, and settlement type are all categorical. Age and household size are continuous variables as is shown in Table 1.

The regression analysis was done in three stages corresponding to cooking, water heating, and lighting. In the first part, the determinants of choosing traditional fuels over other fuels are analysed. In the second part of the analysis, the determinants of choosing traditional fuels over modern fuels for water heating are explored. Lastly, the likelihood of transitioning from paraffin to other sources of lighting is explored.

For the model adequacy test, McFadden R^2 or pseudo R^2 is employed. It is defined as shown in Equation (6) (Brooks, 2008).

$$pseudo\ R = 1 - \frac{LFF}{LFF_{02}} \qquad (6)$$

where *LFF* gives the maximized log-likelihood value resulting from the fitted multinomial logit model and LLF_0 gives the value of the null model, that is, where all the coefficients are zero except the intercept β_0. The value of *pseudo* R^2 ranges between 0 and 1, with 0 representing the worst fit and 1 representing a perfect fit. However, unlike the conventional R^2, values of *pseudo* R^2 between 0.2 and 0.4 still represent a very good fit for models applying cross-sectional data (Lee, 2013). In addition to the McFadden R^2, the chi-square statistic was used to evaluate whether there was any association between the dependent and independent variables. The null hypothesis of the chisquare test assumes that there is no association between the choice of a certain fuel and the factors that are thought to influence the decision. In essence, the null hypothesis assumes that the coefficients, β, of the model in Equation (5) are zeros. The alternative hypothesis is that the choice of fuel will change depending on the given factors.

Chapter 5: Results and discussions

5.1 Introduction

This chapter presents the results of the multinomial logit model described above for choosing a fuel for cooking, water heating, and lighting. The model is first computed using aggregated data for the whole country and then performed to a dataset disaggregated by settlement type, that is, rural, peri-urban, and urban. This is done for all three uses of energy within a household. This is because the three settlement types of the country are very different in terms of civilization and access to resources. Accessibility constitutes one of the most crucial factors in the choice of fuel, and urban settlements are likely to benefit from access to modern fuels relative to rural settlement (Hou *et al.*, 2017).

Due to the limited usage of biogas across the country for cooking, the variable was found to be statistically insignificant and hence it was dropped from the model. By dropping the biogas fuel, the model was also tested if it observes the property of the independence of irrelevant alternatives. Since the results for the choice of other fuels (cloths, aloe) were the same irrespective of whether biogas was included or not, the model was found to observe the property. The base category for the choice of fuel was chosen as traditional fuels for cooking and water heating, while the base categories of income class and settlement types were chosen as a lower-income class and rural settlement, respectively, for all models. The choice of other fuels has been reported for the whole country and rural settlements because none of the variables was statistically significant for the choice of other fuels in the peri-urban and urban settlements. The base category of fuels for lighting was chosen as paraffin. Rechargeable battery lamps have been reported for the whole country because at least one variable was statistically significant for their choice. Also, solar products have been reported for the whole country and rural settlements for the same reasons.

This chapter begins by providing the results of the model adequacy tests. This section is followed by the ones that discuss the determinants of choice energy for cooking, water heating and lighting within all settlement types.

5.2 Model adequacy

The model adequacy test results are shown in Table 2. A multinomial model has been fitted based what a fuel is used for and settlement type. The first model estimates the choice of cooking fuel in the whole of Lesotho. The model fits the data well

The models represent a good fit as none of them have *pseudo* R^2 values below 0.2. Unlike the conventional R^2 values above 0.2 show that the model fits the data well and there are correlations between the dependent variable and the independent variable. Furthermore, the likelihood-ratio chi-square statistic test shows that the changes in the independent variables are found to correlate well with shifts in the dependent variable as it is shown by p-values of 0.000 for all models. Hence, all the independent variables used in the model are statistically significant and the null hypothesis is rejected.

Table 2: Model adequacy test results

Model	Settlement Type	R_2	Chis-square	p-value
Cooking	Whole country	0.41	2521.4	0.000
	Rural	0.20	351.93	0.000
	Peri-urban	0.25	141.06	0.000
	Urban	0.25	549.46	0.000
Water Heating	Whole country	0.43	2845.7	0.000
	Rural	0.24	479.5	0.000
	Peri-urban	0.23	138.69	0.000
	Urban	0.30	734.74	0.000
Lighting	Whole country	0.58	3360.3	0.000
	Rural	0.35	1000.7	0.000
	Peri-urban	0.88	274.54	0.000
	Urban	0.79	1093.8	0.000

5.3 Determinants of choice of energy for cooking

The multinomial logit results for the determinants of the choice of fuel for cooking, with traditional fuels as the base category, are shown in Table 3. Gender is generally statistically insignificant for the choice of electricity, LPG, and paraffin over the choice of traditional fuels for cooking purposes across all settlement types. This implies that it cannot be assumed with any certainty whether female-headed households are more likely to choose any cooking fuel over traditional fuels as compared to male-headed households.

Table 3: Determinants of energy choice for cooking

Independent Variables	**Electricity**				**LPG**				**Paraffin**				**Other (cloths, aloe)**	
	Whole Country	**Rural**	**Periurban**	**Urban**	**Whole Country**	**Rural**	**Periurban**	**Urban**	**Whole Country**	**Rural**	**Periurban**	**Urban**	**Whole Country**	**Rural**
Gender: female	0.07 (0.22)	-1.28 (0.85)	1.47* (0.80)	0.25 (0.36)	-0.02 (0.15)	-0.09 (0.20)	0.18 (0.37)	0.20 (0.32)	-0.15 (0.20)	-0.53 (0.37)	-0.38 (0.58)	0.30 (0.35)	0.23 (0.55)	0.25 (0.73)
Age	-0.04*** (0.01)	-0.01 (0.02)	-0.09*** (0.03)	-0.05*** (0.01)	-0.02*** (0.00)	-0.01** (0.01)	-0.03** (0.01)	-0.04*** (0.01)	-0.02*** (0.01)	0.01 (0.01)	-0.06*** (0.02)	-0.03*** (0.01)	-0.02 (0.01)	-0.03 (0.02)
Household size	-0.37*** (0.05)	-0.49*** (0.17)	-0.31* (0.18)	-0.48*** (0.08)	-0.20*** (0.03)	-0.15*** (0.04)	-0.17** (0.07)	-0.32*** (0.07)	0.33*** (0.05)	-0.45*** (0.09)	-0.25* (0.13)	-0.36*** (0.08)	-0.56*** (0.16)	-0.61*** (0.20)
Income class: middle	1.72*** (0.27)	2.27*** (0.79)	2.36** (0.97)	2.00*** (0.42)	1.57*** (0.16)	1.30*** (0.21)	1.59*** (0.43)	2.02*** (0.36)	0.84*** (0.22)	0.99** (0.39)	1.68*** (0.63)	0.96** (0.40)	-0.66 (0.80)	-0.49 (1.08)
Income class: upper	1.09*** (0.31)	1.59* (0.88)	1.44 (1.18)	1.68*** (0.53)	0.95*** (0.19)	0.75*** (0.26)	0.58 (0.49)	1.78*** (0.46)	0.70*** (0.26)	0.92** (0.42)	0.85 (0.69)	1.31** (0.51)	0.30 (0.60)	-0.95 (1.07)
Remittances	0.65*** (0.25)	0.34 (0.62)	1.09 (0.97)	0.84** (0.42)	0.73*** (0.15)	0.60*** (0.19)	0.92** (0.38)	0.97*** (0.36)	-0.06 (0.22)	-0.05 (0.35)	0.26 (0.60)	0.08 (0.42)	-2.10** (1.04)	-1.82* (1.06)
Settlement type: periurban	0.86** (0.42)	-	-	-	1.18*** (0.19)	-	-	-	1.69*** (0.28)	-	-	-	0.43 (0.80)	-
Settlement type: urban	3.06*** (0.32)	-	-	-	2.89*** (0.17)	-	-	-	3.45*** (0.23)	-	-	-	1.61*** (0.60)	-
Education: primary	1.72*** (0.54)	0.17 (0.89)	-1.22 (1.45)	2.66*** (0.83)	1.13*** (0.24)	1.00*** (0.34)	1.60* (0.82)	1.18*** (0.42)	0.84*** (0.30)	1.70** (0.74)	0.61 (0.88)	0.57 (0.46)	0.05 (0.61)	-0.05 (0.73)
Education: high school	2.26*** (0.55)	0.46 (1.00)	-1.56 (1.62)	2.96*** (0.85)	1.81*** (0.27)	1.73*** (0.38)	2.33*** (0.88)	1.55*** (0.47)	0.81** (0.35)	2.37*** (0.80)	0.13 (0.97)	0.09 (0.53)	-0.11 (0.83)	-17.72 5060
Education: tertiary	3.95*** (0.63)	1.31 (1.28)	1.42 (1.83)	22.14 (3446.7)	2.75*** (0.40)	2.23*** (0.53)	3.55*** (1.17)	20.04 (3446.70)	1.12** (0.55)	1.59 (1.28)	1.01 (1.54)	18.18 (3446.70)	-17.80 (10600)	-17.49 10709
Electricity availability	6.24*** (1.01)	21.48 (3507)	4.18*** (1.23)	21.60 (2997.70)	1.24*** (0.16)	1.31*** (0.22)	1.31*** (0.36)	1.06*** (0.31)	-0.59** (0.24)	0.23 (0.50)	0.50 (0.56)	-1.12*** (0.36)	-0.54 (0.79)	-16.81 4440.80

Note(s): Statistical significance level: *** = 1%, ** = 5%, * = 10%. Values in parenthesis represent standard errors

The age of household head is negative and statistically significant, at least at the 5% level, for the choice of LPG over traditional fuels across all settlement types. The same is similar for electricity and paraffin except in rural areas. The implication is that the older household heads are less likely to choose electricity, LPG, and paraffin over traditional fuels as compared to younger household heads. In terms of household size, this variable is negative and statistically significant, at least at the 10% level for the choice of all fuels over the choice of traditional fuels across all settlement types. This shows that large household sizes are less likely to choose any fuel over traditional fuels as compared to the smaller household sizes. Considering income, the middle-class income category variable is positive and significant, at least at the 5% level, for the choice of electricity, LPG, and paraffin over traditional fuels across all settlement types. Comparatively, this means that households in the middle-income class are more likely to choose cleaner fuels over traditional fuels relative to households in the low-income class. Furthermore, the upper-income class variable is generally positive and statistically significant for the choice of electricity, LPG, and paraffin over the choice of traditional fuels across all settlement types. This shows that households that are in the upper-income class category are generally more likely to adopt electricity, LPG, and paraffin as compared to households in the lower-income class category.

Remittances variable is positive and statistically significant for the choice of LPG over traditional fuels across all settlement types. Households that receive remittances are more likely to choose LPG for cooking relative households that do not receive any remittances. It should be noted also that the remittances variable is only positive and statistically significant for the choice of electricity when the whole country is considered or when the urban areas are considered. Households in urban areas are more likely to choose electricity over traditional fuels when they receive remittances. For the primary education category, the variable is broadly positive and significant for the choice of clean energy fuels over the choice of traditional fuels. This means that household heads with primary education are generally more likely to choose clean energy fuels as compared to household heads without any level of education. Similarly, the high school category variable is generally positive and statistically significant. Much like household heads with primary education, household heads with high school education are more likely to adopt cleaner energy fuels over traditional fuels relative to household heads without any level of education. Tertiary education is generally positive and significant for the choice of LPG over traditional fuels across all settlement types. On the other hand, it is only positive and statistically significant for the choice of electricity over traditional fuels when considering the country as a whole. Household heads with Tertiary level of education are more likely to choose LPG and electricity over traditional fuels. Electricity availability is, on a general note, positive and statistically significant for the choice of cleaner energy fuels relative to traditional fuels. This implies that household heads with access to electricity are more likely to adopt cleaner energy fuels relative that households without access to electricity. In between settlements, peri-urban and urban settlements are generally positive and statistically significant for the choice of cooking alternatives over the choice of traditional fuels. The implication is that households in peri-urban and urban settlements are more likely to adopt alternatives over traditional fuels as compared to households in rural areas.

5.4 Determinants of choice of energy for water heating

The determinants of the choice of fuel for water heating purposes, with traditional fuels as the base category, are shown in Table 4. Generally, gender is statistically insignificant for the choice of cleaner fuels over traditional fuels for purposes of water heating. This shows that there is no clear distinction between female-headed households and male-headed households on the preference of cleaner energy fuels over traditional fuels. The age of household head is negative and statistically significant, at least at the 10% level, for the choice of cleaner energy fuels across all settlement types except the rural settlements. This implies that older household heads are less likely to choose cleaner energy fuels over traditional fuels as compared to households headed by younger people for water heating purposes. In terms of household size, this variable is negative and statistically significant, at the 10% level at least, for the choice of LPG over traditional fuels across all settlement types and generally negative and statistically significant for the choice of paraffin. However, for electricity, this is negative and statistically significant at the 1% level when the whole country is considered and in the urban settlements. Lager households are less likely to choose cleaner energy fuels over traditional fuels. In terms of income, the middle-income class category variable is generally positive and statistically significant. Households in the middle-income class are more likely to adopt cleaner energy fuels as compared to households in the lower-income classes.

Table 4: Determinants of energy choice for water heating

Independent variable	**Electricity**				**LPG**				**Paraffin**				**Other (cloths, aloe)**	
	Whole Country	**Rural**	**Periurban**	**Urban**	**Whole Country**	**Rural**	**Periurban**	**Urban**	**Whole Country**	**Rural**	**Periurban**	**Urban**	**Whole Country**	**Rural**
Gender: female	-0.24 (0.20)	-0.43 (0.46)	0.07 (0.54)	-0.12 (0.35)	-0.24 (0.16)	-0.27 (0.24)	0.06 (0.40)	-0.06 (0.33)	-0.26 (0.17)	-0.61** (0.27)	-0.10 (0.49)	0.12 (0.34)	0.01 (0.54)	-0.39 (0.76)
Age	-0.01** (0.01)	0.09 (0.01)	-0.04** (0.02)	-0.03** (0.01)	-0.02*** (0.00)	-0.01* (0.00)	-0.02 (0.01)	-0.03*** (0.01)	-0.01** (0.01)	0.04 (0.00)	-0.04*** (0.02)	-0.03*** (0.01)	-0.03* (0.02)	-0.04* (0.02)
Household size	-0.23*** (0.04)	-0.04 (0.09)	-0.02 (0.10)	-0.36*** (0.07)	-0.21*** (0.03)	-0.25*** (0.05)	-0.16* (0.08)	-0.25*** (0.07)	-0.20*** (0.04)	-0.2*** (0.05)	-0.11 (0.11)	-0.24*** (0.07)	-0.13 (0.11)	-0.22 (0.14)
Income class: middle	1.69*** (0.23)	1.91*** (0.47)	1.34** (0.61)	1.98*** (0.40)	1.44*** (0.17)	1.34*** (0.24)	0.65 (0.44)	1.90*** (0.38)	0.91*** (0.19)	1.10*** (0.27)	0.49 (0.56)	1.12*** (0.40)	-1.45 (1.06)	-2.05 (3065.70)
Income class: upper	1.11*** (0.27)	0.73 (0.58))	1.31* (0.79)	1.63*** (0.48)	0.31 (0.22)	0.18 (0.34)	-0.18 (0.58)	0.95** (0.46)	0.489** (0.23)	0.64* (0.33)	0.60 (0.59)	0.82* (0.47)	-0.01 (0.66)	-0.77 (1.07)
Remittances	0.30 (0.22)	-0.03 (0.42)	0.25 (0.66)	0.59 (0.39)	0.45*** (0.16)	0.43** (0.22)	0.50 (0.41)	0.66* (0.38)	0.20 (0.18)	0.17 (0.24)	0.13 (0.50)	0.44 (0.39)	0.10 (0.51)	0.42 (0.60)
Settlement type: periurban	0.36 (0.31)	-	-	-	1.08*** (0.21)	-	-	-	1.06*** (0.25)	-	-	-	-0.29 (1.07)	-
Settlement type: urban	2.77*** (0.25)	-	-	-	2.87*** (0.19)	-	-	-	3.16*** (0.20)	-	-	-	1.95*** (0.59)	-
Education: primary	1.88*** (0.39)	1.40* (0.83)	0.76 (1.24)	2.09*** (0.52)	1.29*** (0.28)	1.00** (0.39)	0.97 (0.84)	1.50*** (0.47)	0.70*** (0.25)	1.14*** (0.42)	0.76 (0.85)	0.44 (0.43)	0.17 (0.68)	-0.07 (0.72)
Education: high school	2.93*** (0.41)	3.0*** (0.90)	1.60 (1.29)	2.90*** (0.58)	2.13*** (0.31)	1.72*** (0.44)	2.07** (0.89)	2.15*** (0.54)	0.99*** (0.29)	1.81*** (0.48)	0.35 (0.94)	0.50 (0.52)	0.46 (0.84)	-0.67 (1.23)
Education: tertiary	3.77*** (0.52)	3.35*** (1.22)	2.52 (1.54)	4.88*** (1.13)	2.31*** (0.44)	1.90*** (0.64)	2.65** (1.14)	3.40*** (1.12)	1.30*** (0.45)	1.14 (0.86)	1.47 (1.27)	2.19* (1.13)	-17.11 (15853.00)	-2.00 (8366.00)
Electricity availability	5.95*** (0.52)	2.58 (2410.00)	4.23*** (0.82)	5.63*** (0.77)	0.99*** (0.18)	1.08*** (0.28)	1.32*** (0.39)	0.53 (0.33)	-0.43** (0.22)	0.03 (0.42)	0.35 (0.52)	-1.01*** (0.34)	-1.06 (1.06)	-2.00 (3177.00)

Note(s): Statistical significance level: *** = 1%, ** = 5%, * = 10%. Values in parenthesis represent standard errors.

Considering the upper-income class category, this variable is generally positive and statistically significant for the choice of electricity and paraffin of traditional fuels. Therefore, households that are in the upper-income class are more likely to choose electricity and paraffin over traditional fuels as compared to households in the lower-income class category. Remittances variable is positive and statistically significant for the choice of LPG over traditional fuels across all settlements except the peri-urban settlements. This implies that households that receive remittances are more likely to adopt LPG relative to households that do not receive any remittances. For primary education level, the variable is generally positive and statistically significant for the choice of cleaner energy fuel over traditional fuels. Similar behaviour is observed for both high school and tertiary variables. This shows that household heads with some level of education are more likely to choose cleaner energy fuels over traditional ones as compared to household heads without any level of education. Electricity availability is generally positive and statistically significant, at the 5% level, for the choice of cleaner energy fuels relative to traditional fuels. This means that households with access to electricity are more likely to adopt cleaner energy fuels for water heating over the use of traditional fuels. Comparing settlements amongst themselves, the peri-urban settlement type variable is only positive and statistically significant for the choice of LPG and paraffin over traditional fuels for water heating. Hence households in the peri-urban settlements are more likely to adopt electricity and paraffin over traditional fuels, relative to households in the rural settlements. For urban settlement variable, this is positive and statistically significant for the choice of all alternatives over the choice of traditional fuels. Thus households in the urban areas are more likely to choose alternative fuels over traditional fuels for water heating.

5.5 Determinants of choice of energy for lighting

The determinants of the choice of energy for lighting, with paraffin as the base category, are shown in Table 5. Gender is, on the whole, statistically insignificant for the choice of electricity over paraffin for purposes of lighting. This implies that there is no clear distinction between femaleheaded households and male-headed households in terms of preference for electricity over paraffin. However, gender is negative and statistically significant for the choice of candles over paraffin when considering the whole country and the rural settlements.

Table 5: Determinants of choice of energy for lighting

Independent Variable	Electricity				Candle			Rechargeable Battery Lamps	Solar	
	Whole Country	Rural	Periurban	Urban	Whole Country	Rural	Urban	Whole country	Whole Country	Rural
Gender: female	-0.69 (0.45)	0.98 (1.06)	0.57 (0.92)	-1.42* (0.75)	-0.46*** (0.17)	-0.42** (0.19)	1.27 (0.77)	0.30 (0.53)	0.44* (0.25)	0.38 (0.27)
Age	-0.01 (0.01)	0.00 (0.01)	-0.16** (0.07)	0.02 (0.02)	0.01* (0.00)	0.00 (0.01)	0.04*** (0.01)	0.00 (0.02)	0.00 (0.01)	0.00 (0.01)
Household size	-0.15 (0.10)	0.14 (0.22)	-0.31 (0.29)	-0.27* (0.15)	-0.09*** (0.03)	-0.09*** (0.03)	-0.08 (0.10)	-0.02 (0.09)	0.07* (0.04)	0.05 (0.04)
Income class: middle	1.25** (0.51)	1.71 (1.36)	3.13* (1.72)	1.51* (0.81)	-0.51*** (0.20)	0.23 (0.03)	-1.36*** (0.51)	-0.54 (0.68)	0.37 (0.26)	0.48* (0.27)
Income class: upper	1.31** (0.59)	1.86 (1.66)	2.03 (1.52)	1.60 (1.02)	-0.07 (0.22)	-0.17 (0.26)	-0.05 (0.54)	0.65 (0.56)	0.55* (0.30)	0.53 (0.32)
Remittances	0.78* (0.46)	1.16 (1.21)	0.18 (1.30)	1.27* (0.77)	-0.18 (0.16)	-0.05 (0.17)	-1.12* (0.60)	-0.82 (0.58)	0.18 (0.23)	0.17 (0.24)
Settlement type: peri-urban	2.31*** (0.60)	-	-	-	-0.03 (0.27)	-	-	-0.62 (1.05)	-0.94* (0.53)	-
Settlement type: urban	1.46*** (0.52)	-	-	-	-0.07 (0.22)	-	-	-0.77 (0.80)	-1.00** (0.40)	-
Education: primary	0.28 (0.75)	-0.47 (1.56)	-31.58 (41983.0)	1.85 (1.18)	0.48** (0.21)	0.70*** (0.24)	-0.76 (0.54)	0.08 (0.60)	0.10 (0.29)	0.21 (0.31)
Education: high school	1.09 (0.82)	0.75 (2.06)	-1.69 (1.76)	1.72 (1.22)	0.08 (0.29)	0.44 (0.35)	-1.25* (0.67)	0.07 (0.83)	0.33 (0.42)	0.15 (0.40)
Education: tertiary	0.76 (1.15)	0.21 (4.39)	-17.08 (29861.00)	3.43** (1.49)	0.72 (0.47)	0.77 (0.61)	-0.32 (1.00)	-17.76 (17195.00)	1.57*** (0.50)	0.70 (0.70)
Electricity availability	9.67*** (0.60)	11.94*** (1.58)	44.09 (41983.00)	9.50*** (0.93)	-0.27 (1.08)	-18.76 (23755.00)	0.06 (1.29)	2.42** (1.11)	0.76 (1.09)	-17.61 (23587.00)

Note(s): Statistical significance level: *** = 1%, ** = 5%, * = 10%. Values in parenthesis represent standard errors

This means that female-headed households are less likely to choose candles over paraffin for lighting. In terms of solar products, gender is positive and statistically significant for the choice of solar products over paraffin when the model is computed for the whole country. This purports that female-headed households are more likely to adopt solar products for lighting as compared to male-headed households. Age is, generally, statistically insignificant for the choice of all the alternatives over the choice of paraffin for lighting. This indicates that, on a general scale, there is no clear difference in the preference of paraffin and its alternatives when comparing older and younger household heads. Predominately, household size is statistically insignificant for the choice of electricity over paraffin. This indicates that it cannot be said with any certainty whether household size affects the choice of electricity over paraffin for lighting. On the other hand, household size is predominately negative and statistically significant, at least at the 1% level, for the choice of candles over paraffin. This alludes that the larger the household, the less likely the household will opt for candles over paraffin for purposes of lighting. For the choice of solar products, household size is positive and statistically significant when considering the country as a whole. This implies that larger households are more likely to adopt solar products than smaller households. In terms of income, households in the middle-income class category are more likely to adopt electricity over paraffin as compared to households in the lower-income class category. This is because the middle-income class category variable is generally positive and statistically significant for the choice of electricity over paraffin.

Moreover, the middle-income class variable is predominantly negative and statistically significant for the choice of candles over paraffin, showing that middle-income class households are less likely to adopt paraffin over candles as compared to lower-income class households. Middleincome class households in rural areas are more likely to adopt solar products over than paraffin relative that lower-income middle-class households. This is shown by the positive and statistically significant, at the 5% level, middle-income class variable for the choice of solar products over paraffin. The upper-income class variable is generally insignificant for the choice of all alternatives over the choice of paraffin for lighting. This implies that there is no clear distinction in terms of choosing all the alternatives over the paraffin for households in the upper-income class as compared to households in the lower-income class. Remittances, generally, are insignificant for the choice of all alternatives over the choice of paraffin. Largely, this implies that there is no clear distinction between the choice of alternative fuels and paraffin for households that receive remittances versus households that do not receive any remittances.

For household heads that have some level of education; primary, high school, and tertiary, as compared to household heads without any education, there is no clear preference of the alternative fuels for lighting over the choice of paraffin. This is illustrated by the general statistical insignificance of the education category variables for the choice of lighting fuel. Electricity availability is statistically significant for the choice of electricity over paraffin for lighting across all settlement types and only significant for the choice of rechargeable battery lamps over paraffin when the whole country is considered. This demonstrates that households with access to electricity are more likely to adopt electricity for lighting over paraffin and also more likely to adopt rechargeable battery lamps over paraffin. A comparison between settlement types shows that households in the peri-urban and urban settlements are more likely to choose electricity over paraffin relative to households in the rural settlements. This is shown by the positive and highly significant peri-urban and urban settlement type variables. Furthermore, households in the periurban and urban settlements are less likely to choose solar products over paraffin relative to households in rural settlements. This is attributed to the negative and statistically significant periurban and urban settlement type variables.

5.6 Robustness test

A robustness test was carried out to identify the importance of including the settlement type variable, since this is the variable of interest in this study. If this variable is correlated to the dependent variable, and it is omitted, a bias in the regression results is likely to occur. The model that aggregates the data into the whole country was re-estimated with this variable dropped and the resulting chi-square compared to that shown in Table 2. When this variable is dropped for the cooking model, the chi-square statistic changes from 2521.4 to 2074. The decrease in the statistic means that the value of the p-value increase, hence becoming less significant. For water heating, dropping the variable, the chi-square statistic changes from 2845.7 to 2586.2 and the same things happens with the p-value decreases hence decreasing the significance. For the lighting model, dropping the variable changes the chi-square statistic from 3360.3 to 3329.8. The chi-square decreases when this variable is dropped, indicating that the model fits the data less when this variable is dropped. Since its inclusion increases the chi-square, meaning the p-value further approaches zero, the variable cannot be dropped from the model.

5.7 Discussions

A variety of factors influence a choice of a particular fuel for certain household use as it has been observed from sections 5.3, 5.4, and 5.5. The gender of the household head is, in large part, statistically insignificant for the choice of fuels for cooking, water heating, and lighting. These findings are in accord with the findings of Nlom and Karimov (2015) and Zhou and Luo (2019). A possible explanation could be that, in as much as a household may be headed by a male, a woman within that household is likely to be the one that makes or influence the decision of the choice of fuel used in the households. This is because women are more likely to spend a lot of time in the house relative to men. In terms of age of the household head, the finding is that, generally, older household heads are less likely to use cleaner fuels than their younger counterparts for cooking and water heating purposes. This might be because older people are associated with reluctance to change and often adhere to their social norms. Moreover, it could be associated with a perception that is common among older household heads that fuel sources such as electricity and LPG are not safe to use and not readily accessible and affordable like traditional fuels (Gould and Urpelainen, 2018; Malakar, 2018). However, this finding is contrary to what Bamiro and Ogunjobi (2015) found. They found that the age of the household has no significant influence on the choice of the household of a fuel used within the household. But when the model is re-estimated for the rural settlements, age in statistically insignificant for the choice of electricity over traditional fuels for both cooking and water heating, indicating that some factors other than age play a role in the choice of energy fuel in the rural settlements.

Household sizes that are large are less likely to use clean energy fuels over traditional fuels. The observed results are in line with the findings of Mensah and Adu (2015). This may be attributed to the fact that large households have enough labour for collecting traditional fuels as opposed to opting for paid fuels. These households are likely to have higher household energy demands than smaller households and hence traditional fuels become an attractive option because they are usually available at little or no monetary cost (Özcan et al., 2013a; Uhunamure et al., 2017a). However, the results refute the findings of Zou and Luo (2019), who show that larger households tend to adopt clean energy fuels such as LPG for cooking over the adoption of traditional fuels as modern households a likely to use fuels of better quality and efficiency. However, when the model is re-estimated for the rural settlements only and the peri-urban settlements only for water heating, household size is not significant for the choice of electricity over traditional fuels.

Predominantly, households in higher-income classes are more likely to choose clean energy fuels for cooking and water heating. Sehjpal *et al.* (2014) argue that household maximise their utility subject to constraints such as income and as such, an increase in income may lead to the use of energy fuels such as electricity and paraffin. A similar view is shared by Arthur *et al.* (2010) and Couture *et al.* (2012), that poor households are most likely to rely on firewood for household energy use, especially in the rural settlements. These findings are in accord with the energy ladder model that higher-income class households are associated with clean energy fuels. However, this is not the case for the choice of electricity for lighting over the choice of paraffin for the rural settlements. This implies that households in the rural areas are not influenced by income to choose electricity over paraffin for lighting, which refutes the energy ladder model.

Education is, on the whole, a key factor for the choice of clean energy fuels within households. An increase in the education level of household head raises awareness of the health and environmental impacts of using traditional fuel and therefore adoption of clean energy fuels (Behera et al., 2015a). However, Sehjpal *et al.* (2014) argue that in their study, education does not have a direct impact on the choice of household energy fuel choices. The argument is that education may indirectly influence the adoption of clean energy fuels if only it leads to employment, which in turn may lead to an increase in income (Guta, 2018; Hou *et al*., 2017). But whether education influences the adoption of clean energy fuels directly or indirectly, the general consensus is that education plays a vital in influencing the adoption of clean energy, especially for the adoption of solar products for lighting (Lay *et al.*, 2013). However, if the settlements are disaggregated, education is not important for the choice of electricity over traditional fuels for cooking and the same applies for the choice of electricity over paraffin for lighting.

Access to electricity is also crucial for the adoption of clean energy fuels within households. These findings are in agreement with the findings of Rahut *et al.* (2014), who assert that electricity connection is essential for households to adopt electricity within households. Electricity is associated with convenience and improved standard of living, hence households that are connected to the grid are likely to adopt clean fuels over traditional fuels. Adopting electricity within a household means that households can allocate more time to productive uses as opposed to collecting traditional use such as engaging in income-generating activities (Pueyo and Maestre, 2019). On the contrary, Trac (2011) shows that electricity availability within a household is not necessarily mean the adoption of clean fuels for all energy requirements. Some meals may still be cooked using traditional fuels because of social norms while electricity may be used for lighting only. This is in agreement with the fuel stacking theory. But the in the rural settlements, electricity availability is not enough for the choice of electricity over traditional fuels over the traditional fuels.

When the data is disaggregated into different settlement types, some variables do not become significant, relative to when the data is aggregated. It has been observed that for the rural settlements, most variables become statistically insignificant whereas they were significant when the model was aggregated for the whole country. Most notably, this occurs for the choice of electricity over traditional fuels for cooking and heating and for the choice of electricity over paraffin for lighting. Age, despite being statistically significant across most settlement types, it is insignificant in the rural settlements for the choice of electricity over traditional fuels for cooking and water heating. This essentially means that older household heads do not seem to show any preference for choosing traditional fuels over electricity compared to their younger counterparts. Education is also insignificant for the choice of electricity over traditional fuels in the rural settlement. Comparing educated households heads with household heads without any education, there is no preference for electricity over traditional fuels for one group versus the other. An educated household head does not directly imply the use of electricity for cooking. Also, of importance is the lack of influence of income for the choice of electricity over paraffin for lighting. Increase in income does no guarantee the preference of electricity over paraffin for lighting.

A comparison within the settlement types shows that households in the peri-urban and urban settlements are more likely to adopt clean energy fuels as compared to households in the rural settlements. The reason could be that urbanisation increases the chance of engaging in incomegenerating activities such as employment. Furthermore, the standard of living associated with urban settlements is usually higher than the standard of living in the rural settlement and hence the adoption of fuels associated with such a standard will likely be adopted (Hiemstra-van der Horst and Hovorka, 2008). In some cases, the availability and accessibility of traditional fuels in the urban areas may become a challenge and hence force households to opt for cleaner energy fuels that are readily available (Hou *et al.*, 2017)

Chapter 6: Conclusion and policy recommendations

The determinants of the choice of household energy use in Lesotho have been modelled using multinomial logistic regression. The household energy uses were classified into cooking, water heating, and lighting. The county is characterized by high dependence on traditional fuels for cooking, accounting for at least 50.3% penetration. Similarly, for water heating, traditional fuels account for at least 51%. For lighting purposes, the most dominant fuel is paraffin with an overall penetration of 49%. It was found that both demographic and socio-economic factors influence a household decision to choose one fuel over the other. However, one factor may influence the choice of a fuel in one settlement type, while it does not have any effect in another settlement type within the country. All the variables are except gender are statistically significant for the choice of choice of electricity over the traditional fuels. However, when the settlements are disaggregated, it has been observed that some variables such as age and education of household head become insignificant in the rural settlements, although they are significant when considering the whole country and the urban settlements. The findings for lighting fuel choice also dispute the energy ladder model as income has no influence on the choice of electricity over paraffin in the rural settlements, despite this being significant for the whole country, the peri-urban and the urban settlements.

As hypothesised by the energy ladder model, income plays an important role in the choice of energy fuel. Households in higher-income classes are more likely to choose cleaner fuels for cooking and water heating. But in terms of lighting, the energy ladder model does not hold in the rural settlement for choosing electricity over traditional fuels. Gender plays a limited role in the choice of cooking and water heating fuels across all settlement types, yielding similar results to Nlom and Kamirov (2015). It is only significant for the choice of electricity for cooking over traditional fuels at a 10% level in the peri-urban settlement and 5% for the choice of paraffin for water heating over traditional fuels in the rural settlements. This has been attributed to the fact that women within households have a great influence on the choice of fuel used in the house even though the head of the household may be a male.

The observations of this study indicate that most socio-economic parameters are irrelevant for the choice of electricity over traditional fuels in the rural settlements, despite being relevant when the whole country is considered, as well as other settlement types. This implies that extending the electricity grid to the rural areas is a gamble as it cannot be predicted, based on the socio-economic factors of a household, whether it will be chosen, especially for cooking and water heating. This is further confirmed by the observation that electricity availability is not significant for the choice of electricity for cooking purposes. Because of the mountainous terrain of the country and the prohibitive costs of extending the grid to the rural settlements, based on this findings, grid extension to the rural settlements is not encouraged. Furthermore, electricity availability highly influences the use of LPG, especially for cooking in the other settlements apart from the rural settlements. This confirms fuel stacking for cooking as both electricity and LPG are preferred over traditional fuels. These observations shed light on why there has been declining average household electricity consumption. In the rural areas, the uptake of electricity is not influenced by the usual socio-economic factors and in the urban settlements, fuels are stacked, based on the same socioeconomic factors.

For policy formulation such as electrification master plans, the whole country should not be treated as uniform. Energy choice depends very much on settlement type and what might seem significant when the whole country is considered is not necessarily the case when settlements are disaggregated. This means that cheaper alternatives to grid extension such as mini-grids, solar home systems and improved cookstoves should be explored for provision of clean energy in households. Furthermore, some studies in Lesotho have focused on affordability and willingness to pay as proxies for the adoption of electricity within rural households. This study shows that income is insignificant for the choice of electricity for lighting in the rural areas, hence affordability and willingness are not good for assessing the choice of electricity of other fuels such as paraffin.

For actions of further research, Lesotho has recently (2019) introduced a lifeline tariff for the first 30 kWh to meet the energy needs of the poorest of the poor (LEWA, 2019a). This pro-poor policy was designed to counter the decreasing average household consumption in the country by encouraging the use of electricity for cooking and water heating, therefore it would be important to assess the determinants of choice of energy fuel under the policy. The policy may have an influence on the determinants of energy choice especially in the rural settlements where electricity has been used primarily for lighting.

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