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Charging Ahead: Managing Grid Impacts from Widespread EV Adoption in African Cities

High-level takeaways from Lukuyu, J., Shirley, R. & Taneja, J. "Managing grid impacts from increased electric vehicle adoption in African cities." *Sci Rep* 14, 24320 (2024)

Summary: For many African cities, electric vehicle (EV) adoption promises reduced dependence on imported fossil fuels, lower emissions, and economic growth. But it also risks putting additional strain on power grid infrastructure that is already struggling. How can African cities position themselves to assess and manage this challenge? This memo summarizes key findings from a recent study exploring strategies for managing grid impacts from rapid EV adoption in African cities with aging power infrastructure and constrained distribution networks, using Nairobi as a prime case study.

Why it matters: African countries including Cape Verde, Rwanda, Zimbabwe, South Africa, Egypt, Ghana, Ethiopia, and Kenya have all announced policies to encourage electric mobility over the past six years.[1] But they continue to face massive challenges with grid quality and electricity access. The EV transition offers cities like Nairobi opportunities to improve urban air quality, modernize transportation infrastructure, and expand access to sustainable mobility options. Yet, without thoughtful management, rapid EV adoption can overwhelm the power grid and trigger costly infrastructure fixes. Through robust data analytics, targeted smart charging policies, and strategic infrastructure investments, Nairobi can advance electric mobility while preserving and potentially improving grid reliability. Nairobi's experience sets a precedent for other rapidly growing African cities where similar studies could help shape adaptable strategies for sustainable EV integration.

Simulating Impacts of EVs on Nairobi's Distribution Grid

Our study analyzes how expanding EV fleets affect electricity grids in African cities, focusing on Nairobi's growing metropolitan area. We examine the effects of converting major vehicle fleets, including paratransit fleets (privately owned, informally operated 36-seater buses and 14-seater *matatus*), commercial fleets, and private vehicles on Nairobi's bulk power supply and distribution grid. We built granular models simulating traffic patterns, EV charging, and transformer utilization to analyze the effects of progressively greater EV adoption on key indicators of grid stability. We sourced vehicle registration data from KRA, power consumption & transformer data from the Kenyan power utility KPLC, and hourly traffic data from Uber. Our approach provides insights for Nairobi while offering a replicable framework for other African cities.

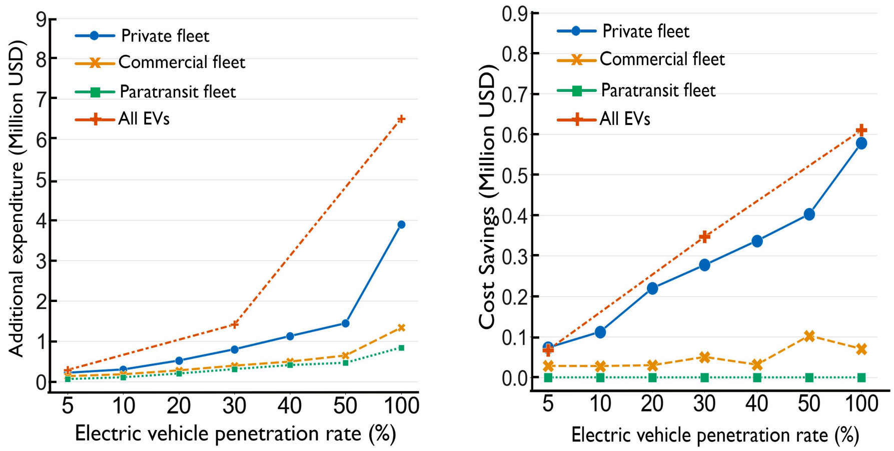
Key Takeaways: Balancing Benefits and Risks

This study offers important insights into the potential benefits and risks of adopting EVs across different fleet types in Nairobi.

- **Unmanaged private EV adoption may strain the grid.** Unmanaged home charging could significantly exacerbate already constrained evening peak demand–increasing daily peak electricity demand by 24% in Kenya if the country's 5% EV adoption target is met, and leading to costly transformer repairs.
- **Range anxiety could further impact peak demand and grid efficiency.** Drivers charging proactively at 45% battery level (versus waiting until 30%) can increase peak charging demands by 2.5 times, exacerbating grid strain during peak hours.
- **Managed charging offers significant savings.** Implementing smart charging practices—such as time-of-use pricing and coordinated charging—can mitigate peak demand (Figure 1), reduce transformer stress, and deliver cost savings of up to 40%. At even moderate levels of fleet conversion (such as 10% EV adoption), this approach matches the benefits of a $15 million battery storage investment while preventing $100,000 in early transformer replacements. Even so, the required investment in grid upgrades remains significant, far exceeding these savings.
- **Paratransit and commercial EVs could enhance grid efficiency.** Paratransit EVs, like buses and *matatus*, and commercial EV fleets charge during off-peak hours, offering low-risk opportunities to improve energy utilization and reduce peak demand, particularly in areas with high peak electricity consumption.
- **But they will likely require multiple recharging events per day.** Paratransit EVs typically require multiple charges per day. Only 15% of matatu routes, and 60% of bus routes can be completed on a single charge, requiring strategic placement of charging stations without disrupting operations.

We modeled two-wheelers as a subset of the private and commercial vehicle fleets, and our findings indicate that independent of four-wheelers, they do not impose a significant strain on the grid. However, limited data prevented detailed analysis of their usage patterns.

FIGURE 1: [Left panel] Additional expenditure in transformer upgrades and replacements at the 5-year mark due to additional loading from unmanaged electric vehicle demand. [Right panel] Cost savings from a simple managed charging strategy.



Policy Recommendations: Preparing for the EV Surge

African countries need tailored solutions for successful EV integration. Actionable recommendations include:

- **Develop fleet-specific EV strategies.** Develop distinct approaches for paratransit, commercial, and private EVs, with infrastructure and management plans optimized for each fleet type to optimize grid efficiency, reduce overloading, and support sustainable growth.
- **Prioritize paratransit electrification.** Focus *first* on electrifying paratransit systems, which dominate public transport in African cities, leveraging their predictable routes and charging patterns for efficient grid integration.
- **Support data-driven planning and multi-stakeholder coordination for optimal charging infrastructure placement.** These findings demonstrate how crucial a managed and coordinated transition to electric mobility will be in Africa. Utilities, city planners, and policymakers must work together and leverage mobility and grid data to inform strategic placement of charging stations. This will ensure that infrastructure investments are optimized for actual local demand and reduce the likelihood of under- or over-utilization.
- **Strategically invest in grid upgrades.** Prioritize strategic investments in distribution transformer and feeder upgrades in high-demand areas, particularly those with expected surges in private EV use, to prevent transformer overloading and minimize costs associated with premature replacements.
- **Promote smart charging and behavioral incentives for private EVs.** Implement time-of-use pricing and support home-based smart charging, via subsidies and public campaigns, to manage peak demand.

Next Steps: Moving From Models to Real-World Insights

Although this study provides valuable insights, critical gaps in real-world data limit the validation of our prediction models and a comprehensive understanding of potential EV impacts on Nairobi's grid. The lack of high-resolution data on EV usage, charging behaviors, and grid performance hinders precise demand forecasting. Additionally, local consumer behaviors, such as range anxiety and charging patterns, are poorly understood, complicating accurate impact assessments. Two specific recommendations would help:

- **EV stakeholders should share real-world data as it becomes available to improve forecasting and grid planning.** Gathering empirical data from pilot EV projects, and real-time monitoring of transformer health and grid reliability could refine predictive models and guide infrastructure decisions.
- **Analysts should do further research evaluating the trade-offs of emerging charging models against traditional grid integration approaches.** New models include off-grid battery swapping for electric two- and three-wheelers and dedicated transformers for electric buses. These insights will be crucial for optimizing EV integration strategies in urban contexts. With better data, such research could help to determine the cost and benefit analysis of different policy interventions to influence charging behavior.

Endnotes

1. International Energy Agency. Global EV Policy Explorer. https://www.iea.org/data-and-statistics/data-tools/global-ev-policy-explorer (2024).
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