Kenya's Energy Security: Challenges and Solutions

AUTHORS: Jim Watson [1]; Shiv Shah[2]; Emma Richardson [3]; Martin Kitetu[4]; Alois Mbutura[5]; Raghav Pant [6]

Executive Summary

Energy security is an immediate and daily concern in many low- and middle-income countries (LMICs). Unreliable electricity grids and significant shortfalls in energy access can be a significant barrier to development.

This policy paper discusses the results of an energy security assessment of Kenya. This assessment uses a dashboard of energy security indicators that focus on reliability, availability, affordability, and sustainability. The aim is to help decision-makers understand the current situation, develop plans to mitigate specific risks, and understand how future plans could be adapted to improve energy security.

The results show that Kenya has particularly acute challenges in the electricity system, where households experience frequent outages. There is a lack of generation capacity to meet peak demand, and network losses are high. In addition to this, Kenya faces specific risks due to dependence on imports for all oil products and increasing imports of electricity from countries where power supplies could be impacted by climate change.

The paper makes several recommendations to decision-makers in government and the energy sector. The most important is the need for more investment in the electricity sector. Kenya's electricity system is already based on a diverse mix of renewable technologies. There is an opportunity for further investment that uses Kenya's abundant renewable resources, expands the use of electricity storage, and minimises the need for fossil fuel power plants. This investment would also help to make further improvements in energy access for households and businesses.

Policy Recommendations

- There is a clear need for more investment in the electricity sector to improve security and reliability. Due to Kenya's renewable resources, this investment can focus on expanding the use of renewables and minimising the use of fossil fuels. This will help to insulate Kenyan power prices from international price shocks.
- Achieving universal energy access is an important energy security priority. Better evidence is required to understand the extent to which energy access is having the desired impact on household energy security.
- Decision-makers also need to pay attention to specific risks to energy security. This briefing highlights the risk of depending too much on particular sources of electricity or oil products. There is also a smaller risk of climate impacts on hydro capacity. Both point to the need for a continuing focus on diversity.

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Laying high voltage transmission lines in rural Kenya

- Energy security has multiple dimensions and cannot be monitored using a single indicator. A targeted 'dashboard' of energy security indicators would allow decision-makers to track the current situation, develop plans to mitigate specific risks, and understand how future plans could be adapted to improve energy security.

Introduction

Energy security is one of the most important energy policy objectives for most countries. While there is a global imperative to reduce greenhouse gas emissions, energy systems also need to be secure, reliable, and affordable. In some low- and middle-income countries (LMICs), security is an immediate and daily concern. Unreliable electricity grids and significant shortfalls in energy access can be a significant barrier to development, with knock-on effects on public services, livelihoods, and businesses [1]. In addition, the impacts of climate change are exacerbating some risks to energy security – for example by reducing the availability of hydropower.

It is therefore important for energy planning processes in LMICs to consider how future energy systems can improve security and resilience, as well as deliver environmental sustainability and affordability. A key challenge is that energy security is a multi-dimensional phenomenon that is open to a wide range of interpretations. While some perspectives focus exclusively on the risks of imported energy, others focus on the reliability of electricity grids or the exposure of countries to international markets for critical minerals.

This briefing discusses the results of a multi-dimensional energy security assessment for Kenya, and it sets out some policy implications of this assessment. The aim is to improve understanding of energy security synergies and trade-offs in Kenya, including how security could change as Kenya's energy system changes in future.

Methods

To carry out the assessment, an energy security indicator framework was adapted from a framework developed and applied to the UK by Emily Cox [2] and the UK Energy Research Centre [3]. The adaptation process was informed by a literature review of indicator frameworks that have been applied to LMICs [4–6] and discussions with research project partners in Kenya (EED Advisory) and Ghana (KNUST)[1]. The adapted framework groups indicators into four categories that are used in Cox's framework:

- Reliability, including supply–demand balancing within the electricity system
- Availability, including diversity of energy sources, imports, and supply routes
- Affordability, including average household energy costs and energy access rates
- Sustainability, with a particular focus on climate impacts (eg on hydro power)

The final indicator framework is summarised in **Table 1**. The final choice of indicators took into account the relevance of indicators to an LMIC country context and the availability of data or analysis tools that could be used to apply these indicators in Kenya. Most indicators are applied to the current Kenyan energy system, while some are also applied to potential future energy system scenarios. Published scenarios of the future energy system were used due to their familiarity to Kenyan analysts and decision-makers. They were analysed using a combination of the OSeMOSYS energy systems model (which is used to explore long-term scenarios) [7] and the FlexTool model (which focuses on electricity system balancing) [8].

[1] The analysis of Ghana's energy security is being carried out in a separate CCG project in collaboration with a team at Kwame Nkrumah University of Science and Technology (KNUST). The results will be published at a later date.

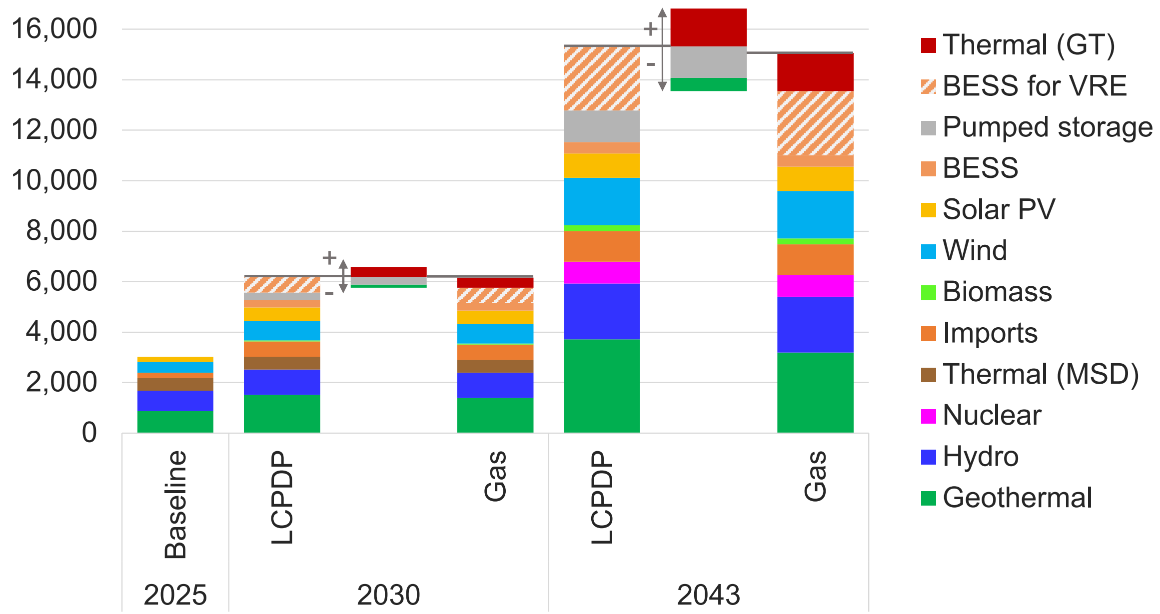
***Table 1.** Final set of energy security indicators*

Category	Indicator	Definition	Data Sources
Reliability	Electricity reliability	Annual duration of interruptions for average household customer (hours)	Energy and Petroleum Regulatory Authority [9]
	Electricity transmission and distribution (T&D) losses	Percentage of electricity lost between generation and supply to customers (%)	Energy and Petroleum Regulatory Authority [9]
	Derated capacity margin	Surplus installed generation capacity relative to expected demand (%)	International Energy Agency data [10]; OSeMOSYS modelling
	Electricity flexibility	Technical potential for matching electricity supply and demand in real time	FlexTool modelling
Availability	Energy diversity	Shannon-Wiener Index combines variety (the number of sources) with balance (the relative shares of these sources)	Energy Transition and Investment Plan [11]
	Electricity diversity	Shannon-Wiener Index combines variety (the number of sources) with balance (the relative shares of these sources)	Least Cost Power Development Plan [12]
	Import dependence and diversity	Imports of electricity (GWh) and oil products (kg), including sources and percentage of demand (%)	Kenya Power and Lighting Company [13] and World Bank World Integrated Trade Solution [14]
Affordability	Levelised cost of electricity	Average levelised cost of electricity (KSh/kWh)	OSeMOSYS modelling
	Average electricity tariffs	Published electricity tariffs (KSh/kWh)	www.Stimatracker.com [15]
	Energy access rates	Proportion of households with access to electricity: urban, rural and total (%)	World Bank Energy Sector Management Assistance Programme [16]
Sustainability	Climate impacts on hydropower	Gross hydropower capacity under 1.5 °C and 2 °C average warming (MW)	Paltán *et al.* [17]

Four future scenarios were analysed, which were taken from the Kenyan governments' Least Cost Power Development Plan (LCPDP) [12] and Energy Transition and Investment Plan (ETIP) [11]. The LCPDP is Kenya's electricity system expansion plan covering the period from 2024 to 2043. We modelled the LCPDP's Reference Scenario as well as a Gas Scenario. This is based on the LCPDP Scenario but includes some natural gas capacity to reflect Kenyan government plans for investment in gas-fired generation. The ETIP covers all energy sectors and has a longer time horizon, focusing on the period from 2020 to 2050. It includes Business as Usual (BAU) and Net Zero scenarios.

For electricity security indicators, we focused on the LCPDP scenarios, while for indicators relevant to the wider energy system, we used the ETIP scenarios.

***Figure 1.** LCPDP electricity sector scenarios modelled in FlexTool. The choice of technologies in LCPDP scenarios to be displaced by gas in the Gas Scenario was based on the difference between the LCPDP Reference and Low Demand scenarios. Note: BESS = Battery Energy Storage System; GT = Gas Turbine; MSD = Medium-Speed Diesel; PV = Photovoltaic; VRE = Variable Renewable Energy*



Finally, the results of the energy security assessment were presented and discussed with energy sector stakeholders at a workshop in Nairobi in February 2026.

Results

Kenya's energy system has some features in common with other LMICs: a high share of renewable electricity generation coexists with persistent energy access challenges, supply vulnerabilities, weak transmission and distribution infrastructure, and affordability constraints. The energy security assessment across four dimensions reveals both strengths and critical vulnerabilities that threaten energy security.

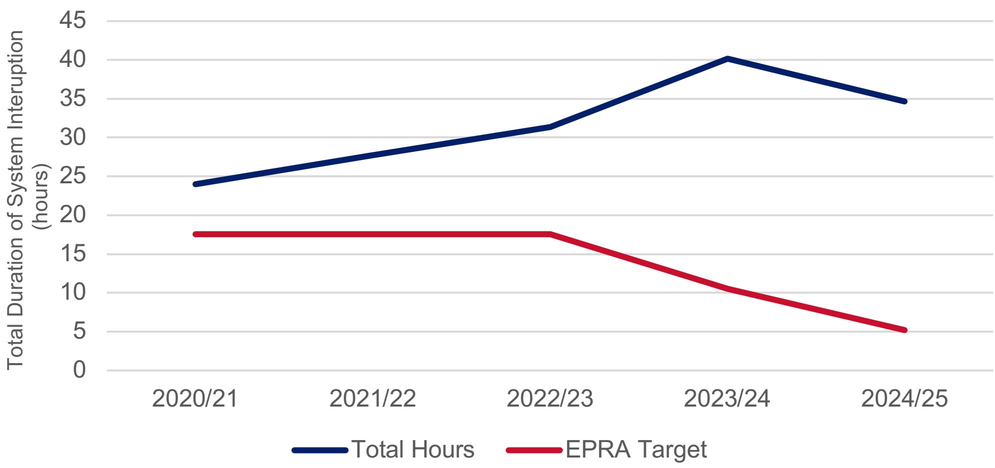
Reliability

Reliability assesses whether the electricity system can consistently meet power demand when needed. This is a fundamental challenge in LMIC contexts where generation deficits and fragile network infrastructure lead to frequent outages.

Electricity reliability

This indicator uses data published by the Energy and Petroleum Regulatory Authority (EPRA). It provides the annual duration of interruptions for the average household customer in hours [9]. **Figure 2** shows an upward trend in the duration of interruptions for an average household over the past few years. This has reached 30–40 hours per year and reflects a decline in reliability. The gap between this reality and the regulator's target has also grown.

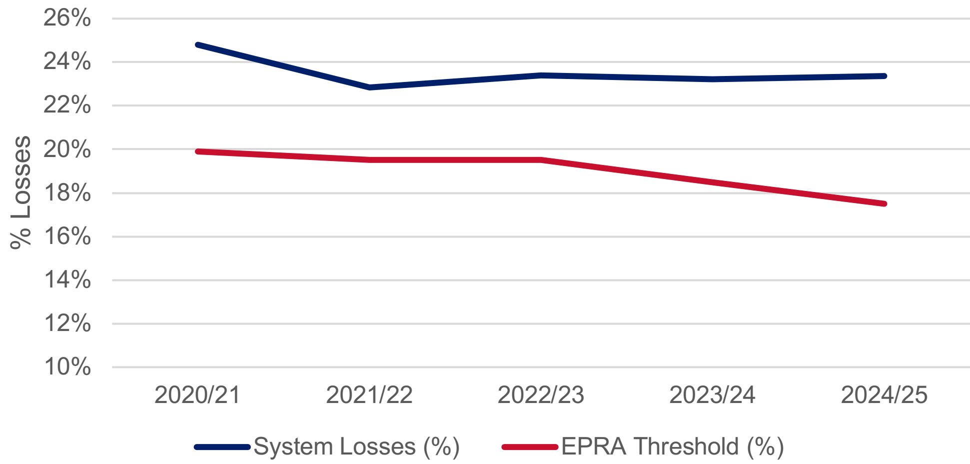
Figure 2. *Total hours of interruption for an average household consumer [9].*



Electricity transmission and distribution losses

This indicator measures the percentage of electricity lost between generation and supply to final consumers. High losses can indicate both infrastructure inefficiency, such as aged power lines and transformers, and non-technical losses (eg theft or poor metering). **Figure 3** shows that the annual losses have remained relatively stable at around 23%, and that the gap to the regulator's threshold is gradually increasing. This indicates the need for improvements to the grid and the need to tackle theft and other non-technical causes of system losses [9].

Figure 3. *Annual electricity system losses [9].*



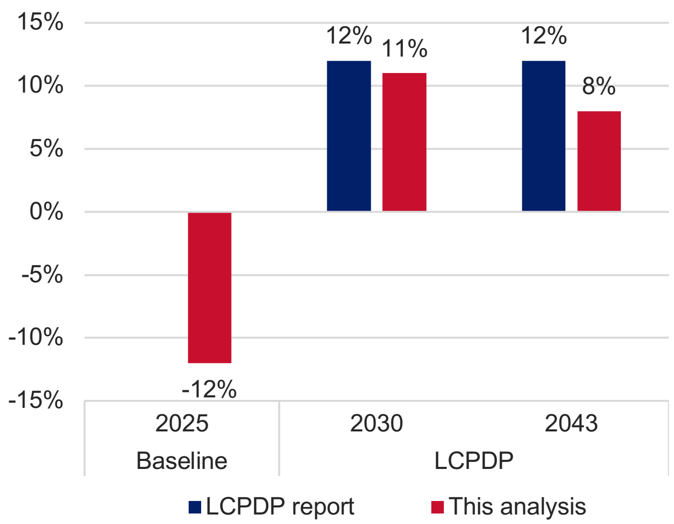
Derated capacity margin

The derated capacity margin is a measure of surplus installed capacity relative to expected demand [18]. The level of surplus is designed to ensure there is sufficient capacity given uncertainties in peak demand and availability of electricity generation. The installed capacity of each technology is derated using a factor which indicates the portion of nameplate capacity (the maximum rated output of a technology) that is reliably available during times of high system stress [18]. Variable renewable technologies (eg solar) tend to have much lower derating factors than those that can provide power when required (eg geothermal).

Figure 4 shows derated capacity margins for the electricity sector scenarios. In 2025, the Kenyan electricity system had a derated capacity margin of −12%, indicating insufficient capacity to meet demand throughout the year. This is consistent with observed load shedding and electricity rationing in Kenya and the electricity reliability data discussed above. While losses are high, an important cause is supply shortages [19].
For 2030 and 2043, the LCPDP reports a reserve margin of 12% for the Reference Scenario [12]. This value is broadly consistent with planning reserve margins in many electricity systems, which are typically 10–20% [18]. If achieved, this reserve margin would substantially improve system reliability.

Our analysis of the LCPDP scenarios found lower reserve margins than those reported by the LCPDP itself, particularly in 2043. This is because we used more conservative derating factors than the LCPDP for several technologies. This highlights the sensitivity of reserve margin to derating assumptions and the importance of considering uncertainty [18].

***Figure 4.** Derated capacity margins in 2025, 2030, and 2043. Authors' calculations using LCPDP scenario data and derating factors from a variety of sources.*



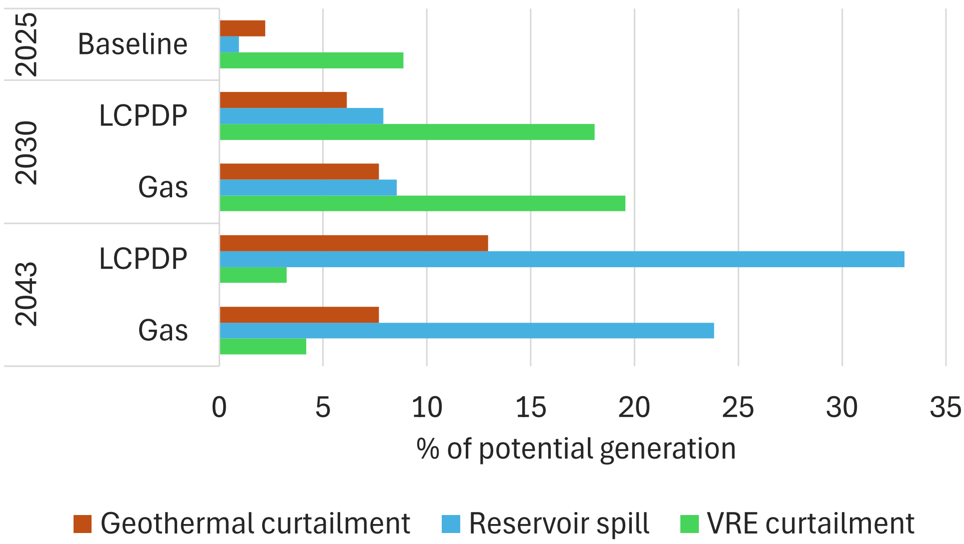
Flexibility

As electricity sectors transition towards high shares of variable renewable energy, increased power system flexibility is needed to accommodate fluctuations in renewable output [20]. Flexibility allows power systems to adjust generation, demand, storage, or network flows over different timescales, from sub-second to seasonal, to maintain the real-time balance between electricity supply and demand [20].

Flexibility modelling of the electricity sector scenarios for Kenya using FlexTool suggests that there would be sufficient technical flexibility to match supply and demand in real time. This is due to the LCPDP Scenario's diverse technology mix, which includes flexible technologies such as reservoir hydro, pumped hydro, and batteries. Therefore, while gas generation is a crucial source of flexibility in many electricity systems, the LCPDP Scenario has enough flexibility without it.

In addition to reliability, flexibility promotes economic efficiency by reducing curtailment [20]. However, as shown in **Figure 5**, the modelled systems have some curtailment of renewable energy[2]. The Gas Scenario exhibits higher renewable energy utilisation because a portion of the reserve margin is provided by gas capacity, whose unused capacity does not appear as underutilisation. A cost-optimised system generally has some amount of curtailment, and further modelling in FlexTool or another power system model could determine which levels of underutilisation are most cost-effective under different scenarios, as well as the potential role of demand response and sector coupling for improving utilisation in a cost-beneficial way [20].

***Figure 5.** Underutilisation of renewable energy resources in the electricity sector scenarios from FlexTool modelling. Geothermal potential generation is based on a 93% capacity factor. VRE includes run-of-river hydro.*



Availability

Availability indicators focus on the security of fuel and resource supply chains.

Energy and electricity diversity

Diversity of fuels, sources of fuels and electricity, and supply routes can all help to strengthen energy security. This indicator uses the Shannon-Wiener Index to represent the diversity of energy sources. A value closer to 1 indicates a less diverse system.

Figure 6 shows how diversity of Kenya's energy and electricity mixes could change from the current situation, using the ETIP scenarios (for energy) and the LCPDP scenarios (for electricity). Energy diversity increases over time in the BAU Scenario due to a steady reduction in the share of energy from biomass: from around 60% now to approximately 30% in 2045. It increases more quickly in the Net Zero Scenario because the shift away from biomass is faster, and this is accompanied by a shift from fossil fuels to a diverse mix of low carbon electricity.

[2] In practice, wind and solar generation in Kenya is prioritised due to take-or-pay contracts. Geothermal plants are usually curtailed first as a consequence of these contracts.

Electricity diversity does not change as much, but it increases under the LCPDP Scenario due to a greater variety and balance of renewable sources. Under the Gas Scenario, diversity is lower because gas generation displaces a combination of different renewables.

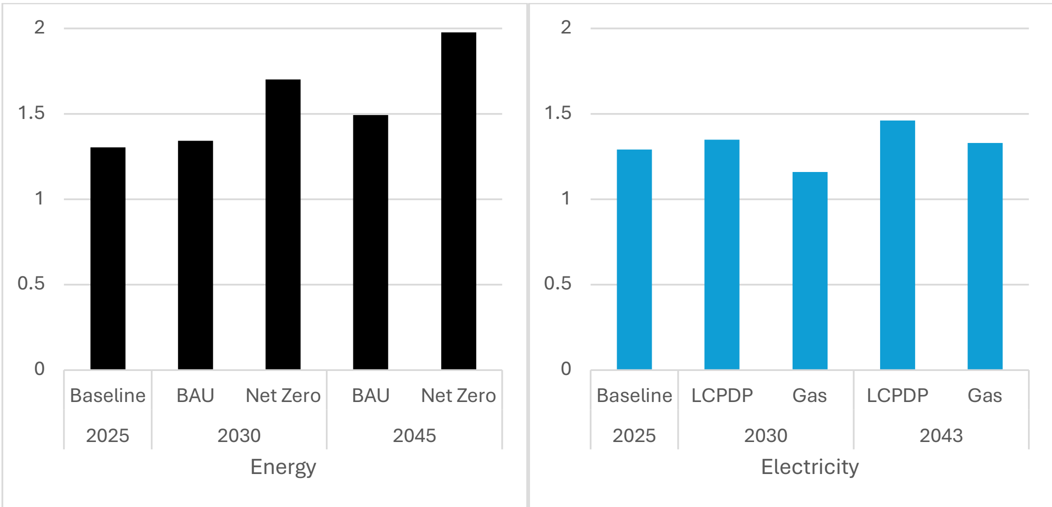


***Figure 6.** Shannon Wiener indices for energy and electricity under the modelled scenarios.*

Import dependence and diversity

This is a measure of reliance on external energy sources. While imports are not necessarily less secure than domestic sources of energy, they can build in reliance on unstable sources of supply. Additionally, they have important macro-economic implications for LMICs with limited foreign currency reserves. Historical data for electricity imports [13] and oil products imports [14] are shown in **Figure 7** and **Figure 8** respectively.

Imports of electricity have increased over the past few years, and they now account for 11% of electricity. The largest source of imports since 2022/23 has been Ethiopian Electric Power. Kenya has no local oil refining and processing, and it imports all its oil products. Figure 8 shows that while imports of oil products have reduced from 2019 and 2021 levels, Kenya remains reliant on a primary source, the United Arab Emirates (UAE). As the current conflict in the Middle East illustrates, the reliance on specific countries in this region is potentially risky.

***Figure 7.** Electricity imports by source [13].*

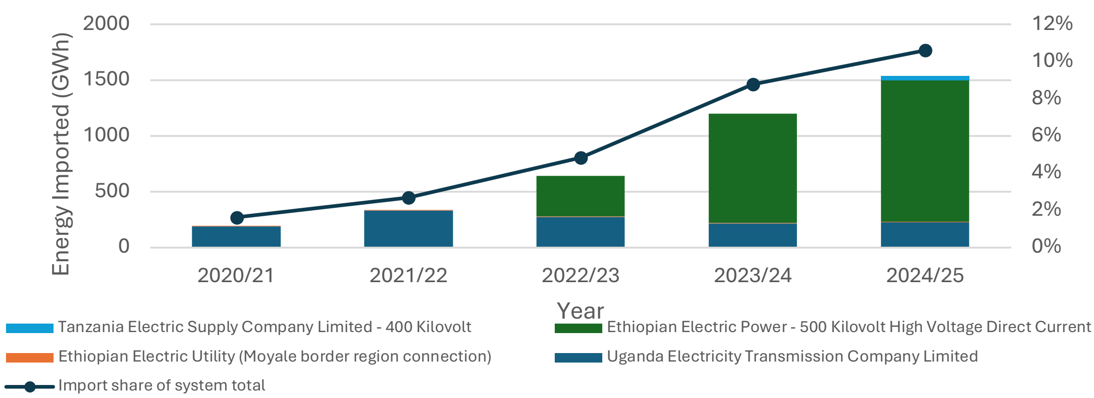
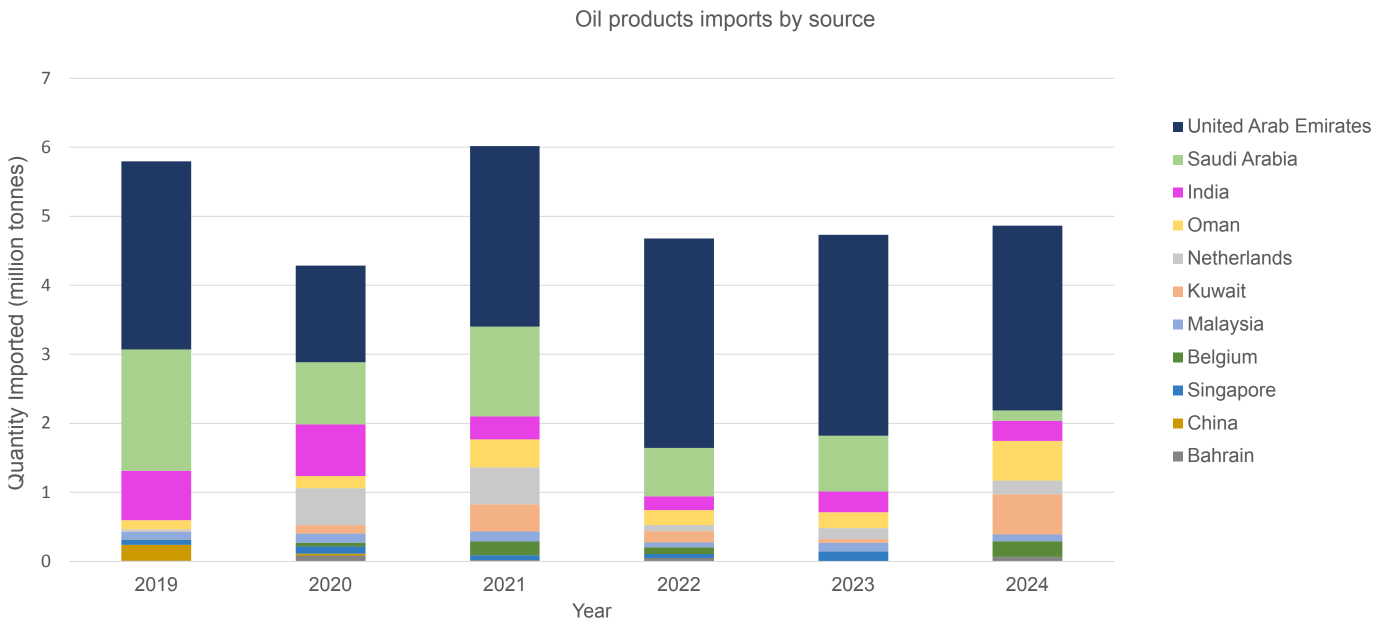


Figure 8. *Oil product imports by source. Note that only the top 11 exporters over this six year period are shown [14].*



Affordability

Affordability is an important dimension of many energy security definitions. Even if supplies and supply routes are reliable, high costs can limit the ability of some consumers to access energy services.

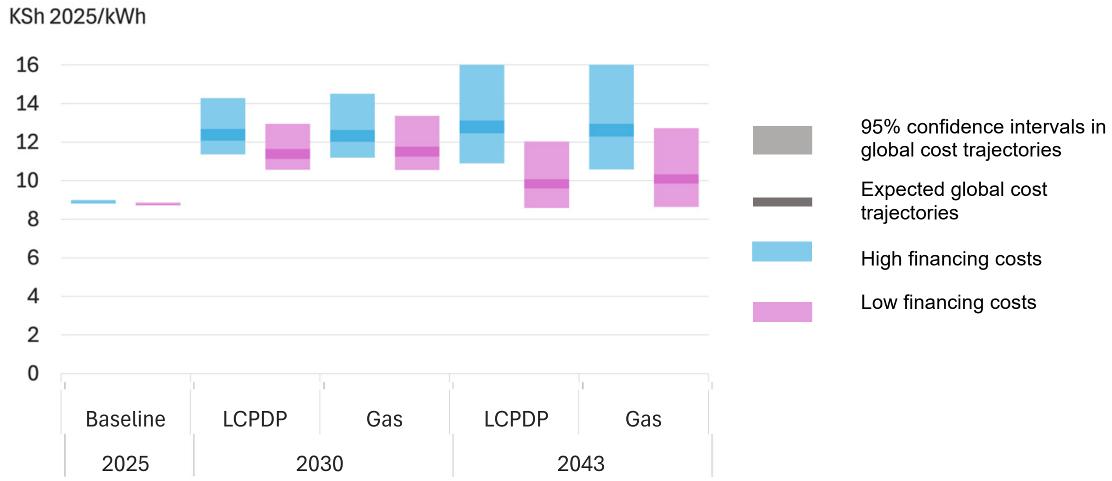
Levelised cost of electricity (LCOE)

While retail energy costs or bills are the most relevant indicator of affordability, one of the underlying drivers of these costs is the generation cost of electricity. A common measure of generation cost is the levelised cost of electricity (LCOE). This particular measure is relatively easy to calculate, but it has significant shortcomings, especially in electricity systems that have high shares of variable renewables. **Figure 9** shows the LCOE for the LCPDP Reference Scenario and the LCPDP Gas Scenario variant.

The LCOE generation in both scenarios is similar, owing to their similar capacity mixes. Expected LCOE increases from 9 to 12 KSh/kWh between 2025 and 2030 reflecting the investments required to increase the capacity margin. LCOE returns to near-baseline levels by 2043 if the cost of financing decreases to levels common in Europe today. This also reflects costs reductions due to technological learning for batteries, wind, and solar [21]. However, if financing costs (measured by the weighted average cost of capital) rise to 13%, the expected LCOE will continue increasing to 13 KSh/kWh.

As LCOE is highly dependent on the cost of capital, policies aimed at reducing financing costs are critical to affordability. These policies and the mix of technologies that are deployed could both have a significant impact on LCOE.

***Figure 9.** The levelised cost of electricity in Kenya under the modelled electricity scenarios. Excludes transmission and distribution as well as gas infrastructure costs. Base year capital, fixed, and variable costs for Kenya are from [22]; global technology and fuel cost trajectories are from [23]; cost of capital values for 2021 are from [24] and vary linearly to high and low values of 13% and 2% real, pre-tax weighted average cost of capital by 2050.*



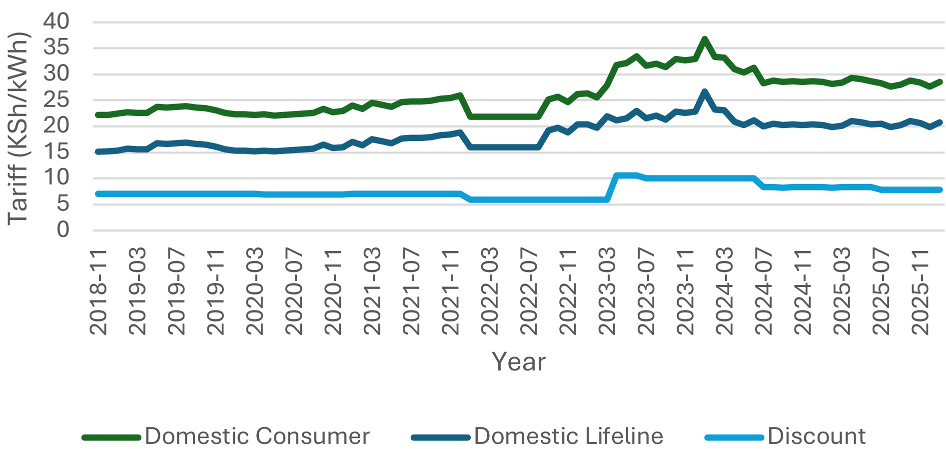
Average electricity tariffs

Modelling future energy costs for households and businesses is very difficult due to the number of variables involved. However, it is still useful to examine recent trends in household electricity tariffs and compare these to current and potential future electricity generation costs. The tariff data for Kenya was found from [Electricity cost in Kenya] [15]. These tariffs include a Foreign Exchange Rate Fluctuation Adjustment (FERFA) which accounts for the impacts of exchange rates on costs that are in a foreign currency.

In Kenya, the state plays a role in keeping costs down by providing a subsidised tariff to consumers who use less than 30 kWh per month. This tariff is shown in Figure 10 alongside the standard tariff. The subsidy is between 7 and 8 KSh per kWh.

Overall tariffs have increased since 2022 for three reasons: a scheduled review which increased all tariffs by 50%, depreciation of Kenya's currency against the US dollar, and an increase in the rate of VAT (value added tax).

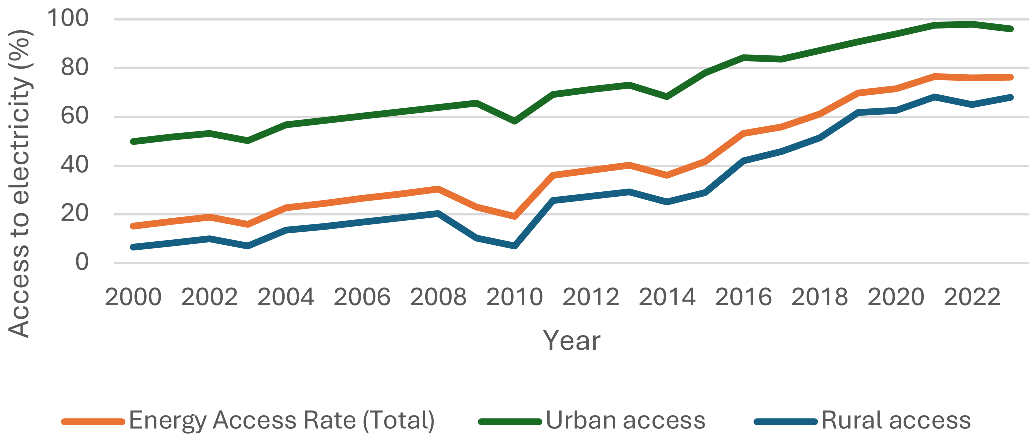
***Figure 10.** Subsidised versus standard domestic consumption tariff [15].*



Energy access

This indicator measures the proportion of households that have a connection to the grid or access to electricity via decentralised systems. Note that this simple measure of energy access does not include information about the reliability of the connection – or about what services households are able to access or afford [25]. The data is taken from the World Bank's Energy Sector Management Assistance Programme [16]. As shown in **Figure 11**, the overall energy access rate in Kenya has been improving, with a 76% access rate in 2023. The rate of electrification for urban areas is much higher than rural areas, with nearly 98% urban electrification rate versus a 65% rural rate in 2022. However, the gap has been steadily reducing.

Figure 11. *Energy access rates [16].*



Sustainability

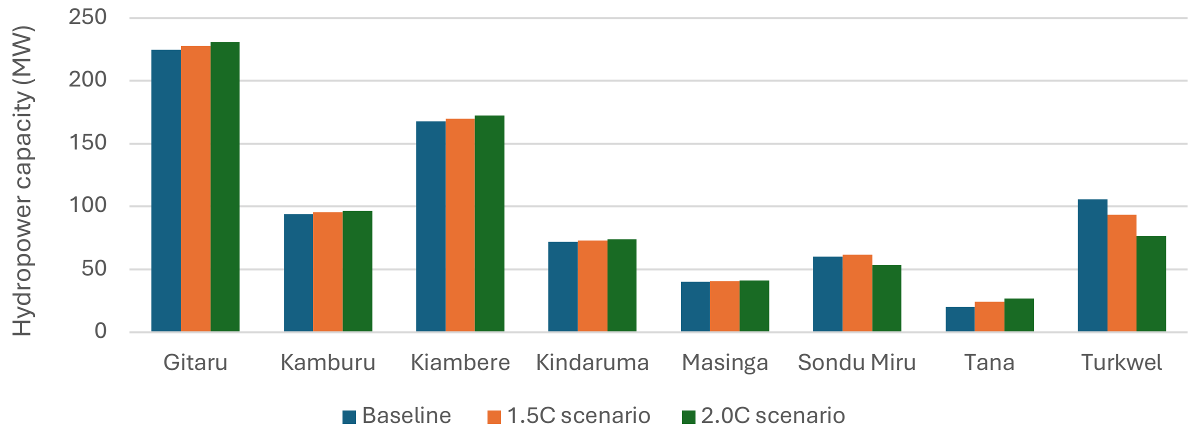
Sustainability evaluates the reciprocal relationship between the energy system and the environment – particularly the vulnerability of the energy system to natural resource constraints and to climate-driven disruptions. In this pilot study, only one aspect of sustainability is assessed: the potential impact of climate change on hydropower production. This reflects stakeholder feedback that identified this as the primary concern relative to other natural resource risks. Future research could expand the analysis to other climate and natural resource risks.

Climate impacts on hydropower

This indicator uses data from Paltan et al. [17] to show the potential change in hydropower generation in Kenya under 1.5 °C and 2 °C climate scenarios. This is based on climate scenarios that estimate the duration, intensity, and frequency of floods and droughts.

Under both scenarios, the hydropower capacity at most Kenyan plants increases slightly (**Figure 12**). However, one plant (Turkwel) could have a significant reduction in capacity – and therefore in output. It is important to note that while some plants have increased capacities, the higher water level in flood conditions could result in spillage rather than increased hydropower generation potential. This is because the reservoirs are too small to accommodate the increased water levels.

Figure 12. *Relative change in hydropower capacity [17].*



Key insights

The energy system in Kenya has significant energy security challenges. This briefing has highlighted some of the key risks that affect the system now, and how these risks could change in the medium and longer term.

The key insights from our analysis include:

1. Kenya's energy security challenges are particularly acute in the electricity system, where households experience outages of at least 30 hours per year. This is partly due to insufficient generation capacity, which is shown by the negative capacity margin. It is also exacerbated by high levels of transmission and distribution losses.
2. Diversity of the energy system is low, due to the large role biomass plays outside the electricity sector. While this does not necessarily constitute a security risk, dependence on biomass can lead to scarcity (eg of wood fuel) and negative impacts (eg indoor air pollution from cooking).
3. Energy diversity is significantly higher than electricity diversity. This is due to demand for bioenergy and oil products outside the electricity sector. Diversity is also higher in scenarios that shift more quickly to clean energy. It will be important to ensure that diversity remains an important goal as the electricity sector continues to expand.
4. Kenya depends on imports for both oil products, due to a lack of refining capacity, and electricity. While there is some diversity in these imports, specific sources are important for both – Ethiopian hydropower for electricity, and the UAE for oil products.
5. The price of electricity has risen since 2022, including the level of the lifeline tariff for households that use less than 30 kWh per year. There is likely to be upward pressure on electricity generation costs in the medium term due to the investment required to meet Kenyan demand. There will also be a need to invest in the electricity network to connect new generation, improve reliability, and reduce losses.
6. Energy access rates for both urban and rural households are improving steadily due to a combination of grid connections and off-grid investments. However, this does not necessarily mean that energy security is improving for all households since that depends on reliability and the extent to which

a grid connection provides access to the full range of affordable energy services.

7. Climate change and natural resource constraints could also pose a risk to energy security in Kenya. Climate change is expected to have particularly important impacts on hydropower generation in many countries. In Kenya, the evidence suggests that these impacts will be modest – and will only reduce capacity in some regions.

Based on this preliminary assessment, what are the implications for decision-makers in Kenya? We suggest three priorities.

First, there is a clear need for **more investment in the electricity sector** to meet demand and improve reliability. As the LCPDP Scenario illustrates, this investment can focus on expanding the use of renewable resources and minimising the use of fossil fuels. Further investment in variable renewables such as solar and wind should be accompanied by battery storage and/or other forms of flexibility. In addition to meeting environmental goals, this would also reduce the risk of sharp rises in electricity bills due to international fossil fuel price spikes. Many parts of the world are currently experiencing their second price shock in five years.

Second, there is a need to **achieve universal energy access while ensuring that households and businesses have access to the full range of affordable energy services**. This includes implementing Kenya's national and clean cooking strategies in full. While there has been very good progress with increasing electricity access, better evidence is required to understand the extent to which this access is having the desired impact on household energy security.

Third, decision-makers need to **pay particular attention to specific risks to energy security**. These include the risk of depending too much on particular sources of oil products. The current war between Israel, the US, and Iran has severely affected supplies from that region. There is also a risk that climate change will impact hydro capacity in countries that export electricity to Kenya (particularly Ethiopia). Both of these examples point to the need for a continuing focus on diversity – in sources, supply routes, and technologies.

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CRediT author statement

[1]**Watson, Jim** *(UCL, Institute for Sustainable Resources):* conceptualisation, analysis, writing.
[2]**Shah, Shiv** *(UCL, Institute for Sustainable Resources):* analysis, writing.
[3]**Richardson, Emma** *(UCL, Energy Institute):* modelling, analysis, writing.
[4]**Kitetu, Martin** *(EED Advisory)*: analysis, review.
[5]**Mbutura, Alois** *(EED Advisory):* analysis, review.
[6]**Pant, Raghav** *(Environmental Change Institute, University of Oxford):* data provision.

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