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Integrating E-mobility with Mini Grids in Rural Nigeria

SIPA Capstone Team

John Golden, Samantha Yujun Huang, Jonty Katz, Dylan Malloy, Assel Mukasheva, Safiya Noel, Raihan Amir Rashidi, Nursultan Ubbiyev and Jaisheng Wang

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Columbia University, School of International and Public Affairs (SIPA)

Nigeria Rural Electrification Agency (REA)

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Acknowledgments

This report was researched and written by a team of student consultants, completing their Master's degree from Columbia University's School of International and Public Affairs (SIPA Capstone Team)– John Golden, Samantha Yujun Huang, Jonty Katz, Dylan Malloy, Assel Mukasheva, Safiya Noel, Raihan Amir Rashidi, Nursultan Ubbiyev and Jiasheng Wang

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Any errors and omissions are solely the responsibility of the Capstone team.

Executive summary

Nigeria faces significant challenges in electricity access, with approximately 86 million people, mostly in rural areas, lacking access to electricity. To address this, the Nigerian Electrification Project (NEP), facilitated by the Rural Electrification Agency (REA) in collaboration with the World Bank Group and the African Development Bank Group, aimed to significantly increase electricity access through the development of solar hybrid mini grids. This initiative resulted in the deployment of 150 mini grids as of the first quarter of 2024, with additional 261 projects being under development, providing access to electricity to approximately 5.5 million unserved and underserved Nigerians.

Despite the progressive growth and substantial impact of the NEP program, solar mini grids encountered several hurdles including underutilization of capacity, financial constraints, technical issues, and supply chain bottlenecks. These issues were exacerbated by the unstable national grid and strictly regulated tariffs that do not adjust to reflect increased operational costs. The SIPA Capstone Team's main objective was to analyze potential solutions to these challenges, specifically to examine the integration of electric vehicles (EV) into the existing solar mini grids for increased utilization and economic viability. This opportunity emerged as a result of the removal of fuel subsidies, which led to a threefold increase in petrol prices, making operating costs of Internal Combustion Engine (ICE) vehicles more expensive. This integration could potentially utilize surplus energy production during off-peak hours for EV charging, creating a new revenue stream for mini grid operators and offering a cleaner, more affordable transportation alternative for the rural population.

The analysis revealed that, over their lifetimes, EVs have comparable Total Operating Costs (TCO) to ICE vehicles. This was largely due to lower operating and maintenance costs, despite higher upfront costs for EV acquisition. The financial models highlight that the cost per km for EVs becomes competitive with increased usage (with longer distances traveled per day), emphasizing the economic feasibility for frequent users like taxi drivers and farm managers. To make this model economically viable, a lease-to-own model combined with battery swapping could be an optimal solution. The lease-to-own model aims to alleviate the high upfront costs associated with EV acquisition, while granting ownership to users, thus addressing the major barrier for EV adoption. The battery swapping model fits well with the lease-to-own model, where batteries are owned by the charging station provider, and customers pay only for a fully charged battery. Battery swapping is convenient for riders as it does not require upfront costs and eliminates the need for riders to wait while bikes charge.

International examples of EV integration show varied approaches with both successes and challenges. Developed countries have used substantial government support to boost EV markets. For instance, the U.S. and Norway have implemented favorable tax policies and subsidies to stimulate EV purchases and infrastructure

development. In Africa, Kenya leads in EV investments, focusing on integrating EVs with existing energy systems. Successful EV markets in Africa are generally supported by government policies that provide financial incentives.

The major barriers to EV adoption in Nigeria include high upfront costs, limited charging infrastructure, and lack of consumer awareness. The unfamiliarity with EV technology and the perceived risks of adoption also hinder progress. EV companies face challenges like grid instability and high import tariffs, which are particularly pronounced in Nigeria compared to other African markets. The development of favorable policies and incentives, akin to those in Rwanda and Kenya, could catalyze the EV market. This includes reducing import duties on EVs and offering subsidies for local assembly and purchase.

The SIPA Capstone Team's recommendations include focusing on two-wheeler electric vehicles with a lease-to-own model to minimize initial costs and simplify charging logistics through battery swapping stations. The REA should facilitate and prioritize subsidies for EV adoption, aligning them with broader national goals for renewable energy and transportation. Collaboration between the REA, local and international partners, as well as multilateral institutions for funding, will be key for successful implementation of the recommended strategies.

Abbreviations

BEV	Battery Electric Vehicle
CSP	Concentrated Solar Power
DARES	Distributed Access to Renewable Energy Scale-Up Project
EV	Electric Vehicle
EPSRA	Electric Power Sector Reform Act
FCT	Federal Capital Territory
FGN	Federal Government of Nigeria
ICE	Internal Combustion Engine
NADDC	National Automotive Design and Development Council
NEP	Nigerian Electrification Project
NEP*	National Energy Policy
PHEV	Plug-in Hybrid Electric Vehicle
PUE	Productive Uses of Energy
PUE*	Productive Use and Equipment
REA	Rural Electrification Agency
REF	Rural Electrification Fund
RESIP	Rural Electrification Strategy and Implementation Plan
TCN	Transmission Company of Nigeria
TCO	Total Cost of Ownership
MSME	Micro, small, and medium enterprises
2W	2-Wheelers

Introduction

In partnership with the Rural Electrification Agency (REA), the SIPA Capstone Project focuses on a comprehensive study of the viability of e-mobility infrastructure development and integration into existing solar mini grids in rural and peri-urban settings in Nigeria. Leveraging data from the Nigeria Electrification Project (NEP) implementation, **this report will assess the technical, economic, policy, and regulatory aspects to analyze e-mobility integration in two existing mini grid sites**: Toto in Nasarawa state, a hybrid system, and Petti in the Federal Capital Territory (FCT), which is fully solar.[1]

Project analysis is focused on 2-wheeler (2W) Battery Electric Vehicles (BEVs), as these vehicles are the primary mode of transportation in rural communities and represent the greatest opportunity. 2W's are low cost compared to other vehicles but their design is durable, enabling residents to carry large loads a long distance. However, these vehicles are not suited to Plug-in Hybrid Electric Vehicles (PHEVs) due to the lack of space for both a battery and an internal combustion engine (ICE).

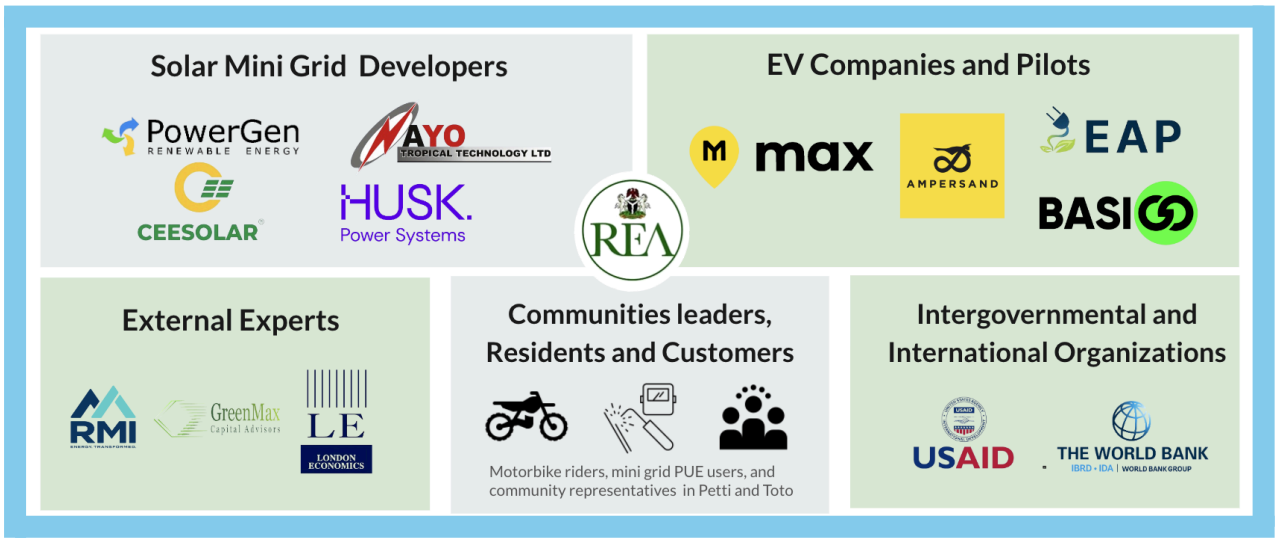
The research for this report will assess the utilization of existing solar mini grids, conduct a comparative analysis of e-mobility business models, and explore the demand for electric vehicles (EVs)– in terms of distance, vehicle type, Productive Use of Energy (PUE) activities, etc. Additionally, this report analyzes the current policy and regulatory framework as well as what future policies and frameworks may promote or hinder EV adoption. Through stakeholder interviews, case study reviews, and financial analysis, this final report will suggest specific recommendations tailored to business case scenarios and financial models for REA.

[1] Appendix

Methodology

This report was constructed after 20+ in-country interviews in Nigeria and virtual interviews across stakeholder groups. The Columbia SIPA Capstone Team met with various members of the Rural Electrification Agency of Nigeria. Site visits were conducted at existing solar mini grid communities in Petti (Federal Capital Territory) and Toto (Nasarawa State). Meetings with solar mini grid developers, Nayo and PowerGen, were held. The Columbia Capstone Team interviewed approximately 10 ICE motorcycle owners in the Petti and Toto communities. Owners represented a range of professions, including taxi drivers, delivery men, and farm workers. The Team also interviewed community members engaged in the business of rice thrashing, welding, cold storage, and medical services, to understand the variety of produce uses of energy in each rural community.

The Team also conducted market research with various EV mobility companies, including MAX Mobility, BasiGo, Ampersand, etc. Lastly, the Team met with The World Bank, GreenMax Capital Advisors, RMI, Husk Power, USAID, and more to round out a comprehensive review of the financial and regulatory environment in Nigeria and the subsequent effects on EV adoption.



The Team conducted interviews across stakeholder groups to gain insights and data used to develop total cost of ownership (TCO) models, potential EV business models, and vehicle owner personas. Data collected through semi-structured, in-person interviews with vehicle owners and community members provided the Team with information on real daily kilometers driven, fuel costs, vehicle costs, maintenance costs, petrol consumption, income, electric vehicle awareness, and electric vehicle appetite. Blended with case study findings from proximate African markets, the Team was able to assess the viability of pairing electric vehicles with existing mini grids in rural Nigeria, understand barriers to deployment, and make

targeted business strategy and policy recommendations to foster EV adoption in rural and peri-urban Nigeria.

Context

The Nigerian Energy Access Challenge

The rural Nigerians constitute 102 million people, or 46% of the total population.[2] The total final energy demand under current and planned policies grows from 2 155 PJ in 2015, to 3 765 PJ in 2030, and 10 351 PJ in 2050, increasing by over a factor of four in less than 35 years. The total final energy demand of the transport sector grows at the fastest rate, with a compound annual growth rate of 6.8%.[3] In addition, by 2050 the transport sector will have the largest percentage share of the country's energy demand– approximately 45%.[4]

Electricity access remains a significant challenge in Nigeria. As of 2021, about 86 million people lack access to electricity. In rural areas, only 26% of the population has access to electricity. There are three technologies used for the generation and distribution of electricity in Nigeria: national grid, mini grids, and standalone systems such as generators. Diesel fuel generators also support the national grid in case of energy instabilities and lack of power availability. Households connected to the national grid frequently experience instability and unreliability. From 2017 to 2023, the national grid collapsed 46 times, due to aged infrastructure and vandalism.[5] This increased dependency on backup generators for 40 percent of electricity consumption in Nigeria.

Table 1. Timeline of Nigeria's electricity grid collapse between 2017 and 2022, according to the Transmission Company of Nigeria (TCN).

Year	Total Collapse Number
2017	15
2018	12

[2] World Bank. 2018. "Rural Population (% of Total Population) - Nigeria | Data." Worldbank.org. 2018. https://data.worldbank.org/indicator/SP.RUR.TOTL.ZS?locations=NG.
[3] "Renewable Energy Roadmap Nigeria Summary of Key Recommendations and Findings." 2023. https://www.nigeria-energy.com/content/dam/markets/emea/nigeria-energy/en/2023/docs/NE23-NigeriaEnergyRoadmap-Report.pdf
[4] "Renewable Energy Roadmap Nigeria Summary of Key Recommendations and Findings." 2023. https://www.nigeria-energy.com/content/dam/markets/emea/nigeria-energy/en/2023/docs/NE23-NigeriaEnergyRoadmap-Report.pdf
[5] Agbetiloye, Adekunle. 2023. "Timeline: Nigeria's Electricity Grid Collapsed 46 Times from 2017 to 2023." Business Insider Africa. September 14, 2023. https://africa.businessinsider.com/local/markets/timeline-nigerias-electricity-grid-collapsed-46-times-from-2017-to-2023/8y4xn4y#:~:text=Nigeria%20has%20experienced%20a%20total,for%20over%20400%20consecutive%20days

2019	9
2020	4
2021	2
2022	4

Source: *Agbetiloye 2023*

To solve the electricity challenge in rural areas, mini grids have emerged as an effective solution. Nigeria has natural resources, which is essential for sustainable development in the country. The country has significant solar potential, characterized by an average annual global horizontal irradiation ranging between 1600 kilowatt hours per square meter (kWh/m2) and 2200 kWh/m2, located in the northern part of the country.[6] [7]

Table 2. Key economic and energy indicators based on World Bank Data and IEA

Economic and Energy Indicators	Value
Population	218,524,212 (2022)
Urban Population	54% (2022)
GDP Per Capita	USD 2,162.6 (2022)
Access to electricity	59.6 % (2022)
Renewables	22.2% share of power generation (2021)
CO2 emission (metric tons per capita)	0.5 (2020)/ 101 Mt (IEA, 2021)

Sources: *World Bank 2022, IEA 2022*

NEP and REA

The Federal Government of Nigeria (FGN) recognized an urgent need to address energy challenges and actively initiated a series of reform acts and initiatives. Thus, the National Energy Policy (NEP*) was approved by FGN in April 2003.[8] The fundamental principle of the policy was to leverage the nation's energy resources

[6] International, and Energy Research Andrew Marquard. n.d. 2013. "CSP Technology and Its Potential Contribution to Electricity Supply in Northern Nigeria" 3 (3). https://dergipark.org.tr/en/download/article-file/148304

[7] "Renewable Energy Roadmap Nigeria Summary of Key Recommendations and Findings." 2023. https://www.nigeria-energy.com/content/dam/markets/emea/nigeria-energy/en/2023/docs/NE23-NigeriaEnergyRoadmap-Report.pdf

[8] "ENERGY COMMISSION of NIGERIA FEDERAL MINISTRY of SCIENCE, TECHNOLOGY AND INNOVATION FEDERAL REPUBLIC of NIGERIA." n.d. 2022. https://www.energy.gov.ng/Energy_Policies_Plan/APPROVED_NEMP_2022.pdf

and provide access to electricity through the development of international cooperation.

In March 2005, the Electric Power Sector Reform Act (EPSRA) was enacted by the FGN. REA was established by Section 88 of the EPSRA, and the Board and Management of the Agency was inaugurated on March 16, 2006.[9] REA was founded as an independent and accountable agency, responsible for coordination of rural electrification activities in Nigeria.

The Rural Electrification Strategy and Implementation Plan (RESIP) was approved in July 2016. The Plan proposed deploying both, mini grids and the National Grid in rural areas of the country.[10]

The REA's Solar Mini Grid Program to Date

Nigeria Electrification Project

The REA launched NEP in 2018 in partnership with the World Bank Group and the African Development Bank Group. The main objective of the program was to increase access to electricity for households, public educational institutions, and underserved micro, small, and medium enterprises (MSMEs) in rural areas. The NEP was designed to be a large-scale program to catalyze further private sector investment in Nigeria's off-grid electrification, especially in rural areas. It was structured to promote a competitive environment for private investments, leveraging substantial private funding from solar energy developers alongside loans from the multilateral development banks (MDBs) and commercial banks. The project adopts a market-driven approach to ensure cost-effectiveness and sustainability, focusing on areas with significant economic potential and ensuring the inclusion of gender-specific strategies to enhance social equity.

The program consisted of three components: 1) Solar Hybrid Mini Grids for Rural Economic Development, 2) Standalone Solar Systems for Homes and MSMEs, and 3) Energizing Education Program Phase. Development of mini grids in rural areas was addressed through the "Solar Hybrid Mini Grids for Rural Economic Development" component. Encompassing a total funding of $550 million ($350 million from the World Bank and $200 million from the African Development Bank), the primary objective of this component was to enable the development of private sector-operated mini grids in unserved and underserved areas, targeting approximately 300,000 households and 30,000 MSMEs. To achieve this, it leveraged two investment sub-components:

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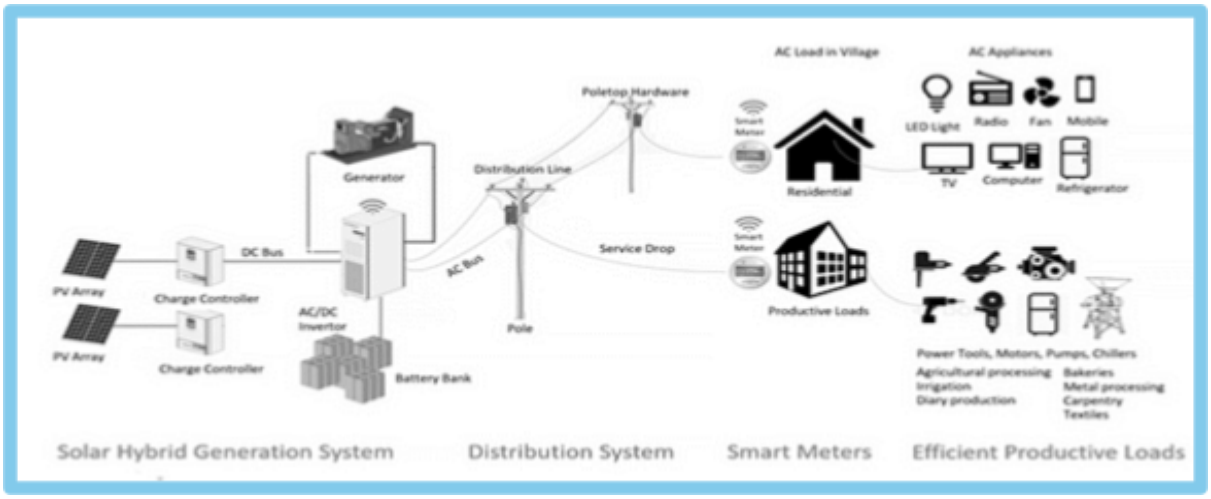
[9] "History." 2017. Rural Electrification Agency. August 21, 2017. https://rea.gov.ng/history/#:~:text=The%20Rural%20Electrification%20Agency%20was,inaugurated%20on%20March%2016%2C%202006.

[10] "Rural Electrification Strategy and Implementation Plan (RESIP)". Prepared by Federal Ministry of Power, Works, and Housing, For implementation by Rural Electrification Agency (REA). . 2016. Federal Republic of Nigeria. https://rea.gov.ng/wp-content/uploads/2017/09/RESIP.pdf

1. **Minimum Subsidy Tenders (MST)** aimed at inviting private developers to bid for projects by offering the minimum capital cost subsidies required to make their projects viable.
2. **Performance-Based Grants (PBG)** to be provided to mini-grid operators based on the number of new customer connections they establish. This continuous incentive was designed to support ongoing expansion and sustainability of electricity services.

According to our interview with an REA representative, subsidies were supposed to cover up to 50% of capital expenditures (CAPEX). Subsidies allocation and distribution were based on a first come first served basis given that developers met all the milestones required by the programme.

Figure 1. Third generation mini grids with solar hybrid generation, AC-grid-code distribution system, smart meters and efficient consumptive and productive appliances



Source: *World Bank, 2018*

The NEP Implementation Results

As of the end of Q1 2024, the NEP has significantly impacted rural economic development by providing reliable electricity to 63,686[11] connections across 125 mini grids[12]. An additional 261 projects, expected to impact almost 1.4 million people, were signed and were under various stages of preparation or construction[13]. The program improved access to electricity to over 5.5 million underserved and unserved Nigerians. Furthermore, the project catalyzed significant private sector engagement. Approximately $252 million in semi-commercial financing has been mobilized to support mini grid electrification efforts, showcasing a robust public-private partnership model. Every dollar spent from public funds has attracted an additional $1.3 from private sources, i.e. project developers and commercial financiers. In

[11] Rural Electrification Agency, NEP Achievement Databoard 2024. https://nep.rea.gov.ng/neptool/

[12] Rural Electrification Agency, NEP Activities Highlights 2023. https://nep.rea.gov.ng/nep-activities-highlights-2023/

[13] World Bank. Nigeria Electrification Project Implementation Status & Results Report, 2024. https://documents.worldbank.org/en/publication/documents-reports/documentdetail/099031324181039832/p1618851b3f9ef0e41bf7b1bcafc815c295

terms of socio-economic impact, the NEP has been instrumental in job creation, with over 100,000 direct and indirect jobs estimated to have been generated.

Solar Mini Grids Face Challenges

The NEP's solar mini-grid program has proven to be a great success. However, as such programs continue to expand, challenges persist in technical, financial, and supply chain aspects.

Pressure imposed by growing electricity demand and unstable national grid

The rapid growth of electricity consumption in rural areas, which are underserved or unserved by the national grid, continues to drive significant momentum for the mini grid expansion. From 2000 to 2021, electricity consumption per capita in Nigeria increased by 50%[14]. However, this surge in electricity demand also places considerable pressure on mini grids to deliver more reliable power supply 24/7. This pressure is further compounded by a large influx of individuals to rural communities, driven by escalating living expenses in urban areas[15].

In the Toto community, the first Nigerian Interconnected Mini-Grids (IMGs) pilot site integrates mini grids with the national grid. Yet, the national grid's instability undermines the mini grid's performance, especially during nighttime peak periods[16]. To counter this, solar mini grids require expanded storage capacity to bridge power gaps and ensure reliable electricity supply. This challenge needs more attention as more mini grids aim to connect with the national grid.

High upfront costs require adequate financing

In the last decade, mini grid expenses have decreased notably, with capital costs dropping from $8,000/kWfirm in 2010 to $3,660/kWfirm in 2023[17]. However, solar mini grid developers continue to suffer from the substantial upfront expenses, with solar PV modules, batteries, and the distribution grid constituting an average of 11%, 15%, and 14% of total costs, respectively[18]. Notably, energy storage systems have emerged as the most expensive component – in some cases, batteries can account for up to 39% of the total costs.

Such high upfront costs necessitate substantial capital investment. While the World Bank has provided substantial grants since 2018, diversifying capital sources is

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[14] "Nigeria - Countries & Regions." n.d. IEA. https://www.iea.org/countries/nigeria/electricity

[15] Interview with PowerGen. Columbia University. 2024. Interview with PowerGen

[16] Interview with solar developers, during site visit in the Toto community

[17] "Expanding Mini Grids for Economic Growth". Energy Sector Management Assistance Program (ESMAP). February 27 2023. https://www.esmap.org/sites/default/files/2022/MG%20Kenya%202023/booklet%2025%20feb%20rev.pdf

[18] Greacen, Chris. 2019. "MINI GRID COSTING and INNOVATION MINI GRIDS for HALF a BILLION PEOPLE". World Bank. https://observatoire-europe-afrique-2030.org/wp-content/uploads/2024/01/World-Bank-2020-capital-cost-electricity-price-.pdf

crucial for rapid expansion and long-term financial sustainability of the mini grids. Mini grid projects typically require long-term funding (10-15 years)[19] with low capital costs, but commercial banks often shy away due to fund limitations or risk aversion related to high or uncertain inflation rates, as seen in Nigeria where the bank lending rate exceeded 15% in February 2024[20]. Additionally, commercial loans come with high collateral requirements[21], posing further challenges for developers.

Revenue streams face uncertainty

Developers encounter several challenges, including strictly regulated tariffs by the National Electricity Regulatory Commission (NERC) to comply with the Multi-Year Tariff Order (MYTO), which may not adequately reflect costs to compensate developers. Moreover, there's a high risk of currency fluctuations, exemplified by the official naira exchange rate plummeting to 1531 per dollar from 900 in February 2024[22], further adding to financial risks. Additionally, on the demand side, the low affordability of rural residents, especially in the underdeveloped regions, also contributes to significant uncertainty in the developers' revenue streams.

Supply chain bottlenecks restrict further scale-up

Supply chain bottlenecks pose a significant challenge for Nigerian solar mini grid companies, which heavily rely on imported components, primarily sourced from China. Replacing degraded or malfunctioning batteries can take over a month to be sourced from the original equipment manufacturer[23].

Import duties further exacerbate the import challenge, with the Nigerian Customs Service imposing a 5% duty and a 5% Value Added Tax (VAT) on solar panels since 2018, while batteries face a 20% duty, significantly impacting the sustainability of the solar energy market[24]. As a result, logistics and supply chain issues are cited as the

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[19] "Challenges and Needs in Financing Mini-Grids | Mini-Grids Support Toolkit | Energy | U.S. Agency for International Development." 2018. Www.usaid.gov. February 13, 2018. https://www.usaid.gov/energy/mini-grids/financing

[20] "Nigeria Bank Lending Rate, 2006 – 2021 | CEIC Data". 2006-2024. https://www.ceicdata.com/en/indicator/nigeria/bank-lending-rate

[21] Ogba, Desmond and Eigbobo, Michelle. April 2021. "Financing Mini-Grid Projects in Nigeria - Mitigating the Risks". Templars. https://www.templars-law.com/app/uploads/2021/04/Financing-Mini-Grid-Projects-in-Nigeria-%E2%80%93-Mitigating-the-Risks.pdf

[22] Dzirutwe, Macdonald. "Nigeria's latest devaluation may be 'turning point' in currency reform drive" Reuters. February 5, 2024. https://www.reuters.com/world/africa/nigerias-latest-devaluation-may-be-turning-point-currency-reform-drive-2024-02-05/

[23] Interviews and Research on Solar Developer. Columbia University. 2024. Interview with PowerGen , Draft research Responses from Hadiza.docx

[24] Payton, Ben. 2024. "Nigeria's Shift to Renewables Picks up Momentum." African Business. January 22, 2024. https://african.business/2024/01/energy-resources/nigerias-shift-to-renewables-picks-up-momentum

most critical challenge for solar developers in Nigeria[25], with regulatory hurdles such as extensive permitting requirements also acting as disincentives.

Solar Mini Grid Opportunities: Productive Use of Electricity and Demand generation

Pairing solar mini grids with EVs in rural areas could contribute to both, improvement of the energy access and development of mobility in rural areas. The World Bank defines productive uses of energy as "value-adding activities which increase income or productivity."[26] Based on the economic activities within rural off-grid communities, there were four categories of the productive uses identified: agricultural, industrial, commercial, and social.[27]

Productive uses of electricity

Currently, the largest share of productive uses of electricity are associated with agricultural activities. In 2022, agriculture contributed nearly 23.7% to Nigeria's GDP, providing job opportunities for 75% of workers.[28] Examples of agricultural activities include milling, threshing, drying, chilling and cold storage. Commercial and industrial activities involve 20% of customers in rural off-grid communities.[29] These activities include welding, hairdressing, viewing centers/local cinemas, restaurant business, phone-charging, retail cooling, tailoring, carpentry, electronic and auto repair.

The deployment of EVs in rural areas can be an alternative productive use, benefiting customers and solar mini grid developers. As per RMI Report, It would take eight E2Ws to match the 1.7 megawatt-hours required for a single mill to process 90 tons of rice per year.[30] High EVs utilization contributes to the lower electricity tariffs and stimulates more demands for electricity.

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[25] Eleanya, Frank. 2023. "20% Lithium Battery Duty Slows Solar Energy Growth." Businessday NG. January 6, 2023. https://businessday.ng/technology/article/20-lithium-battery-duty-slows-solar-energy-growth/#:~:text=From%20a%20zero%20percent%20duty,a%20sustainable%20solar%20energy%20market.

[26] "Beyond Connections: Energy Acess Redefined". ESMAP, World Bank. https://documents1.worldbank.org/curated/en/650971468180259602/pdf/105054-ESM-P148200-ADD-SERIES-PUBLIC-FINAL-ESMAP-Beyond-Connections-TR008-15-optimized.pdf

[27] "The Market Opportunity for Productive Use Leveraging Solar Energy (PULSE) in Sub-Saharan Africa". 2019. Lighting Global. https://www.lightingglobal.org/wp-content/uploads/2022/04/PULSE-Report.pdf

[28] O'Neill, Aaron. 2022. "Nigeria - GDP Distribution across Economic Sectors 2018." Statista. February 15, 2022. https://www.statista.com/statistics/382311/nigeria-gdp-distribution-across-economic-sectors/

[29] "Market study to support the Nigeria Electrification Project. Component 2: Results – Based Finance Programme for Productive Use Appliances and Equipment for Off-Grid Communities". 2021. Rural Electrification Agency (REA). https://nep.rea.gov.ng/Market-Study-to-Support-the-Nigeria-Electrification-Project.pdf

[30] Allee, Andrew, et al. 2022. "Powering Small-Format Electric Vehicles with Minigrids: Assessing the Viability of Two-and Three-Wheeled EVs for Rural Mobility". RMI. https://rmi.org/wp-content/uploads/dlm_uploads/2022/04/powering_small_format_electric_vehicles_with_minigrids.pdf

Vehicle electrification opportunities

Vehicle electrification is a potential solution to the challenges of rural mobility, rising fuel prices and vehicle decarbonization. Further, the proliferation of mini grids in rural Nigeria providing reliable electricity supply - and some offering spare generation capacity - makes vehicle electrification achievable.

Nigeria has the second-largest vehicle stock in sub-Saharan Africa. This number is projected to grow from 14 to 37 million by 2040. [31] The removal of fuel subsidies influenced petrol prices. The recent report by the Powering Renewable Energy Opportunities program emphasised that EVs will play a key role in the sustainable transportation development in sub-Saharan Africa. The report also outlines that the e-mobility market value will grow to $5.07 billion by 2027.[32]

The FGN is in the process of executing a plan to promote local assembly capacity for EVs. In July 2023 the National Automotive Design and Development Council (NADDC) revealed that their Electric Vehicle Development Plan had entered the final stage for implementation.[33] The plan focuses on the production of electric public transport, paratransit vehicles, two-wheelers and tricycles in Nigeria with the help of agreements with Japan and Israel. With all the promising opportunities and conditions, there are still a few things for consideration for EV development, such as the vehicles' high upfront costs, lack of charging infrastructure, high customs duties, bad road infrastructure in Africa and slow maintenance service.

The phase out of petrol fuel subsidies

In May 2023, Nigeria underwent a significant economic shift with the removal of its petrol fuel subsidy. Fuel subsidies have strained Nigeria's finances significantly, especially during the last few years, starting from 2021 given the rise in oil prices[34]. For instance, in 2022 alone, the government allocated approximately $9.7 billion to

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[31] International Energy Agency. 2019. "Nigeria Energy Outlook – Analysis - IEA." IEA. 2019. https://www.iea.org/articles/nigeria-energy-outlook

[32] Michael, Chinwe. 2024. "How Rising Fuel Cost Boost Electric Vehicle Adoption in Nigeria Market." Businessday NG. March 30, 2024. https://businessday.ng/bd-weekender/article/how-rising-fuel-cost-boost-electric-vehicle-adoption-in-nigeria-market/#:~:text=With%20the%20rise%20in%20fuel,fuels%2C%20as%20a%20viable%20alternative.

[33] Roychowdhury, Amunita. 2023. "World EV Day 2023: Why Electric Mobility in Nigeria Is an Opportunity to Leapfrog in the Global South." Down to Earth. September 9, 2023. https://www.downtoearth.org.in/blog/africa/world-ev-day-2023-why-electric-mobility-in-nigeria-is-an-opportunity-to-leapfrog-in-the-global-south-91656

[34] Simpson, Nick et al. 2024. "Towards Sustainable Fuel Subsidy Reform in Nigeria: Evaluating progress and pathways to success". ODI Working Paper. March 2024. https://odi.org/en/publications/towards-sustainable-fuel-subsidy-reform-in-nigeria/

fuel subsidy payments, which represented a staggering 2.2% of GDP — more than four times the health budget[35]. Such expenditures hindered investment in critical sectors like education, healthcare, and infrastructure. Furthermore, according to reports from PwC and ODI, the subsidy disproportionately benefited wealthier citizens who consumed more fuel, while the poorer segments gained less but were more adversely affected by price hikes due to their larger relative expenditure on transport. The removal of the subsidy led to immediate economic effects, notably a more than 200% increase in petrol prices overnight. This drastic price rise significantly impacted lower-income and rural households, exacerbating the economic pressures on these already vulnerable groups. Therefore, considering that fuel prices have risen almost 3x times, utilizing spare capacity of solar mini grids to charge electric vehicles could potentially be an optimal solution. This could also potentially increase the economic viability of solar mini grids.

EV and ICE Vehicles– cost comparison

Executive summary:
There is a wide range of Total Costs of Ownership (TCOs) for EVs and ICE vehicles depending on the consumer profile and economic assumptions. However, modelling reveals that EVs have a lower TCO than fuel inefficient ICE bikes, and that the upper end of EV price performance is comparable with the upper end of ICE price performance. This suggests that the key barrier to EV adoption is implementing solutions to ease higher upfront cost of EVs - such as supportive business models - and developing charging infrastructure.

Electric vehicles offer a variety of benefits in terms of supporting mini grid financial sustainability and decarbonization. Nigeria has a Nationally Determined Contribution under the Paris Agreement of a 47% reduction (conditional on international support) in CO2 emissions below BAU by 2030.[36] This decarbonization goal would be greatly supported by progress in decarbonizing transportation.

Further, vehicle electrification also offers the promise of lower ongoing costs for drivers as a solution to financial difficulties arising from rising fossil fuel prices. Although EVs have substantially higher upfront costs (in the range of N2,000,0000 to N3,500,0000 compared to N800,000 to 1,000,000 for ICE vehicles) when normalized across vehicle life, EVs can be cost competitive or lower cost than ICE vehicles.

Cost category breakdown

Across the lifetime of the vehicle, there are three major cost categories: fuel, ownership and maintenance cost. For EVs it is also possible to split out battery cost

[35] PricewaterhouseCoopers. 2023. “Fuel Subsidy in Nigeria - Issues, Challenges and the Way Forward.” PwC. May 2023. https://www.pwc.com/ng/en/publications/fuel-subsidy-in-nigeria-issues-challenges-and-the-way-forward.html.
[36] Climate Action Tracker. 2023. “Nigeria”. July 13, 2023. https://climateactiontracker.org/countries/nigeria/

from ownership cost due to the significance of this expense and different methods of paying for it.

Ownership cost: Covers the cost of purchasing the vehicle, leasing the vehicle or repaying a loan on the vehicle. To normalize this to a per kilometer figure, it is necessary to determine the total expenditure on acquiring the vehicle and divide it by the total kilometers the bike travels in its life.

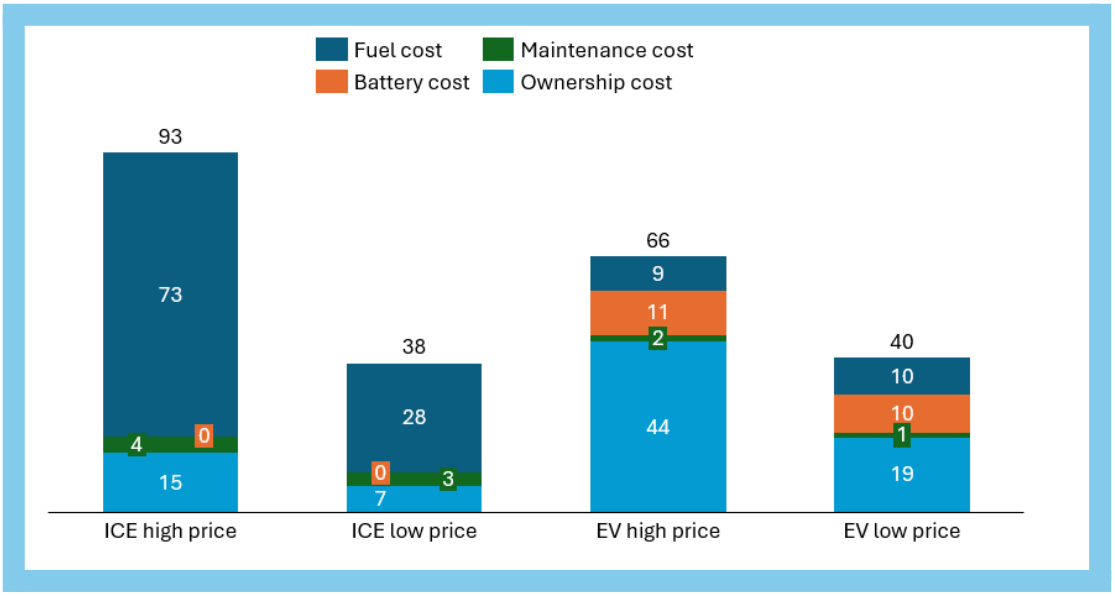
Fuel cost: The cost of purchasing petrol, diesel or in the case of an EV recharging the battery. Is determined by the price of fuel (naira per liter, or naira per kWh), and the energy/fuel efficiency of the vehicle.

Maintenance cost: Covers the cost of servicing, repairs and replacement parts across the vehicle lifetime. Normalized to a per kilometer figure by determining the annual maintenance cost and dividing it by the number of kilometers traveled in a year.

Battery cost: For an EV, this is a major cost component, and can encompass either purchasing the battery with the vehicle, or the cost of participating in a battery swapping scheme. The battery cost per kilometer is calculated by taking the price of the battery, and dividing it by the number of cycles it lasts for to reach a cost per cycle figure. This is then divided by the average number of kilometers in a cycle (i.e. between charges).

Cost comparison

Figure 2. Comparison of total cost of vehicle ownership (TCO), ₦/km



Source: *SIPA Capstone Team. Financial Model. 2024.*

As Figure 2 demonstrates, the main cost drivers for EV bikes are the cost of vehicle purchase and battery use, with dramatically lower fuel and maintenance costs than comparable ICE bikes. In particular, the financial suitability of EVs is highly determined by the total number of kilometers an EV travels in its lifetime, as a longer

distance travelled makes the cost of purchase per kilometer lower. In comparison, ICE bikes are most sensitive to fuel price changes and the fuel efficiency of the vehicle.

Personas suitable for EV adoption

In-country interviews revealed five vehicle owner personas in rural and peri-urban Nigeria. These personas are taxi drivers, both short range and long range, delivery drivers, farm managers, and personal vehicle owners.

- **Short-range taxi drivers** traverse approximately 50 kilometers per day, servicing multiple rides over short distances of 1-3 kilometers per ride.
- **Long-range taxi drivers** traverse approximately 80 kilometers per day and service both more rides per day and rides over longer distances.
- **Delivery drivers** traverse about 30 kilometers per day and shuttle physical goods such as SIM cards, electronics, and produce between commercial centers and local communities.
- **Farm managers** can traverse up to 100 kilometers a day and use their vehicle to visit various farms and agricultural locations related to agriculture production.
- **Personal vehicle owners** possess a vehicle for leisure / personal use and intermittent business purposes. The report estimates that personal vehicle owners traverse about 20 kilometers per day.

Of the many ICE motorcycle owner personas in rural Nigeria, analysis suggests that three persona types are ideal for early adoption of EV's. Moto taxi drivers, both short range and long range, and farm managers traverse enough kilometers per day to make the investment in an electric motorbike financially appealing.

Table 3. Comparison of total cost of vehicle ownership (TCO), N/km, per persona

		ICE Vehicle	Electric Vehicle
Taxi Driver Short Range	Vehicle cost per km	24.11	60.22
	Energy cost per km	60.00	12.00
	Total cost per km	84.11	72.22
Taxi Driver Long Range	Vehicle cost per km	18.42	37.80
	Energy cost per km	60.00	7.50
	Total cost per km	78.42	45.30
Delivery Driver	Vehicle cost per km	13.24	45.84
	Energy cost per km	30.00	20.00
	Total cost per km	43.24	65.84
Farm Manager	Vehicle cost per km	8.66	13.49
	Energy cost per km	30.00	6.00
	Total cost per km	38.66	19.49
Personal Owner	Vehicle cost per km	23.01	58.48
	Energy cost per km	30.00	30.00
	Total cost per km	53.01	88.48

Source: *Petti and Toto, Nigeria 2024*

As shown in Table 3 above, electric motorbikes are cheaper on a naira (₦) per kilometer basis for short range and long range taxi drivers and farm managers. Based on in-country interviews, these personas can drive between 50 and 100 kilometres per day. Assuming ICE fuel efficiency of 15 km/L for taxi drivers and 30 km/L for farm managers, the amount of fuel at current prices required to traverse long distances each day makes EV's an attractive alternative. Electric motorbikes require less maintenance than traditional ICE motorcycles, further reducing cost per kilometer of EVs. Vehicle owners traversing shorter daily distances, however, benefit from ICE vehicles due to lower upfront bike costs.

Analysis suggests that financial incentives should focus on vehicle owners that traverse long distances for business purposes, such as taxi services and farm management that requires frequent multiple trips to various locations. Support to transition existing vehicle owners to EVs should come in the form of buyback or trade-in programs that give existing vehicle owners credit for their existing ICE bikes

that can be used toward the purchase of a new EV. Electric vehicle mobility companies, financial institutions, and government agencies must work together to provide attractive financing options to Nigerians to facilitate financial readiness. Lease-to-own programs coupled with concessional term loans below market rate will likely be required to catalyze early adoption of EVs. Electric vehicle mobility companies will also need to structure vehicle and battery ownership to match demand potential. Nigerians are accustomed to buying ICE motorcycles outright in cash, immediately converting cash into a standalone revenue-generating vehicle asset. Purchase of the EV chassis plus battery would be required to be considered a one-to-one transition from ICE to EV. The right balance of battery ownership, swapping, and/or charging must be considered.

Potential business models for vehicle electrification

Executive summary: *The recommendation is that the preferred model for vehicle electrification combines lease to own with battery swapping. This is for two reasons. First, adopting a lease to own model reduces or eliminates the high upfront cost of electric vehicle purchases. Second, battery swapping eliminates the potential issue of charge times as a barrier to adoption. Further, if battery swapping was used without a lease to own model, it would reduce upfront capital costs by ~25%.*[37]

Introduction

In a developed electric vehicle market it is possible to provide charging infrastructure for vehicles and rely on demand for charging from existing EVs and newly purchased EVs. However, in the context of rural Nigerian communities this approach is unlikely to be successful as there are substantial barriers to adopting EVs that go beyond lack of existing charging infrastructure. These barriers include a lack of awareness of EVs, the high upfront cost of EVs, concerns about charging time, range and performance of EVs, and the lack of access to consumer finance to support EV purchases.

To address these challenges, it is necessary to support new EV charging infrastructure with a complementary business model to encourage adoption and use of electric vehicles. The question of which business model or models are most useful is separate from if and how to subsidise the adoption of EV in rural communities where mini grids are present.

There are two categories of business/technical models to support EV adoption. The first concerns the ownership and purchase model for electric vehicles. Here, upfront purchase is the standard model for ICE bike purchases, but this is unlikely to be feasible for EVs given their high upfront costs. As such, there are four potential ownership models to drive EV adoption which are daily rental, ongoing subscription, lease-to-own and retrofitting of existing ICE bikes.

These are further complemented by differing models for battery ownership and charging. The default option here is pay for use battery charging with the rider owning the battery. However, there is also the option for pay for use battery charging, but the battery is not owned by the rider (and as such the rider also pays a battery use fee), or a battery swap model where the rider pays to swap a battery with a pre-charged one available at the charging station.

[37] Financial modelling results

Ownership models

As the electric vehicle market rapidly develops, an array of innovative ownership models has emerged for consumers. These models aim to reduce upfront costs and provide a more flexible user experience, both of which are crucial for overcoming major barriers to EV adoption. Four types of EV ownership models are discussed in detail below: outright purchase, daily rental, subscription, lease-to-own, and retrofitting, compared with the standard outright purchase model generally used for ICE vehicles.

Outright purchase

Outright purchase entails paying for a vehicle in full, a model unlikely to be viable in rural Nigeria due to the significant price disparity between EVs and ICE vehicles. Interviews with bike riders in Toto and Petti indicate that the purchase price for an ICE ranges between ₦800,000 and ₦1,000,000.[38] In contrast, a new EV bike costs between ₦3,000,000 and ₦4,000,000.[39] Without access to cheap consumer credit, this is not a feasible solution for rural riders, despite the lower ongoing costs that an EV offers.

Daily rental

Daily rental, widely adopted for e-bikes, involves centrally managing bikes at charging stations, allowing customers to rent them on a daily basis. Unlike ownership, riders do not possess the bike but benefit from a significantly lower upfront cost, typically with a refundable deposit, and greater flexibility in usage duration. Although such rental costs may exceed those of leasing or subscription on a daily basis, they are adjustable based on actual usage needs. In essence, this model caters to consumers with short-term e-bike requirements and limited budgets for long-term ownership.

Financial modelling in the context of a rural Nigerian mini grid suggests that the daily rental fee would be approximately ₦8,500.[40] This is based on the assumption that bikes are rented out for only one day at a time, and that ~80% of the bikes available for hire are rented out on any given day. If rental periods were for longer, and as such more than 80% of bikes were on hire at any point in time then the rental fee would be lower. At 90%, the fee could drop to ₦4,500, or at full utilization it would be ₦7,500.[41] All of these assume a 35% operating margin for the mobility company running the bike rental business.

[38] Interviews conducted in Toto and Petti
[39] Market research
[40] Financial model results
[41] Financial model results

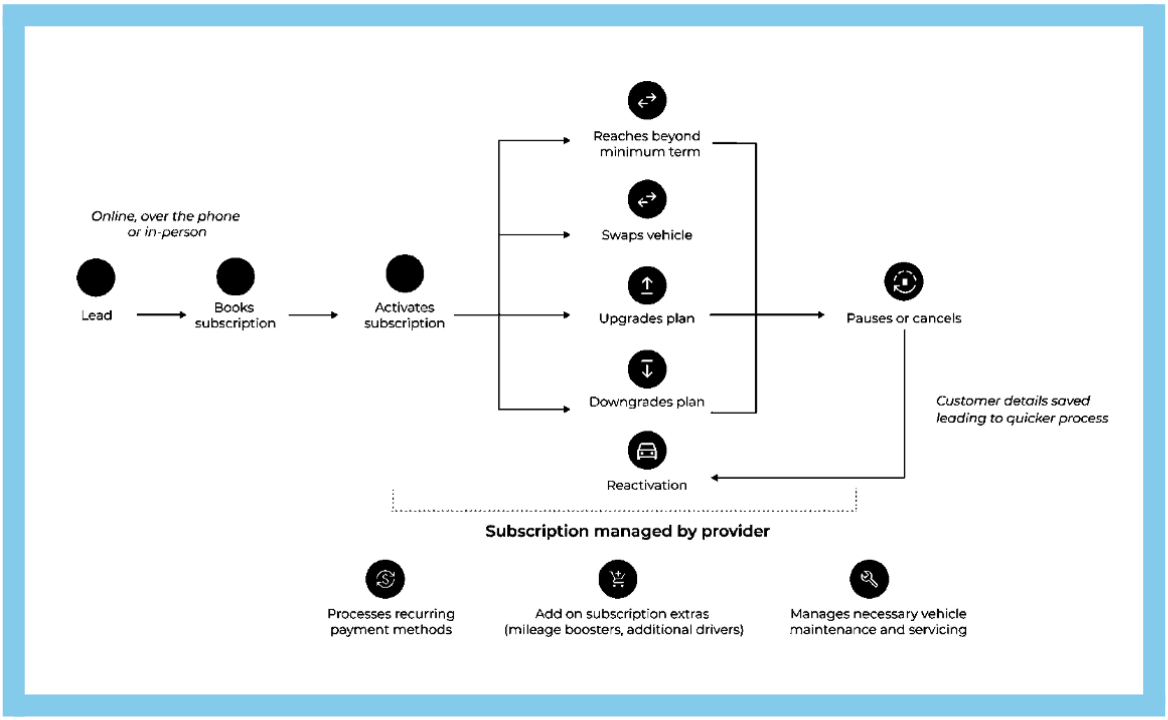
Subscription

The vehicle subscription model, also known as Vehicle-as-a-Service (VaaS), is also gaining momentum in the EV market. This model consolidates all expenses into a single payment, potentially covering maintenance, insurance, and roadside assistance. Customers can enjoy using EVs and all bundled services without owning the vehicle or committing to long-term contracts. Some providers even offer vehicle swapping to enhance the user experience.

Similar to daily rental, the subscription model requires only a refundable deposit for the upfront cost, tailored to actual needs, making EV access more accessible. It also offers flexibility in terms of duration and vehicle selection. However, it does not confer full ownership of the vehicles, as the contract eventually expires.

As an emerging business model, vehicle subscription is being piloted and adopted in more advanced EV markets. However, due to the requirement for sophisticated subscription fee design and digital management solutions, scaling up in rural Nigeria is not currently considered feasible. As a result, it is not included in the financial modeling analysis below. Nevertheless, its development should be closely watched due to its potential to reduce consumer costs and attract consumers in need of more flexible vehicle business models.

Figure 3. Vehicle Subscription Model



Source: McClatchey 2023

Lease to own

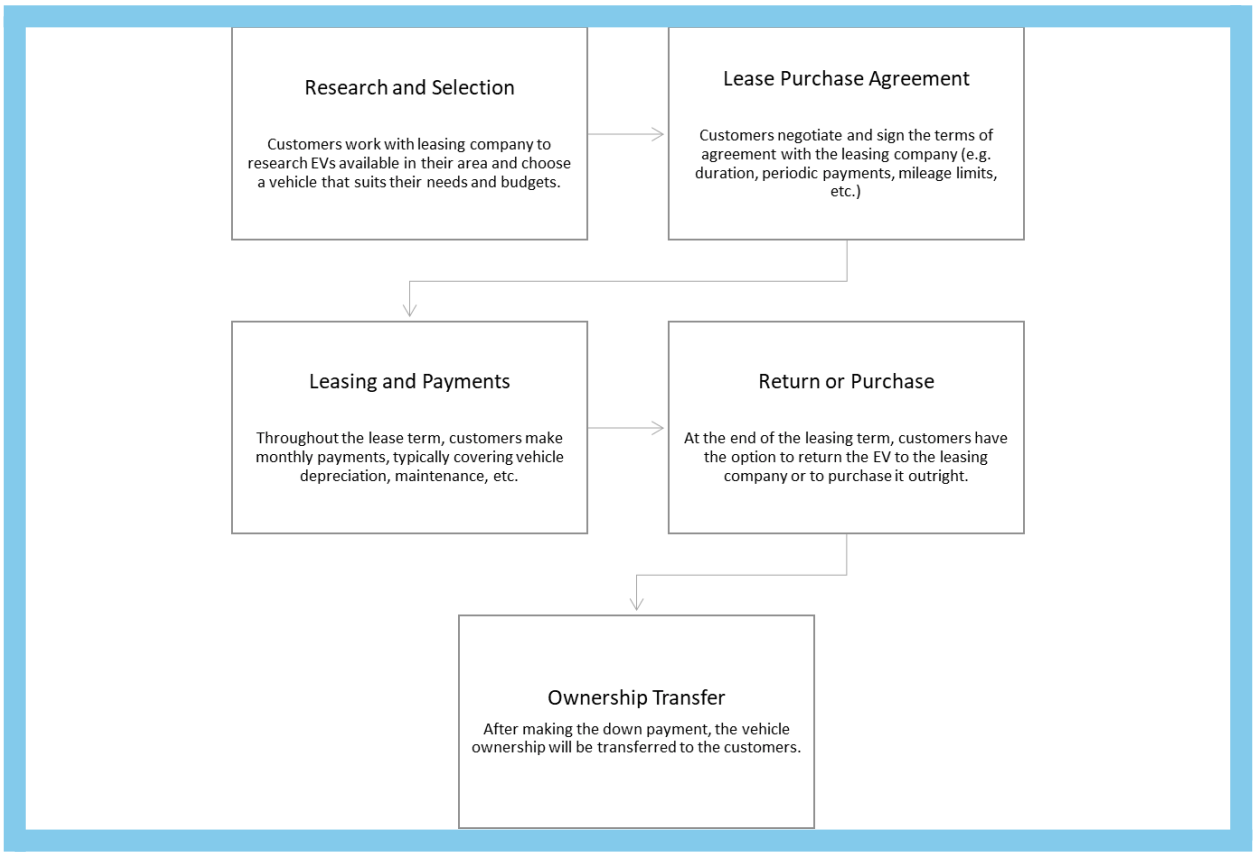
Lease-to-own entails drivers acquiring an electric bike and paying a daily, weekly, or monthly rental fee. For one to two years, they fully pay for the bike and no longer

need to pay regular rental fees. The rental fee may include or exclude maintenance and other servicing costs.

Based on financial modeling, a monthly fee for Lease-to-Own would be ₦252,000, or if the battery was not covered by the agreement it would be ₦188,500[42]. However, if the battery is not covered it would have to be paid for through a separate battery business model as discussed below. These figures are calculated using a 25% interest rate. If instead the interest rate was 15%, the costs would fall to ₦213,000 per month including the battery and ₦160,000 without it.[43]

Based on this assumption, the fee would need to be paid monthly for two years, and at the end of this period, the rider would eventually own the bike. At this stage, they would need to separately pay for battery recharging, as well as maintenance costs (although these could be provided by the leasing company).

Figure 4. Lease to Own Model



Source: *SIPA Capstone Team 2024*

[42] Financial model results
[43] Financial model results

Retrofitting

Another increasingly prevalent model in the EV market involves retrofitting existing ICE vehicles into electric ones. This model offers a service where owners of ICE bikes can pay to have them converted to EVs. Retrofitting is particularly suitable for customers who already own ICE bikes, as it significantly reduces the upfront cost compared to purchasing a new EV.

However, this model also presents several disadvantages compared to rental, subscription, and lease-to-own options. These include less flexibility in duration and a higher one-time payment for the retrofitting service. Additionally, retrofitting a worn vehicle may lead to higher maintenance costs in the future.

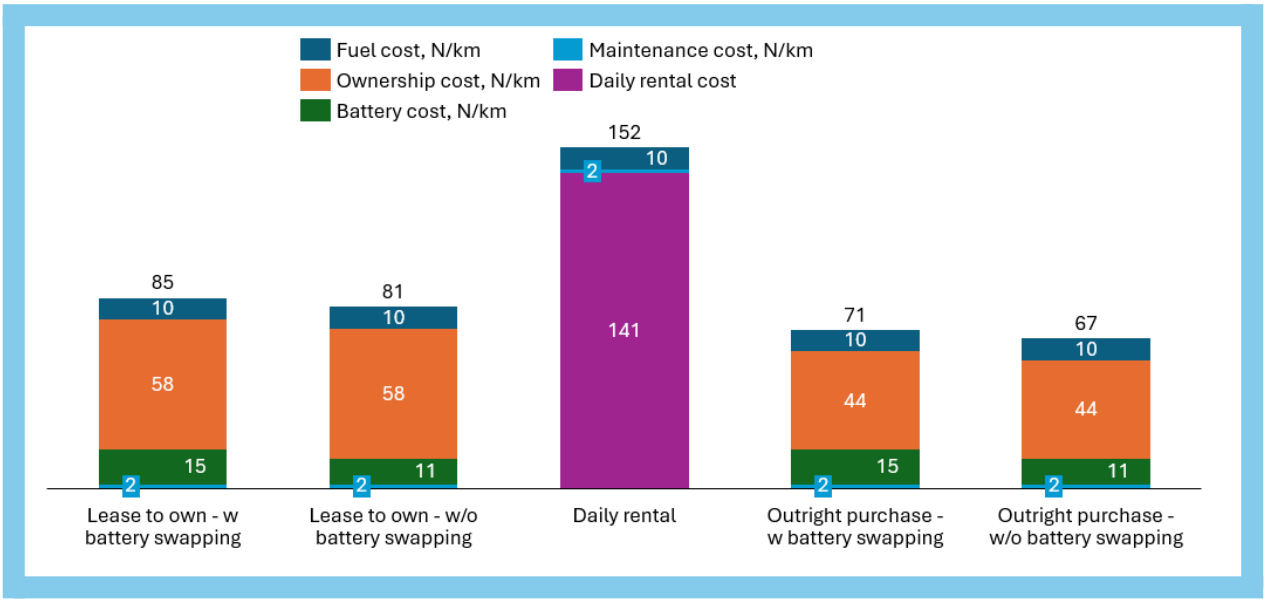
Table 4. Comparison of four vehicle ownership models

Model	Rental	Subscription (VaaS)	Lease-to-own	Retrofitting
Key features				
Consumer ownership	No ownership	No ownership; switches allowed	Ownership secured at the end	Full ownership
Duration	Short-term (hours to months), generally up to 3 months; Fixed term	Short-term to long-term (daily to years); Flexible terms with rolling contract	Long-term (years), typically 1-5 years; Fixed term	Varies; Depends on the life-cycle of the vehicle
Model selection	One model per time	Able to swap vehicles	One model per time	Specific model selected
Initial/upfront cost	A refundable deposit, generally not significant	A refundable deposit, generally not significant	A non-refundable down payment, generally 1-12 months' rental	High initial investment
Regular payment	Daily/weekly/monthly rates; variable costs;	Daily/weekly/monthly rates; variable costs	Fixed monthly payments; penalties for early termination	Only one-time cost, no follow-up payment is needed - long-term savings potential
Maintenance service	Included in rental	Included in subscription	Generally not included	Owner's responsibility for ongoing maintenance
Other services Included	Insurance, road tax	Insurance, road tax, sometimes electricity, and other add-on services	N/A	N/A
Advantages and Disadvantages Comparison				

Pros	Low upfront cost; Flexible duration	Flexible duration; Vehicle swapping available; One-stop service; low upfront cost	Ultimate ownership, low upfront cost compared to purchase	low upfront cost compared to purchase;
Cons	Higher cost on an average basis; Add-on services not included	Not able to own the vehicle at the end	Less flexible	Expensive compared to other rental models; not flexible in usage

Source: *Created by the author. Reference: Pickering,Chris 2024. Deloitte 2023*

Figure 5. Comparison of of Total Cost of EV Ownership by business model, ₦/km



Source: SIPA Capstone Team. Financial Model. 2024.

The above TCO comparison converts all costs associated with vehicle use into a per kilometer figure. This enables the direct comparison of upfront and variable costs. As demonstrated, outright purchase results in a lower TCO per kilometer than lease to own or rental, however this comes at the cost of infeasible upfront costs to the rider.

The addition of repayment over time converts these upfront costs into ongoing costs, but also raises the TCO of EVs due to the high cost of capital (25% interest rate) and the margin that needs to accrue to the mobility service provider (35%). Further, the addition of flexibility in rentals leads the daily rental price to be significantly higher than the lease to own model which gives the mobility provider a higher degree of certainty.

Battery ownership and charging solutions

There are three combined battery ownership and charging solutions models under consideration. The first is battery charging and rider ownership of the battery. The second is battery charging and charge provider ownership of the battery. The third is battery swapping with charge provider ownership of the battery.

Standard charging and rider ownership

In this model the ownership of the battery is bundled with ownership of the bike. This means the rider either pays a higher upfront purchase price for the bike, or pays a larger amount in their monthly lease to own payments. The rider then pays the charging station provider (likely the local mini grid owner) to charge the battery when needed.

Standard charging and charging station provider ownership

In this model the charging station provider owns the battery, and the rider pays to charge and use the battery. This lowers the riders' upfront purchase price or monthly repayment, but increases the cost of recharging the battery, as that price now includes the price of renting the battery as well.

Battery swapping

A battery swapping business model is one where batteries are centrally owned by the charging station provider, and the rider pays to swap the battery in their bike for a fully charged battery. This can complement a lease to own model, a retrofitting model or exist separately. The advantage of this model is that it reduces the upfront cost or rental cost of an EV. Further, it enables battery swapping as a charging solution, eliminating the need for riders to wait while bikes charge.

Modelling assumes a fee for each time the battery is swapped at the charging station. However, there is an alternate model (Battery as a Service) where the rider pays a monthly subscription and can swap their battery up to a certain number of times each month. Such a model could provide additional revenue certainty to the charging station provider.

Comparing the charging models

Table 5. Comparison of charging model for EV's

	Standard charging, rider ownership	**Standard charging, battery owned by charge provider**	**Battery swapping**

Upfront cost to consumer	High	Low	Low
Ongoing cost to consumer	Moderate	Low	High
Convenience of use	Inconvenient wait times for charge	Inconvenient wait times for charge	Highly convenient, time at charging station of <5 minutes

As can be seen in the above chart and in Figure 5, using battery swapping instead of charging moderately increases the total cost of ownership of the EV. However, this comes at substantial benefits in terms of both increased convenience for bike riders, and lowering upfront costs of use.

International best practices

Electric vehicles were some of the first vehicles to be invented and used over 100 years ago. Eventually the invention of the diesel engine and mass production of internal combustion vehicles made them much more affordable and easy to mass produce than EV options. Electric vehicles did not become competitive in the vehicle market once again until the 2000s. As seen from our research and in-country interviews, the primary reason for not buying EVs is its high upfront cost. Countries that have developed successful EV markets have had to use significant government intervention to do so.

Macroeconomic environment

Non-African Countries
The electric vehicle market continues to grow around the world. The growth in the market is also driving a growth in investment in the market. China has not only led the way in EV investment and adoption domestically, but it has also invested in EVs internationally. In 2023, China invested approximately $28.2 billion in EVs with three quarters of this sum being invested in Europe, the Middle East, and Asia.[44] In 2022, venture capital investments in startup EV companies grew 30% from 2021 to a total of $2.1 billion in the United States.[45]

African Countries
In Africa, there is a slow, but slight growth in investment in the EV market. Of these investments, Kenya leads the way with over one third of all EV investment taking place within the country. Investment in the EV market is expected to reach $21.39b by 2027, up from only $11.94b in 2021.[46]

During conversations with the African Finance Corporation, Kenya was specifically mentioned as a desirable investment environment due to the maturity of its electricity system, currency stability, debt environment, and overall risk assessment. Conversely, Nigeria was highlighted as a challenge due to its currency instability and capital controls as well as grid instability. Such an environment does not encourage investment and when it does, it is only when a project is clearly defined and a "guaranteed win." Such barriers will continue to pose a challenge for possible investors.

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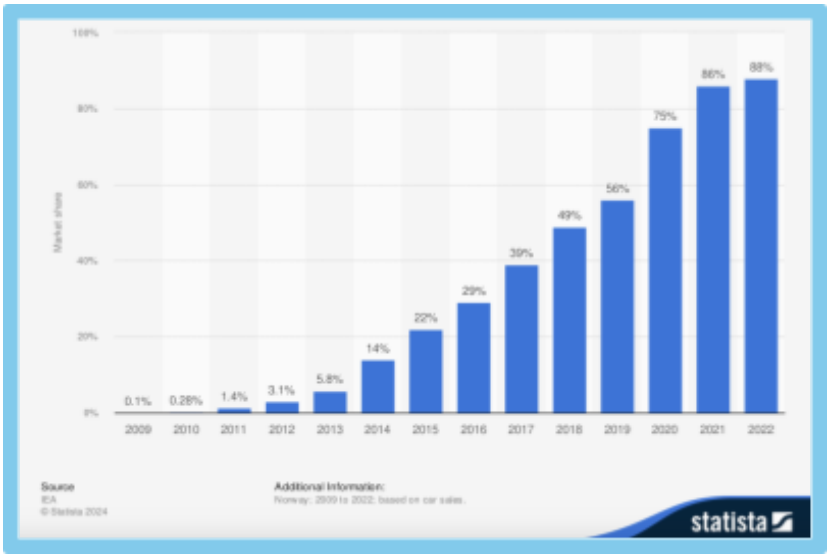
[44] Meyer, Armand et al. 2024. "Pole Position: Chinese EV Investments Boom amid Growing Political Backlash." Rhodium Group. February 29, 2024. https://rhg.com/research/pole-position-chinese-ev-investments-boom-amid-growing-political-backlash/
[45] IEA. 2023. "Executive Summary – Global EV Outlook 2023 – Analysis." IEA. 2023. https://www.iea.org/reports/global-ev-outlook-2023/executive-summary.
[46] Koigi, Bob. n.d. "Inside Africa's EV Revolution." FairPlanet. https://www.fairplanet.org/story/africa-electric-vehicle-charging-station-startup/#:~:text=The%20EV%20race.

Vehicle electrification strategies

Non-African Countries

Internationally, several countries have used creative tax incentives to drive EV adoption. Norway was one of the first countries to do so, enacting policies such as progressive taxes based on a vehicle's weight and emissions, exemption from value added taxes on EV purchases and leases, exemptions or minimum 50% reduction in road tolls, as well as lower parking fees and access to bus lanes for EVs.[47] These policies have led from a 1% market share for EVs as a proportion of new cars sold in 2011 to 88% market share by 2022.[48]

Figure 6. Market shares of electric cars (BEV and PHEV) in Norway, 2009-2022



Source: *Wagner 2021*

The United States has also heavily subsidized its EV industry. Although there is a fairly robust electric vehicle industry today and Tesla is widely regarded as a leader within the industry, this was only accomplished through heavy government intervention. Tesla received a $465 million preferential loan from the Department of Energy in 2010 as well as tax credits for consumers to purchase Tesla vehicles. An estimate of total government support that Tesla has received pegs the mark at approximately $3 billion.[49]

African Countries

A major issue in electric vehicle adoption in Sub-Saharan Africa is the prohibitive up front cost of EVs. Vehicles are abundant, particularly two wheelers but the market is dominated by used vehicles imported from primarily western countries. These

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[47] "Norway's Electric Vehicle Incentives – Policies." n.d. IEA. https://prod.iea.org/policies/17809-norways-electric-vehicle-incentives.

[48] Wagner, I. 2021. "Norway: PHEV and BEV Market Share 2009-2020." Statista. February 19, 2021. https://www.statista.com/statistics/1029909/market-share-of-electric-cars-in-norway/.

[49] Fernholz, Tim. 2023. "Elon Musk's SpaceX and Tesla Get Far More Government Money than NPR." Quartz. April 13, 2023. https://qz.com/elon-musks-spacex-and-tesla-get-far-more-government-mon-1850332884.

vehicles are also quite old, which leads to them being less energy efficient and contribute more heavily to pollution than newly produced vehicles. As of 2022, only 7 countries have banned the import of used vehicles over 5 years old or adopted the Euro 4 emissions standard for imports.[50]

Several countries have enacted policies that have shown immediate impact on EV adoption as well as local production. Yet most African countries do not have any or a robust enough EV policy to help spur adoption. As of 2022, only 6 countries had adopted any sort of EV policies.[51] Overall, African governments have a long way to go on the policy front to help encourage investment in the EV industry and build production domestically.

Additional Supportive policies

Non- African Countries

Globally, China has enacted the most supportive policies for EV adoption. They accounted for more than half of the world's EV's on the road, and experienced significant boost in sales of BEVs and PHEVs this past year[52]. This is attributed to the government's determination to increase the supply and demand of electric vehicles. With the infrastructure already in place– roads, electricity, expertise– the government handed out financial subsidies and tax breaks to EV companies. They also removed barriers for EV users, such as the lengthy process for license plate registration. Finally, they take their public private- partnerships very seriously, ensuring they experience domestic and international growth[53].

BEV and PHEV production is significantly increasing throughout Europe and in the US, as well. Germany has the most supportive policies in Europe given the government's increased support after COVID. They also offered purchasing incentives and financial breaks for EV companies. In the US, the Bipartisan Infrastructure Law strengthened support for EV charging and allocated funding towards EV rollout[54].

African Countries

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[50] Conzade, Julian et al. 2022. "Power to Move: Accelerating the Electric Transport Transition in Sub-Saharan Africa | McKinsey." February 23, 2022. https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/power-to-move-accelerating-the-electric-transport-transition-in-sub-saharan-africa.

[51] Khan, Tanzila, Sumati Kohli, Zifei Yang, and Josh Miller. 2022. "Zero-Emission Vehicle Deployment: Africa." April 2022. https://theicct.org/wp-content/uploads/2022/04/africa-hvs-zev-deploy-africa-apr22.pdf.

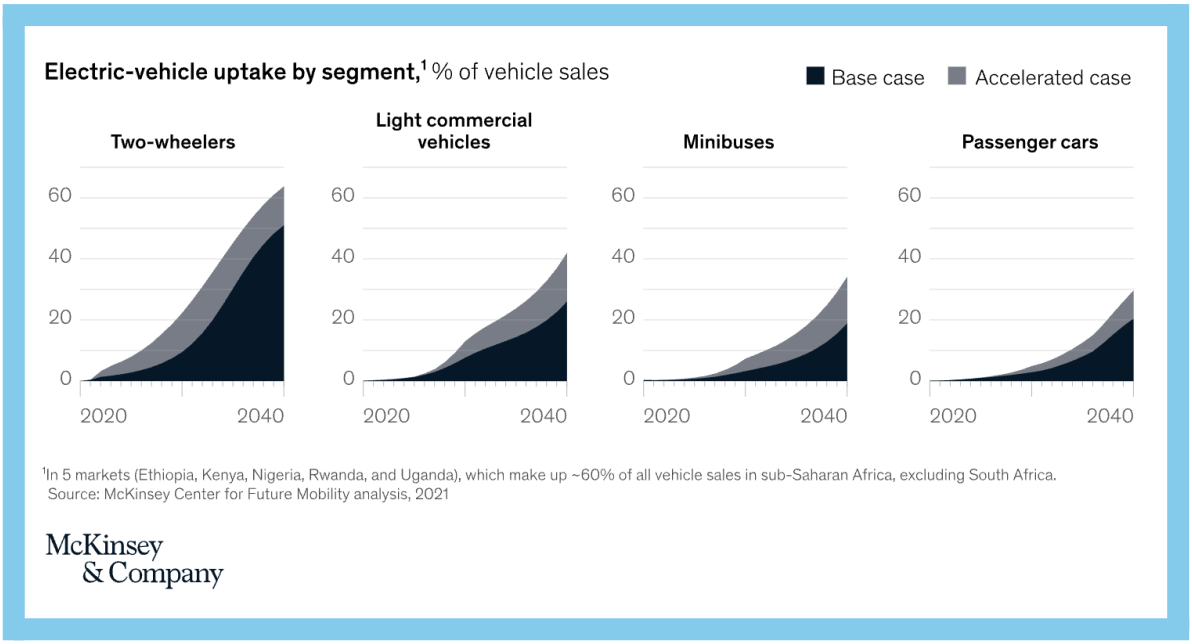
[52] "Trends in Electric Light-Duty Vehicles – Global EV Outlook 2023 – Analysis." n.d. IEA. https://www.iea.org/reports/global-ev-outlook-2023/trends-in-electric-light-duty-vehicles#abstract.

[53] Yang, Zeyi. 2023. "How Did China Come to Dominate the World of Electric Cars?" MIT Technology Review. February 21, 2023. https://www.technologyreview.com/2023/02/21/1068880/how-did-china-dominate-electric-cars-policy/.

[54] "Trends in Electric Light-Duty Vehicles – Global EV Outlook 2023 – Analysis." n.d. IEA. https://www.iea.org/reports/global-ev-outlook-2023/trends-in-electric-light-duty-vehicles#abstract.

Throughout the continent, there has been a steady emergence of EV development. Governments throughout sub-Saharan Africa have committed to electrifying their transport sector through different means, and there has been a considerable growth in EV startups. Rwanda is rolling out reductions on import duties and lower taxes on EV parts. Their EV startup, Ampersand, also raised $9 million in 2021 to scale up EV motorcycles in Rwanda and Kenya[55]. Some countries, like Morocco, banned imports of older vehicles and set emission standards to discourage ICE vehicles[56]. The graph below reflects the impact of supportive policies on EV adoption throughout Africa[57]:

Figure 7. EV adoption in sub-Saharan Africa is expected to be highest for 2-wheelers, but other segments can grow significantly in an accelerated case



Source: *Conzade et al 2022.*

As population and emission increase, African governments are moving to incentivize EV adoption and scale up production. However, most countries cannot accommodate the infrastructure. While EV goals are put in place, the rollout is slow. Building the roads, electricity, and chargers for EVs is also a timely process that Africa, historically, has struggled to stay ahead of. Finally, the cost of living makes consumers very hesitant or indifferent to purchasing expensive EV's[58]. There are still many more supportive policies to be enacted.

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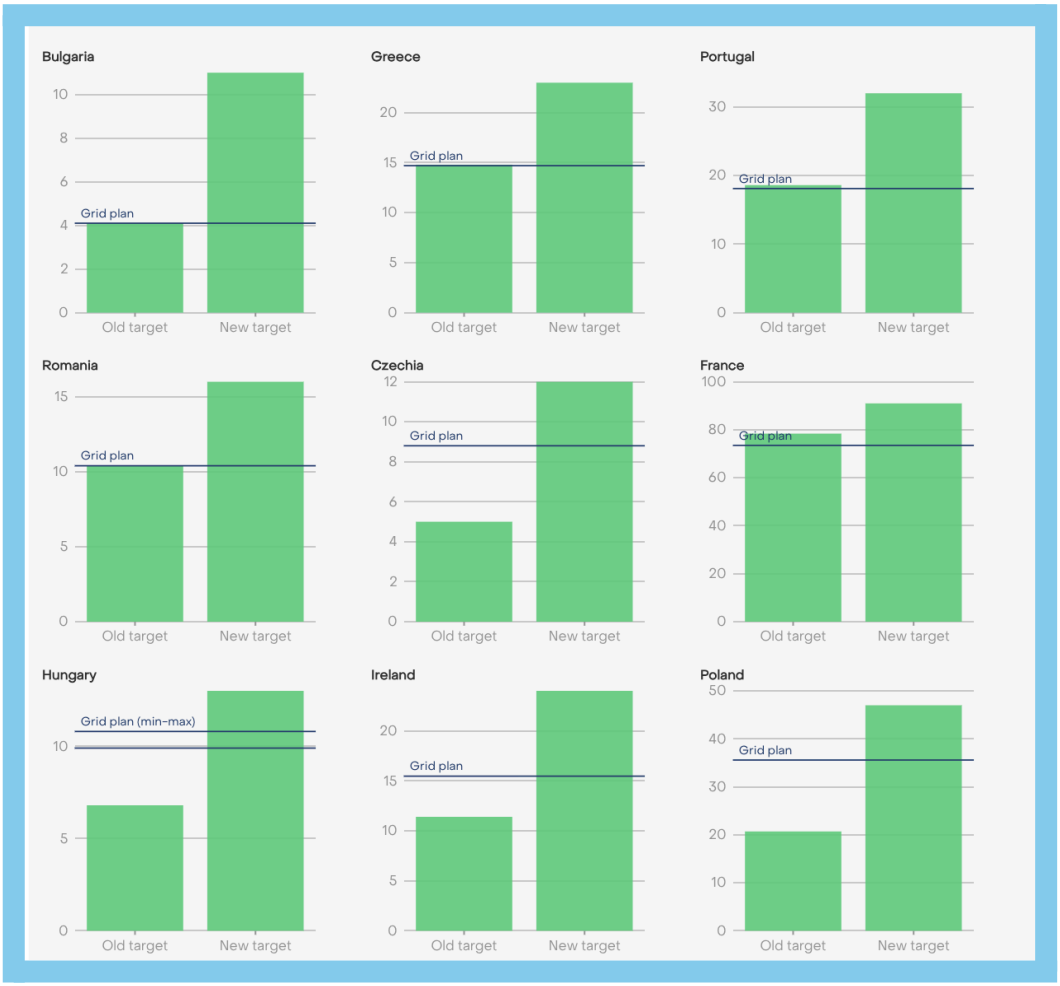
[55] "Financing the Transition to Electric Vehicles in Sub- Saharan Africa." 2022. https://shellfoundation.org/app/uploads/2022/02/EV-Report-McKinsey.pdf.
[56] "The Renewable Energy Transition in Africa." n.d. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2021/March/Renewable-Energy-Transition-Africa_Country_Studies_2021.pdf.
[57] Conzade, Julian et al. 2022. "Power to Move: Accelerating the Electric Transport Transition in Sub-Saharan Africa | McKinsey." February 23, 2022. https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/power-to-move-accelerating-the-electric-transport-transition-in-sub-saharan-africa.
[58] https://centurionlg.com/2022/05/03/electric-vehicles-is-the-timing-right-for-africa/

Grid stability

Non- African Countries

In recent years, the world has been experiencing increased stress on power grids. In the US, power has become less reliable and more fragile. As the country transitions a complicated grid system away from fossil fuels, RE sources are overwhelmed by consumer demand, leading to increased blackouts and brownouts[59]. European countries face similar challenges in grid capacity. Many countries have outdated infrastructure and have not sufficiently expanded their networks. This is related to the time lag between policy and implementation, as well as the misalignment between target goals and actual grid plans, as seen below:[60]

Figure 8. Grid plans in Europe are based on energy scenarios that trail behind the national targets for 2030 wind and solar capacity (GW)



[59] Ezrati, Milton. 2023."America's Electric Grid Is Weakening." Forbes. March 24, 2023. https://www.forbes.com/sites/miltonezrati/2023/03/24/americas-electric-grid-is-weakening/?sh=8ac4cfef7e9e.

[60] "Grids for Europe's Energy Transition." 2024. Ember. March 13, 2024. https://ember-climate.org/insights/research/putting-the-mission-in-transmission-grids-for-europes-energy-transition/.

Source: *Ember 2024*

This has created concerns about EVs creating further strains on power grids. In the US, almost 80% of charging occurs at home for those who can afford to install one. For those who live in apartments, the entire residence would need a charging system, which is a costly and challenging project for older buildings. When it comes to traveling, the charging network across the US is the still being developed to keep up with the increasing number of EV's, creating range anxiety for users[61]. EU countries have similar roadblocks, which shows that the lagging progression of grid stability has made it difficult to incentivize EVs over ICE vehicles.

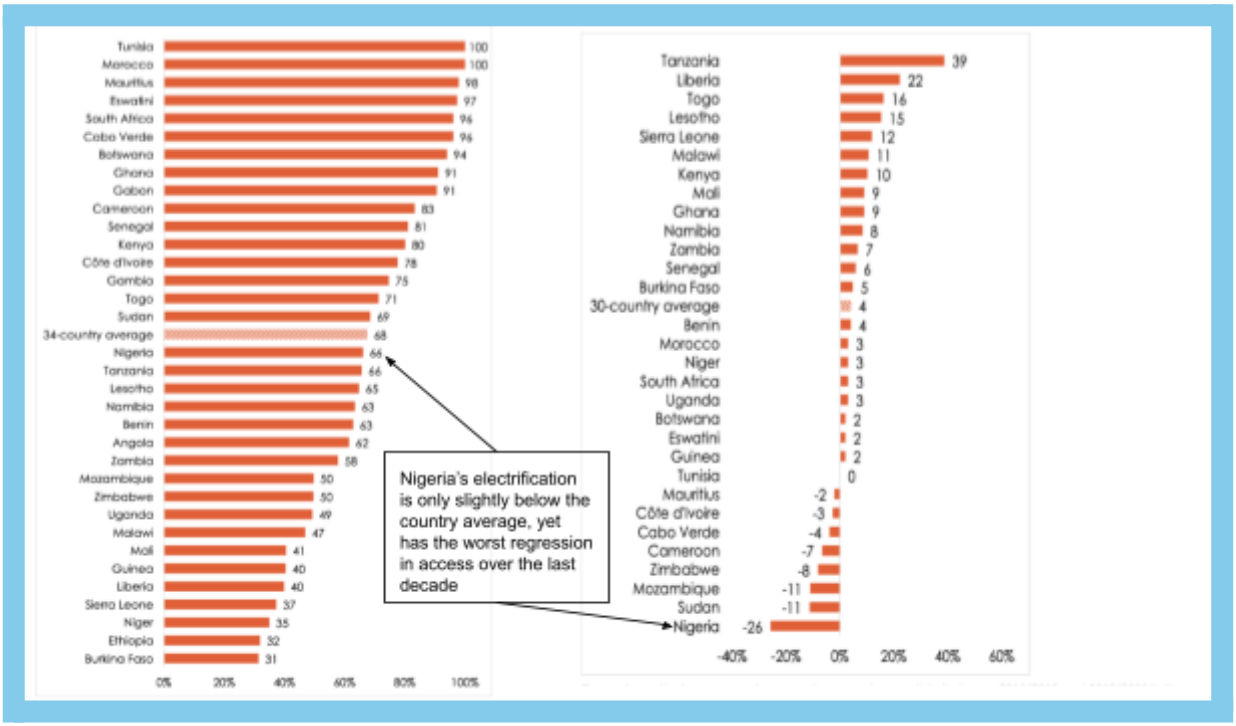
African Countries

In a survey of 34 countries conducted by the research network, Afrobarometer, a little over two-thirds (68%) of African citizens live in areas with access to an electrical grid. As seen in the chart below, this average is a 4% increase from ten years ago, but there are significant disparities between countries in their accessibility and progress[62]. Compared to more developed nations, grid instability is an issue for everyday needs, so EV adoption is especially challenging.

Very few countries have excess supply in power generation, and for most of them, it is not significant enough to handle the increased demand. Generation capacity is a concern throughout the continent, as well as the reliability of many national grids. South Africa has been experiencing an increased number of blackouts on their power grid. If citizens cannot go through a day with reliable lighting, there is little faith in the government's ability to handle EVs[63]. There is increased focus on using off-grid systems to power EV's, but these can be costly for communities and vehicles might not be their priority for power use.

[61] *MarketWatch*. 2023. "The Future of Electric Cars: What's Holding Us Back?," August 29, 2023. https://www.marketwatch.com/guides/car-warranty/the-future-of-electric-cars-whats-holding-us-back/.
[62] Hee, Eun Lee, et al. 2022. "Still Lacking Reliable Electricity from the Grid, Many Africans Turn to Other Sources." Afrobarometer. April 8 2022. https://www.afrobarometer.org/wp-content/uploads/2022/04/ad514-pap10-still_lacking_reliable_electricity_from_the_grid-many_africans_turn_to_alternative_sources-afrobarometer-10april22.pdf.
[63] ECOFLOW. 2024. "Impacts of Grid Collapse in South Africa." EcoFlow. February 19, 2024. https://blog.ecoflow.com/za/impacts-of-grid-collapse-south-africa/.

Figure 9. Access to electrical grid for 34 countries (2019/2021); change in access to the electrical grid for 30 countries (2011- 2021)



Source: *Hee et al. 2022*

Case Studies for Analysis

Considering the factors that influence international best practices, three countries were selected to assess their electric vehicle markets compared to Nigeria: Kenya, Ghana, and Rwanda. Although no country is a perfect match, all three have similarities to Nigeria, whether that be through the maturity of the electric vehicle market, electricity access, or demographics and geography. All three can also create paths forward for Nigeria through the policy and economic decisions they have made to grow their electric vehicle markets.

Kenya

Relevance to Nigeria

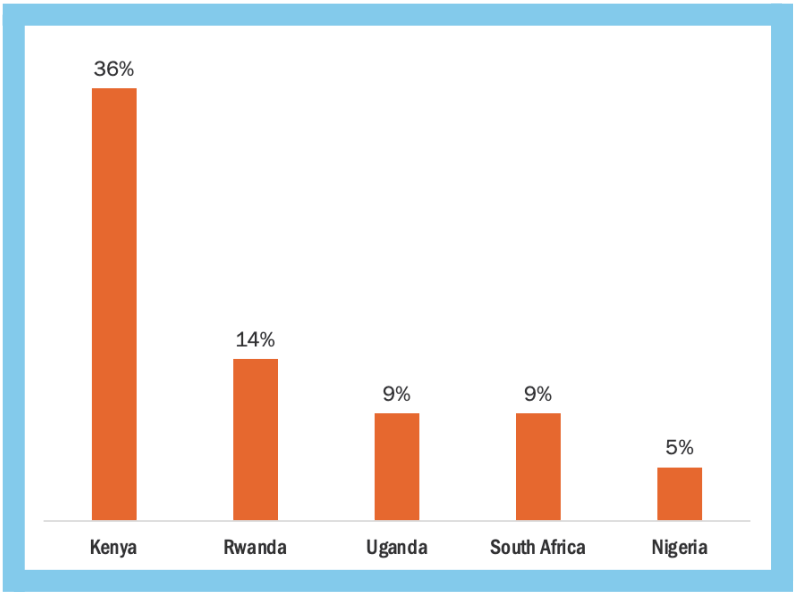
Kenya and Nigeria have quite a few similarities within their mobility markets. Kenya and Nigeria both have poor road infrastructure and overwhelmingly rely on second hand vehicles which compose 95% of all vehicles imported to Kenya. Although Nigeria is larger both by population and gross domestic product, on a per person basis, both countries are quite similar in terms of GDP, GNP, imported and exported

goods.[64] Kenyan companies have also creatively utilized mobile applications to help in EV adoption, with apps providing information on charging stations and battery charging percentages. This is another similarity with Nigeria, the continent's largest mobile phone market as well as mobile app development.[65]

Differences from Nigeria

Although these countries share some similarities, there are also some major differences. Nigeria has over four times the population of Kenya which poses significant challenges to EV roll out as well as electric infrastructure as a whole. Kenya's population also has a much larger percentage of people with electricity access: 85% vs. 60%. Kenya has a sizable amount of excess capacity while Nigeria struggles to support its large population with its existing infrastructure. Kenya also has a more robust EV industry and market than Nigeria. The country has a few domestic producers and possesses the highest level of investment in EVs in Africa. Below is a graph illustrating closed EV startup deals from 2019-2023 by country:[66]

Figure 10. EV startup deals from 2019 to Q1 2023, by country



Source: *Larson 2023*

Overcoming barriers

Over the past three years, Kenyan companies have started manufacturing, designing, assembling and selling electric bikes. They have also teamed up with local creditors to offer cheap loans, the only way many riders can afford their bikes. Similar to leases in the U.S. some companies take a down payment and then

[64] "Country Comparison Kenya : Nigeria." n.d. Worlddata.info. https://www.worlddata.info/country-comparison.php?country1=KEN&country2=NGA.
[65] Okafor, Tage-Kene. 2021. "Nigeria Leads Mobile App Market Growth in Africa as Use of Gaming Apps Surge 44% from Q1 2020." n.d. TechCrunch. July 13, 2021. https://techcrunch.com/2021/07/13/nigeria-leads-mobile-app-market-growth-in-africa-as-use-of-gaming-apps-surge-44-from-q1-2020/.
[66] Larson, Andrew. 2023. "Insights on the EV Sector across Africa.". Renew Capital. May 10 2023.. https://www.renewcapital.com/newsroom/insights-on-the-ev-sector-across-africa.

monthly installments to pay off the bike. Most companies also use battery swapping, which drops the cost of the bikes even further. These bikes and battery swapping stations utilize apps to find charged batteries and where to place empty ones. The government has focused on developing the infrastructure in the city first, then expanding out into rural areas.[67]

Government supports

Kenya has adopted several policies to encourage EV adoption such as banning second-hand cars that are older than 7 years old and halving excise duty from 20% to 10% for EVs. The Nigerian National Automotive Design and Development Council has also laid out their tax plans to encourage domestic production and adoption although they have not been enacted yet. These plans include a reduction in import taxes for EVs as well as a 3-year tax holiday for taxis and two wheelers that purchase EVs.[68]

Through this research they discovered a sizable excess in electricity supply that could accommodate a large increase in EVs within Kenya. In terms of electricity coverage nationwide, 85% of Kenya's population had electricity access as of 2019, while Nigeria sat at 59.50% as of 2021.[69] The favorable policies put in place by the Kenyan government have led to investment and domestic production of EVs from companies such as Roam.[70]

The President of Kenya announced the country's commitment to EV adoption. The government has partnered with Spiro, a private company, to build 3,000 battery charging and swapping stations throughout the country.[71] The government has also set up a 14-person task force to guide e-mobility policy. The Task Force was created to help develop a National Electric Mobility Policy (the e-Mobility Policy) covering all modes of transport (road, air, rail, and maritime). This aims to create an enabling environment for the development, growth and adoption of electric vehicles in Kenya.[72]

Overall Insights

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[67] Asare, Paa Kwesi. 2024. "Kenya's Push to Make 'Boda-Boda' Motorbike Taxis Go Electric," January 7, 2024. https://www.bbc.com/news/world-africa-67781109.

[68] "Nigerian Automotive Industry Development Plan Nigerian Automotive Industry Development Plan." 2023. https://naddc.gov.ng/wp-content/uploads/2023/06/Nigerian-Automotive-Industry-Development-Plan-2023.pdf.

[69] "Nigeria Electricity Access 1990-2023." n.d. https://www.macrotrends.net/countries/NGA/nigeria/electricity-access-statistics#:~:text=Access%20to%20electricity%20is%20the.

[70] "Roam Hub." https://www.roam-electric.com/roam-hub.

[71] Kemp, Yunus. 2023. "Kenya: Major Plan for Roll-out of Electric Vehicles, Infrastructure." ESI-Africa.com. September 5, 2023. https://www.esi-africa.com/business-and-markets/kenya-major-plan-for-roll-out-of-electric-vehicles-infrastructure/.

[72] Ministry News. 2024. "Dawn of New Era as Ministry Launches Draft Electric Mobility Policy," Ministry of Roads and Transport. https://www.transport.go.ke/dawn-new-era-ministry-launches-draft-electric-mobility-policy

Although Kenya has a growing EV market, supportive business environment, and government will, there are still challenges to adoption. If only two wheel vehicles shifted to EVs and not all vehicles, it would still likely overwhelm Kenya's electricity grid. Therefore the transition to electric vehicles must be well planned and gradually instituted. Although Kenya currently has excess supply, it will need to increase its electric generation capacity to meet the inevitable increase in demand as more vehicles on the road become electric vehicles. Even more importantly, more electric vehicles calls for greater electric power generation and the need to carefully consider existing electricity supply and demand to more optimally utilize the generation capacity.[73]

Ghana

Relevance to Nigeria

As neighboring countries, Ghana and Nigeria have some similarities within their mobility market. Both countries have poor road infrastructure– especially in the rural regions– and limited intra-city transport. This has led to the prominence of motorcycle use, for the sake of cost and convenience, but they also rely on second-hand vehicles which make up 80% of Ghana's vehicle imports[74]. Nigeria's population and GDP is more than 6 times that of Ghana. Nigeria also imports and exports goods almost 3 times more, but have similar GDP per capita and annual growth as Ghana[75] [76]. Both countries are often the focal points to scale up EV companies, given their proximity and positions as leading countries in West Africa. Similar to Nigeria, Metro African Xpress (MAX), the mobility company, also operates in Ghana to help spur EV adoption. The company recently received $31 million to expand into Ghana and Egypt[77].

Differences from Nigeria

Nigeria has an overall population that is six times larger than Ghana, which poses significant challenges to electrification rates and EV adoption. However, 74% of Ghana's rural population is electrified compared to 26% in Nigeria. Ghana has also been experiencing excess capacity– although there are concerns about this

[73] Pawlak, Jacek, Aruna Sivakumar, Winston Ciputra, and Tang Li. 2023. "Feasibility of Transition to Electric Mobility for Two-Wheeler Taxis in Sub-Saharan Africa: A Case Study of Rural Kenya." *Transportation Research Record* 2677 (12): 359–70. https://doi.org/10.1177/03611981231168122.
[74] Wahab Lukuman and Jiang, Haobin. 2018. "FACTORS INFLUENCING the ADOPTION of ELECTRIC VEHICLE: THE CASE of ELECTRIC MOTORCYCLE in NORTHERN GHANA." 2019. *INTERNATIONAL JOURNAL for TRAFFIC and TRANSPORT ENGINEERING* 9 (1): 22–37. https://doi.org/10.7708/ijtte.2019.9(1).03.
[75] "Country Comparison: Ghana / Nigeria." n.d. Worlddata.info. https://www.worlddata.info/country-comparison.php?country1=GHA&country2=NGA#energy.
[76] "World Bank Open Data." n.d. World Bank Open Data. https://data.worldbank.org/?locations=NG-GH.
[77] Ekwealor, Victor. "Why African EV Startups Are Struggling." 2023. Rest of World. February 15, 2023. https://restofworld.org/2023/africa-ev-startup-max/.

decreasing– while Nigeria struggles to support half its population consistently[78]. Ghana has also been very focused on developing the transport sector to reduce carbon emissions. The country developed a solar-powered taxi service and aims for a complete transition to electric buses by 2050. They also installed 200 chargers across Southern Ghana, simultaneously tackling EV infrastructure and rollout[79]. This has given Ghana a considerable advantage for investments and partnerships in e-mobility, despite having only a sixth of the population of Nigeria.

Overcoming barriers

Ghana's transportation accounts for almost half of greenhouse gas emissions (GHGs) in the energy sector. E-mobility adoption and scaling would dramatically reduce Ghana's carbon footprint and accelerate its goals in renewable energy adoption. Over the past five years, The Energy Commission of Ghana facilitated the importation of 17,660 electric vehicles into the country. More than half of the imports were BEVs, most 2 and 3-wheel vehicles, while PHEVs were the second largest model. They currently have four AC public charging stations in Accra, with a fifth one undergoing construction[80]. There are efforts from automobile companies, both international and domestic, to sell more hybrid and EVs, although this is in the early stages[81]. Ghana is also continuing to form partnerships with other countries, as they recently confirmed collaborating with the UK to explore EV adoption. [82]

Government supports

Ghana has enacted several policies over the years to develop EV infrastructure and promote large-scale rollout. As part of the proposed 2024 budget, the Ghanaian Finance Ministry waived import duties on electric vehicles for public transportation for eight years. This not only reduces the upfront cost of purchasing EVs, but also presents business opportunities for manufacturers of e-buses and large EVs[83]. The Ministry of Transport also drafted an *Electric-Vehicle Policy* framework to guide the development of EVs, specifically to educate the community. With this framework, the Ghanaian government could introduce targeted policies that promotes EV purchase

[78] "World Bank Open Data." n.d. World Bank Open Data. https://data.worldbank.org/indicator/EG.ELC.ACCS.RU.ZS?locations=GH-NG.
[79] Khan, Tanzila, Sumati Kohli, Zifei Yang, and Josh Miller. 2022. "Zero-Emission Vehicle Deployment: Africa." April 2022. https://theicct.org/wp-content/uploads/2022/04/africa-hvs-zev-deploy-africa-apr22.pdf.
[80] Donkor, Richard, et al. 2022. "Energy Commission, Ghana." Energy Commission. https://www.energycom.gov.gh/files/DEI%20BASELINE%20REPORT.pdf.
[81] "Ghana Electrical Vehicle Sector." International Trade Administration (ITA). https://www.trade.gov/market-intelligence/ghana-electrical-vehicle-sector.
[82] Kemp, Yunus. 2024. "Ghana-UK Partnership Look to Unlock EV Potential." ESI-Africa.com. February 13, 2024. https://www.esi-africa.com/business-and-markets/ghana-uk-partnership-look-to-unlock-west-african-nations-ev-potential/.
[83] "Ghana Electrical Vehicle Tariffs". International Trade Association (ITA).December 27, 2023. https://www.trade.gov/market-intelligence/ghana-electrical-vehicle-tariffs.

and professional training in manufacturing[84]. Overall, Ghana is striving to create a flexible environment for companies, riders, manufacturers to invest in EVs.

Before these developments, Ghana had several supportive policies for RE deployment, setting the stage for EVs. Their Renewable Energy Act in 2011 set aside funds and developed targeted goals for RE transition in heat and power generation. The NEP* in 2010 pushed the transition to RE sources in the transport sector, which likely set up the Ministry's EV Policy[85]. These structures that Ghana put in place towards their energy goals highlighted the importance of electric vehicles.

Government support in e-mobility start-ups are especially important, as they reflect the success of public-private partnerships in EV development and potential areas for improvement. Solar Taxi is one of their popular companies that not only provide affordable and reliable vehicles, but also train women and youth in EV engineering and operations. The company also utilizes mobile applications to help in EV adoption, with ride and delivery apps. While the Ministry of Finance has addressed the high import duties, there aren't many financial incentives for consumers and the charging infrastructure is still far behind EV development. There is a need for awareness campaigns so consumers have a better understanding of Ghana's supportive policies[86].

Overall Insights

Although Ghana's EV market is rapidly growing and has a supportive environment, there are still challenges to adoption. For consumers, there is an awareness of EVs but much less understanding of the benefits compared to ICE vehicles. Barriers to adoption include the high upfront costs of the vehicle, 'range anxiety' for users who need inter-city transport for long hours, and the limited charging infrastructure[87]. While Ghana does have excess energy supply, there are concerns that EV adoption would overwhelm the power systems. Ghana is similar to Nigeria in many ways, as electrification rates are very low in rural households. Technologically, there are concerns about grid instability and design flaws affecting utilization. Investors also face high upfront costs and there are limited financial options to scale up pilot programs. Finally, there is not much cohesion amongst manufacturers, distributors, and the Ghanaian government, creating weak coordination and support for an

[84] "MINISTRY of TRANSPORT LAUNCHES NATIONAL EV POLICY." Ministry of Transport. December 6 2023. https://www.mot.gov.gh/10/16/1/151/ministry-of-transport-launches-national-ev-policy.
[85] Ibrahim, I.D., Y. Hamam, Y. Alayli, T. Jamiru, E.R. Sadiku, W.K. Kupolati, J.M. Ndambuki, and A.A. Eze. 2021. "A Review on Africa Energy Supply through Renewable Energy Production: Nigeria, Cameroon, Ghana and South Africa as a Case Study." *Energy Strategy Reviews* 38 (November): 100740. https://doi.org/10.1016/j.esr.2021.100740.
[86] Odoom, C., & Awuah, G. B. (2023). *Supporting E-mobility Start-ups in Africa: A Case Study of Ghana's Solar Taxi Limited*. Centre for Business and Development Studies. Centre for Business and Development Studies. Policy Brief No. June 2023.
[87] Agyemang, Ernest & Amankwaa, Ebenezer & Essandoh-Yeddu, Joseph. (2022). Exploring the Barriers to Consumer Adoption and Applications of Electric Vehicles: Ghana's Experience. 1-5. 10.1109/IUCE55902.2022.10079349.

e-mobility infrastructure[88] [89]. It is clear that e-mobility is relatively a new technology for Ghana and, despite their enthusiasm, there are a lot more barriers to address through long-term planning.

Rwanda

Background

As of now, Rwanda's electricity access is estimated at 71.9%, with approximately 18.3% of the population not connected to the grid[90]. The country possesses a variety of distributed energy resources (DERs)[91] such as solar, biomass, hydro, methane gas from Lake Kivu, and geothermal. Additionally, the feasibility of implementing mini grids that utilize diverse DERs including photovoltaics, battery storage, diesel generators, and electric vehicles is well-established. Sustainable development remains a critical pillar for Rwanda and poses challenges for future communities. Rwanda's specific commitment is to reduce GHG emissions to 63.0% of its baseline from 2015 to 2030, which translates to a 37.0% reduction in GHGs, amounting to 4.6 million tonnes of CO2 by 2030[92]. From an energy generation perspective, the Rwandan government is focusing on expanding the use of renewable energies through technologies such as mini grids and EV technologies, still in their nascent stages, to meet the growing energy demand and address gas emissions. Additionally, the implementation of EVs and vehicle fuel economy guidelines are projected to be key in the planning for the coming decade, influencing new vehicle integration into the fleet, the development of charging infrastructure, and the decarbonization rate of the electricity grid.

Relevance to Nigeria

Rwanda and Nigeria are undergoing transitions towards e-mobility, though their contexts and approaches have differences, they share several similarities in this area:

- *Government Support and Policy Initiatives*: Both Rwanda and Nigeria have demonstrated government support for the adoption of electric vehicles (EVs) through a range of policy initiatives. Rwanda has proactively facilitated the deployment of EVs by enacting policies favorable to electric mobility, such as

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[88] Ayemang, Ernest and Amankwaa, Ebenezer Forkou. 2022. "National Electric Mobility Policy and Market Readiness Framework for Ghana." January 2022. https://unepccc.org/wp-content/uploads/2022/06/national-electric-mobility-policy-framework-ghana-final.pdf.

[89] Ayemang, Ernest and Amankwaa, Ebenezer Forkou. 2022."National Electric Mobility Roadmap in Ghana."https://unepccc.org/wp-content/uploads/2022/08/national-electric-mobility-roadmap-upload-25072022.pdf.

[90] Zingiro, Armand. Rwanda Energy Group. "Annual Report 2022-2023". REG_ANNUAL_REPORT_2022-2023.pdf

[91] S. Bimenyimana, G. N. Asemota, and L. Li, "The state of the power sector in Rwanda: a progressive sector with ambitious targets," Frontiers in Energy Research, vol. 6, p. 68, 2018.

[92] S. G. Yoon and S. G. Kang, "Economic microgrid planning algorithm with electric vehicle charging demands," Energies, vol. 10, no. 10, p. 1487, 2017.

tax incentives for EV imports and local assembly[93]. Similarly, Nigeria has made significant progress with policies designed to encourage electric vehicle use, including exempting EV and steels from VAT[94] and promoting local manufacturing, thereby aligning with global trends in sustainable transportation expansion.

- *Renewable Energy Integration*: Rwanda and Nigeria are integrating their e-mobility initiatives with broader renewable energy objectives. Rwanda, which has significantly invested in renewable resources, sees e-mobility as an integral part of achieving its sustainability goals[95]. Similarly, Nigeria, endowed with substantial solar energy potential, is exploring renewable sources to power electric vehicles as part of its strategy to lessen the environmental impact of its transportation sector.

Differences from Nigeria

While Rwanda and Nigeria share several similarities, there are also distinct differences shaped by their energy resources, geographic focus, and social environments:

- *Energy Resources for Power Supply*: In 2023, Nigeria primarily generates its electricity from natural gas for 75.6% of its power supply[96]. In contrast, Rwanda's main source of electricity generation is hydropower, contributing approximately 41.2% to its total energy generation in the same year[97].
- *Urban vs. Rural Focus*: Rwanda's e-mobility solutions are predominantly focused on urban centers, especially the capital city, Kigali[98], where the high population density necessitates solutions for urban pollution and traffic congestion. In contrast, Nigeria faces transportation challenges in both urban and rural settings. While urban centers such as Lagos and Abuja are key focuses, there is also a pressing need to enhance transportation infrastructure in rural areas that lack grid access, possibly by employing decentralized renewable energy systems.

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[93] Agenda, Davos. 2022."'The Electric Age Is Here - for Everyone': How an E-Motorcycle Start-up in Rwanda Is Fast-Forwarding Africa's Green Future." n.d. World Economic Forum. May 10 2022. https://www.weforum.org/agenda/2022/05/electric-motorbikes-rwanda-ampersand/.

[94] "Nigeria Customs Exempts Electric Vehicles and Steel Imports from VAT – VATupdate." 2024. VAT Update. https://www.vatupdate.com/2024/01/22/nigeria-customs-exempts-electric-vehicles-and-steel-imports-from-vat/.

[95] "In Face of Rising Air Pollution, Rwanda Turns to Electric Vehicles." 2022. UNEP. October 31, 2022. https://www.unep.org/news-and-stories/story/face-rising-air-pollution-rwanda-turns-electric-vehicles

[96] "Understand Low-Carbon Energy in Nigeria through Data | Low-Carbon Power." n.d. https://lowcarbonpower.org/region/Nigeria.

[97] Rwanda Energy Group Annual Report 2022-2023. REG_ANNUAL_REPORT_2022-2023.pdf

[98] '*Kigali, Rwanda's capital is among the fastest growing cities in Africa, with an urbanization annual growth rate of 4% and it contributes over 41% of the national GDP. In Kigali, there are about 26,000 moto taxis in operation, most of which are powered by gas engines.*' - [Solar-Powered Battery Swap Stations Could Speed Rwanda's Shift to Electric 'Motors'], WRI, 2024

- *Technology and Local Manufacturing*: Rwanda has advanced in local assembly and manufacturing[99], especially through partnerships with foreign entities such as Volkswagen and Ampersand, which bolster local capacity and employment opportunities. Similarly, Nigeria is actively engaging in this sector but confronts challenges attributed to its larger size. Nonetheless, the potential of its vast domestic market attracts local and international investors to establish more extensive manufacturing and assembly operations, offering significant economic opportunities.

Overcoming behavioural barriers

In Rwanda, a nation with a population of 13.3 million, motorcycles, or "motos," are a vital part of daily life. They are used for a variety of tasks including commuting, fetching water, and running errands, and many rely on them for income as taxi drivers. Despite their convenience, these fossil fuel-powered vehicles pose significant environmental challenges, contributing to greenhouse gas emissions, noise pollution, and air quality issues. They are responsible for over a quarter of the transportation sector's emissions, which constitutes 13% of Rwanda's national emissions, and more than 90% of particulate matter air pollution[100].

Electric motorcycles, particularly those powered by renewable sources, present a valuable opportunity to decrease emissions, enhance air quality, and deliver economic advantages. Despite growing interest in EVs in Rwanda, significant obstacles[101] still hinder widespread adoption among residents:

1. **Initial Purchase Cost:** The primary deterrent for many potential EV owners is the high initial cost[102]. While the operating expenses of EVs are considerably lower than those of ICE vehicles, and the availability of used EVs is increasing, the upfront price of new EVs continues to be a substantial barrier. This challenge is expected to diminish as more used EVs enter the market and battery costs decrease.
2. **Charging Infrastructure:** The decision to buy an EV is heavily influenced by the availability of convenient charging options. Currently, the charging infrastructure is insufficient[103], which can discourage potential buyers.

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[99] *BBC News*. 2021. “Rwanda Goes Electric with Locally Made Motorbikes,” November 9, 2021, sec. Business. https://www.bbc.com/news/business-58820548.
[100] Zhang, Cheng, and Miao Hong. 2024. “Solar-Powered Battery Swap Stations Could Speed Rwanda’s Shift to Electric 'Motors.’” https://www.wri.org/insights/solar-powered-battery-swap-stations-rwanda-shift-electric-motos.
[101] “REPUBLIC of RWANDA MINISTRY of INFRASTRUCTURE STRATEGIC PAPER on ELECTRIC MOBILITY ADAPTATION in RWANDA.” 2021. https://www.mininfra.gov.rw/fileadmin/user_upload/Mininfra/Publications/Laws_Orders_and_Instructions/Transport/16062021_Strategic_Paper_for_e-mobility_adaptation_in_Rwanda-Final.pdf.
[102] AfricaNews. 2019. “Rwandans Switching from Petrol to Electric Motorcycles.” Africanews. 2019. https://www.africanews.com/2019/08/31/rwandans-switching-from-petrol-to-electric-motorcycles//#:~:text=He%20also%20says%20using%20an.
[103] Wei, Chong Xin. 2023. “Supply Problem, Lack of Charging Stations Stall Uptake of Electric Bikes in Rwanda.” *The Straits Times*, November 13, 2023. https://www.straitstimes.com/world/supply-problem-lack-of-charging-stations-stall-uptake-of-electric-bikes-in-rwanda.

3. **Range Concerns and Knowledge Gaps:** Anxiety about the vehicle's range and confusion over the various types of charging infrastructure can also prevent people from choosing an EV.

Government supports[104]

Over the past ten years, Rwanda has committed to enhancing its transport systems to be both effective and sustainable. This initiative is in line with the country's Green Growth and Climate Resilience Strategy (GGCRS)[105], under which the Rwandan government has implemented various projects aimed at advancing sustainable transportation and supporting the broader green economy. Specifically, the Rwandan government is enhancing resilient and efficient transport systems across both national and local levels through six key initiatives:

1. **Crafting a national sustainable mobility policy:**
   Rwanda is formulating a national sustainable mobility policy to support the shift towards electric mobility, as part of its ongoing efforts to achieve low carbon economic growth. This policy[106] aims to bolster partnerships between the private sector and the Rwandan government, attract investments in electric mobility solutions, spur new transportation innovations, and increase the adoption of non-motorized transport within a broader transit-oriented development framework.

2. **Encouraging investments in electric mobility:**
   Rwanda's conducive business environment has attracted significant investments in e-mobility. Companies like VW Mobility Solutions, Victoria Autofast Rwanda, Ampersand, Rwanda Electric Motorcycle Ltd, and Safi/Gura Ride have made substantial investments in electric cars and motorcycles. Rwanda continues to welcome investments that aid the shift towards clean and sustainable mobility.

3. **Implementing incentives for electric mobility adoption:**
   The shift towards electric mobility in Rwanda carries an estimated cost of US $900 million, focusing primarily on the adoption of electric vehicles. Despite this substantial financial requirement, the transition to electric motorcycles alone is projected to save the Rwandan economy approximately Rwf 23 billion

[104] "Six Ways Rwanda Is Building Climate Resilient Transport Systems." February 4 2022. https://climatechange.gov.rw/index.php?id=35&tx_news_pi1%5Bnews%5D=213&tx_news_pi1%5Bcontroller%5D=News&tx_news_pi1%5Baction%5D=detail&cHash=3b76287af0d65472ea107b485b254f0e.
[105] "Rwanda Launches Revised Green Growth and Climate Resilience Strategy." 2023. https://www.environment.gov.rw/news-detail/rwanda-launches-revised-green-growth-and-climate-resilience-strategy.
[106] "Republic of Rwanda Ministry of Infrastructure National Transport Policy and Strategy for Rwanda". April 2021. https://www.mininfra.gov.rw/fileadmin/user_upload/Mininfra/Publications/Policies/Transport/NATIONAL_TRANSPORT_POLICY_AND_STRATEGY_APRIL_2021.pdf.

(US $22 million) annually in fuel imports[107]. This significant cost-benefit highlights the economic efficiency of adopting e-mobility in the country.

To accelerate this transition and stimulate further investments in this emerging sector, the Government of Rwanda has introduced a variety of fiscal and non-fiscal incentives[108]:

- *Fiscal Incentives:*
  - Electricity tariffs for charging stations to be capped at the industrial tariff and and even lower rates during off-peak hours (11pm to 8am). This means that charge point operators will be billed at close to 10 cents/kWh instead of close to 20 cents/kWh.
  - Electric vehicles, spare parts, batteries, and charging station equipment will all be exempted from import and excise duties. All of these would also be treated as zero rated VAT products and will also be exempt from withholding tax.
- *Non-Fiscal Incentives*
  The government is providing rent-free land for the establishment of EV charging stations and integrating EV station requirements into building codes and urban planning. A green license plate system has been introduced, offering preferential parking and exemption from congestion charges for EVs. Further incentives include allowing EVs access to dedicated bus lanes and prioritizing them for government vehicle procurements. Measures such as implementing age restrictions on the importation of used vehicles aim to control environmental impact and vehicle quality. Additionally, specific zones have been designated where only environmentally friendly vehicles can enter, and the enforcement of emission standards has been strengthened to reduce the prevalence of high-polluting vehicles.

4. **Expanding and improving public transport networks:**
   Rwanda has been focused on improving its public transport system through various national and local initiatives. In 2012, the government launched the Public Transport Policy and Strategy, tasking the Ministry of Infrastructure with expanding and upgrading the national road network. This effort was bolstered in April 2021 with the Cabinet's adoption of a comprehensive National Transport Policy and Strategy, aiming to connect different regions of the country to promote sustainable economic growth. Concurrently, the City of Kigali has been enhancing its public transport network, increasing bus

[107] "Six Ways Rwanda Is Building Climate Resilient Transport Systems." February 4 2022. https://climatechange.gov.rw/index.php?id=35&tx_news_pi1%5Bnews%5D=213&tx_news_pi1%5Bcontroller%5D=News&tx_news_pi1%5Baction%5D=detail&cHash=3b76287af0d65472ea107b485b254f0e.

[108] Kuhudzai, Remeredzai Joseph. 2023. "KABISA Is Launching an Awesome Electric Mobility Ecosystem in Rwanda." CleanTechnica. January 23, 2023. https://cleantechnica.com/2023/01/23/kabisa-is-launching-an-awesome-electric-mobility-ecosystem-in-rwanda/.

stations and upgrading infrastructure to boost the capacity and efficiency of its system.

5. **Elevating the quality of public transport systems:**
   The Government of Rwanda, through the Rwanda Utilities Regulatory Authority, has recently launched the Public Transport Generation 2 system to enhance public transportation by incorporating advanced technology, optimizing route planning, diversifying vehicle types, and introducing scheduled services. As part of making public transport more appealing, buses in Kigali now offer free internet to passengers under the Smart Kigali Initiative, initiated in 2013, which provides free Wi-Fi in buses, taxis, airports, hotels, and restaurants. This initiative is aimed at reducing the use of private cars. Additionally, in a push towards electrification of transport, Rwanda plans to convert 20% of all buses to electric by 2030, anticipating a significant decrease in carbon emissions by approximately 72,000 tCO2eq[109].

6. **Collaborating to promote sustainable mobility:**
   The Rwandan government is partnering with international bodies like the Global Green Growth Institute, UNEP, KfW, the International Finance Corporation, and the World Bank to create a sustainable transport system using electric vehicles (EVs). This collaboration includes feasibility studies for EVs, e-mobility technology showcases, and electric bus deployment plans. Significant initiatives include infrastructure development for electric buses in Kigali, public-private partnership models for EV expansion, and the introduction of Rwanda's first PHEVs, focusing on environmental sustainability and economic benefits such as job creation and energy savings.

Overall Insights

- **Insufficient and Unstable Power Supply**: According to data released by Rwanda Energy Group in 2023[110]Rwanda's total percentage of households connected to electricity equals about 71.9%. The existing power installations are unable to meet the rapidly growing demand for additional electricity load. Moreover, Rwanda continues to import about 13.04% of its power from other countries, the existing power grid infrastructure is weak, and the instability of the power supply is also a prominent issue.
- **Mountainous Geography of Rwanda:** Rwanda's mountainous geography presents significant challenges for infrastructure development, including the construction of transportation networks, buildings, and utility distribution systems. The rugged terrain increases the complexity and costs of building roads and bridges, requires specialized engineering for construction on slopes to mitigate risks like landslides, and complicates the extension of utilities such

[109] "Rwanda Aims to Have 20% of All Buses Transition to Electric by 2030." n.d. GGGI - Global Green Growth Institute. https://gggi.org/rwanda-aims-to-have-20-of-all-buses-transition-to-electric-by-2030/.
[110] Zingiro, Armand. Rwanda Energy Group. "Annual Report 2022-2023". REG_ANNUAL_REPORT_2022-2023.pdf

as water and electricity. Additionally, the limited arable land restricts agricultural productivity and poses difficulties for mechanization. Despite these challenges, Rwanda has made notable progress by implementing innovative solutions such as terracing and investing in road improvements, although ongoing efforts are essential to ensure sustainable and equitable development throughout the country.

Barriers to success and potential solutions

Consumers

Barriers

The major barrier to EV adoption for consumers is the upfront cost of bikes. Electric motorcycles are two to five times more expensive than standard ICE motorcycles. A consumer can purchase an ICE bike for between ₦400,000 and ₦1,400,000.[111] Market analysis suggests the price for electric vehicles to be between ₦2,800,000 and ₦4,800,000.[112] Rural Nigerians are accustomed to saving and buying ICE motorcycles outright in one payment.[113] The high upfront cost of an electric motorcycle would require Nigerians to finance the purchase. A high interest rate of about 24.75% further complicates the path to EV adoption as the final cost of the bike increases by nearly 50% over a 2-year payback period.

Additional barriers to consumer adoption of EVs include infrastructure, on-the-ground operations, and consumer education. Charging stations have yet to scale and most consumers are not familiar with electric vehicles nor battery charging or swapping mechanisms. Lack of familiarity with EVs and the associated infrastructure and operations causes range anxiety, as early adopters sense risk associated with transitioning away from a vehicle technology with which they are already familiar.

Potential solutions

Overcoming the barriers for consumers should prioritize reducing upfront and operation costs, as well as fostering customer engagement. Cost reduction efforts include subsidy programs, business model innovation, vehicle conversion, and EV zones. Consumer engagement would vary from organizing customer education campaigns, making better use of user data, and initiating test rides.

Strategies in reducing upfront and operation costs:

- *Implementing financial incentive programs:* In addition to subsidies targeting electric vehicles manufacturers, financial incentives should also be provided at the end-user fronts to encourage a faster adoption of EVs. Although the

[111] Interviews with bike owners / research on resell websites
[112] Interviews with electric vehicle companies
[113] In- person interviews with vehicle owners

current purchasing power for Nigerian rural residents is not sufficient for EV outright purchase, the following policies should be considered to further boost EV purchase in the future:
    - Providing rebates at the time of purchase, immediately reducing the purchase price of EVs.
    - Issuing tax credits or exempting sales tax, effectively reducing the tax costs of EV purchases.
- *Accelerating business model innovation*: As alternatives to outright purchases, business model innovation is a must to expand EV excess for Nigeria's rural consumers. In addition to the lease-to-own model coupled with battery swapping, as recommended in the previous section, pilots of other emerging models should also be encouraged to explore further cost effective options for consumers, such as:
    - EV-car-sharing enables different users to share the ownership of an e-bike to split costs and increase utilization efficiency.
    - Battery-as-a-Service (BaaS) allows consumers to subscribe to a battery service, including upgrading to the newest technology, instead of taking the outright ownership.
    - Evolving charging technologies such as fast charging and dynamic charging provide customers with more flexible and efficient charging options. These systems remain expensive for now, but the development of such technologies should be closely watched.
- *Supporting ICE-to-EV conversion*: For those rural residents who already own ICE vehicles, smooth transition to electric vehicles needs firm support. Besides the retrofitting model that has been discussed in detail above, trade-in or buy-back programs would provide great incentives for consumers to trade their existing ICE bikes for new electric ones.
- *Designating EV zones:* Establishing "green transportation zones" or "low emission zones" aims to provide exclusive access or reduce the entry fees for EVs, also indirectly reducing the operation costs of e-bikes when compared with ICE bikes.

Table 6. Hero Electric in India - Successfully reduce costs to attract future customers

Hero Electric (HE) is one of the leading e-bike manufacturers in India, which has been at the forefront of promoting e-bikes as affordable and environmentally friendly alternatives to traditional two-wheelers[114]. Below are some key strategies HE used to reduce costs for engaging more potential e-bike consumers:

- FAME India Scheme: HE leveraged the Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME) scheme[115], which offers subsidies directly linked to the battery capacity of the vehicle. By designing e-bikes to

[114] "About Hero Electric Bikes." n.d. Hero Electric. https://heroelectric.in/about-hero-electric/.
[115] IEA. 2023. "Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME) Scheme - Phase I & II – Policies." IEA. January 7, 2023. https://www.iea.org/policies/12517-faster-adoption-and-manufacturing-of-hybrid-and-electric-vehicles-fame-scheme-phase-i-ii.

maximize subsidy benefits, HE effectively reduced the consumer price.

- Battery swapping: HE also partners with battery providers to offer swapping stations to alleviate concerns about charging infrastructure and time.
- Microfinancing and EMI options: HE collaborates with financial institutions to offer low-interest loans and attractive EMI (equated monthly installment) options[116] to make e-bikes more accessible to a broader segment of the population.
- Purchase assistance: HE offers test rides for customers with only basic information and contact information are needed. Customers could simply use an online sheet to book a HE e-bike[117].
- Customer education: HE also organizes frequent consumer education campaigns on safety issues and guidance[118].

These strategic initiatives have significantly boosted the adoption of e-bikes in India, making Hero Electric a leader in the e-bike market.

Fostering customer engagement:

- *Organizing customer education campaigns*: Policymakers and community leaders should design and organize a series of education campaignsregularlys. In particular, such campaigns should be tailored to target the consumers that are ideal for early adoption: Moto taxi drivers, both short range and long range, and farm managers that traverse enough kilometers per day. In such campaigns, key topics should include:
  - Benefits of electric vehicles such as energy efficiency and lower costs in the longer term.
  - Access to financial incentives: introduction of financial incentive programs available for electric bikes, and hands-on guidance on how to obtain such benefits.
  - Charging solutions: options available to charge EVs, customized advice for choosing the suitable charging plans, and relevant support for charging – this is key to ease the range anxiety of new EV users.
  - Safety guidance: apart from encouraging EV adoption, guidance should also be provided in terms of safely storing and charging the EV to avoid safety incidence.
- *Making better use of data and best practice cases to inform decision making:* During the campaigns, data visualization and data storytelling are crucial for educating rural customers to understand the benefits of electric bikes compared to ICE vehicles – in particular, long-term cost, financial support, and energy efficiency. Interactive immersion, real-life case studies, best practice, are all much needed to further enhance the quality of such campaigns.

[116] "Hero Electric Scooters Loan EMI Calculator Online." n.d. Hero Electric. https://heroelectric.in/emi-calculator/.
[117] "Hero Electric Bike Test Ride - Book Now!" n.d. Hero Electric. https://heroelectric.in/test-ride/.
[118] "ABB Launches New Robots for EV Makers." n.d. Autocar Professional. https://www.autocarpro.in/news-national/abb-launches-new-robots-for-ev-makers-81495.

- *Initiate test rides*: Test rides for different vehicle models could be made available for customers to enable an immersive experience, oftentimes being the most effective way to persuade customers into buying/renting/retrofitting a new e-bike. Although companies might have concerns related to vehicle overdue, damages, or even losses, safely monitored test rides are still one of the best ways of interactive customer engagement methods.

Electric Vehicle Companies

Barriers

Electric vehicle companies face more barriers to entry in Nigeria than other African markets. Interviews with several African electric vehicle mobility companies revealed that EV companies operating in markets like Rwanda, Kenya, and Uganda are wary of expanding to Nigeria due to relatively higher national grid instability, import tariffs, and nascent consumer demand. EV mobility companies in Nigeria face the same barriers and have thus ruled out scaling operations in Nigeria for the time being, servicing markets like Ghana instead.[119] National grid instability has not yet been offset by distributed renewable energy production. Although there are over 140 mini grids that are operational across Nigeria, the dynamics of pairing electric vehicles with existing mini grids are still being assessed. Pilot projects suggest that, from an operational perspective, pairing electric vehicles with mini grids is possible. This Capstone report suggests that the model is financially possible as well. Unlocking the right model still requires significant investment in infrastructure and consumer demand generation, however.

Potential solutions

EV companies can prioritize two solutions to reduce barriers to entry in Nigeria:

The first solution is to help spur consumer adoption of EVs by offering attractive financing options for electric motorcycles. EV companies should work closely with international financial institutions and financial advisors to offer consumers loan terms below market rate with reasonable monthly payment requirements. EV companies need to understand the upper bound of consumer willingness to pay given the reduction in fuel and maintenance costs consumers can expect by switching to electric motorcycles. Suppliers can price loan terms accordingly. Electric vehicle companies must be cognizant of the current state consumer dynamics with respect to vehicle ownership. As investment in a vehicle equates to ownership of a revenue-generating asset, Nigerians need to be confident that the electric vehicle will provide the same level of service when switching from ICE vehicles to EVs.

[119] MAX Mobility interview. 3/15/24. Lagos, Nigeria.

Nigerians are attracted to a lease-to-own model that converts monthly payments into long-term vehicle ownership[120].

The second solution approach that electric vehicle companies should pursue is multi-stakeholder coordination with government agencies, specifically targeting import tariffs on electric vehicle parts. Import tariffs as high as 35% applied to vehicle parts dramatically increase the final cost of electric vehicles sold in the country. These costs are passed along to the consumer, further complicating ownership financing. Electric vehicle companies can work together with government agencies to draft new policies that reduce tariffs on imports, encourage domestic production and assembly of chassis and batteries, and provide good paying jobs for nationals that result in reduced total cost of electric vehicles.

Implementation Recommendation Plan for REA

The rollout of EVs in rural areas needs to be carefully coordinated between REA and relevant stakeholders to ensure the sustainable development of communities and the technology. Contrary to other countries mentioned above like Kenya and Rwanda that currently prioritize EV development in urban areas, REA faces a much bigger challenge given the need to increase electricity excess and stabilize power supply in peri-urban and rural communities. As discussed, EVs are seen as an opportunity to create positive ripple effects in the economy through lower fuel costs, improved rural mobility, reduced reliance on oil imports, robust domestic automotive industry, increased job creation, and lower greenhouse gas emissions.

Acknowledging that EVs are a new industry in Nigeria – let alone in the rural parts of the country – its expansion and success will take time and will depend on the harmonization of key areas/players as well as a consistently enabling environment. Based on the analysis conducted by the SIPA Capstone Team and the government's long-term Energy Transition and Automotive Industry Development Plans, the Capstone team formulated recommendations on near term implementation strategies to spur rural e-mobility adoption in Toto and Petti communities.

Business model recommendation:
The SIPA Capstone Team recommends focusing on the adoption of electric two wheelers with a lease-to-own business model along with battery swapping systems for both communities. This is due to the lower upfront costs compared to outright purchase, eventual ownership of vehicles, and the eliminated wait times at charging stations.

Implementation recommendations for REA:
Government support in terms of funding should be central to develop this nascent technology in these communities. The SIPA Capstone Team recommends that the REA prioritize:

[120] Ibid.

1. Reducing the high upfront cost of EVs
2. Setting a goal of the number of EVs and charging stations deployed in rural communities by the end of the decade.

This can be done by dedicating a proportion of the USD 750 million of the Distributed Access to Renewable Energy Scale-up (DARES) Project[121], which comes into effect in late 2024[122], toward subsidizing EVs as a PUE. The funding should be directed to four stakeholders:

1. EV supplier
2. Charging station owner
3. Battery owner*
4. EV consumer (Targeted EV users for the program are short and long range taxi drivers and farm managers due to their further distance travelled, hence lower TCO)

Below are ways in which the financial incentives can be implemented by the Agency:

Table 7. Suggested subsidy mechanisms targeted for EV stakeholders

Stakeholder	**EV Supplier**	**Charging Station Owner**	**Battery Owner**	**EV Consumer**
Subsidy mechanism	• Provide grants for local EV manufacturing and assembling • Offer grants for test ride programs	• Offer cash grants for charging infrastructure installations • Provide performance-based incentives	• Provide cash grants for battery purchase	• Provide rebates during time of purchase • Provide tax credits for EV purchase • Offer credit through buyback programs of ICE vehicles in exchange for EVs
Potential risk mitigation	• Reduce financial burden of high import tariffs • Educate rural communities on EVs	• Lower upfront costs of purchasing and installing chargers • Encourages operational efficiency that lowers operating costs	• Ensures sufficient batteries for smooth battery swapping	• Reduce high upfront cost • Lower monthly lease-to-own installments

[121] DARES is a continued and expanded version of the NEP
[122] World Bank and REA meeting. March 14, 2024. Abuja, Nigeria
*Ideally, battery owners are the same as the charging station owners, but for this report, a division of labor is assumed

Mini grid developers are also key stakeholders in the EV ecosystem as electricity providers and typically, charging station owners as well. However, they have existing financial incentive provisions in REA's NEP program, which will continue in the DARES initiative, along with some adjustments. Current subsidy programs are not directed to stakeholders mentioned above, which is why there is an opportunity for REA to support more participants, creating a well-rounded environment for EVs.

Recommendations for other stakeholders to contribute toward an enabling ecosystem for rural EV integration in mini grids:

- **Mini grid developers**
  Power Gen, the developer for the Toto mini grid, faced issues with lack of excess capacity and relies on a hybrid system, which includes a diesel generator. To manage additional load for EVs, Power Gen needs to expand the capacity of solar. Typically, developers would need to increase electricity tariffs to reflect the additional capacity. However, Power Gen is only allowed to charge a fixed tariff to customers per their agreement. One recommendation for mini grid developers is to partner with charging station owners to assess potential demand growth concerning EVs and optimize the charging infrastructure. This can reduce the need for additional investments through load management strategies that balances charging demand with available capacity and grid stability.

- **Private financing institutions**
  Financial institutions such as African commercial banks should consider piloting blended finance tools such as Green4Access in rural areas.[123] This tool offers a first loss guarantee where if a rural EV customer defaults on their loan, 100% of the losses will be covered and up to a certain cap of the bank's total energy access loan portfolio. From the local lender's perspective, the customer is sufficiently de-risked. This also allows the fund's investors to receive modest returns that make the EVs sustainable.

- **Government agencies:**
  The key to enforcing regulations and incentives, increasing investor confidence, as well as forging a clear, forward-looking implementation plan lie on the strong linkages and alignment between government sectors. As the ETP and NAIDP aim for 100% EVs by 2060 and 30% of local automotive production to be EVs by 2033 respectively, several government ministries play essential roles in making this ambition a reality, which ultimately supports REA's mission in increasing rural access to clean electricity.
    - **Ministry of Transportation**
      The SIPA Capstone Team recommends that the ministry 1) enforces progressive vehicle emissions standards to phase out ICE vehicles, 2)

[123] "GreenMax Capital Group and CLASP Launch Green4Access First Loss Facility to Drive Uptake of Renewable Energy Solutions in East and West Africa." n.d. CLASP. https://www.clasp.ngo/updates/greenmax-capital-group-and-clasp-launch-green4access-first-loss-facility-to-drive-uptake-of-renewable-energy-solutions-in-east-and-west-africa/.

improves rural road conditions, 3) sets strict EV safety and standards, and 4) incentivizes the buildout of charging stations across rural and peri-urban areas. These can improve the financial and physical sustainability of EVs as well as address safety and range anxiety among EV users.

- **Ministry of Industry, Trade, and Investment**
  The author of the NAIDP, the Nigerian Automotive Design and Development Council, sits under this ministry. The SIPA Capstone Team recommends for the ministry to 1) restrict the amount and standards of vehicle imports and 2) prioritize securing partnerships with private players such as OEMs, software companies, and solar developers to encourage investments in the EV sector. Husk Power, one of the developers that the SIPA Capstone Team interviewed with, has recently secured $20 million debt financing from the European Investment Bank (EIB) to expand solar mini grids.[124] Husk aims to build out at least 500 mini grids in the next five years, which is a significant goal. The ministry should focus on facilitating deals like this that incentivize private sector investments in clean electricity, especially in rural areas.
- **Ministry of Budget and Economic Planning**
  One of the main objectives of the ETP and NAIDP is to promote economic development through a robust domestic EV/automotive industry. The SIPA Capstone Team recommends this ministry to prioritize funding for in-house workforce and skills development to promote economic advancement. It should go toward implementing training programs at vocational schools or technical colleges, creating partnerships with industry for hands-on training and job placement opportunities, and supporting entrepreneurs and small businesses in or adjacent to the EV sector, especially in rural communities. This goes a long way toward building a domestic EV supply chain through skills development and training and technology transfer and innovation.
- **Ministry of Finance**
  The Nigerian Custom Services (NCS) under this ministry regulates import tariffs, which includes levies, duties, and value-added-tax (VAT) for vehicle imports. Currently, EV parts' imports have a 35% duty and 35% levy.[125] This is a huge barrier for EV suppliers like MAX Mobility to pay such high upfront costs.[126] Delays at customs also prevent them from receiving EV components for assembly within a reasonable timeline. The Capstone team recommends that the NCS 1) dedicate a port delivery route for automotive imports and exports and 2) enforce

[124] Husk Power closes $20 million in financing from the European Investment Bank (EIB) to scale in Nigeria. 2024. "HUSK." https://huskpowersystems.com/husk-power-closes-20-million-in-financing-from-the-european-investment-bank-eib-to-scale-in-nigeria/

[125] International Trade Administration. 2021. "Nigeria - Automotive Sector." October 13, 2021. https://www.trade.gov/country-commercial-guides/nigeria-automotive-sector.

[126] MAX Mobility. March 15, 2024. Lagos, Nigeria.

the comprehensive tariff plan for EVs laid out in the NAIDP that range from 0-20%.[127] These would allow for faster clearance of EV equipment and reduced barriers to entry for new EV suppliers to enter the market.

    - **Ministry of Power**
      As the ministry that oversees REA, they provide an ecosystem and resources that allow the Agency to fulfill its mandate. One recommendation is for the ministry to leverage a task force that involves the sectors mentioned above to enact a comprehensive and aligned regulatory framework that champions policies mentioned above. In addition to that, the ministry should adopt grid integration and management measures, which includes dynamic pricing strategies for electricity use for charging EVs at different times (peak versus off-peak).

- **Development finance institutions**
  DFIs such as the World Bank have been integral in securing funds for the NEP and DARES. To further support decreasing the burden of high upfront costs of EVs, one recommendation is for DFIs to partner with local banks on accessing funding on concessional terms or with low interest-rates. DFIs can provide long-term financing or subsidized loans to banks for lending to high-impact projects with development objectives such as EV adoption. These mechanisms may offer preferential interest rates or flexible repayment terms for rural consumers. In turn, this lowers the monthly lease-to-own installment payments to purchase the EV.

- **Foundations**
  Bloomberg Philanthropies and IKEA Foundation, amongst others, have been instrumental in providing grants and capacity building to support sustainable development in Nigeria and neighboring countries. Foundations should continue to directly provide funding for the development of solar mini grids and EV infrastructure through grants, and also invest in the monitoring and evaluation of programs, capacity building of partnerships between REA and private companies to run pilot projects and expansions, and local skills and workforce development.

Recommendations for future research:

- Addressing supply chain obstacles: Supply chain complications stand as a formidable barrier within Nigeria's electric vehicle sector. This study has outlined potential solutions, inspired by the successful strategies of Kenya, Ghana, and Rwanda. These include the exemption of import duties and the promotion of local manufacturing and assembly capacities. Nevertheless, a deeper analysis drawing from international experience is needed in the future to further enrich the understanding and recommendations.

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[127] "Nigerian Automotive Industry Development Plan Nigerian Automotive Industry Development Plan." 2023. https://naddc.gov.ng/wp-content/uploads/2023/06/Nigerian-Automotive-Industry-Development-Plan-2023.pdf.

- Broadening case study selections for deeper insight: The current research utilizes case studies from three African countries, chosen for their macroeconomic and geographical parallels to Nigeria. To yield a more robust understanding, future research should incorporate countries with proven success in initiating domestic electric vehicle markets under similar urban-rural dynamics.
- Integrating a spectrum of scenarios for enhanced analysis: Considering the particular rural backdrop of Nigeria, the transition to electric vehicles should be equitable, steady, and expeditious. Future analytical models would benefit from including a diverse array of scenarios, including hybrid vehicle technologies, to more accurately mirror the Nigerian context and propose viable solutions.

Conclusion

This report was created by the SIPA Capstone team, in partnership with the Rural Electrification Agency of Nigeria (REA), to explore and assess the feasibility of integrating e-mobility infrastructure with existing mini grid projects in rural Nigeria. The REA was established by the FGN to find innovative solutions– such as the NEP, which brought Solar Hybrid Mini Grids, Standalone Solar Systems and Education Programs to rural communities. Solar Mini-grids have several productive uses for households and businesses, but this report presents an alternative PUE: Vehicle Electrification. Using case studies, economic analysis, and field research, it was found that EV adoption in rural areas would greatly benefit customers and solar mini grid developers. High utilization stimulates demand, lowers electricity tariffs and addresses the need for efficient transportation in rural communities. EV's are beneficial to a wide range of drivers and the most cost-effective business model combines lease-to-own with battery swapping. There are some challenges, such as the upfront cost of the bike for consumers and challenging regulations for EV companies–national grid instability and import tariffs– compared to neighboring countries. However, the long-term implications for energy access and electrification proves EV's are a viable means of integrating e-mobility into rural Nigeria.

The outlook for EV's is for this solution to transform mobility in rural Nigerian communities. Vehicle electrification promotes clean, renewable energy for economic activity and improves overall quality of life. However, this rollout will take time and needs to be carefully coordinated between the FGN, REA and relevant stakeholders to ensure sustainable development. Based on site visits in Petti and Toto, the SIPA Capstone Team recommends EV adoption in these two areas using the 'lease- to-own with battery swapping' business model. To ensure successful EV adoption, reduce the high upfront cost of EVs and set a goal for the number of EVs and charging stations deployed in Petti and Toto by the end of the decade. The key partners are EV suppliers, charging station owners, battery owners, and targeted EV consumers. Other stakeholders include mini grid developers, government agencies, private financing institutions, development financing institutions, and foundations. All of these groups play important roles in creating a suitable environment for EV

development through their funding, infrastructure development, EV manufacturing, and phase out of ICE vehicles.

Important next steps for the REA, starting with Petti and Toto, include:

- **Collaborating with Key Partners and Stakeholders** to facilitate EV development and adoption.
- **Expanding Charging Infrastructure** to install and maintain a sufficient number of battery swapping stations in rural communities
- **Assess Nigeria's Regulatory Framework** to advocate for supportive policies incentivize EV investment from companies, and EV use from consumer
- **Continue Community Engagement** to understand barriers to EV adoption and raise awareness about its benefits in meeting their mobility needs.

Appendix

Toto and Petti Mini Grid Sites

01 Toto

- 352.5 KWp, Interconnected
- 1440 households + MSMEs
- Buildings and PUE

02 Petti

- 60 KWp, Off-grid
- 266 households + MSMEs
- Buildings and agriculture

The SIPA Capstone Team's in-person visit with the REA and developers, Power Gen and NAYO, in Toto (left) and Petti (right).

TCO Assumptions

Assumption	Units	ICE upper bound	ICE lower bound	EV upper bound	EV lower bound
Purchase price	N	1,000,000	800,000	2,894,598	2,251,354
Maintenance	N/Year	96,000	96,000	38,400	38,400
Electricity price	N/kWh	-	-	180.00	180.00
Petrol price	N/L	1,100	850		
Battery cost	N	-	-	964,866	964,866
Battery capacity - max	kWh	-		3.00	3.00

Average battery recharge capacity	kWh	-	-	2.40	2.40
Battery cycles	#	-	-	1,400	1,750
Distance per average battery charge	km	-	-	61	57
Petrol use	km/L	15	30	0	0
Electricity use	km/kW	0	0	20.20	18.87
Distance a day	km/day	60	80	60	80
Lifetime of bike	Years	3	4	3	4
Distance per year	km/year	21,900	36,500	21,900	36,500

TCO Persona Assumptions

		Taxi Driver Short Range	Taxi Driver Long Range	Deliveries Driver	Farm Manager	Personal Owner
Individual Details						
Distance per day	km/day	50	80	30	100	20
Distance per year	km/year	18,250	29,200	10,950	36,500	7,300
Existing bike trade-in value	N	500,000	500,000	100,000	200,000	700,000
ICE Vehicle						
Vehicle price	N	800,000	1,000,000	500,000	1,000,000	1,200,000
Vehicle longevity	Years	4	4	20	10	25
Maintenance cost	N/service	10,000	12,000	10,000	12,000	10,000
Maintenance service per month	#/month	2	2	1	1.50	1
Maintenance cost per year	N/year	240,000	288,000	120,000	216,000	120,000
Fuel efficiency	km/L	15	15	30	30	30
Electric Vehicle						
Vehicle price	N	4,800,000	4,800,000	4,000,000	4,000,000	4,000,000
Vehicle longevity	Years	4	4	8	8	8
Battery longevity	Years	8	8	8	8	8
Maintenance cost	N/service	10,000	12,000	10,000	12,000	10,000
Maintenance service per month	#/month	0.20	0.20	0.12	0.12	0.12
Maintenance cost per year	N/year	24,000	28,800	14,400	17,280	14,400
Battery swaps per day	#/day	1	1	1	1	1
Battery swaps per year	#/year	365	365	365	365	365
Energy Source Inputs						
Petrol price	N/L	900	900	900	900	900
Battery swap price	N/swap	600	600	600	600	600