

Patterns, Purchases, and Policy: Understanding Domestic Electricity Use in Rural and Peri-Urban Uganda

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ABSTRACT

This study examines electricity consumption patterns among rural and peri-urban households in Uganda, using a dataset of over 150,000 domestic customer accounts. We combine descriptive analysis, policy simulation, and unsupervised clustering to assess consumption levels, purchasing behavior, and the impact of the lifeline tariff. Our results show that consumption is highly skewed: the median household uses just 20.6 kWh per month, the mean is 32 kWh, and many low-income households purchase electricity in fewer than seven months per year. Seasonal variation and the COVID-19 lockdown further shape purchasing behavior, particularly among poorer households. Policy simulations reveal that the lifeline tariff disproportionately benefits wealthier customers with regular purchasing habits, while many poorer households miss out on the subsidy due to irregular or bulk purchasing patterns. Clustering analysis identifies four distinct consumption trajectories—declining, rising, U-shaped, and peaking—linked to geography and expenditure levels. The findings underscore the need for energy access policies and subsidy designs that account for temporal variability, welfare status, and behavioral patterns to promote more equitable and effective electricity access.

KEYWORDS: electricity access, clustering, tariffs, low-income

1. Introduction

Access to reliable and affordable electricity is a cornerstone of socio-economic development, yet millions of households across Sub-Saharan Africa (SSA), particularly in rural and peri-urban areas, remain underserved in terms of both connection and consumption. In Uganda, efforts to expand electricity access over the past two decades have significantly increased the number of grid-connected households, primarily through public-private partnerships and rural electrification initiatives ([ADB, 2015](#)). However, connection alone has not guaranteed meaningful or sustained use of electricity. Many newly connected households exhibit low and irregular consumption, raising important questions about the effectiveness of policies designed to promote energy equity.

In this context, understanding how electricity is consumed, not just whether it is consumed, has become a critical focus of energy access research. Studies have increasingly shown that post-connection behavior varies substantially across income groups, seasons, and geographic areas, often reflecting broader structural constraints such as affordability, agricultural

cycles, and access to appliances ([Fink et al., 2020](#); [Lee et al., 2020](#); [Tamele et al., 2025](#)). In response, electricity utilities and policymakers have adopted measures such as lifeline tariffs, subsidized rates intended to support low-income users, to address affordability barriers. Yet the actual impact of these interventions remains unclear, particularly in settings where household purchasing behavior is shaped by irregular incomes and patterns.

This paper contributes to this growing body of research by analyzing electricity consumption patterns among customers of the Uganda Electricity Distribution Company Limited (UEDCL). Established in 2001 and initially operating alongside a private concessionaire Umeme Limited, UEDCL assumed full operational control of Uganda's electricity distribution network in 2025, marking a major transition in the country's energy sector ([Reuters, 2025](#)). Prior to this takeover, UEDCL's customer base primarily consisted of rural and peri-urban households, offering a valuable window into consumption dynamics outside of major urban centers.

Using a dataset of over 150,000 customers with monthly consumption records spanning 2019 to 2023, we explore several core questions: (1) What is the nature and distribution of electricity usage among domestic customers? (2) How frequently do customers purchase electricity, and how is this behavior shaped by seasonality, income, or external shocks? (3) To what extent does the design of a lifeline tariff succeed in reaching the poorest consumers? (4) What underlying patterns of consumption behavior can be uncovered through unsupervised clustering techniques?

To answer these questions, we employ a combination of descriptive statistics, policy scenario simulations, and unsupervised machine learning techniques. We begin by profiling UEDCL's historical role and customer base, focusing on customers connected before 2019 to ensure full data coverage and behavioral stabilization. We then analyze key features of domestic consumption, its distribution, frequency, and seasonality across energy expenditure quartiles. Our analysis of the lifeline tariff simulates alternative billing scenarios to evaluate its effectiveness in reaching energy-poor customers. Finally, we use clustering methods to uncover latent behavioral patterns in monthly electricity consumption, capturing how different customers respond to policy changes and macroeconomic shocks over time.

Our findings show that while the vast majority of UEDCL customers are classified as domestic, their aggregate consumption is significantly lower than that of commercial or industrial users. Electricity usage among domestic customers is highly skewed, with a median of only 20.6 kWh/month and an average of 32 kWh/month, and pronounced heterogeneity in both volume and frequency of use. Seasonal trends, likely driven by Uganda's agricultural calendar, income fluctuations, and cultural events, further underscore the importance of context-sensitive energy planning. Moreover, we find that the current design of the lifeline tariff inadvertently penalizes irregular, low monthly average consumers, thereby excluding many of the poor from receiving intended subsidies. Clustering results reveal distinct behavioral archetypes, rising, declining, U-shaped, and peaking consumption, which vary by geography and expenditure level.

These insights have important implications for electricity tariff design, targeting of subsidies, and broader energy access strategies. As Uganda and other countries in the region strive toward universal electrification, understanding how customers actually engage with electric-

ity post-connection is essential for crafting interventions that are not only equitable but also financially and operationally sustainable.

2. A History of UEDCL

The UEDCL was established on April 1, 2001, as part of the unbundling of the Uganda Electricity Board (UEB), a process mandated by the Electricity Act of 1999 to liberalize Uganda's electricity sector. The reform created separate entities for generation, transmission, and distribution, with UEDCL designated to own and manage the distribution network operating at voltages of 33 kilovolts (kV) and below ([UEDCL, 2025](#); [World Bank, 2000](#)).

To attract private investment and improve efficiency, the Government of Uganda entered into a 20-year concession agreement with Umeme Limited, effective March 1, 2005. Under this arrangement, Umeme operated, maintained, and expanded the distribution network, while UEDCL retained ownership of the infrastructure and monitored compliance with concession terms. The concession aimed to facilitate investment, reduce technical losses, and enhance service delivery ([ERA, 2025](#)).

During the concession, UEDCL managed approximately 5% of the national grid, primarily rural and peri-urban networks where private investment was less viable. The company also oversaw off-grid networks in specific districts, completed grid expansion projects initiated by the Rural Electrification Agency, and operated electric pole treatment ([UEDCL, 2025](#)).

As the concession neared its conclusion in 2025, the Government of Uganda opted not to renew the agreement. UEDCL thus resumed full responsibility for the country's electricity distribution, marking a major transition in Uganda's power sector as the company now leads efforts to ensure reliable and efficient power delivery amid rising national demand ([Otim Deo, 2025](#); Reuters, 2025).

3. Data

This study utilizes a dataset acquired in 2024, prior to the expiration of Umeme's concession, and therefore covers only customers who were served by UEDCL before the national grid takeover. The dataset contains monthly electricity consumption records for approximately 150,000 customers spanning the years 2019 to 2023. For each customer, the dataset includes the geographical location (service territory and district), the date of connection to the UEDCL grid, and the customer category (classified as domestic, commercial, industrial, or street lighting). The customer base is overwhelmingly domestic, with 97% classified as domestic customers, 2.5% as commercial, and the remaining 0.5% as industrial or street lighting.

UEDCL's operational footprint is organized into regional service territories, which are mapped in Figure 1. Prior to resuming full control of the national distribution network, UEDCL primarily operated in rural and peri-urban areas, with limited presence in major urban centers such as Kampala. Figure 2 illustrates the inverse relationship between district urbanization and customer density. Each scatterpoint represents a district served by UEDCL in the dataset; rural districts tend to account for a larger share of UEDCL customers, while urban districts are comparatively underrepresented.

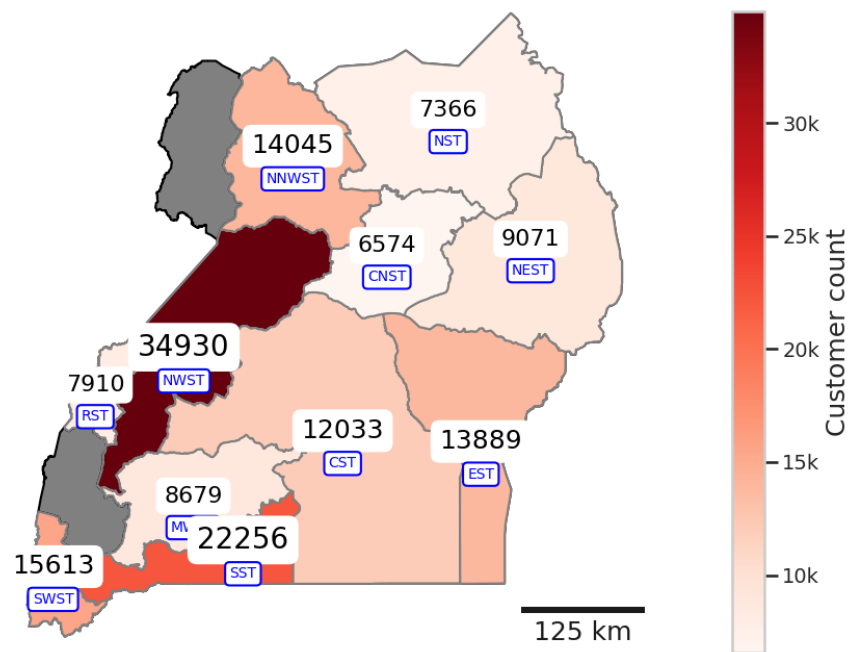


Figure 1. Map of Uganda showing the distribution of customers across UEDCL service territories. Each territory is labeled with its abbreviation (e.g., NWST for North West Service Territory) and total customer count. Color intensity represents relative customer density, with darker shades indicating higher numbers.

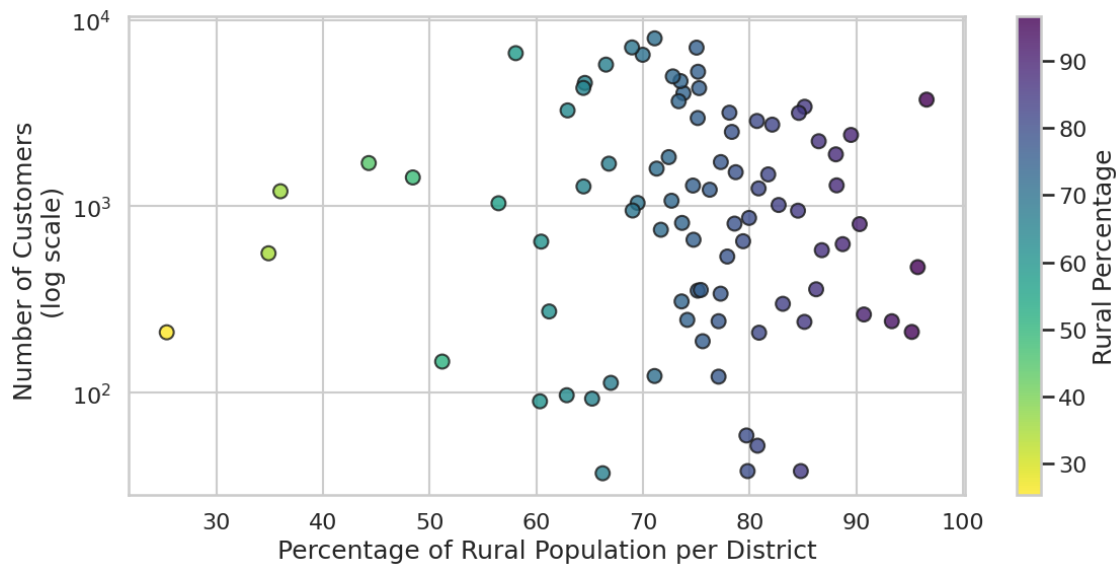


Figure 2. Relationship between district rural population share and number of UEDCL customers. Each point represents a district served by UEDCL. The x-axis shows the percentage of the rural population per district; the y-axis (log scale) indicates the number of UEDCL customers in that district.

For the remainder of this analysis, we focus on customers connected to the grid prior to 2019. This selection ensures a complete five-year consumption history (2019–2023) for each customer. We further exclude customers with gaps of 12 months or more in their recorded consumption during this period. Applying these criteria yields a refined analytical sample of approximately 49,000 customers. This filtering approach reflects evidence that electricity consumption typically stabilizes within the first three months following grid connection, as households acquire appliances and integrate electricity into daily routines ([Mugenyi et al., 2025](#)).

The following sections focus primarily on domestic customers, employing descriptive statistics and clustering techniques to characterize their consumption and purchasing behaviors.

4. Domestic Consumption

This section examines electricity consumption patterns among domestic customers. It compares their usage with non-domestic categories, analyzes variation in consumption levels and purchasing frequency, and explores seasonal dynamics.

4.1. *Domestic vs. Non-Domestic Consumption*

To contextualize domestic consumption, we begin with a comparison against non-domestic users. Domestic users make up 97.4% of the customer base but account for just 55% of total consumption. In contrast, commercial customers, who represent only 2.5% of users, consume nearly 40% of the electricity. Medium industrial users, though just 0.04% of all customers, account for 5.4% of consumption.

These disparities underscore the highly skewed nature of electricity demand, where a small share of commercial and industrial customers drives a disproportionate share of consumption. This pattern is consistent with findings across Uganda and Sub-Saharan Africa, where electricity use is concentrated among economic actors rather than households. ([Mawejje & Mawejje, 2016](#)) note that Uganda's electricity demand is dominated by commercial and industrial users, even though the majority of connections are to households. These imbalances have important implications for tariff design, cross-subsidization, and the financial sustainability of utilities operating in predominantly residential and low-income areas.

4.2. *Distribution of Domestic Consumption*

Figure 3 shows the distribution of average monthly electricity consumption among domestic customers. The data are strongly right-skewed: while some households consume substantial amounts of electricity, many use relatively little. The median household consumes just 20.6 kWh per month, well below the mean of 32.05 kWh, underscoring the predominance of low-consuming households. At the median level, a typical household could power basic lighting, charge phones, operate a television, and run a fan, but would lack sufficient energy for higher-demand appliances such as refrigerators or electric cooking equipment.

This skewed distribution reflects broader trends in the energy access literature, which emphasize that grid connection alone does not translate into high or reliable electricity use.

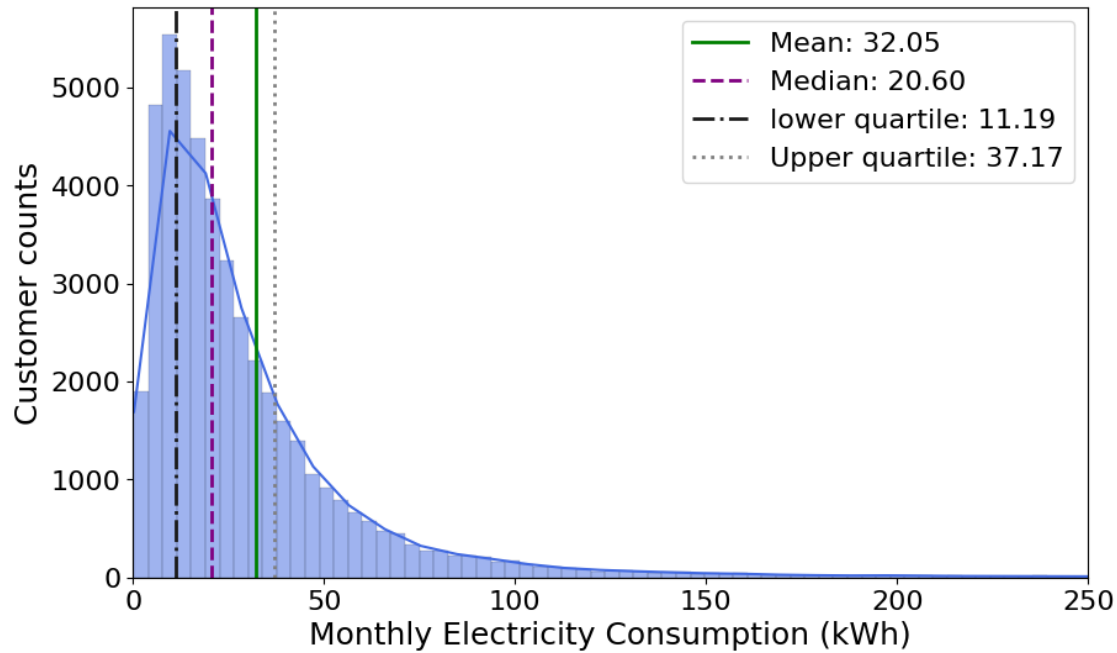


Figure 3. Distribution of average monthly electricity consumption (kWh). Summary statistics: mean = 32.05, median = 20.60, lower quartile = 11.19, upper quartile = 37.17.

Prior studies (Lee et al., 2020; Lenz et al., 2017; Masselus et al., 2024) have shown that rural and low-income urban households often remain in the low-consumption category due to affordability constraints, appliance scarcity, and unreliable supply.

To explore heterogeneity within the domestic customer base, we divide households into four energy quartiles based on their average monthly usage. These quartiles serve as proxies for household welfare, consistent with the literature using electricity consumption as an indicator of financial wellbeing and living standards (Pachauri & Spreng, 2004; ul Husnain et al., 2021). Households consuming below 11.19 kWh/month are categorized as “energy poor,” while those above 37.17 kWh/month are classified as “energy rich.” Table 1 presents the full classification.

Table 1. Categorization of domestic customers by average monthly electricity consumption.

Energy Quartile	Consumption Range (kWh/month)
Energy Poor	≤ 11.19
Lower-Middle	$11.19 < X \leq 20.6$
Upper-Middle	$20.6 < X \leq 37.17$
Energy Rich	> 37.17

4.3. Electricity Purchasing Behavior

Patterns in electricity purchases offer further insight into domestic usage, especially in prepaid metering contexts. Figure 4 displays the average number of purchase months per year

between 2019 and 2023, disaggregated by energy quartile.

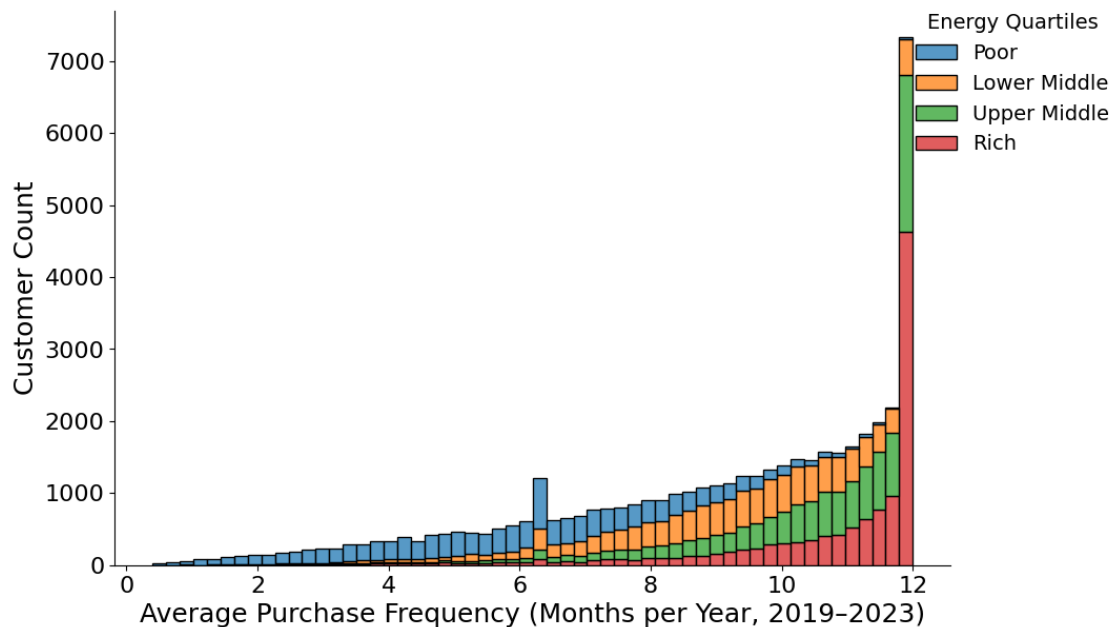


Figure 4. Electricity purchasing behavior by energy expenditure quartile, 2019–2023. Poor households purchase electricity less regularly, with many buying in fewer than seven months per year. Wealthier households exhibit more consistent purchasing patterns, supporting stable energy use.

Clear disparities emerge across energy quartiles. Customers in the lowest quartile are overrepresented among those purchasing electricity fewer than seven months per year, suggesting inconsistent or seasonal usage is likely linked to income variability or reliance on alternative energy sources. In contrast, “energy-rich” households more often purchase electricity in all twelve months, indicating both higher financial capacity and more stable electricity needs, such as refrigeration.

These differences align with the energy stacking literature, which shows that lower-income households frequently combine grid electricity with other energy sources, while wealthier households tend to rely more consistently on the grid (Dumga & Goswami, 2023; Wernecke et al., 2024).

The heterogeneity in purchasing frequency challenges assumptions that electrification guarantees consistent or modern energy use. These findings underscore the need for electrification strategies that go beyond connection targets to address affordability, appliance ownership, and long-term consumption behavior.

4.4. Seasonal Variation in Electricity Purchases

Figure 5 illustrates monthly electricity purchasing patterns across household energy expenditure quartiles. Each boxplot represents the number of customers making at least one electricity purchase in a given month, aggregated across the years 2019–2023.

A clear seasonal pattern emerges across all quartiles, except the Rich, characterized by a surge in purchases during December and January, followed by a marked decline in February.

These fluctuations reflect increased household expenditure during the holiday season, likely driven by remittances, income bonuses, and heightened household activity.

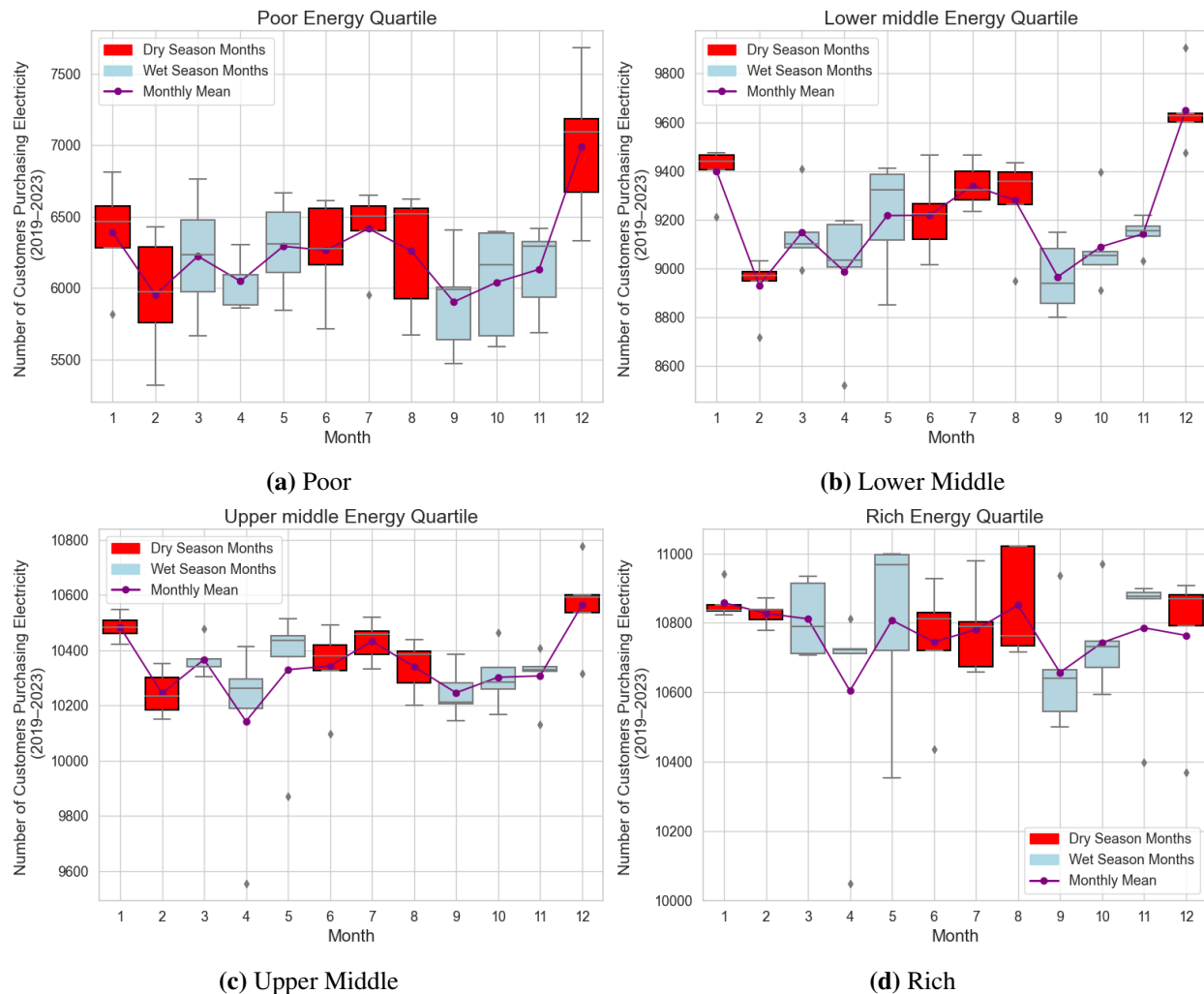


Figure 5. Monthly seasonality in electricity purchasing behavior across energy quartiles, 2019–2023. Each panel shows the number of customers making at least one electricity purchase in each month, disaggregated by energy expenditure quartile. Boxplots depict the distribution across five years; the purple line indicates the monthly mean. Dry-season months are shown in red; wet-season months are shown in blue.

Another notable pattern is the consistent dip in electricity purchases each September across all quartiles. This seems to align with Uganda’s agrarian calendar, as the short rains (September–November) mark the start of a major planting season (Mubiru et al., 2018; Nimusiima et al., 2023). During this period, rural households often redirect financial resources toward agricultural inputs, constraining discretionary spending on electricity.

This seasonal effect is reinforced by Uganda’s economic structure, where approximately 70% of the population engages in agriculture (Statistics, 2016), and 78% live in predominantly rural areas (Fowler & Rauschendorfer, 2019). As (Fink et al., 2020) note, limited savings and credit options restrict households’ ability to smooth consumption across “lean” pre-harvest months, exacerbating income volatility and reducing non-essential spending.

A sharp decline in purchases is also evident in April 2020, coinciding with Uganda's COVID-19 lockdown. The lockdown disrupted incomes, particularly among informal and agricultural workers. Studies by (Musoke et al., 2024) and (Kansiime et al., 2021) document the resulting declines in household purchasing power and food security, which likely suppressed electricity spending.

Conversely, purchases rise modestly between May and August, particularly among Lower Middle and Upper Middle quartile households. This period follows the long rains' harvest, when agricultural sales improve household liquidity (Kabir, 2023).

Rich quartile customers exhibit more stable purchasing patterns year-round, reflecting higher and more predictable incomes and less dependence on agriculture. However, even this group displays a September dip, indicating that seasonal factors affect consumption across income levels.

Overall, these patterns highlight how household energy use is shaped by agricultural seasonality, climatic cycles, and economic shocks. Recognizing these dynamics is critical for designing energy access and tariff policies that address household vulnerability and seasonal demand variation.

5. Lifeline Tariff Policy

Many SSA countries implement lifeline tariffs, which are subsidized electricity rates intended to enhance affordability for low-income households (Foster & Witte, 2020). In Uganda, UEDCL introduced such a tariff in July 2021, applying a subsidized rate of UGX 250 per kWh to the first 8 kWh consumed monthly by domestic customers (UEDCL, 2021).

While intended to alleviate energy poverty, lifeline tariffs often benefit higher-income households disproportionately. Wealthier users typically consume electricity more consistently and in larger volumes, enabling them to capture a greater share of the subsidy, while poor households with irregular consumption patterns frequently miss out (Briceño-Garmendia & Shkaratan, 2011; Klug et al., 2022; Tsimpo & Wodon, 2016). Additionally, shared metering further disadvantages poor households. In many low-income settings, multiple households share a single meter, and miss out on subsidized tariff rates (Kojima & Trimble, 2016).

Even when individual metering is in place, tariff structures can remain regressive. Wealthier households, though consuming well beyond the lifeline block, still enjoy subsidized rates on their initial usage. In Kenya, for example, when the lifeline band covered 0–100 kWh (2018–2023), about 71% of residential customers benefited, far exceeding the share of poor households (EPRA, 2025). Similarly, in Tanzania, the lifeline tariff does not effectively target the poor (Peng & Poudineh, 2016).

To evaluate UEDCL's lifeline tariff impact, we analyze two scenarios:

- **Scenario 1:** The current structure, where all domestic customers receive a lifeline subsidy for their first 8 kWh each month.
- **Scenario 2:** A counterfactual where consumption is averaged monthly, assuming consistent purchases and the same tariff structure.

Figure 6 shows the distribution of total electricity expenditures per customer from July

2021 to December 2023, grouped by energy expenditure quartile.¹ For each customer, expenditures over this period are summed to create an individual total, from which the distributions are constructed. Under Scenario 1, poor households often forgo lifeline subsidies due to irregular and bulk purchasing patterns, resulting in higher effective expenditures. Scenario 2 demonstrates that consistent monthly purchases would enable these households to fully benefit from the lifeline rate and reduce costs. In contrast, wealthier households exhibit minimal differences between scenarios, as their regular purchasing patterns already ensure uninterrupted access to the subsidy.

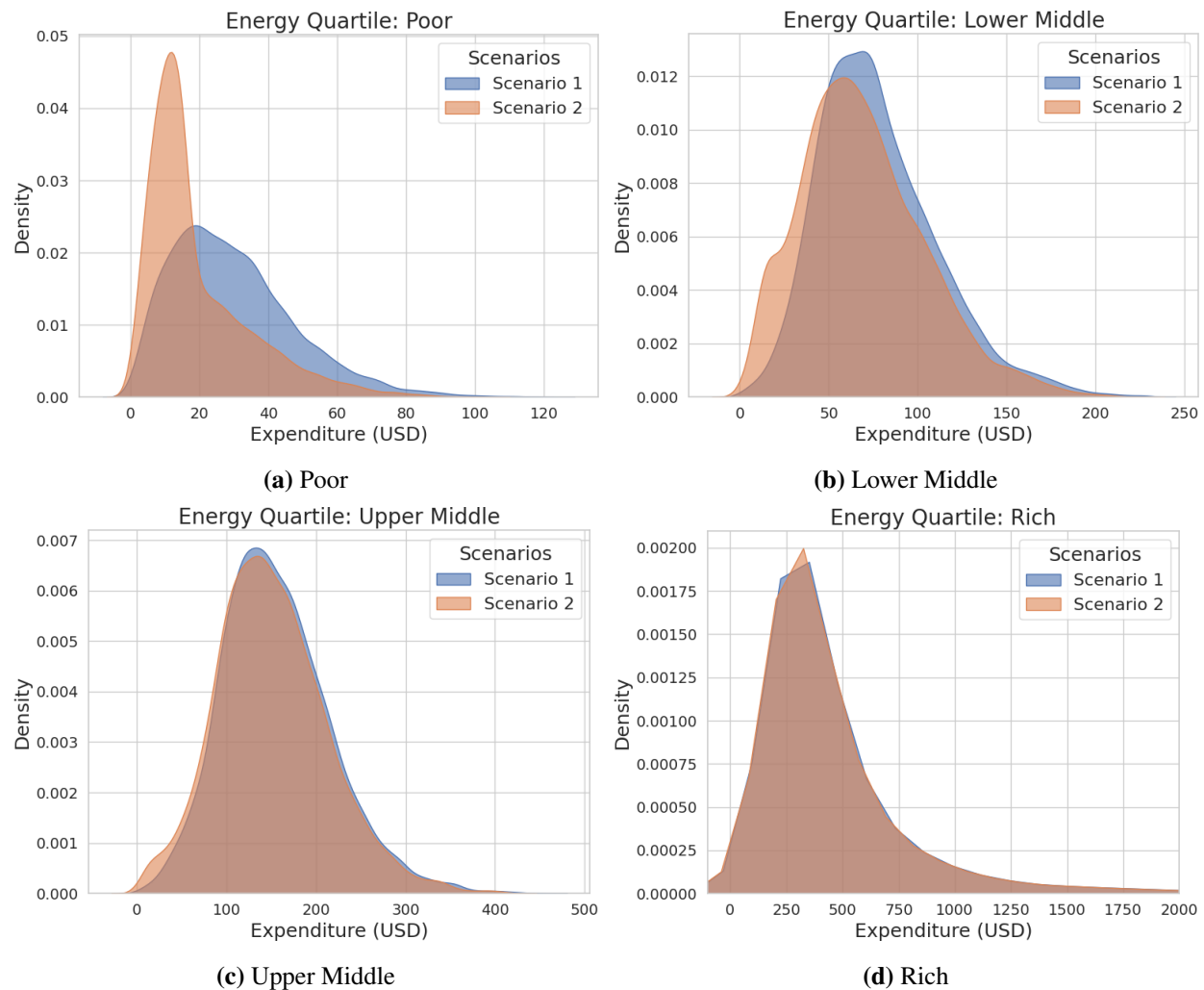


Figure 6. Distribution of customer electricity expenditures under two tariff scenarios, disaggregated by energy expenditure quartile. Each panel shows expenditures for: Poor, Lower Middle, Upper Middle, and Rich customers.

These results echo prior research showing that lifeline tariffs often fail to effectively target the poorest. In Addis Ababa, for example, the poorest quintile received just 12% of electricity subsidies, while the richest quintile received 31% (Cardenas & Whittington, 2019a,

¹Expenditures are converted to USD using an exchange rate of 1 USD = 3,600 UGX.

2019b).

UEDCL's current tariff structure likely unintentionally penalizes low-income customers with irregular purchasing patterns, undermining the policy's equity objectives. To improve targeting, policymakers could explore mechanisms that account for consumption variability, such as geographic targeting or adjusting eligibility based on purchase frequency.

6. Clustering of Customer Monthly Consumption

To uncover latent consumption patterns among domestic electricity users, we applied unsupervised machine learning techniques to monthly electricity consumption data from 2019 to 2023. Analyzing such high-dimensional time series presents challenges due to the "curse of dimensionality" (Bellman & Kalaba, 1959), which can weaken the effectiveness of distance-based clustering methods. To mitigate this, we first standardized each customer's time series using Z-normalization and then applied Principal Component Analysis (PCA) to reduce dimensionality while preserving key variance in the data. We then performed K-Means clustering on the PCA-transformed data, selecting four clusters ($K = 4$) based on visual inspection of within-cluster variation (Okereke et al., 2023).

Figure 7 presents the resulting clusters, each depicting the average standardized monthly electricity consumption trend over time. Two key events, the COVID-19 lockdown (April 2020) and the introduction of the lifeline tariff (July 2021), are annotated to help contextualize observed shifts in consumption.

The clusters reveal substantial heterogeneity in household electricity consumption dynamics. Cluster 1 exhibits a steady decline in consumption over time, while Cluster 2 shows a consistent upward trend following the COVID-19 lockdown. Cluster 3 follows a U-shaped trajectory, with declining consumption that reversed after the introduction of the lifeline tariff. In contrast, Cluster 4 peaks around mid-2021 before declining from early 2022 onward.

Figure 8 highlights the geographic distribution of these patterns. Cluster 3 is the most prevalent across many territories, particularly in SWST and CNST, where a large share of low-consuming households increased their usage after the lifeline tariff was introduced. In this analysis, households consuming below the national median of 20 kWh per month are classified as low consumers, while those consuming above this threshold are considered high consumers. Cluster 2 is predominantly associated with high-consuming households in CNST, EST, MWST, NEST, and NNWST, reflecting steadily increasing electricity use in these regions. By contrast, Clusters 1 and 4 are more evenly distributed across the service territories.

Overall, the clustering results demonstrate that electricity consumption behavior varies across both geography and welfare status. These patterns highlight the importance of tailoring energy access policies and tariff structures to account for heterogeneous customer needs and evolving consumption trajectories.

7. Discussion

This study provides new empirical insights into electricity consumption behavior among rural and peri-urban households in Uganda, based on a large dataset of UEDCL customers from

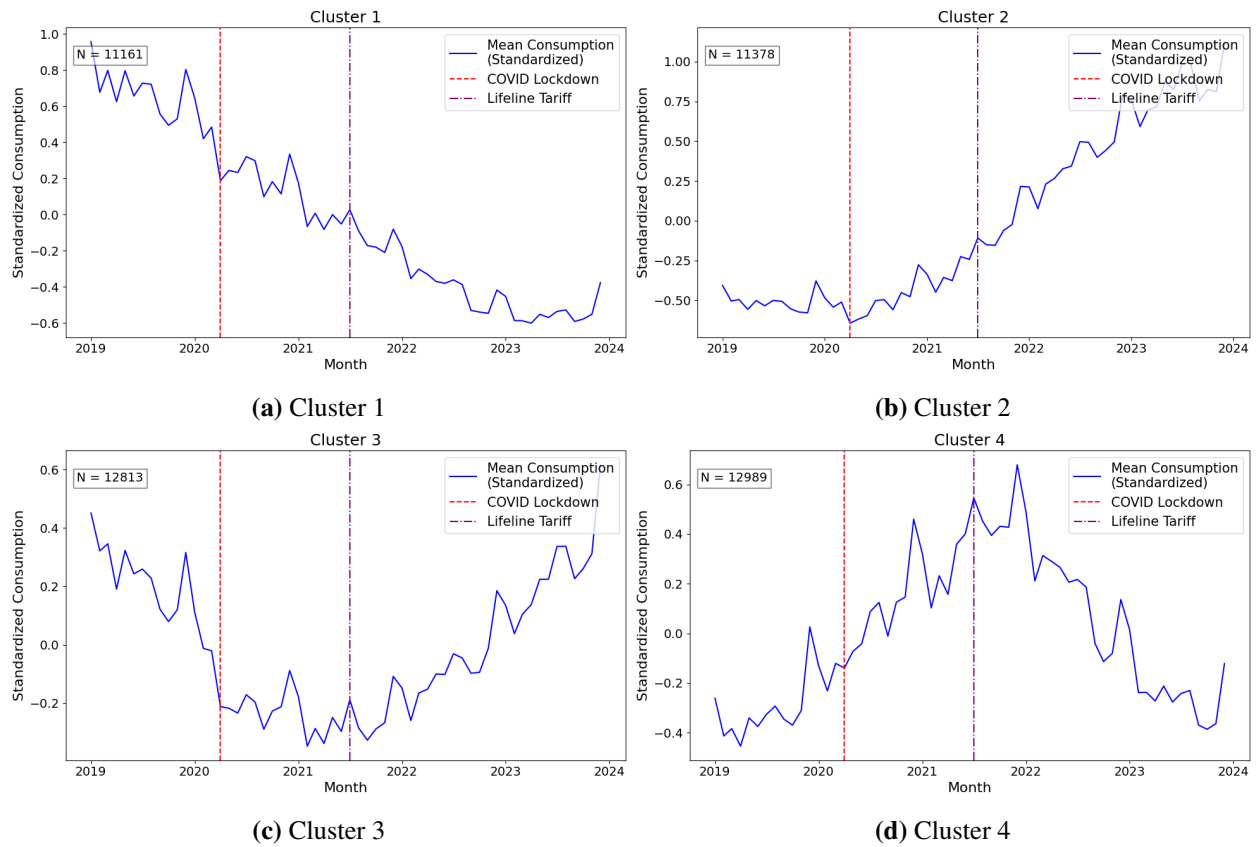


Figure 7. Trends in standardized monthly electricity consumption across four household clusters, 2019–2023. Each panel shows average standardized consumption over time. The COVID-19 lockdown (April 2020, red dashed line) and introduction of the lifeline tariff (July 2021, purple dash-dot line) are indicated.

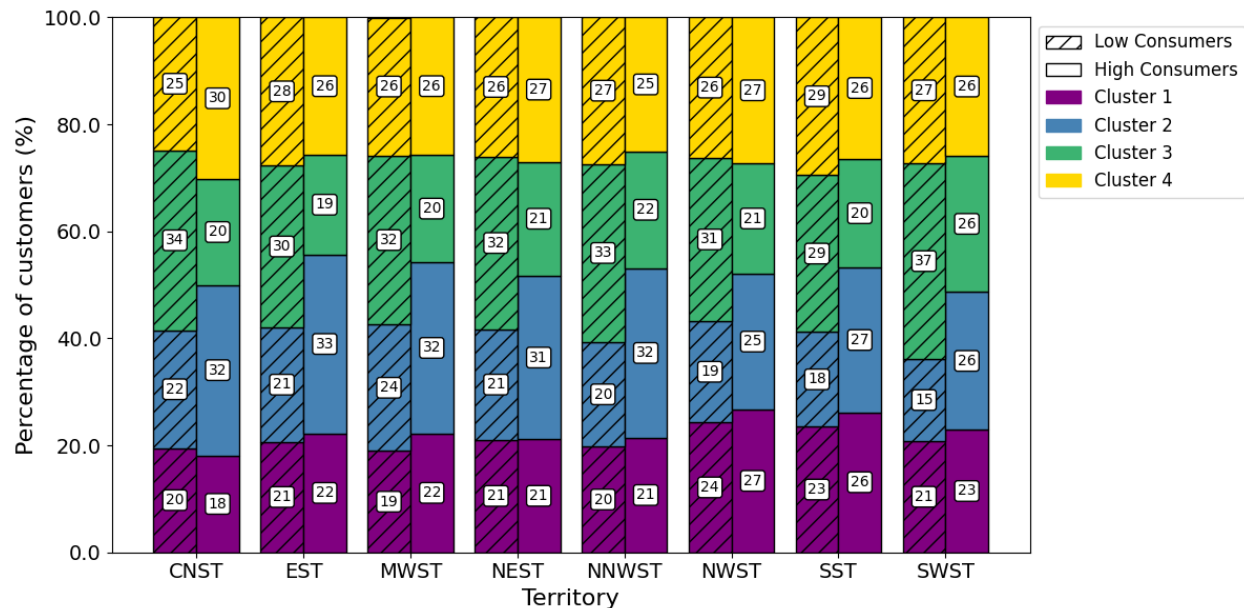


Figure 8. Distribution of electricity consumption clusters across UEDCL service territories, segmented by consumption level. Bars show the percentage of customers in each cluster (1–4) per territory, with low consumers (<20 kWh/month, hatched) and high consumers (≥ 20 kWh/month, solid).

2019 to 2023. The findings reveal substantial heterogeneity in both the volume and regularity of household electricity use, with important implications for energy equity, subsidy design, and distribution planning.

Domestic customers account for over 97% of UEDCL’s customer base but just 55% of total electricity consumption. Among domestic users, consumption is highly skewed: the median household consumes only 20.6 kWh per month, and many purchase electricity in fewer than seven months of the year. Notably, more than half of domestic customers consume at or below the Tier 3 “meaningful access” threshold (21 kWh/month) defined in the Multi-Tier Framework (Bhatia & Angelou, 2015), highlighting that grid connection alone has not yet translated into fully modern electricity use for many households.

Our policy simulation highlights critical flaws in the current lifeline tariff. Although designed to reduce the cost burden for low-income households, the subsidy disproportionately benefits wealthier customers with regular purchasing patterns. Poorer households, whose irregular purchasing behavior reflects broader economic vulnerability, often fail to access the subsidy despite low consumption. Similar shortcomings have been observed in Kenya, Tanzania, and Ethiopia (Cardenas & Whittington, 2019a; Kojima & Trimble, 2016; Peng & Poudineh, 2016).

Seasonal purchasing patterns highlight the need for tariff structures and planning frameworks that reflect the timing of both agricultural and holiday-related income cycles. Peaks in electricity purchases during December–January and declines during the September planting season closely mirror these seasonal variations in household cash flow. Rigid tariff designs are poorly aligned with such cyclical consumption patterns.

Our clustering analysis further reveals diverse consumption trajectories. Encouragingly,

many low-income households increased electricity use following the introduction of the lifeline tariff, suggesting that well-designed reforms can stimulate demand. However, the observed heterogeneity also shows that the policy strategies, such as the lifeline tariff, are unlikely to be effective across all customer segments.

Together, these findings carry several key implications. First, tariff design must accommodate temporal variability in household electricity use, with more flexible subsidy mechanisms such as rolling averages or cumulative thresholds. Second, seasonal and behavioral factors should be integrated into demand forecasting and policy design. Finally, post-connection support, addressing barriers such as limited appliance access and credit access, is essential to enable more meaningful and sustained electricity use.

8. Conclusions

This study provides new insights into household electricity consumption among UEDCL customers in the five years preceding the utility's full operational takeover of Uganda's national distribution network. Using a unique dataset of over 150,000 rural and peri-urban customers, combined with descriptive analysis, policy simulation, and clustering techniques, we examine electricity demand, usage behavior, and subsidy targeting in a low-income electrification context.

While domestic customers make up the majority of connections, many remain low consumers: half use electricity at or below the Tier 3 "meaningful access" threshold. Irregular purchasing patterns, driven by affordability constraints and seasonal income cycles, further limit consistent electricity use.

Our findings reveal that UEDCL's lifeline tariff disproportionately benefits wealthier customers with regular purchasing habits. Reforms are needed to align subsidy delivery with actual consumption dynamics and safeguard utility revenues needed to support grid expansion.

Clustering analysis highlights the diversity of household consumption trajectories, shaped by geography, socio-economic status, and responses to policy and external shocks. These patterns underscore the need for more differentiated and targeted energy service planning.

As Uganda transitions to fully public electricity distribution, these insights provide a foundation for more adaptive, data-driven strategies to expand access and improve impact. Future research should track how consumption patterns evolve under UEDCL's expanded mandate and assess whether tariff and service reforms advance affordability, inclusion, and equitable energy access.

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