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Transitioning to cleaner solutions and moving away from precautionary energy stacking in Lesotho households

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Abstract

The optimism that the world will be heading for 100% renewable energy has recently heightened within academia and policymakers. This paper interrogates the prevailing energy patterns in Lesotho, where households depend on multiple energy sources, combining renewables and non-renewables. While there is increased access to grid electricity and solar technologies, the data reveals a persistent reliance on biomass, paraffin, coal, and liquefied petroleum gas. Drawing on qualitative fieldwork, the study demonstrates that the current trend is not merely transitional but is shaped by distinct socio-economic and infrastructural realities. Three key factors underpin the continued preference for energy combinations. First, renewable energy penetration in rural areas remains limited. Second, affordability concerns, particularly the cost of connection and usage, severely constrain households. Third, precautionary behaviours in response to unreliable electricity supply and the perceived inefficiency of some renewable technologies push households to keep alternative sources on standby. Efforts to abandon fossil-based energy use will remain aspirational unless energy transitions account for these patterns and the reasons behind them. Meaningful progress towards sustainable energy in Lesotho requires a deliberate shift in how communities are engaged. Strategies must move beyond top-down electrification, but instead emphasise local knowledge and user priorities, which are key.

Keywords Energy transition, Energy mix, Energy stacking, Public participation, Lesotho

1 Introduction

The transition to renewable energy is critical for mitigating the adverse impacts of climate change, realising energy security, reducing energy poverty, and promoting sustainable development [47, 48]. Over the last three decades, the global development agenda has officially claimed to reduce carbon dioxide emissions while promoting development for all. This aim was re-emphasised in 2015 by the Convention of the United Nations Framework for Climate Change Convention (UNFCCC) through the Paris Agreement that seeks to limit global warming to 1.5 °C [46]. Lesotho responded to the call by being a signatory to the Paris Agreement [14]. This endeavour coincides with the Sustainable



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Development Goal (SDG) 7, which aims to promote access to reliable, affordable, sustainable energy for all by 2030 [45]. However, significant problems persist, undermining the penetration of renewable energy, especially in rural areas [44].

The ambitious Intergovernmental Panel on Climate Change (IPCC) Special Report of 1.5 °C suggests that the total global CO₂ emission must be reduced by 45% from 2010 levels by 2030 and reach net zero before 2050 [19]. Both this IPCC report and Wim-badi and Djalante [52] acknowledge that those ambitious targets can only be achieved through societal choices.

Fankhauser and Jotzo [11] purport that the future could enjoy zero carbon while the present demonstrates an incremental decline in the demand for fossil fuels. However, Ediger [9] reminds us that the world's energy system is 85.5% dependent on fossil fuels, with the diversification of energy regimes and not a significant transition from fossil fuels. Some of the literature offers a misleading picture of energy shifts by implying that the world is heading towards a zero-level consumption of fossil fuels. Williams et al. [51] suggest that net-zero carbon emission could be feasible only with investment in large-scale infrastructure transformation. Sohag et al. [37] and Dogan and Pata [8] noted that if countries fail to implement effective policies for combating climate change, it is estimated that greenhouse gas emissions will grow by about 52% by 2050.

Eweade et al. [10] argue that renewable energy combinations could gradually reduce dependence on fossil fuel use. This could lead to environmental degradation mitigation and contribute to global climate targets, it would also be recommended for countries grappling with the abandonment of fossil fuels due to economic and infrastructural constraints. However, Pata and Karlilar [30] contend that African countries have yet to fully realise the benefits of these combinations. To realise the full benefits, they must increase their capacity, enhance the utilisation of renewable sources, boost investment in renewable energy infrastructure, and support all these efforts with political commitment.

Despite significant progress, access to electricity and clean cooking solutions remains challenging across many African countries. Presently, 600 million people, constituting approximately 43% of the total population, lack access to electricity, most of whom reside in sub-Saharan Africa [18]. Countries like Ghana, Kenya, and Rwanda are on track to achieve full electricity access by 2030 through targeted investments and policy frameworks prioritising renewable energy expansion [18]. Solar PV, in particular, has been identified as the cheapest power source in several regions and is projected to out-compete all other energy sources continent-wide by 2030 [18]. Nevertheless, access to clean cooking technologies still needs to be attained for 970 million Africans. Liquefied petroleum gas (LPG), considered a viable solution in urban areas, and has become unaffordable for many due to recent price spikes. This situation has driven 30 million people back to using traditional biomass, contributing to deforestation and health issues [18]. To address this, African countries are reassessing their clean fuel subsidy schemes and exploring alternatives like improved biomass cook stoves, electric cooking, and biodigesters [18, 53].

The continent has abundant renewable resources, holding 60% of the world's best solar resources, yet it only accounts for 1% of installed solar PV capacity globally [18]. This disparity is primarily attributed to infrastructural constraints, inadequate investments, and policy gaps [39]. Encouragingly, renewables such as solar, wind, hydropower, and geothermal are expected to contribute over 80% of new power generation capacity in

Africa by 2030 under the Sustainable Africa Scenario (SAS) [18]. Scholars like Karekezi and Kithyoma [20] argue that effectively integrating these renewable energy sources could mitigate environmental degradation and drive socio-economic transformation. Lesotho imports coal and electricity from its neighbours, mainly South Africa, whereas commitment to a transition implies that only renewables would be preferred.

2 Methodology

The study examines the potential of realising an energy use shift from the current mix regimes to a more complete transition to renewable energy. The paper focuses on Lesotho, an understudied developing country grappling with access to energy. The main aim of this study is to unpack the factors underlying the process of household energy transition, leaving aside transition in mining, industry, and services. This research employed a qualitative design incorporating primary and secondary data sources to analyse the socio-cultural, economic, and institutional determinants of households' energy choices.

The study's data were gathered through the combination of document analysis, structured interviews, and surveys. Concerning primary data, the authors' investigation relied on statistical data from the Lesotho Electricity Company (LEC); interviews from purposively selected 10 key informants (community leaders and LEC officials) and 25 interviewees from the ten different districts of Lesotho; the selection was based on snowballing with the traditional community chiefs helping identify knowledgeable community members who willingly participated in the study. All 35 participants were fully informed of the study's purpose and provided their responses freely.

The structured interviews were in the form of open-ended and close-ended questions to capture the energy choices of respondents, the factors influencing such choices, and related justifications. On the other hand, the surveys conducted with LEC helped collect data on energy consumption. Secondary data comprised reports from LEC, the Lesotho Energy Policy and relevant scholarly articles on energy production, distribution, and consumption trends over time in Lesotho. As the data was being coded, recurring themes, patterns and relationships were identified to reduce the identified themes and merge them under the above-specified generic thematic areas. The study uses pseudonyms when citing interviewees for confidentiality. Figure 1 illustrates the procedures followed by this study to reach conclusions.

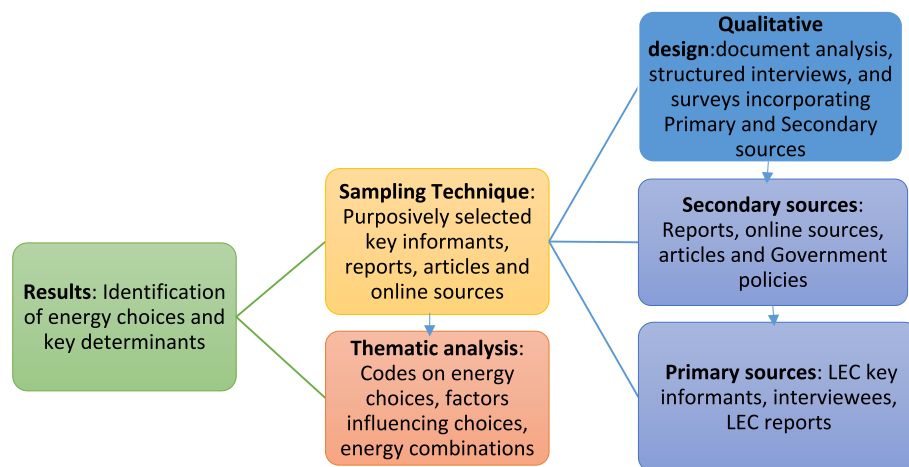


Fig. 1 Procedures and methods for this study on Lesotho households' choices. Source: Authors' own

The paper's contribution to the energy transition scholarship is twofold. Firstly, unlike most studies whose transition focus is mainly technological, this paper investigates the value of communities' socio-cultural aspects and how these values can be expressed via community participation by portraying a well-grounded outlook of households' energy use constellations. Secondly, this article examines the nexus between energy access, consumption, affordability and reliability, emphasising their critical role in determining household energy preferences and adoption.

In this regard, the study poses the following question:

- What are the households' preferred energy combinations in Lesotho and what are the factors influencing these combinations?

3 From a technical shift/combination to socio-cultural changes for a complete energy transformation

The United Nations Conference on Trade and Development (UNCTAD) regards energy transition as a broad shift from traditional energy systems relying on fossil fuels to sustainable energy systems largely dominated by renewable energy sources. UNCTAD's [48] definition of energy transition includes the replacement of fossil fuels with renewables and the adoption of new technologies that enhance energy efficiency and help restructure energy systems to promote sustainability and resilience.

Araújo [2] considers energy transition as a shift in the pattern or nature of how systems utilise energy. The author illustrates this with the Danish energy system shift of electricity mix, where wind share changed from less than 1% in 1980 to 33% in 2013. In contrast, Ahlborg [1] warns that energy transitions cannot be complete without consideration of energy governance's constitutive powers that determine decentralisation and centralisation. Avelino et al. [3] assert that energy transition is "not only about a socio-technical transition from fossil-based fuels to renewable energy, but it is also a socio-political transition from centralised for-profit energy companies to decentralised, not-for-profit community-based and/or Third Sector-based energy cooperatives." Naumann and Rudolph [26] argue that energy transition is impossible if it leaves behind rural areas.

O'Connor [27] defines energy transitions as "a particularly significant set of changes to the patterns of energy use in a society, can affect any step in this chain, and will often affect multiple steps" (p. 8). Other definitions are underpinned by a technologically centred and market-driven system change model [5, 40]. Consequently, the role of citizens or consumers in energy transition is under-conceptualised and underrated in academia and practice. Hendriks and Grin [15] consider aspects of legitimacy, accountability, and other democratic criteria for public inclusion. Ferguson's [12] case of Lesotho's Thaba-Tseka Development Project demonstrates how imposition undermines transitions.

The United Nations Development Programme [44] defines energy transition as an integrated, people-centred approach in which all available energy technologies are essential in transforming local and national energy systems.

Almost every definition of energy transition in Table 1 implies a shift from fossil fuel to renewable energy. Hence, the transitory literature alludes to a change in one form of energy use to another where the new, desirable, and sustainable form replaces the old. However, some parts of the literature also imply energy mixes or constellations rather than a complete shift [5].

Table 1 Energy Transition Definitions

Definition of Energy Transition	Source
A significant set of changes to the patterns of energy use in a country which may affect resources, converters, carriers and services	Peter O'Connor [27]
The switch from an economic system dependent on one or a series of energy sources and technologies	Roger Fouquet and Peter Pearson [13]
Shift in the source of fuel for energy production and the technologies valuable for its exploitation	Richard Hirsh and Christopher Jones [16]
A change in fuels, such as a shift from the use of wood to coal, coal to electricity and their associated technologies, such as steam engines to combustion engines	Miller et al. [23]
A comprehensive shift from traditional energy systems relying on fossil fuels to sustainable energy systems largely dominated by renewable energy sources	UNCTAD [48]

Source: Adapted from Sovacool [38]

3.1 Operationalising key concepts: precautionary and penurious energy behaviours

Precautionary behaviour in energy transitions refers to applying the precautionary principle to energy technologies, particularly when scientific evidence regarding their safety is incomplete, prompting proactive risk management and flexible decision-making [28]. Penurious behaviour refers to excessively frugal or constrained choices that limit investment in energy efficiency or clean energy, often due to economic hardship, which can lead to continued reliance on inefficient or harmful sources [17].

Precautionary energy stacking refers to using multiple energy sources to ensure supply continuity amidst unreliability or cost issues, an approach especially prevalent in low-income or remote settings [49, 50]. Energy stacking challenges the linear "energy ladder" model and reflects a pragmatic adaptation strategy. [36, 50]. This study employs energy stacking interchangeably with energy mix/constellation, with the latter referring to the blend of electricity with gas, paraffin, or biomass, which is a common trend in Lesotho households.

4 Socio-cultural aspects and public participation for energy transitions

Energy transition scholars argue that leapfrogging energy transitions is a misconception if it fails to identify socio-cultural, economic, and political factors limiting the ability of rural people to swiftly switch to the use of technologies [3]. Scholars believe that transitions depend on the accumulation of technological capabilities. The capabilities alluded to have to do with technical and managerial components manifested as individuals adapt to new technologies and their ability to take economic risks, which will demonstrate their preparedness to modify their behaviour [25].

Sehjpai et al. [34] argue that income and socio-cultural factors determine household energy choices and the pace of energy transition. The authors posit that energy transition could be more effective when women increasingly engage in formal employment. Once educated, women will most likely adapt to energy transition and prefer cleaner fuels. Hence, Sehjpai et al. [34] call for a woman-centred participatory approach to realise proper energy transitions.

Muhoza and Johnson [24] found that less participatory energy projects lead to high consumer energy costs. The authors established that poor expectation management, limited integration of local socio-economic dynamics in energy project designs, and unaffordability caused slow and partial shifts in household energy use in Zambia. Muhoza

and Johnson [24] argued that customers' views should be incorporated into the design, implementation, and evaluation of energy projects to identify obstacles hampering the adoption and transition of electricity technologies.

Yaday et al. [54] established that a lack of knowledge hampered the energy transition in Indian rural and remote communities. The authors explored 700 households to examine the impediments to energy transition and established that awareness-raising campaigns and subsidies meant to promote technologies were ineffective. The households preferred experiential learning and face-to-face discussions with development managers and change agents over the print media advertisements used. The subsidy support the government extended for solar photovoltaic systems was also not adequate as it was advertised through the same media. Consequently, the authors argued that the energy transitions could have been effective had the advertisements been locally organised and delivered through targeted campaigns covering production functionality, knowledge, and information on financing provisions.

In Lesotho, the case for participation has been belaboured in various studies [41–43]. Based on a survey of two Lesotho communities of Ha-Makebe and Semonkong, which were hosting mini-grids, this study assessed the type of governance of energy that favours the emergence of energy democracy or community energy [42]. Ha-Makebe's decentralised energy mini-grid seemed to perform better compared to Semonkong, which was mired in conflicts and community dissatisfaction. The study found that the decentralised energy project was more likely to be sustainable because it was characterised by community participation and engagement.

5 Energy stacking and determinant factors

The belief established by voluminous literature proving that energy transition follows a linear path by abandoning traditional in favour of modern fuels is gradually losing ground. Scholars found that many households prefer energy stacking, especially in developing countries [32]. The behaviour is common in both rural and urban areas. The practice excludes the poor and relatively wealthy and educated households who, under ordinary assumptions, would have been expected to use a single modern fuel source [22].

Paudel et al. [31] found that in India and Bangladesh, energy stacking persists despite improvements in electricity and LPG access. The authors argued that Afghanistan's rural households combine LPG, firewood, and dung due to affordability, availability, and familiarity with biomass. The authors revealed that even average-income households prefer mixing fuels because of unreliable energy supply and high energy prices. These findings show that households' energy stacking does not necessarily reflect a reluctance to adopt cleaner energy but maybe a decisive response to systemic insecurity.

Some studies also revealed that the energy-stacking landscape is not different in sub-Saharan Africa. Rahut et al. [32] surveyed Ethiopia, Malawi, and Tanzania and determined that households mix energy sources to bridge the infrastructure and cost barriers gap. The authors revealed that combining energy sources such as electricity, kerosene, and firewood was common even among wealthier households. Rahut et al. [32] asserted that the cause for this behavioural pattern was energy reliability more than affordability. Equally, the authors found that female-headed households who also preferred cleaner sources of energy also maintained traditional fuels as backup sources. Similarly, Olabisi

et al. [29] observed that in Tanzania, where citizens imported kerosene and rural electrification had soared, many households continually depended on charcoal and firewood for cooking. The authors' explanation pointed to the need for convenience and ingrained practices which lead to the gradual, incremental adoption of new sources of energy.

Moreover, Muhoza and Johnson [24] observed that household transitions to complete renewable energy were misunderstood, as expectations assumed a complete abandonment of traditional sources of energy. The authors uncovered that electricity was largely used for lighting and charging while cooking and heating remained within the domain of firewood and charcoal. The authors note that energy stacking was a fall-back mechanism, especially when affordability was not addressed alongside access.

In South Africa, particularly in Alexandra Township, Masuku [21] revealed that residents combine grid electricity with paraffin, wood, and gas. The combination is not a function of preference but a strategy to mitigate load-shedding, fuel price hikes, and income unpredictability. This observation is reinforced by Wernecke et al. [50], who dismissed the traditional energy ladder concept, arguing instead for a "cleaner stacking" framework that recognises the reality of multi-fuel use as a viable model of transition rather than failure.

The vast literature reviewed above demonstrates a common thread of households using multiple fuels not because of poverty as a key issue but mainly for energy reliability and convenience. This implies that energy stacking will continue until the unseeable future as long as energy reliability and affordability are not addressed as a systemic policy issue of energy design and relevance.

Overall, the trends and practices appearing in Lesotho do not contrast with those observed in other places continentally and globally. The combination of hydroelectricity, paraffin, gas, and firewood for specific motives is neither accidental nor temporary. It is rooted in everyday economic realities, infrastructural deficiencies, and socio-cultural considerations.

5.1 Households' preferred energy combinations in Lesotho

Lesotho submitted its climate action plan to the United Nations Framework Convention on Climate Change on 30 September 2015. Lesotho's carbon emissions of 2021 (2.28 million tons) are not different from those of 2010 (2.28 million tons), which means that within a decade, the country has not attained a genuine transition from fossil fuels to renewables, although the data in between shows declines and increases [33], as shown in Fig. 2.

Biomass fuels such as shrubs, fuel wood, crop residue and animal dung dominate the country's energy regime. Basotho rely on biomass and fossil fuels for heating and cooking purposes, especially in the rural areas where most of the population resides. Taelle and Mokhutšoane [40] found that the largest fuel source in Lesotho was biomass (dung, shrubs, crop residue, and firewood). Most rural households rely on biomass for their heating, lighting, cooking and ironing. The authors established that biomass constituted 69% of the national energy consumption. Hence, the transition from fossil fuels to renewable sources is sluggish at best if it is happening, as biomass accounts for two-thirds of the total energy consumption in the country. Coal, petroleum, gas and electricity constitute the remaining thirty per cent, as stated in the Lesotho Energy Policy [6], as illustrated in Fig. 3.

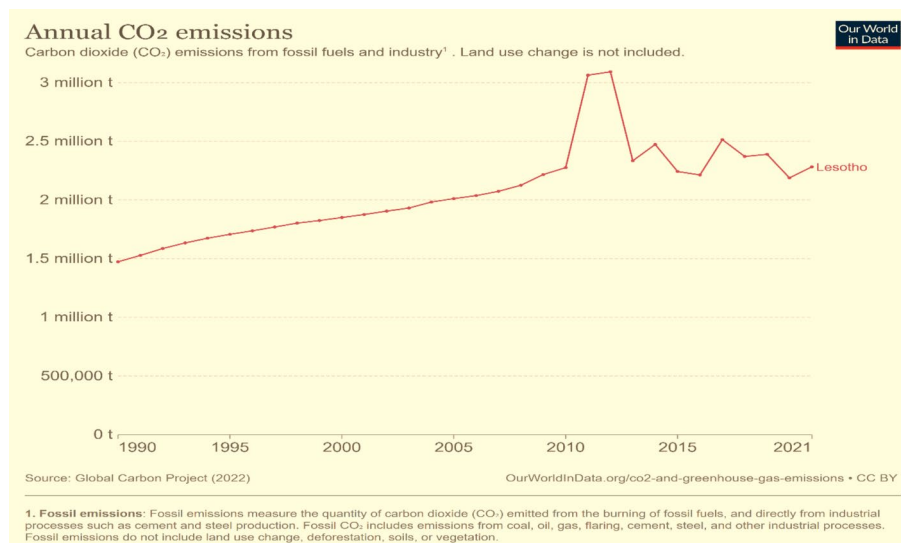


Fig. 2 Lesotho's carbon dioxide emissions from fossil fuels. Source: Ritchie and Roser (2020)

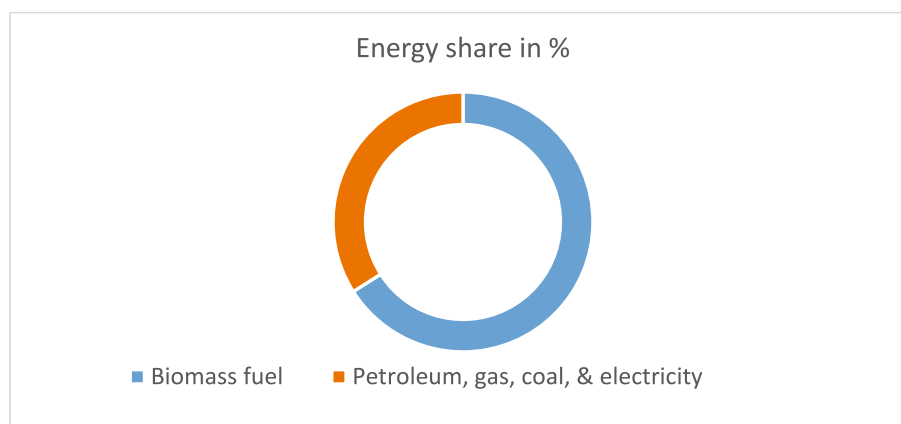


Fig. 3 Lesotho's energy combinations or mixes. Source: Lesotho Energy Policy 2015–2025 (Department of Energy 2024, p. 18)

D'Isidoro et al. [7] and Senatla et al. [35] found that Lesotho reached a 40–42% household electrification in 2015 with a baseload and peak demand of 100 MW and 155 MW, which exceeded local generation which has been steady since 1998 at around 72 MW.

6 Findings from field work: household energy constellations in Lesotho

Data reveals that some Basotho prefer using energy constellations instead of relying on one energy source. Seriti stated: "We use gas for cooking, paraffin for lighting and heating, and wood for cooking outside." Equally, Thlabollo explained: "I use electricity to charge my phone, light up my home, and watch television. I use wood, animal waste, and cobs for cooking and heating." Similarly, Selloane added: "I use gas, wood and paraffin for cooking and heating, and I use solar energy for lighting." Moreover, Karabo explained: "We use animal wastes, maize stalks, and wood for cooking, lighting and heating. Additionally, we use paraffin and candles for lighting." These testimonies reflect the wider trend discussed by Rahut et al. [32] and Masuku [21], where multiple fuels are combined for different tasks depending on cost and reliability. These patterns of energy

constellations seemed common in the rural areas, especially the outskirts of Thaba-Tseka, Mokhotlong, and Botha-Bothe, where people are self-employed.

In contrast, Thlokomelo stated: "I use electricity for cooking and lighting, and paraffin for heating." The latter pattern seems to be common in urban areas, particularly Maseru, where most people have relatively higher incomes. Similarly, Maselimo explained: "I use gas for cooking though I have electricity and prefer it for lighting and powering appliances such as refrigerator and TV. I have electricity because it helps me to charge my phones, listen to the radio, and watch TV." These combinations resemble urban stacking trends observed by Wernecke et al. [50], where electricity is used for communication and entertainment while cooking is reserved for other sources. The trend of combining electricity with gas and using the latter for cooking while the former for lighting and powering electric appliances is common in urban areas of Maseru, Leribe, Botha-Bothe, Mokhotlong, Thaba-Tseka and Mohale's Hoek among the surveyed areas.

The data reveals that Basotho prefer each source of energy for a specific function. From the above interviews, one can rank their energy type based on the function and its preferred function. Table 2 depicts the synthesised energy type preference and function. The first rank indicates that a Mosotho would prefer to use rank one for that specified purpose and combine it with another for a different function. Hence, rank one portrays preferred combinations across the households in Lesotho. Where one does not have a source in rank one, they would perform the task with the source in rank 2, and their final last choice would be rank 3. This tiered preference system affirms Paudel et al.'s [31] finding that stacking choices are function-specific and not merely economic.

Moreover, the data in Table 2 is very similar to trends in household energy use studies in the continent and the region. The reviewed papers argue that energy stacking, the combined or alternating use of multiple energy sources, is commonplace in low-income settings, particularly in South Africa. Masuku [21] highlights that South African urban households and those in informal settlements like Alexandra Township selectively utilise both grid electricity and traditional fuels (wood, paraffin, charcoal) while grappling with infrastructural deficits and energy poverty. Wernecke et al. [50] and Shankar et al. [36] contest the unidirectional "energy ladder" framework by demonstrating that fuel selection goes beyond income to include culture, seasonality, energy requirements, and fuel accessibility. They adopt a "cleaner stacking" framework that addresses social and technological factors needed to mitigate the use of health-harming fuels.

The overarching lesson for Africa and Southern Africa for Lesotho and other similar countries is that energy stacking needs to be regarded as an ingenious and pragmatic response rather than indicative of a failed attempt to transition. Policymakers must devise strategies that enhance mixed energy use while improving access to cleaner alternatives, especially amid gaps in reliability and affordability.

Table 2 Energy combination preferences

Energy source	Rank (1 = high, 3 = low)		
	1	2	3
Lighting	Hydro-power	Solar energy	Paraffin
Cooking	Gas	Paraffin	Biomass and other fossil fuels
Heating	Paraffin	Hydro-power	Biomass/fossil fuel
Powering appliances	Hydro-power	Solar-energy	Diesel powered generator

Source: Authors' own

7 Penurious factors hamper complete energy transitions

One of the main factors hampering the attainment of a complete transition to renewable energy has to do with penurious factors, these being either inability to afford connection fees or electricity bills when connected. Sehloho sustained, "Animal waste, wood, and maize stalks are accessible and less costly. Paraffin and candles are convenient for lighting in our area because we have no access to electricity or solar energy." Mahlomola added, "Candles are employed for lighting during power cuts or when we cannot afford the electricity bill." Similarly, Hlompho explained, "We use solar energy to charge our phones when facing financial challenges with electricity units."

Most households prefer energy constellations to either minimise the costs or when their preferred cheaper energy source is not accessible. The interviewees maintained that they use wood, animal waste, and maize stalks because they are cost-effective or free compared to electricity. "Candles and paraffin are my choices for lighting since they are easily accessible, and our village lacks electricity connectivity", argued Sehlabo. Besides, the interviewees with no access to electricity reported paraffin as their preferred cooking fuel only when wood, animal waste, or maize stalks are unavailable or damp due to rain. This implies that they ranked their preferences based on cost and are inclined to use the cheapest source when they cannot afford their preferred source of energy. Others showed that they resort to paraffin when they find gas unaffordable at certain times since they prefer it over paraffin.

Other determinants of energy preference include familiarity. One interviewee explained that he used gas and wood because he was not too familiar with electricity and that it was too expensive for him. On the other hand, another participant reported using firewood because of their grandmother. Otherwise, they prefer electricity. This implies that either traditional practices or familiarity influences households' preferences, and any quest for a significant transition must have these cultural norms.

8 Precautionary factors determining the pace of energy transitions

Some households with electricity access prefer energy mixes over one preferred source of energy because of reliability questions. Ideally, most Basotho interviewees would prefer to use hydroelectricity to meet most energy demands. However, they pointed out that they keep another source of energy readily available or on standby to guard against power cuts. Hoohlo indicated, "During a power cut, I use gas for cooking and candles for lighting." One Qholaqhoe interviewee also sustained that electricity is not reliable, especially when the weather is bad; hence, she must have an alternative energy source on standby. This aligns with Rahut et al. [32], who noted that stacking was often a pre-emptive response to perceived supply disruptions.

Besides unreliability, another precautionary factor determining the pace of energy is efficiency. The different sources of energy differ in terms of effectiveness, and this varies depending on the purpose for which they are used. For instance, some find cooking certain foods like beans using wood or paraffin because they are faster than some electric cooking stoves. Equally, some reported that solar and hydro-energy are most effective for lighting; hence, they use biomass and fossil fuels for cooking and heating. Most interviewees indicated that they prefer using paraffin for heating, especially in winter, because electric appliances are less effective and efficient relative to other sources of energy. Some who find candles inadequate and ineffective for lighting argue

that they usually resort to batteries and torches for lighting during power cuts. Reatile maintained, "Paraffin remains my preferred heating option as it warms our house more effectively than electricity." This mirrors the findings by Olabisi et al. [29], where households weighed energy sources based on task suitability and practical performance.

9 Prospects of abandoning energy combinations for a complete renewable energy one

Most households are unlikely to make a complete transition from their preferred energy combinations to one renewable energy source because of energy costs. Some interviewees complained that they do not see themselves in the next five years, altering their energy combinations unless their financial situation changes. "I do not think it is wise to use electricity for cooking, as this will increase the power bill," argued Selloane. This implies that energy consumption patterns depend largely on household income. This corresponds with Rahut et al. [32], who showed that affordability remains a defining barrier to clean energy adoption.

Another reason that hampers the shift from energy combination to the use of one source of energy is the reliability of the energy supply. "I think I will continue using the same combination since it does not seem like electricity cuts will stop anytime soon," argued Refiloe. This argument is bolstered by the fact that most interviewees who have access to electricity and prefer it over other sources maintain the combination for precautionary reasons, especially because of the power outages. "During power cuts, I turn to gas for cooking and solar energy for lighting," added Refiloe. Masuku [21] observed similar motivations in South Africa, where load-shedding drives multi-source energy use.

The other determinant of energy transitions is to convince and effectiveness of the energy source. One interviewee argued that paraffin and gas are easily convenient when she is too lazy to collect wood. In contrast, Nthahama explained, "Gas is faster and more efficient for cooking, and paraffin warms our houses better than electricity in winter." As long as energy users believe that one energy source is ineffective for a certain purpose, the prospects for a complete shift from the energy mixes are unlikely. The attainment of a complete transition where renewable energy is a destiny would either require technological improvement or a change of mindset. Limpho reiterated these observations concisely: "I think I will continue with this combination due to frequent blackouts, which necessitates using alternative methods like gas and solar energy. Additionally, the superior warming capability of a paraffin heater compared to an electricity heater makes it likely that we will continue using this combination." This supports Olabisi et al. [29], who noted that perceptions of efficiency play a crucial role in shaping household energy decisions.

10 The nexus between electricity access, consumption and price

One could extrapolate from the data above that some households cannot complete energy transitions because of poor access to renewable energy. However, some connected households fail as well. This paradox is explained by households' income and the price of the energy source. Figure 3 depicts the household connections or access to electricity from 2012 to 2024. It points out that the country's connection rate has been significantly increasing. Hence, Lesotho is committed to ensuring access to clean energy.

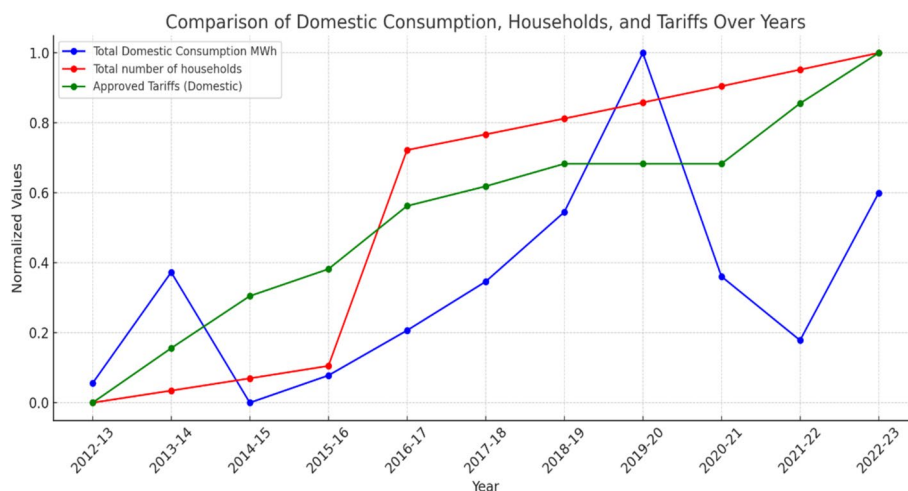


Fig. 4 Comparison of energy household connection, consumption and tariffs increases. Source: Fieldwork

Figure 3 also shows the tariff changes throughout the abovementioned period. The trend demonstrates that tariffs have constantly increased from 2012 to 2019. From 2019 to 2021, the electricity bill charges were stagnant, while from 2021 to 2023, they increased significantly more than any period under review.

The fieldwork data in Fig. 4 reveals a commitment to increasing access to energy in the country. However, it does not show whether the increased access is skewed towards the urban or rural populace. Notwithstanding, it shows that between 2014 and 2015 and from 2019 to 2022, the energy consumption levels declined significantly despite the increasing access to energy. This implies that the increase in household connections was not proportional to household energy consumption.

It could be extrapolated that from 2013 to 2015, consumption declined significantly due to an increase in electricity prices. The period from 2018 to 2019 shows that when the electricity tariff was constant, the consumption increased significantly while the connection rate was constant. This could demonstrate that price is a significant determinant of energy consumption. However, there was a significant decline in consumption in 2019 despite constant prices and increasing household connections. The Covid-19 outbreak accounts for this decline in consumption as Buechler et al. [4], (p. 3) observed, "Results show that, across the 53 countries and regions with daily electricity consumption data, total consumption declined by a daily average of 7.6% in April 2020...". The pandemic undercut several households' income through job losses, hence their ability to maintain high energy consumption levels [4]. Hence, Fig. 3 depicts the consumption levels from the Covid-19 outbreak to 2022 at their lowest since half a decade ago as Lesotho and the rest of the world continue to suffer the economic effects of the pandemic.

11 Areas for further research

This study has added to the contemporary discourse on energy transitions by showing that Lesotho's access to renewable energy is very low [6, 7, 35, 40]. It has shown that the main determinants of energy transitions responsible for Lesotho's current energy combination regimes are threefold. First, energy combinations are accounted for by poor renewable energy penetration. The second-factor accounting for sluggishness in attaining a complete transition is a failure to uplift the impecunious households to participate

actively in energy consumption. The third factor that is attributable to precautionary behaviour is energy reliability, effectiveness, and convenience.

However, this study has not determined the number of citizens involved in non-renewable energy combinations to direct policymakers interested in triggering changes. Hence, future studies could examine the proportion of citizens preferring non-renewable energy mixes and establish mechanisms to trigger changes.

12 Conclusions and recommendations

The extensive literature on energy transitions underscores the necessity of a transition to renewable energy in alignment with Sustainable Development Goal (SDG) 7, which calls for affordable, reliable, sustainable and modern energy for all. This transition implies a final destination where citizens will abandon the use of fossil fuels to rely exclusively on clean energy. However, the reality demonstrates that most societies are currently trapped in a phase of energy combination and mixes that predominantly include non-renewable energy sources. This scenario hinders the progress towards SDG-7 and contributes to continued environmental degradation and energy insecurity.

This study has revealed that shifting from the contemporary energy combination regimes to complete reliance on renewable energy is not feasible for Lesotho due to several factors. First, Lesotho's renewable energy penetration is very limited. Second, some citizens with access to electricity can hardly afford the tariffs, making adopting renewable energy alternatives financially unviable. Third, energy consumers believe that non-renewable sources, such as coal, oil, LPG or traditional biomass, are more efficient and effective for certain functions than renewables like hydro and solar. Fourth, renewable energy from hydropower from the national grid is perceived as unreliable. Fifth, many households prefer to maintain their current energy mix out of familiarity and convenience, often opting for any energy source that is readily accessible and suitable for their needs at the time. This is consistent with evidence from other low-income settings where flexibility and cost drive combinations.

Most importantly, some Basotho believe that they are unlikely to change their energy consumption patterns due to the high cost of electricity bills, the lack of consistent energy supply, and the absence of incentives to adopt clean energy technologies. These precautionary and penurious factors pose significant barriers to attaining 100% clean energy use in Lesotho.

To address these challenges, a shift is needed where policymakers actively engage citizens as prosumers (producers and consumers) rather than mere customers. This could help by emphasising the involvement of communities in energy planning and decision-making processes, fostering a sense of ownership and responsibility towards energy transition. The government, independent power producers, and donors need to embrace public engagement to reduce perceived uncertainties and risks linked to modern renewables, as this could help communities familiarise themselves with these relatively new technologies. Better knowledge and better-concerted implementation can facilitate the adoption and success of renewable technologies at both the household and community levels.

Furthermore, governments and policymakers should determine which renewable energy combinations complement each other, considering the specific energy needs and consumption patterns of different communities. For example, solar and wind energy

could be integrated with small-scale hydropower systems to ensure a more reliable and sustainable energy supply. Such combinations could mitigate the intermittency issues associated with single renewable sources and enhance overall energy security. These hybrid solutions have proven effective in contexts with fragmented infrastructure and diverse local conditions.

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Author contributions

STN and MK wrote the main manuscript text, XL extensively vetted it. All authors reviewed the manuscript.

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Data availability

Data that support findings of this study have been deposited into figshare, accessible here <https://figshare.com/s/d961c0172e0a373df42f>.

Declarations

Ethics approval and consent to participate

The authorization to carry out the study was waived by the Research and Ethics Unit of the Ministry of Health and Social Welfare in Lesotho. The Ministry does not require ethical clearance for non-clinical studies. Additionally, the protocol was approved by the National University of Lesotho Vice Chancellor in accordance with the Code of Conduct as well as other instruments guiding research at NUL.

Informed consent and consent for publication

Prior to participation, all participants were duly informed of their rights and responsibilities. Written informed consents (Consent to Participate and Consent to Publish) were obtained from all participants.

Competing interests

The authors declare no competing interests.

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