POLICY PAPER

Enhancing Ghana's E-Mobility Industry – Opportunities for Green SME's and Essential Policy Reforms

PREPARED BY

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Introduction

1.1. Background and context of e-mobility in Ghana

Electric cars account for one out of every five worldwide cars, reaching 18% of all cars sold in 2023 [1]. Major countries that export vehicles to Ghana have policies to end the sale of internal combustion engine vehicles. The European Union declared that all new buses sold in the region will be electric starting in 2035 [2]. In China, new energy vehicles are to account for 45% vehicle sales by 2027 and 60% by 2030 [3]. The United States expects 100% of its car fleet to be electric by 2035 [4].

Ghana plans to end the sale of internal combustion engine vehicles (ICEV) through its electric vehicle policy by 2045 [5]. The policy envisages that by 2045, about 70% of all vehicles in Ghana should be electric. The electrification of the transport fleet can potentially reduce the carbon footprint of transport significantly. In Ghana, it is estimated that a transition to electromobility could reduce the carbon footprint of road vehicles by 72%, potentially avoiding 2900 premature deaths annually [6].

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Introduction

1.1. Background and context of e-mobility in Ghana

Reducing the overreliance on fossil fuel for transportation could reduce pressure on the forex and significantly reduce the cost of the exchange rate. Similarly, many sustainable development goals (SDGs) are related to sustainable transport, namely SDGs 3, 7, 8, 9, 11, 12 and 14. However, many challenges exist in ensuring a rapid transition to electromobility. Electric cars still account for less than 1% of all African car sales [1]. The challenges include the high cost of electric vehicles, the maintenance skills gap, the high cost of finance, the lack of charging stations, and the electricity grid's reliability [9]. These challenges provide several opportunities for small and medium-sized enterprises (SMEs) to participate in global electric vehicle (EV) supply chains. As electric mobility introduces new technologies, services, and business models, it transforms the traditional automotive supply chain, paving the way for the entry of new players. The SMEs have the potential to develop novel technologies, develop components, assemble electric vehicles, and kick start the adoption with or without the legacy automotive companies.

This research paper seeks to identify barriers SMEs face by proposing solutions and recommendations that could transform their products and services. Globally, electric vehicle startups have been at the forefront of the transition to electromobility. With their flexibility and adaptability, these startups can introduce vehicles to the market faster than traditional automakers, often hindered by intricate organizational frameworks and outdated systems [10]. Shifting from internal combustion engines (ICEs) to electric vehicles (EVs) for the legacy automakers requires completely transforming current manufacturing processes and supply chains. Thus, SMEs such as electric vehicle startups are pivotal to the transition to electromobility and achieving net zero in the transport sector.

1.2. Importance of green SMEs in the e-mobility ecosystem

The recent resurgence of electromobility suggests that the private sector and small and medium-sized enterprises (SMEs) will be instrumental in the e-mobility revolution in any country. It took a private company, Tesla Motors, to revolutionize the automotive industry worldwide and produce the first commercially available electric vehicle in recent years [11]. A single company transformed electric vehicles and battery technology from niche products into mainstream contenders by selling directly to consumers [12]. The emergence of startups in the electric vehicle industry significantly impacts society and the economy. In India, the emergence of SMEs such as Ola Electric, Sun Mobility, Magenta, Numocity, SmartE, Yulu, Lithium Energy Technologies, BluSmart, Revolt, and Bounce have revolutionized the e-mobility ecosystem. In 2023, India overtook China as the world's largest market for electric three-wheelers [1].

These startups also play a vital role in reducing greenhouse gas emissions and enhancing urban air quality by advancing the shift to electric mobility. The expansion of electric vehicle adoption generates employment opportunities in areas such as manufacturing, research and development, and the installation of charging infrastructure. Additionally, the growth of startups drives innovation, promotes competition, and provides consumers with greater options and affordability in the electric vehicle market.

Collaboration and strategic partnerships are essential for the success of startups in the electric vehicle sector. Alliances with established automakers enable startups to capitalize on their manufacturing expertise, extensive distribution channels, and strong brand presence. Such collaborations help startups expedite market entry, reach a broader customer base, and gain credibility through association with reputable partners. Moreover, partnerships with charging infrastructure providers, renewable energy companies, and technology firms strengthen the value proposition of startups, fostering innovation and growth within the EV ecosystem.

1.3. Research objectives

Ghana seeks to promote sustainable demand and support the development of supply chain for electric vehicles. The Ghana EV policy also supports research and policy to facilitate implementation. This research study therefore outlines the objectives as follows:

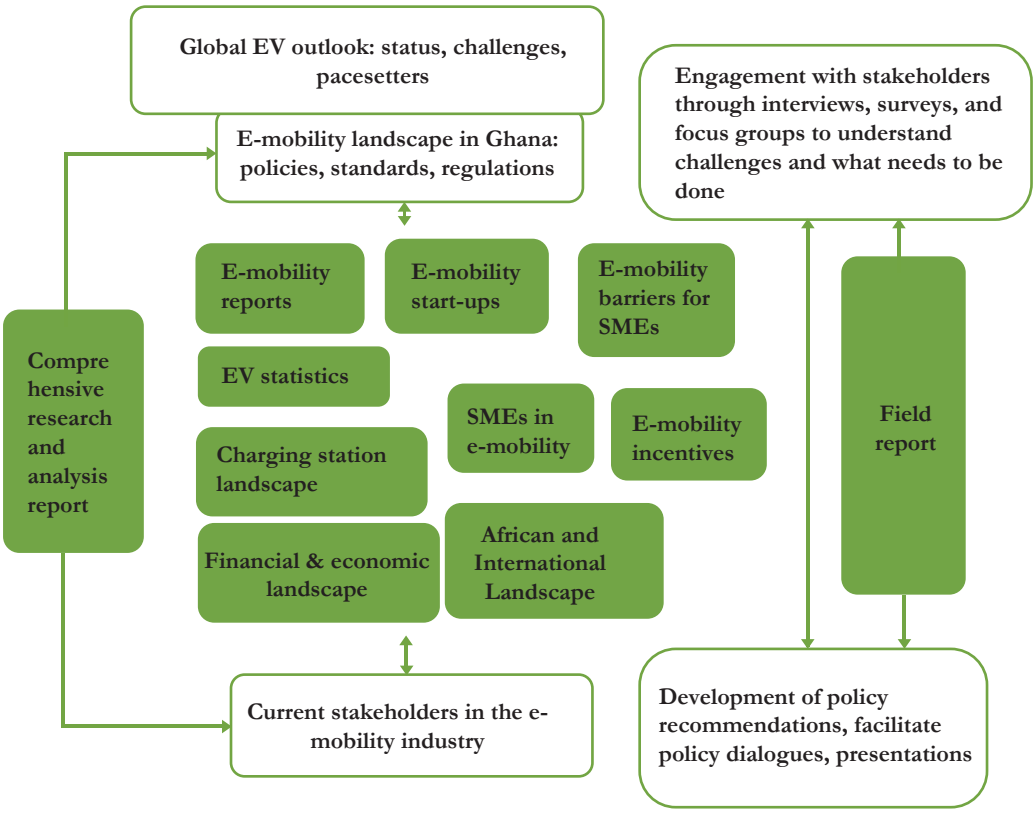
- Assess infrastructure and technology needs
- Learn from global best practices
- Propose policy reforms

The study will outline the infrastructure and technology needs for the e-mobility transition through a global perspective field study and propose business models and policy reforms.

1.4. Approach

Figure 1 shows the approach adopted for the research study. The first approach was to assess the status quo in the electric vehicle industry, including reviewing national policies, plans, regulations, and relevant reports. This will include reviewing documents and understanding national priorities, commitments, targets, budgets, and existing and envisaged actions toward low-carbon initiatives in the transport sector. SMEs in the e-mobility industry were identified, and their business models were discussed. The findings in the local sector were compared to international best practices to identify global challenges.

Figure 1: Approach for the study



A field study was conducted through visits to e-mobility companies and interviews with service providers to examine their business models and identify challenges. The challenges were ranked using five criteria, as shown in Figure 2. A multi-criteria decision-making approach, the Bayesian Best Worst Method (BBWM), was employed to analyze the expert survey for the consistency and appropriateness of the responses. The BBWM also utilized the survey data to assign weights to each criterion. Each initial score for the five criteria was derived based on the expert survey results. The BBWM utilizes computational techniques to evaluate and prioritize multiple criteria, arrtanging them in order of preference to identify the optimal choice among various alternatives based on the intended outcome [13]. The process produces a ranked list of the selected criteria, their respective values, and assigned weights. The BBWM was utilized in this study because it produces highly reliable final weights, enabling more consistent and accurate comparisons. The five critical barriers evaluated were in the broad categories of purchase cost, financing and investment cost, operation and maintenance, charging infrastructure, and technological awareness.

The purchase cost encompasses the initial cost of obtaining an electric vehicle, including purchase price, freight cost, registration, and insurance. Financing and investment costs include obtaining loans and grants, the accessibility to loans, and the cost of borrowing. Operation and maintenance assesses the operational challenges, availability of skills to fix electric vehicles, and the availability of spare parts. The study also evaluates the adequacy of infrastructure available for electric vehicles, the quality of electricity, the charging infrastructure's ability to achieve its rated power, frequency of power outages, and access to electricity. Finally, the study explored the level of technological awareness among the general public in Ghana. Actionable recommendations were drawn based on other regions' current status, challenges, and best practices.

Figure 2: ranking criteria for the challenges

2. Overview of Ghana's E-Mobility Landscape

2.1. Overview of E-mobility Policies in Ghana

Relevant policies related to e-mobility in Ghana are listed in Table 1. Ghana is a lower-middle-income West African nation that contributes 0.1% to global greenhouse gas emissions but falls itn the top climate-vulnerable countries in Africa. Ghana's fourth biennial update report (GFBU) released in 2024 by the Environmental Protection Agency (EPA) indicates that Ghana's total cumulative vehicle population has increased from 2.1 million in 2016 to 6 million in 2021, of which more than 70% are in urban areas [7].

Between 2019 and 2021, transport emissions rose by 73%, driven by increasing fleet, aging vehicle fleets, urban traffic congestion, and poor fuel quality, contributing to increased CO2 emissions from road transport. As a mitigation measure, the GFBU report targets a shift to freight transport from road to rail, electric buses, restricted use of used vehicles, and construction of new bicycle lanes. The Energy Transition and Investment Plan (ETIP) by the Ministry of Trade and Industry (MESTI) recommends six decarbonization technologies for an orderly transition, with transport electrification driving around 40% of abatement [8]. Key technology transitions were identified to achieve net-zero emissions in the transport sector, including enhancing new car efficiency standards and promoting public transportation use between 2025 and 2035.

Table 1:

#	National Policy	Year	Major Transport Targets
1	Ghana's Fourth Biennial Update Report (GFBU)	2024	• Shift freight transport from road to rail • Shift to electric buses • restrict the import of used cars • facilitate the introduction of efficient diesel cars • new bicycle lanes
2	Energy Transition and Investment Plan (ETIP)	2023	• net-zero emissions by 2060 • New car efficiency standards • increase the use of public transport by 2035
3	National Energy Transition Framework (ETF)	2023	• Net-zero emissions by 2070 • introduce a 10% ethanol blend in petroleum products by 2030 • phase out off-road fossil-fueled internal combustion engine vehicles by 2040 • more than 70% of road vehicles are either electric or hydrogen-fueled, • all road and rail mobilities will be either electric or hydrogen-fueled by 2070.
4	Electric Vehicle Policy (EVP)	2024	• Phase out sale of ICE vehicles by 2045 • 70% EV penetration rate by 2045 • All government vehicles procured from 2035 will be EVs • All public institutions to have charge points by 2035 • Development of human capital for EV value chain by 2035

5	National Electric Mobility Policy Framework	2022	• Among the seven barriers listed in the infrastructure category, the lack of charging stations was ranked the highest
6	National Electric Mobility Roadmap	2023	• Promote accessible fast chargers for home charging, multiple intra-city public charging points (at fuel filling stations, parking spaces, street-side parking lots, office parks, service stations and depots in safe sites), and inter-city charging points national highways and major rest stops • Encourage the installation of backup power systems for charging stations for overnight charging and to deal with power outages • Promote battery swapping, recycling and end-of-life disposal systems
7	Baseline Survey Report	2022	• Provide the legal framework and regulation for charging infrastructure and renewable energy integration • Facilitate a well-distributed EV fast-charging network across the country with established standards and regulations to guide the charging market • Conduct grid impact studies of electric vehicle charging stations
8	National Energy Policy	2021	• The introduction of new technologies such as Modern Renewable Energy, Nuclear Power, Carbon Capture Utilization and Storage, Hydrogen and Electric Vehicle (EV) charging stations

The ETIP strategy highly depends on renewable energy provision of 146 GW of solar photovoltaic and 3 GW of nuclear energy by 2060. The Energy Transition Framework (ETF) developed by the Ministry of Energy (MoE) in the same year as ETIF has a different net-zero emission target for 2070. Whereas the ETIP strategy relies on solar PV, the ETF strategy expects nuclear energy to provide nearly half the country's electricity supply by 2070 [14].

The electric vehicle policy (EVP) developed by the Ministry of Transport and other agencies prefers to rely on implementing the renewable energy masterplan 2019 to help meet the additional demand for charging electric vehicles. The EV policy recommends phasing out ICE vehicles by 2045 when it expects electric vehicle penetration to be 70% [15]. The policy does not explicitly state the transition targets for the various vehicle categories, such as electric two and three-wheelers and trucks.

3. Infrastructure and Technological Requirements for Scaling E-Mobility

3.1. Existing charging infrastructure and gaps

Charging stations can be categorized based on accessibility, charging level, connection type, or charging strategy. Regarding accessibility, charging stations are divided into private, semi-public, and public categories [19]. Private charging stations, also called home or residential charging stations, are installed at private homes or personal car parks and intended for use exclusively by the household [20]. Semi-public or workplace charging stations are designed for use by specific groups within a restricted community, such as employees at a workplace. Public charging stations are accessible to all users, typically for a fee.

Charging stations are also classified by their charging levels into three types: level 1, level 2, and level 3. Level 1 chargers are slow AC chargers that do not require installation and are commonly used in homes or any standard socket outlet. Level 2 chargers are faster AC chargers that typically take 1-3 hours for a full charge and often require installation; they can be found in private, semi-public, or public settings. Level 3 chargers are rapid DC chargers, capable of recharging a vehicle in 30-100 minutes, and are generally located at public charging stations [21]. By the end of 2023, level 3 chargers accounted for 35% of the global public charging infrastructure [1].

Battery swap stations (BSS) are another type of charging station that focuses on replacing depleted batteries with fully charged ones, allowing electric vehicles (EVs) to remain operational with minimal downtime. While BSS are not commonly used for full-sized EVs, they are preferred for electric two-wheelers and three-wheelers (E 2&3W) due to the smaller size of their batteries. The challenge of implementing BSS for full-sized EVs arises from the lack of standardization in battery pack sizes, which vary depending on the manufacturer, making it challenging to apply a universal battery swapping system [22].

Broad acceptance of EVs typically follows the installation of many EVCSs in well-chosen locations [18]. Prospective owners often delay their purchase decisions, waiting for an evenly distributed charging station network. Similarly, potential charging station operators hesitate to invest without assurance of profitability, which depends on achieving high utilization rates. This presents a dilemma similar to the chicken-and-egg situation, one of which should be prioritized for increase.

Unlike internal combustion engine vehicles, plug-in electric vehicles do not require fuel because they do not have an engine. They have a sizeable high-voltage battery that needs to be charged frequently depending on the capacity and range on a single charge. The average range of light-duty electric vehicles in 2023 was 150 km compared to 360 km for larger high-end models [1]. This means charging stations need to be spaced every 50 to 100 km on a highway. Another factor to consider is the type of charging station. While a direct current (DC) fast charging station can charge a vehicle up to 80% within 20 minutes, a level 2 (slow charging station) may require four hours of charging to achieve the same capacity [23].

Charging infrastructure gaps are, therefore, a hindrance to scaling e-mobility. Enormous upgrades will be required to the entire electrical delivery system to enable an electric vehicle that provides mobility similar to that of internal combustion engine vehicles in the future. Even slow chargers, such as Level 2 chargers, require dedicated circuits, like electric stoves and air conditioners do [24]. The main circuit boxes in many homes that deliver electricity will need to be upgraded. A future dominated by electric vehicles will necessitate significant infrastructure development for charging systems. Achieving these goals will necessitate the establishment of a reliable and widespread network of highway stations offering fast-charging options to supplement charging at homes, workplaces, and depots. This includes a large-scale construction initiative to establish power plants capable of meeting the increased electricity demand for transportation. Additionally, an extensive distribution network must be developed to supply sufficient electricity to millions of electric vehicles efficiently and reliably, whenever and wherever required.

Meeting the increased electricity demand for a fully electric vehicle in the future will necessitate significant upgrades to the high-voltage transmission network that transports power from large generation facilities. This will involve constructing additional transmission lines to handle the heightened electricity requirements and manufacturing and installing thousands of high-voltage transformers and related infrastructure. For instance, the power consumption of a single charging station could be comparable to that of a small town [25]. The materials and labor requirements needed to accomplish such an undertaking are daunting. The deployment of fast-charging infrastructure will heavily rely on the electric grid. Ensuring prompt and adequate electricity supply to power this highway charging network will demand strategic, data-driven, and cross-sectoral planning. Delivering this amount of power to a single site requires long lead time investments in utility infrastructure.

3.2. Vehicle availability and local manufacturing potential.

As part of its transformation agenda, the Government of Ghana has recognized Vehicle Assembly and Automotive Components Manufacturing as a key industry to be promoted and supported within the framework of the Ten Point Plan for industrial development. Ghana's vehicle assembly history dates back to the 1960s, with Nissan, UAC Motors, SCOA, RT Briscoe/ATS/KOWUS, GHAMOT, and Neoplan Ghana Limited [26]. By 1969, approximately 1,200 units of vehicles were being produced annually.

The auto industry's state-owned and private sector-led initiatives were not sustained due to a lack of policy support [27]. Ghana now has an Automotive Development Policy with the aim of making Ghana a fully integrated and competitive industrial hub for the Automotive Industry in the West African sub-region [28]. About seven assemblers have been registered under the program, as listed in Table 2.

Table 2: Registered vehicle assemblers in Ghana (source: Ministry of Trade and Industry)

#	Assemblers/Manufactuers	Vehicle manufactured	Type of Assembler
1	Kantanka Automobile Limited	VW Tiguan, Amarok, Teramong, Passat, Polo	Semi Knocked Down (SKD)
2	Volkswagen Ghana Limited	Kantanka pick-ups	Enhanced SKD
3	Toyota Tsusho Manufacturing Ghana Limited	Toyota hilux	SKD
4	Japan Motors Limited	Navara	Pre SKD
5	Rana Motors and Metal Works Engineering Company Limited	KIA Picanto, Pegas, Rio, Sonet, Seltos	SKD
6	Stallion Automobile Industries Limited	Hyundai, Changan	SKD
7	Silver Star Automobile Limited	Peugeot 3008 SUV, Landtrek pick up	SKD

Currently, none of the companies have registered to manufacture the vehicles. Thus, the vehicle's components all come from outside the country. Though there is a capacity to manufacture, a supply chain is yet to be developed to harness the raw materials in the country.

None of the registered assemblers produce any electric vehicles. While there is great potential to assemble and manufacture electric two- and three-wheelers, the Automotive Policy only applies to light-duty vehicles and not two- and three-wheelers. The policy needs to be reviewed to cater to electric two- and three-wheelers. Ghana has abundant cobalt, lithium, manganese, and graphite reserves needed for manufacturing electric vehicles. However, adequate skills, resources, equipment, and investment opportunities are limited.

3.3. Integration with renewable energy sources

Electric vehicles are more likely to reduce carbon emissions when the energy source for charging includes a significant proportion of renewable sources. Many researchers have suggested that the electricity generation mix directly influences the overall environmental impact of electric vehicle use in a given country [29, 30]. The benefits of adopting electric vehicles may be limited in countries where the energy mix is not environmentally friendly and fails to reduce greenhouse gas (GHG) emissions [22]. Some researchers have established the carbon dioxide emissions of electric buses charged from various energy sources. The conclusion was that an Internal combustion engine (ICE) bus emits 3.46 times the emissions of a similar electric bus charged from the national energy grid, but if charging is done by renewable energy such as solar electricity, the emission by the ICE bus is 329 times more [31].

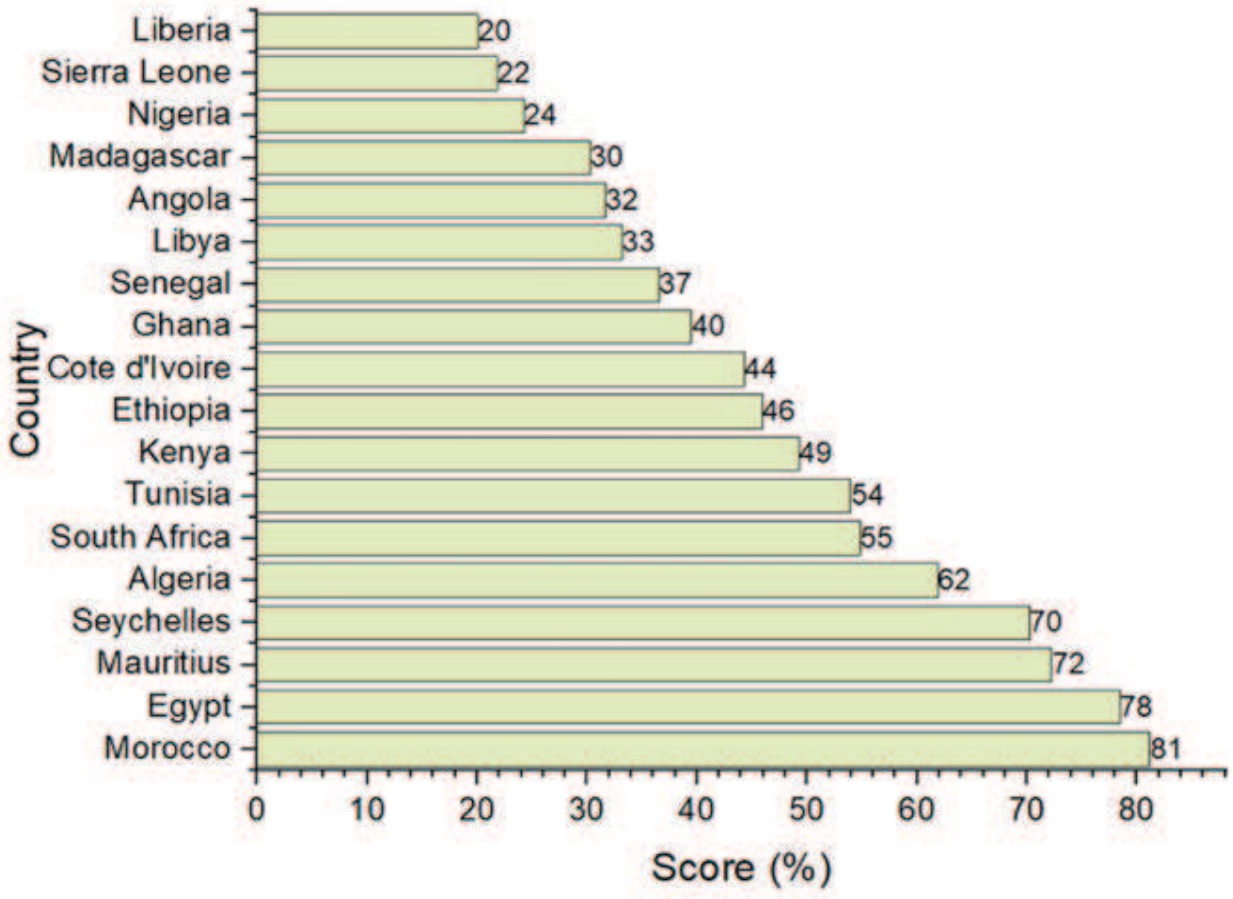
The Ghana national energy mix research also suggests that a 15% and below renewable energy mix will result in more indirect emissions from electric vehicles than conventional vehicles [32]. Renewable energy could also serve as a buffer to stabilize the grid, considering the harmonic instability usually caused by charging electric vehicles. A study in Australia suggests that the present grid infrastructure of Wollongong is incapable of supporting ultra-fast charging of electric vehicles since significant degradation of power quality occurs [33]. Co-locating renewable sources close to charging hubs can help decrease the stress on the local power grid. Daytime charging can be directly coupled with solar by installing solar panels on the roofs of charging depots. This can combine the advantages of intra-day charging using solar energy, which can be used to charge the stationary batteries, and night discharge to reduce power grid load, where electric vehicles can be charged using the stationary batteries [1].

Ghana plans to increase the renewable energy in the power mix to 70% by 2060 [8]. While adequate, the plan does not clearly state what will make this possible. Affordability and import taxes have been a major issue with renewable energy. There must be plans to make renewable energy integration affordable for individuals.

4. Lessons from Successful Global and Regional E-Mobility Initiatives

4.1. Case studies from Africa

Ayetor, Mashele and Mbonigaba [9] examined the advancements made by African countries in transitioning to e-mobility as of 2021. The evaluation considered factors such as electricity access, the reliability of electricity supply, potential for emission reductions, infrastructure development, the maturity of the electric vehicle market (excluding category L vehicles), and the total cost of ownership. Figure 3 shows the ranking of African countries in terms of their readiness for e-mobility.



Morocco is positioning itself as a key player in the global shift toward electromobility, supported by several strategic advantages. These include a strong manufacturing base, expertise in the automotive industry, significant renewable energy potential, abundant raw materials, a strategic geographic location, and free trade agreements. The country aims to lead fully decarbonized automotive supply chains and tap into the growing global electric vehicle (EV) market. With a focus on green technologies and sustainability, Morocco is well-placed to influence the future of electromobility in Africa and on the global stage.

Morocco manufactures approximately 40,000 to 50,000 electric vehicles annually, including models such as the Fiat Topolino, Opel E-Rocks, and Citroën Ami mini-EVs [34].

While the situation is similar to most African countries, some African countries have taken the lead in introducing effective incentives, as shown in Table 3. Rwanda's incentives have put them in the position to halt the registration and licensing of fossil-fueled motorcycles effective 2025. Similarly, Mauritius leads sub-Saharan Africa in the transition to electromobility due to effective incentives implemented over many years [9].

Table 3: Electric Vehicle Incentives in Africa

#	Country	Incentives
1	Rwanda[9]	1. Zero-rated VAT for EVs, their spare parts, batteries, and charging station equipment. 2. Exemption of import and excise duties on EVs, their spare parts, batteries, and charging station equipment. 3. Electricity tariff for charging stations priced at large industry category level. 4. EVs benefit from reduced tariffs during the off-peak time (11 p. m.–8 a.m.). 5. Exemption from withholding tax of 5% at customs. 6. Rent free land for charging stations for lands owned by the government. 7. Building code and city planning rules now have provision for charging stations 8. Free license and authorization for commercial EVs. 9. EV manufacturing and assembly companies are to be given a 15% corporate income tax and tax holiday.
2	Mauritius [35]	1. Waiver of 50% registration duty on Electric Motorcycle 2. Removal of 5% excise duty on electric vans of up to 180 kW 3. EV owners are allowed to install a photovoltaic system not exceeding 10 kW to charge vehicles and export surplus to the grid. 4. Subsidy for the purchase of electric buses is US$22,000 for 9-m buses and US$30,000 for buses above 9-m
3	Morocco [36]	1. Import duties on electric vehicles have dropped to 10% 2. Electric vehicles exempted from VAT and custom duties 3. Green financing scheme and subsidies for EV buyers 4. Tax exemptions for businesses investing in charging stations

4	Ethiopia [30]	15% EV Tax compared to 35% for internal combustion engine vehicles
5	Egypt [30]	1.$1016 tax credit for new EV buyers 2. VAT exemption on EV purchases and related accessories 3. Import duties on EVs reduced to 5% 4. Charging station businesses enjoy tax relief and import tax exemptions on charging station equipment
6	Senegal [37]	1. Zero VAT for electric vehicles and charging infrastructure 2. Import duties on electric vehicles dropped to 5-10% 3. Businesses that purchase electric vehicles for their fleet enjoy a 10-15% rebate on the cost

4.2. Insights from global leaders in e-mobility

Figure 4 shows the leading countries with the highest electric market sales share. Battery electric vehicles (BEVs) accounted for 64.5% of Norway's auto market in 2021, highlighting the country's status as a highly developed and mature BEV market [38]. About 95% of new vehicles sold in Norway in 2024 were BEVs. Several factors account for Norway's leadership in electric mobility. Electric vehicles are exempted from VAT and registration taxes, while electric vehicle owners pay only 50% of road taxes. There are dedicated lanes for electric vehicles, including free parking and tolls. Since 2021, electric vehicles have been more affordable than internal combustion engine (ICE) vehicles in all market segments in Norway[38]. Consequently, Norway has 22,000 charging stations with about 3.5 kW of publicly available charging station capacity for every electric vehicle, as shown in Figure 5 [36].

Figure 4: Electric vehicle as a share of passenger vehicle sales [39]

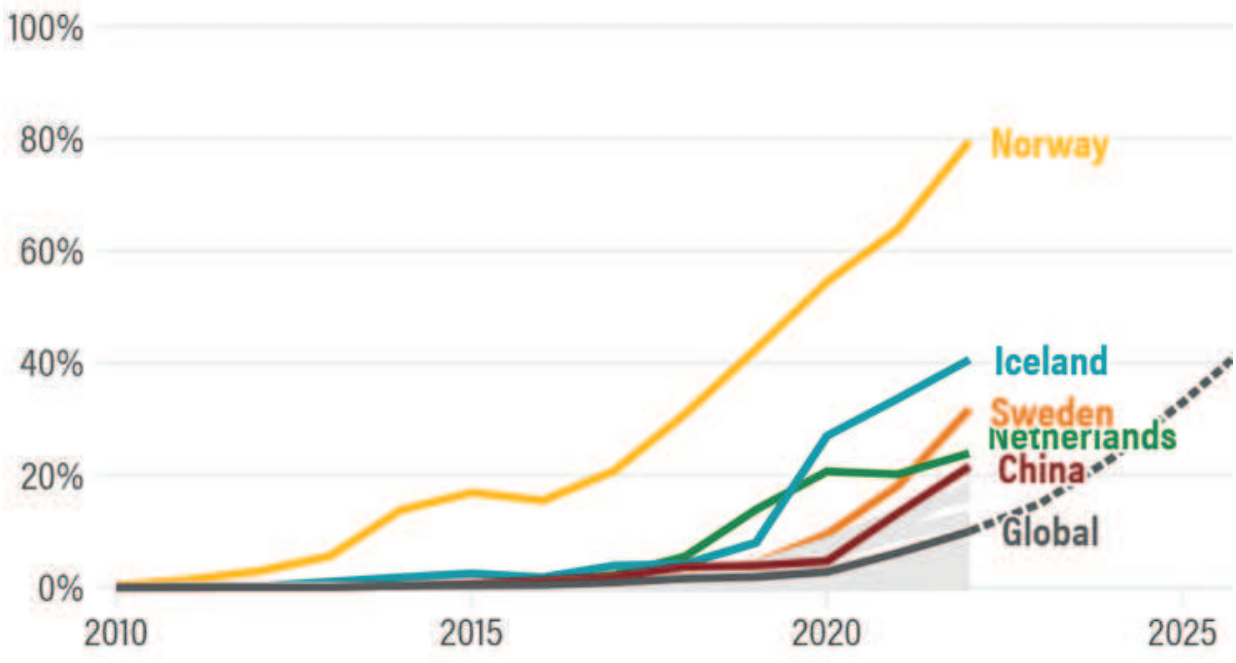
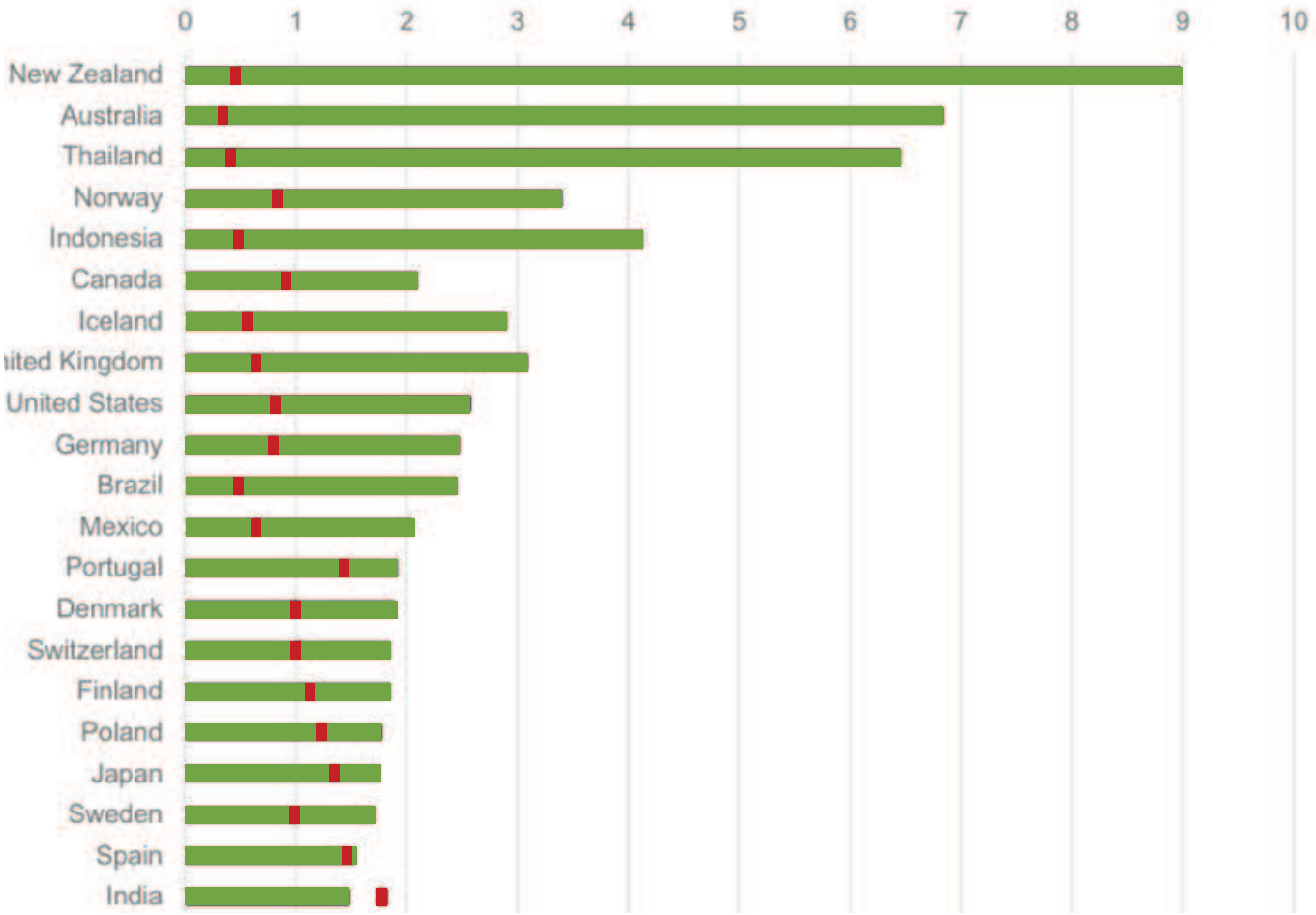


Figure 5: kW of public charging station per electric vehicle [1]



While Norway may be ahead of China in terms of electric vehicle sales share, the world's highest number of electric vehicles is found in China, as shown in Figure 6. In 2023, about 60% of the world's electric vehicle sales were in China. According to the International Energy Agency, the market size for used electric cars was around 800,000 in China, 400,000 in the United States, and over 450,000 across France, Germany, Italy, Spain, the Netherlands, and the United Kingdom. Out of the total registration of 14 million new electric vehicles in 2023, 8.1 million came from China, compared to 1.4 million in the United States [1]. China's leadership in the new energy vehicles (NEV) market is intentional and well-planned. About 70% of the world's venture capital for four-wheeled NEV was spent by China. Similarly, India spent 70% of venture capital in the 2/3-wheeler market, which has propelled it to the world's leading electric three-wheeler market.

Table 4 shows the incentives that have helped China, Norway, and Canada get closer to net zero emissions in the transport sector. The incentives are well-tailored to ensure that consumers do not pay much more than they would have if they had purchased a conventional vehicle. The incentives are well-researched and tailored toward the needs of the country. However, the incentives are gradually removed once price parity is reached.

Figure 6: Global electric car stock trends (2010-2023)[1]

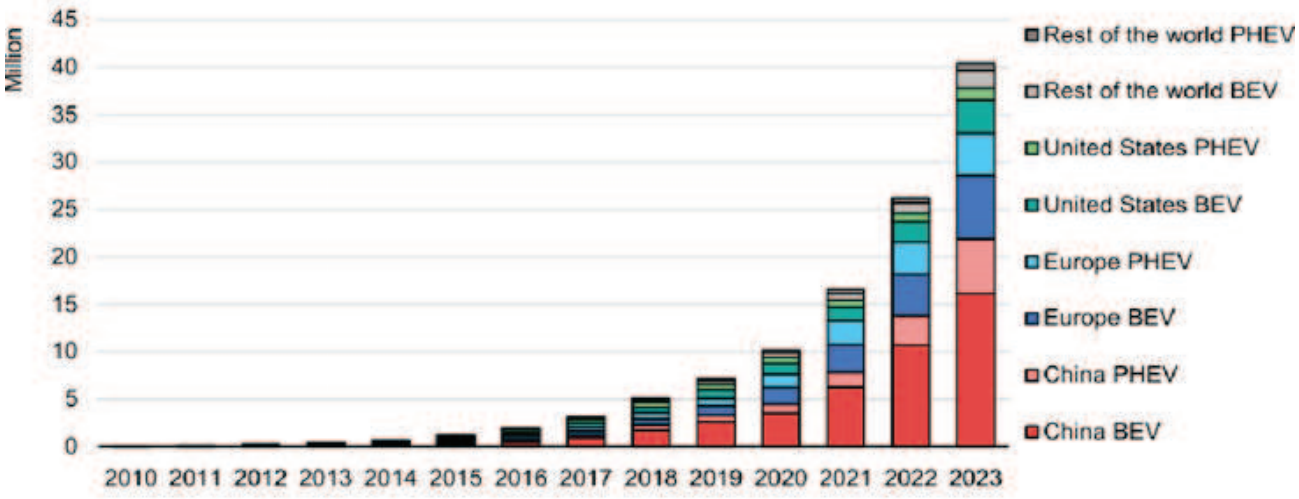


Table 4: Global Electric Vehicle Incentives

#	Country	Electric vehicle incentive
1	Norway [40]	1. No purchase/import tax on EVs (1990-2022). From 2023 some purchase tax based on the cars' weight on all new EVs. 2. Exemption from 25% VAT on purchase (2001-2022). From 2023, Norway will implement a 25% VAT on the purchase price from 500 000 Norwegian Kroner 3.No annual road tax (1996-2021). Reduced tax from 2021. Full tax from 2022. 4. No charges on toll roads (1997- 2017). 5. No charges on ferries (2009- 2017). 6. Maximum 50% of the total amount on ferry fares for electric vehicles (2018) 7. Maximum 50% of the total amount on toll roads (2018-2022). From 2023 70% 8. Free municipal parking (1999- 2017) 9. Access to bus lanes (2005-). New rules allow local authorities to limit access to only include EVs that carry one or more passengers (2016-) 10.10.25% reduced company car tax (2000-2008). 50% reduced company car tax (2009-2017). Company car tax reduction reduced to 40% (2018-2021) and 20 percent from 2022. 11. Exemption from 25% VAT on leasing (2015-) 12. Charging right for people living in apartment buildings was established (2017-)
2	China [41]	1. Five percent price subsidy for new energy vehicle (NEV) purchase 2. Full exemption of NEV purchase tax till 2025 3. Fifty percent exemption of NEV purchase tax from 2026 to 2027 4. NEVs exempted from vehicle and vessel tax 5. Fifty percent investment subsidy for charging stations 6. Daily operation subsidy of 0.016 USD/kWh 7. 784 USD charging subsidy for EV consumers
3	Canada [42]	1. Tax support for electric vehicle charging stations 2. Accelerated capital cost for electric vehicles 3. Grant of 50 to 90% for every charger installed 4. Rebate of 25% for every electric motorcycle

5. Overview of Small and Medium-Sized Enterprises in E-mobility Ghana

A company's business model stands for the logic of firms and how they work to create value [43]. It describes how a company generates revenue, creates value, and operates sustainably. The E-mobility business models in Ghana are being led mainly by the new entrants in the automotive market. Leading legacy companies such as Toyota Ghana have been absent in the battery electric vehicle (BEV) and hybrid market.

Although Toyota Global is the leader in hybrid electric vehicles, its local partner in Ghana has yet to sell any electric vehicle.

But for the timely intervention of the E-mobility start-ups such as SolarTaxi, Wahu! (Formerly Cargo Bikes and Mana Mobility), iJANU and Kofa, there would have been no e-mobility market. Figure 7 shows Ghana's major e-mobility start-ups and/or SMEs as of 2024.

Figure 7: E-mobility start-ups/SMEs in Ghana as of 2024

The emergence of these start-ups also marked a significant increase in vehicles imported from China. About 98% of all the BEVs imported to Ghana between 2017 and 2023 came from China [16]. Historically, Ghana imports most of its vehicles predominantly from the United States of America, but with cheaper electric vehicles from China, this dynamic is changing for BEVs [6, 44]. The e-mobility start-ups in Ghana predominantly adopt a buy-and-sell approach, lacking the capacity for manufacturing and assembly that is usually symbolic of a thriving e-mobility ecosystem. Most of these companies are self-funded, with few benefiting from external funding and hardly making profits, coupled with high attrition rates. Because there were no incentives, the companies had to design innovative business solutions for their products to compete with low-priced internal combustion engine vehicles. Popular among the business models are the lease-to-sell, hire-purchase, and battery-swapping models, which do not require potential users to pay the upfront price for the vehicle. These business models are very popular within the electric 2/3 wheeler market, where they are used predominantly for last-mile delivery. The model employs several unemployed youth who ordinarily do not have the purchasing power to pay outright for a 2/3 wheeler but are allowed to own the electric 2/3 wheeler within two years. The electric four-wheelers are usually patronized through ride-hailing services, on-hire purchases, or sold outright. Drivers on the hire-purchase model are allowed to own the vehicles within six years via weekly payments achieved through offering ride-hailing services. Outright purchases of electric four-wheeled vehicles are usually offered to wealthy clients who already own one or more conventional vehicles. The subsequent sections provide further details of the business models employed by some SMEs.

5.1. Solar Taxi

Solar Taxi, an indigenous Ghanaian e-mobility company, is accorded the pacesetter in the e-mobility industry in Ghana. Their initial focus was selling electric two- and three-wheelers, which also involved the conversion of conventional motorbikes into electric ones. The company operates a ride-hailing platform serviced solely by electric vehicles. The electric motorcycles and vehicles have been used for last-mile delivery services for Jumia, Bolt Food, and other online apps. Thus, their vehicles enable Solar Taxi to deliver a B2B, B2C courier service for food, clothes, electronics, and packages.

Eventually, electric four-wheeled vehicles became part of the package. Figures 8 and 9 show Solar Taxi's latest product, ASEMPA 34, launched in 2024. It is a 37-seater electric bus (e-bus) capable of traveling 400 km on a single charge.

Figure 8: ASEMPA 34 e-bus launched by Solar Taxi in 2024

Figure 9: Interior of the ASEMPA 34 e-bus recently launched by Solar Taxi

They operate a retail model where these vehicles are bought from China and sold to Ghanaians. The company also provides repair services and replacement parts for vehicles sold. Due to many myths associated with electric vehicles, this approach is convenient for Ghanaians. While each vehicle it sells comes with a standard portable Level one charger, Solar Taxi also installs fixed chargers (level 2) for homes and workplaces as part of its business model. Due to the lack of sufficient public charging stations, most of its clients opt to install fixed chargers at home. To reduce the cost associated with parts import and maintaining an electric vehicle, the company launched its lithium-ion battery pack lab on August 6, 2021, to the general public. The lab serves the purpose of indigenizing lithium-ion battery pack engineering and production to meet the growing power needs of EV users in Africa. The cost of traction batteries for battery electric vehicles is approximately 40 to 60 % of the cost of the vehicle itself [32]. Eliminating the need for clients to import these batteries directly could substantially reduce the cost of replacing them. As a pioneer e-mobility company, offering training to its staff and the public became necessary. A solar academy was established to train female engineers and riders. The training focused on introduction to e-mobility, repair, assembly, and driving—the basic training on driving suited motorcycle drivers who needed to understand and operate electric motorcycles. Other e-mobility companies, such as Wahu Mobility, have employed some graduates from the solar academy.

5.2. Wahu! Mobility

Wahu! Mobility is an e-mobility startup that manufactures eco-friendly motorcycles, providing a reliable source of income for youth. The company's main product is the wahu! bike is a robust electric bike (e-bike) with thick tires and reinforced front and rear suspension, which can navigate rough terrain and use (Figure 10). The two-wheelers have pedal assistance and a throttle function aided by the electric mode. They are supplied with two easily replaceable lithium-ion battery packs, which are sufficient for a range of around 140 kilometers. Each battery takes five to six hours, with a slow charger costing about USD 0.27 (GHS 4.34) daily at an exchange rate of GHS 16 to a dollar.

Figure 10: bikes manufactured by Wahu! mobility

The primary business model is the ride-to-own initiative, which allows different payment plans for potential drivers. The company has a dedicated app that provides drivers with information on the battery charge status, distance traveled, and carbon dioxide emissions saved. The app also lists local mechanics and charging options for all e-bikes available in Ghana on a map. This model alleviates the burden of potential riders who cannot afford to purchase the e-bike upfront. The e-bikes cost around USD 2,000 (GHS 32,145), and a financial plan provides installments of USD 30 (GHS 482) per week for 18 to 24 months, depending on the payment plan. Riders are signed on to last-mile delivery apps such as Yango and Bolt, earning between USD 6.22 (GHS100) and USD 12.44 (GHS 200) daily. Compared to fossil fuel-powered motorcycles, the Wahu! e-bike has a potential monthly savings of USD 170 (GHS 2,700). Wahu! Mobility manufactures the bikes locally (except the batteries) to reduce their initial cost. The company targets the manufacture of 200 e-bikes annually as it expands to other countries such as Togo, Nigeria, and Zambia. Wahu! Mobility is also trying to reach net zero by further reducing its carbon footprint. The factory where the bikes are assembled and maintained is solar-powered and completely off-grid, thus advancing renewable energy and sustainability. The company is also promoting the recycling of its lithium-ion batteries. They are the first e-mobility company in Ghana to qualify for a compliance market deal.

5.3. Zerosol Limited

Zerosol Ltd. provides low carbon emission solutions for businesses and projects in Ghana and West Africa. Zerosol Ltd. delivers comprehensive electric mobility and off-grid charging infrastructure solutions, repair services, assembly, manufacturing, renewable energy support, and low carbon emission solutions training. Zerosol supplies many electric vehicles, including cars, buses, trucks, and motorcycles. Zerosol's team of experts assists businesses and projects in selecting the most suitable electric vehicles for their specific needs, considering factors such as range, payload capacity, and charging requirements. The company offers comprehensive after-sales services, including maintenance, repairs, and software updates, ensuring optimal performance and customer satisfaction. The company was contracted on several projects to convert landcruisers and Toyota Hilux to electric for use by mining companies. They have also provided maintenance and repair services for automotive companies. They were involved in the Goldfields material movement decarbonization project.

Recognizing the critical role of a robust charging infrastructure, Zerosol also provides end-to-end solutions for establishing charging stations. Their services include designing, installing, and maintaining charging infrastructure for residential, commercial, and public spaces. Solar off-grid charging infrastructure, combining renewable energy sources for charging electric vehicles, is a core part of Zerosol's charging infrastructure agenda. Zerosol Ltd. also offers renewable energy support to corporations and private homes. The renewable energy support services aim to facilitate the integration of renewable energy technologies into transportation and infrastructure systems, providing a holistic and environmentally friendly solution. Zerosol also conducts training programs and workshops on low-carbon emission solutions. They educate businesses, project managers, and other stakeholders on the benefits and implementation of electric vehicles, charging infrastructure, and solar off-grid charging solutions. Their training is tailored to equip participants with the knowledge and skills to embrace and effectively utilize low-carbon emission solutions.

5.4. SmartTRANSYT

SmartTransyt is an e-mobility company whose business model is to run electric paratransit buses, providing a sustainable alternative to fossil-fueled paratransit buses popularly called "trotro' in Ghana. Ghana's paratransit buses produce high emissions due to age, outdated emission technologies, and lack of adequate maintenance regimes [45]. These buses dominate short vehicle commutes, critical in conveying people to work. Long queues to board these buses in the mornings and evenings suggest they are insufficient. While SmartTransyt seeks to fill this need, it also seeks to transform paratransit transportation by making it more convenient and comfortable. The company provides a Wi-Fi network and air conditioning for all its buses (Figure 11) at no extra cost. Electronic payment options are offered through mobile money options, which provide a touch-free e-payment system. The bus routes prioritize efficient management and operation to reduce traffic congestion. A SmartTransyt digital wallet that is easily topped up with Mobile Money is also available. Efficient and high-capacity charging stations have been influential in the success of SmartTransyt buses. The company has installed a 120 kW charging station at its depot powered by a high-capacity transformer and a voltage stabilizer.
The company provides opportunities for other companies and individuals to own e-buses in their fleet. SmartTransyt facilitates purchases from its bus manufacturers to enable individual ownership of the buses, which can be assimilated into its fleet. Drivers of the buses are also allowed to own the buses through the lease-to-own option.

Figure 11: On the left is the smartTRANSYT bus, and on the right is the conventional paratransit bus

5.5. Kofa Technologies

The company unveiled the second version of its motorcycle (Figure 12), the Jidis, alongsideKofa, an e-mobility company, specializes in selling electric motorcycles and establishing battery swap stations. The company began operations in Ghana in 2021, introducing the Volta motorcycle and deploying 40 units across Accra as part of a pilot program. Supported by the Shell Foundation, the UK's FCDO, Wangara Green Ventures, and Mercy Corps Ventures, Kofa unveiled Ghana's first connected battery swap network featuring the Kore1 battery in early 2023. the versatile Kore2 battery. The Kore2 battery offers a wide range of applications and delivers powerful performance at a cost more affordable than traditional fuel. For example, it can sustain the basic operations of a small urban store, including running a refrigerator, lights, and fans for up to 15 hours. Furthermore, it supports heavy-duty tools such as drills, embossers, and power saws for approximately 2 to 4 hours. The Kore2 battery also powers the TAILG Jidi electric

motorcycle for up to 100 kilometers on a single charge. To create the Jidi e-motorcycle tailored to African needs, Kofa partnered with TAIL-G, a global leader in e-motorcycle manufacturing. Additionally, Kofa collaborated with MAX to facilitate financing for the TailG Jidi motorcycle, an environmentally friendly electric bike introduced in Ghana. MAX Ghana employs a hire-purchase model, providing motorcycles to unemployed individuals. Riders primarily use the motorcycles for deliveries and can gain full ownership after two years of regular payments, made six days a week. These motorcycles feature removable batteries, allowing them to be swapped at designated stations for a fee, with each motorcycle requiring two batteries. MAX can deactivate the motorcycle remotely if a rider defaults on payments. This approach enables Kofa to sell motorcycles, encourages using its battery swap stations, and contributes to youth employment. Figure 9 depicts one of Kofa's battery swap stations powered by solar energy. Kofa is focused on building an affordable, user-centric electricity network that integrates portable batteries and renewable energy. Its "Swap & Go" system offers a distributed battery network, allowing users to exchange depleted batteries for fully charged ones in seconds. By January 2023, the startup had established over ten battery swap stations in Accra, deploying 500 Kore2 batteries and 150 Jidis. Information about eight swap station locations is available on the Energy Commission website. (https://www.energycom.gov.gh/newsite/index.php/initiatives/drive-electric-initiative-main/battery-swap-stations). The enhanced network of ten strategically placed swap stations, some powered by solar energy, supports more than 20,000 monthly battery swaps in Accra.

Figure 12: One of Kofa Technologies Battery Swap Stations

5.6. iJANU Ghana Limited

iJANU Ghana Limited, based in the North Industrial Area of Accra, commenced operations in Ghana in 2021. As an e-mobility technology company, iJANU promotes sustainable and inclusive mobility solutions for African markets. iJANU also facilitates affordable access to EV ownership and provides maintenance and servicing options for electric vehicles. It also operates as a wholly owned subsidiary of Group Spectre Limited, a registered provider of EV charging technologies. The company implements commercial level 2 and 3 EV charging solutions, utilizing proprietary Energy Storage Systems powered by renewable energy sources, including solar photovoltaics and vertical wind turbines, alongside grid electricity.

The company has diversified its services to include electric vehicle solutions to reduce operational costs for potential customers. Its business model primarily targets commercial drivers and high-income individuals capable of purchasing EVs. Commercial drivers utilize these vehicles for ride-hailing services and last-mile deliveries. Additionally, the company benefits from collaborations with automobile firms that acquire vehicles for their drivers to engage in various commercial ventures, such as ride-hailing operations.

This evolving model has facilitated the establishment of Ghana's first DC fast-charging station in the North Industrial Area of Accra. The station, with a 60 kW capacity, connects to a 500 kVA transformer serving the area. It operates as a hybrid system powered by 60% solar electricity and 40% national grid energy, supported by a Drive Booster Battery Energy Storage System capable of storing energy from solar, wind, and the national grid. The station advertises a 60 kWh capacity and has type 2 connectors, GB/T connectors, Tesla Supercharger cables (now NACS), and combined charging system (CCS2) connectors. The addition of charging infrastructure to the model is to increase profitability (Figure 13).

Figure 13: iJANU charging station

iJANU Limited operates a network subscription model for customers utilizing its public EV charging stations. The subscription costs $62 monthly (GHS 1,022) and includes a session fee of $0.27 (GHS 4.45), with a daily power consumption limit of 35 kWh. Alternatively, the charge-as-you-go option is priced at $0.34/kWh (GHS 5.61/kWh) with an additional session fee of $0.39 (GHS 6.43/kWh). Access to the subscription service is not exclusive to iJANU customers.

In the charge-as-you-go model, payments are typically handled by an attendant present at the station. Users can call for a unique code to activate the charging session even when no attendant is available at the charging station. However, since payment is required only after the session, there is a risk of non-payment in cases where an attendant is not present.

5.7. Nastech Power Solutions

Nastech Power Solutions specializes in developing and manufacturing solar generators, power inverters, and lithium battery packs using recycled electronic waste from discarded materials. Their relevance in the e-mobility industry is emphasized by their focus on recycling electric vehicle batteries and inverters. Recycling batteries and utilizing renewable energy sources can significantly reduce battery-related pollution, thereby increasing the attractiveness of electric vehicles to potential consumers.

In 2016, Ghana introduced the Hazardous and Electronic Waste Control and Management Act (Act 917) and its associated legal instrument (LI 2250). Ghana became the first African nation to implement the Technical Guidelines on Environmentally Sound E-waste Management [46].

The LI 2250 recommends that the Environmental Protection Agency (EPA) and the Minister for the Environment facilitate the establishment of an e-waste recycling facility and supporting infrastructure in Ghana, financed through the e-waste fund. Currently, Ghana lacks a state-owned e-waste recycling facility. Nastech Power Solutions and other private facilities such as Electro Recycling Ghana, Neweco E-waste Recycling, and the Agbogbloshie E-waste Recycling Centre are trying to fill this gap.

By adopting a circular economy model, Nastech Power Solutions manufactures solar energy systems to deliver affordable renewable energy solutions, providing electricity to support businesses and communities in Africa facing challenges with reliable access to power. The Nastech solar generator is a dependable 2000W power solution engineered to meet various electrical demands efficiently. Its robust output supports various appliances, such as televisions, fans, lights, and refrigerators, ensuring consistent performance.

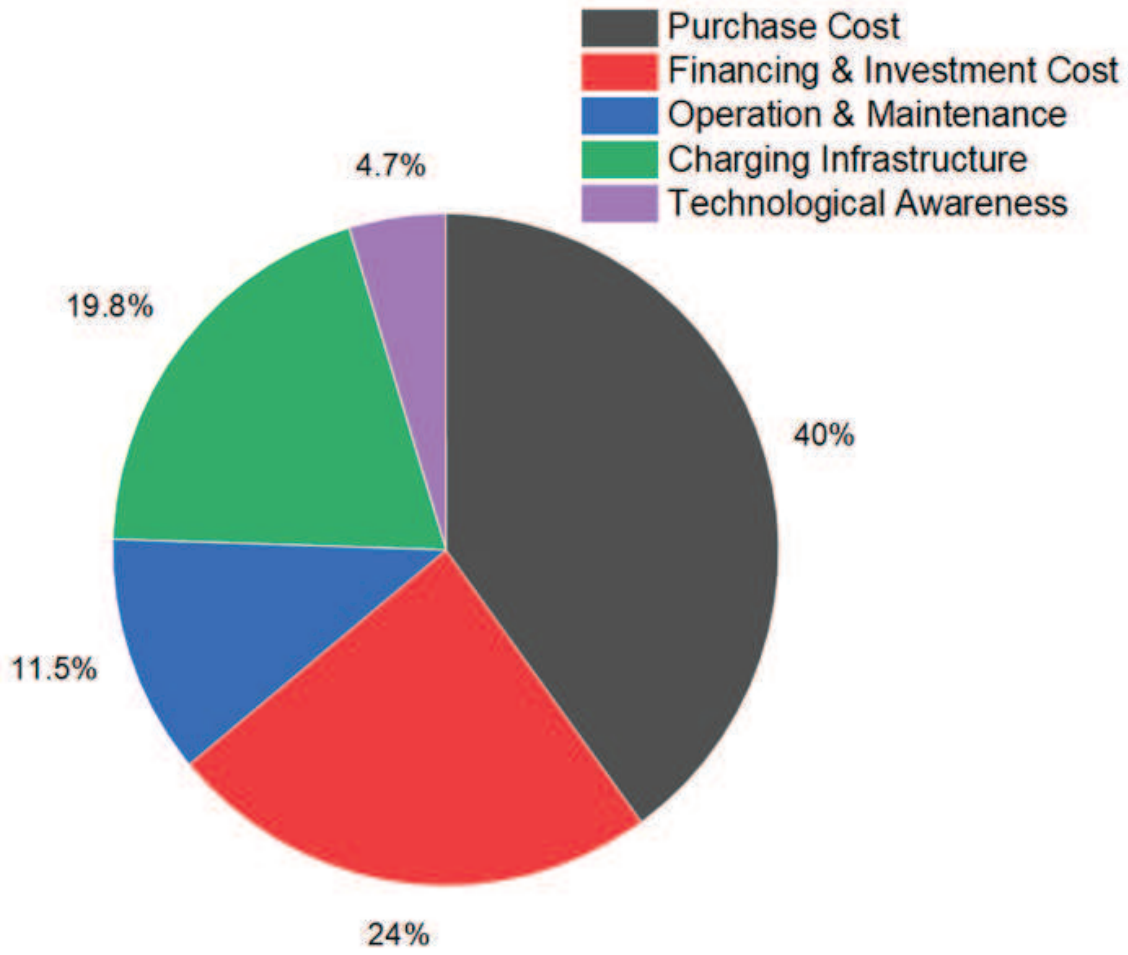
5.8. Key Attributes of E-mobility Startups in Ghana

The e-mobility startups (Table 5) in Ghana are still in their infancy and facing many challenges. Almost all of them are running more than one business model. Solar Taxi Ghana assembles electric two and three-wheelers and sells them directly to customers. The company also sells electric four-wheelers, including buses, and installs charging stations. Though iJANU Ghana is known for its public charging station, its core business is selling and leasing electric vehicles and installing level 2 charging stations. All the e-mobility startups have a lease-to-own option for all the vehicles they sell. Kofa Technologies offers its unique

6. Barriers to E-mobility Growth in Ghana

The e-mobility companies were interviewed to understand the challenges faced by their businesses. Based on their responses, five challenges were identified and weighted, as shown in Figure 14. The purchase cost accounts for 40% of the challenges. The cost of finance and investment (24%) ranks next, followed by the availability of charging infrastructure (19.8%), operation and maintenan ce (11.5%), and technological awareness (4.7%). The consistency ratio of 0.078 (less than one) obtained for the expert survey confirmed that the opinions were consistent.

Figure 14: Weight distribution as obtained from the interview



6.1. Purchase Incentive

All the e-mobility companies interviewed in unison indicated that the high cost of purchasing electric vehicles was the biggest challenge in their business. Especially considering that electric vehicles are not manufactured in Ghana. Electric vehicles are becoming more affordable due to increasing competition, especially in China. However, in other markets, they are still priced higher than internal combustion engine vehicles. Over 60% of electric vehicles sold in China in 2023 were estimated to be more affordable than the average internal combustion engine counterparts [1]. In contrast, electric vehicles in Europe and the United States remain 10% to 50% costlier than combustion engine models, varying by country and vehicle segment.

electric motorbikes to unemployed youth with the option to pay off within two years. Wahu! Mobility and Kofa Technologies additionally create job opportunities for the lease-to-own option by going the extra mile to liaise with last-mile delivery companies.

It is simply not a viable venture to rely on one business model in the e-mobility space in Ghana. Several business models have to be combined to remain viable. Some e-mobility companies rely on external green funds from Siemens Stiftung, KLIK International, and others to remain viable.

Table 5: E-mobility start-ups in Ghana

Startup	Core Activities	Business Model	Unique Features
Solar Taxi	Produces and sells electric two-, three-, and four-wheelers; offers ride-hailing and courier services.	Retail model; sells imported vehicles, provides repair services, and installs home chargers.	Lithium-ion battery lab; solar academy for female engineers; ASEMPA 34 e-bus launched in 2024.
Wahu! Mobility	It manufactures eco-friendly e-bikes and focuses on youth employment.	Ride-to-own initiative with flexible payment plans.	Solar-powered factory; app for riders; promotes battery recycling.
Zerosol Limited	Supplies EVs, off-grid charging solutions; repairs and trains on low-carbon mobility.	B2B services; customized EV solutions for businesses.	Converts conventional vehicles to EVs; involved in mining decarbonization projects; solar off-grid charging.
SmartTRANSYT	Operates electric paratransit buses for public transport.	Lease-to-own option for drivers; bus fleet sales.	120 kW charging station; Wi-Fi and air conditioning in buses; digital wallet for payments.
Kofa Technologies	Sells electric motorcycles; operates a battery swap network.	"Swap & Go" system for battery swapping; hire-purchase financing for riders.	Kore2 battery powers motorcycles and small businesses, solar-powered swap stations; over 20,000 swaps monthly.
iJANU Ghana Ltd.	Provides EV charging solutions and promotes EV adoption.	Subscription and pay-as-you-go charging models.	Ghana's first DC fast-charging station is a hybrid charging system that uses solar and grid energy.
Nastech Power	Develops solar generators and power inverters and recycles EV batteries.	Circular economy model using recycled e-waste materials.	Focus on reducing battery pollution; partnerships to address Ghana's e-waste gap.

In Ghana, the average price of a new electric vehicle is three times that of an equivalent conventional vehicle, and it takes 11 to 20 years for electric vehicles to reach cost-parity with conventional vehicles [6]. Current trends indicate that price parity between electric and internal combustion engines could be achieved by 2030 in major markets outside China for most models [1]. Ghana may take longer to transition due to the economic preference for used vehicles. The high purchase price of electric vehicles will remain a deterrent until more affordable options become available. Following in the footsteps of China by providing purchase incentives and waivers for vehicle manufacturing is essential to reduce the purchase price.

The Ghana Automotive Development Policy, launched in 2019, sought to encourage the establishment of assembly plants in Ghana to provide jobs and make vehicles cheaper to own. In the 2024 budget, the finance minister announced the extension of this policy to electric vehicle assembly and manufacturing [47]. However, none of the e-mobility companies interviewed admitted to benefitting from this measure. The required number of assembled electric vehicles has still not been achieved by any e-mobility company to merit the reprieve. Thus, the measure did not provide any advantage to electric vehicle assembly compared with internal combustion engine vehicle assembly. The 2024 budget also announced a waiver of import duty for electric vehicles for public transportation. In practice, this waiver has been limited to commercial buses. Again, none of the e-mobility companies interviewed, including those who import commercial electric buses, have benefitted from this. Instead, the vehicles attract higher taxes than internal combustion engines (ICE). The Ghana electric vehicle baseline survey report mentions that electric vehicles are subjected to an import tax of 20%, while most ICE vehicles attract as low as 5% [16].

6.2. Financing and Investment

The second critical challenge to SMEs in the e-mobility sector is the high cost of borrowing, lack of affordable green loans, and lack of investment. Due to the high cost of electric vehicles and charging stations, financing becomes critical to invest in the e-mobility business. Foreign currency (USD and Yuan) is preferred when pricing electric vehicles and their accessories. E-mobility companies must obtain these currencies to purchase vehicles even though they have to sell them in Cedis. Unfortunately, the Ghanaian cedi faced sustained pressure in October 2024, recording a 3.95% loss against the US dollar, which brought its year-to-date depreciation to approximately 29% [48]. The borrowing cost is also high, with some bank interest rates quoted in foreign currency. Ghana has one of the highest interest rates in Africa, rivaling only Egypt, Nigeria, and Zimbabwe. For example, the Bank of Ghana reports the interbank interest rate to be 27.02% as of November 15, 2024, compared to 12% for Kenya [49]. Some e-mobility start-ups, such as Wahu! Mobility has had to collaborate with financial service provider Letshego to make electric vehicle ownership more affordable and accessible in Africa. Through Letshego's financial expertise, users will benefit from affordable financing options, making it easier to transition to environmentally friendly vehicles. Kofa Technologies Ltd has also partnered with impact investor PASH Global to establish the special purpose vehicle, which is backed by a GBP 2.35 million (US$3 million) commitment from Shell Foundation and the UK Government's Transforming Energy Access (TEA) platform [50]. Many of the e-mobility providers have recommended interest rates below 10% to accelerate vehicle purchases. Ayetor and Andoh [14] mentioned in their research publication that electric vehicles' nominal cost per mile is lower than ICE vehicles only when import duty is wholly waived and the lending rate is reduced to 10%. The current interest rates, therefore, do not foster a transition to e-mobility.

6.3. Operation and Maintenance Challenges

A significant challenge in maintaining electric and hybrid vehicles is the limited availability of parts in the market and the shortage of adequately qualified and competent personnel [51]. Some e-mobility companies have many electric vehicles under repair, while charging stations often break down. Providing adequate training for relevant professions is a crucial aspect of sustainable development and the successful implementation of electromobility in any country, whether in Ghana or globally. The skills gap shortage in the e-mobility sector is a general challenge of the automotive industry in Ghana. The advent of engine management systems in cars raised the skill level required to diagnose circuits and sensors, even in conventional vehicles. E-mobility companies in Ghana fly their workers abroad for training, and in some in stances, expatriates are contracted to train their personnel in Ghana at a high cost. Some of the vehicles also remain unattended due to lack of spare parts.

The informal sector dominates the Automotive repair industry with no formal training for a highly technological sector requiring formal training. The United States refers to formally trained mechanics as journeyman mechanics. Journeyman mechanics are skilled professionals specializing in inspecting, servicing, and repairing vehicles' mechanical and electrical systems, including cars, buses, and commercial trucks. They are commonly employed by auto body shops, dealerships, and fleet maintenance companies, though some also work in automobile manufacturing or pursue self-employment. Achieving journeyman status involves significant effort, including completing an apprenticeship following primary education. Additionally, candidates must pass a certification exam to demonstrate their expertise in mechanical systems.

The Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, is the only institution that has started formal training in mechanics in the new energy vehicle sector. To support the government's goal of transitioning to sustainable mobility, the KNUST, through The Brew-Hammond Energy Centre (TBHEC), established the New Energy Vehicle and Sustainable Transport team to focus on research and training within the New Energy Vehicle sector. In October 2024, the Centre launched Level 1 training focused on Electric Vehicle Safety Awareness [52]. The program is set to expand in 2025, introducing Level 2 and Level 3 certifications for High Voltage Electric Vehicle and Battery Technicians. The charging station installation and maintenance skills are also non-existent. The result is that most public charging stations in Ghana are almost always under repair. The Energy Commission of Ghana provides formal training for licensed electricians for household and industrial wiring. Electric vehicle infrastructure installation and maintenance is yet to be added to the package. Thus, formal training programs for vehicle repair and charging infrastructure are needed.

6.4. Charging Infrastructure Challenges

As of December 2024, seven public electric vehicle (EV) charging stations have been installed across Ghana. The iJANU charging station in the North Industrial Area of Accra is currently the only publicly accessible DC charging station in Ghana, offering a capacity of 60 kW. However, its full potential remains underutilized due to technical issues. POBAD International operates two additional AC charging stations, each with a capacity of 22 kW. One is at A&C Mall in East Legon, while the other is at Stanbic Heights.

Additionally, three Level 2 charging stations, each with an 11 kW capacity, are operated by Porsche Ghana and are strategically located at Kempinski Hotel, Palace Mall, and 37 Liberation Link near Golden Tulip. The most recent installation is managed by Silver Star Tower Limited and is located in Airport City, Accra. This 22-kW charger, primarily powered by solar energy, is equipped with a type 2 connector and is compatible with Chinese-manufactured electric vehicles requiring GB/T connectors. Seven public charging stations imply that the ratio of electric vehicles to charging stations in Ghana is 2,428:1, far exceeding the recommended 10:1 [9]. Ghana has no incentives for electric vehicle charging stations like other African countries. While fast charging station costs vary from USD 5000 to USD 10,000 in China, the same chargers cost about USD 30,000 in Ghana due to additional taxes. The strategic placement of public electric vehicle charging stations (EVCSs) is vital in increasing EV adoption and alleviating concerns about range anxiety.

Strategically locating public electric vehicle charging stations (EVCSs) plays a vital role in promoting the adoption of electric vehicles (EVs) and alleviating range anxiety. Electric vehicle adoption tends to accelerate after many EVCSs have been established in key areas. Site selection for EVCSs is typically influenced by traffic and population density, access to electricity, and grid reliability [30]. Highways necessitate additional considerations, including broad coverage, amenities for long-distance travelers, and backup power solutions in the event of grid failure.

Uneven distribution of EVCSs contributes to range anxiety, particularly on highways, hindering the broader uptake of EVs. Several countries have implemented specific regulations, policies, and targets for charging station deployment. For instance, New Zealand plans to establish charging hubs every 150-200 km on major highways and install at least 200 stations in rural areas. The United States aims to deploy 500,000 charging stations by 2030. Australia proposes placing charging stations every 150 km along highways, while Norway targets one fast charging station every 50 km on main roads. India seeks a denser network with charging stations every 25 km along major highways [11].

The e-mobility operators consider the access to electricity and quality of electricity essential to a thriving e-mobility industry. Ghana's Energy Statistics 2024 report indicates that national electricity access had risen to 88.85% by the close of 2023, marking significant progress from the 64.4% recorded in 2010 [53]. However, the quality of electricity remains an issue for charging stations. Figure 15 shows the peak load data from September 1 to October 2024 obtained from GRIDCO. Generation averages about 3000 MW at peak compared to about 3700 MW demand, resulting in a shortfall of 700 MW daily within the period under study.

The reliability indices for the Electricity Company of Ghana (ECG) in 2023 are depicted in Figure 16. The System Average Interruption Frequency Index (SAIFI) calculates the number of outages experienced by an average customer annually, with recorded values of 12.1 for Metro areas, 18.2 for Urban areas, and 16.5 for Rural areas. These figures significantly exceeded the regulatory benchmark of six (6), with neither ECG nor NEDCo achieving compliance in any operational area. This underscores the ongoing prevalence of outages. Considering the sporadic power disruptions observed during the first and second quarters of 2024, SAIFI levels are anticipated to increase further in 2024 and beyond.

The result is frequent outages, sudden voltage surges, low voltages requiring alternative power, and complicated charging station designs. Charging stations must be equipped with voltage transformers, voltage stabilizers, residual current devices, and current transformer meters to protect the vehicles they charge, resulting in expensive charging station installations.

Figure 15: System peak demand and power generated at peak

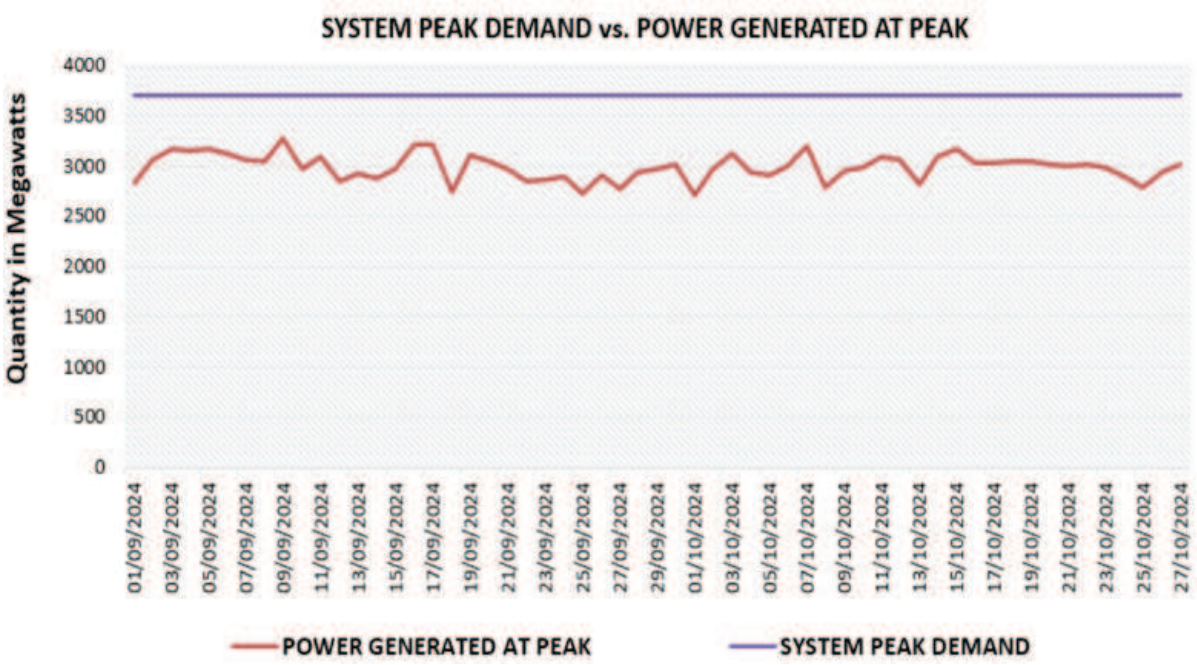
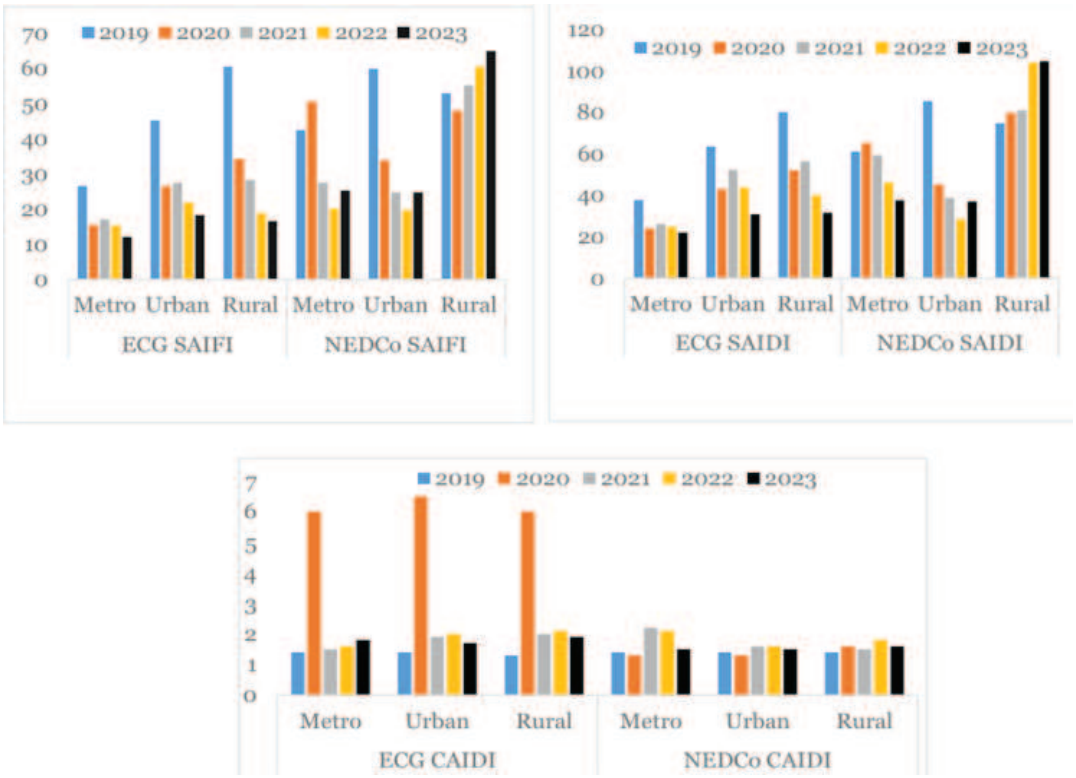


Figure 16: Distribution regulatory indices [53]



6.5. Technological Awareness

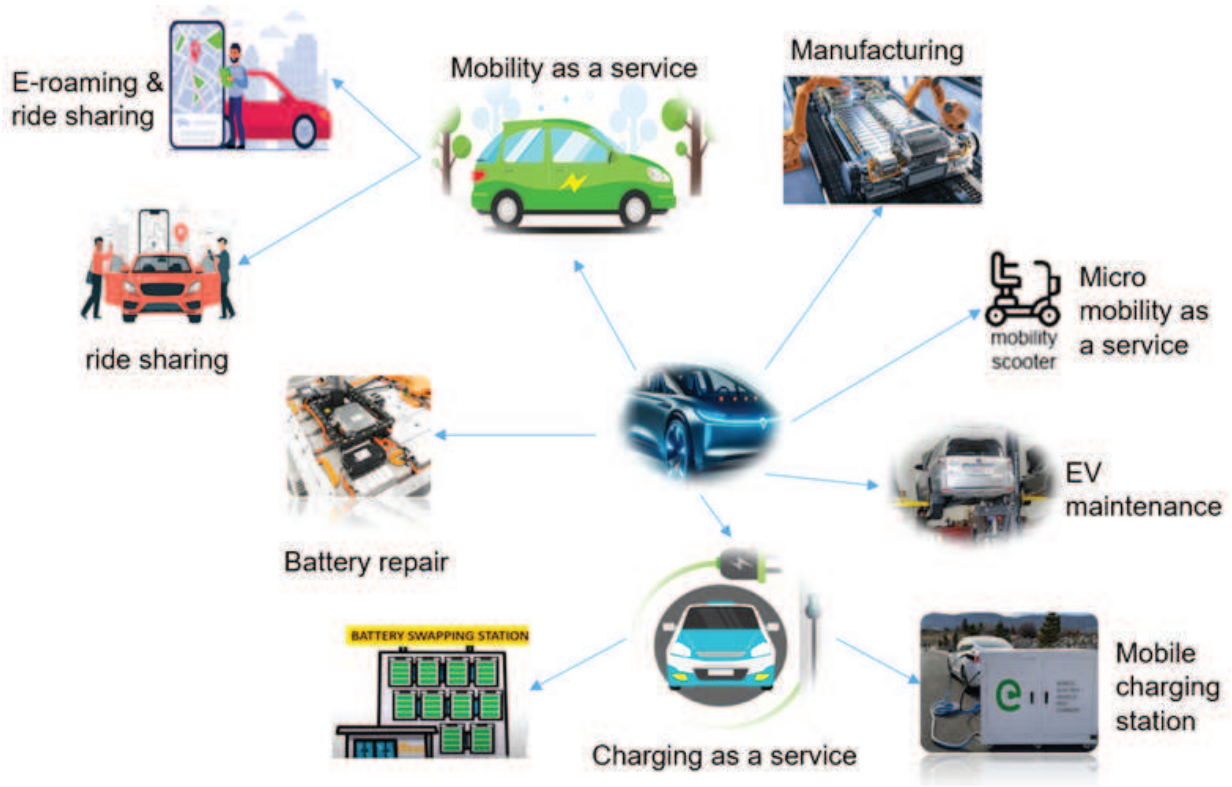
The myth of owning an electric vehicle is very rife among the population in Ghana, as is the case in many other countries. One of the major concerns is the limited driving range of electric vehicles, which is often shorter than that of conventional vehicles. This limitation raises concerns among potential buyers, who worry it may affect their flexibility and require more careful planning for longer trips. E-mobility providers are frequently forced to seek out long-range electric vehicles to offer, but these tend to come at a higher cost. A preference for higher battery capacities also means a preference for expensive electric vehicles, which is out of range for most car owners. In 2023, the average range of small electric cars was 150 km compared to 360 km for large cars and 380 km for medium-sized sports utility vehicles [1]. Comparatively, the average driving range for gasoline-powered vehicles ranged from 400 to 600 km. On the other hand, lower battery capacities will also mean frequent charging. Buying an EV with a higher battery range is unnecessary in an environment where charging stations are common. The solution to this challenge is to increase the visibility of charging stations.

Another technological challenge is battery charging duration, which is considered more time-consuming than refueling a gasoline-powered vehicle. This could be addressed by ensuring public charging stations are available at malls, hotels, restaurants, public parks, rest stops, and other places, providing opportunities for consumers to engage in other activities while charging. Another solution is to encourage the siting of high-capacity and fast charging stations along highways to reduce the charging duration. Thus, decision-makers should strive to reduce the anxiety related to these barriers by offering options like rapid chargers, battery swapping stations, and improving battery performance. Most developed countries require that fast chargers sited along highways should have at least 150 kW capacity [54].

7. Opportunities for Electric Mobility Small and Medium-Sized Enterprises in Ghana

The e-mobility ecosystem in Ghana is currently in its infancy, and there are many growth opportunities. Figure 17 shows some business opportunities needed for the sector to thrive.

Figure 16: Business opportunities in the e-mobility business in Ghana



7.1. Micro mobility

The micromobility sector in Ghana is dominated by Wahu! Mobility with e-bikes as a product, and Kofa Technologies with electric motorcycles as a product. Many other Indigenous companies, such as Elephant Company, import all electric micro-mobility scooters into the country. Ghana's business models for electric micromobility include last-mile delivery and personal use. However, micromobility companies only operate in Accra and, in some cases, Kumasi. There is more room for expansion to other towns and cities which rely primarily on scarce and unreliable public transport. Cities like Tamale, Bolgatanga, and Wa, which rely on conventional motorcycles, have yet to witness the influx of electric two- and three-wheelers. Typical examples of successful micromobility companies in India are Bounce, Vogo, Yulu, and ZYPP.

7.2. Charging as Service

Micromobility companies such as Kofa Technologies have added battery swapping as another source of revenue. The addition of battery swapping reduces the initial cost of owning the electric motorcycle since the battery is not sold. The battery-as-a-service model replaces the swappable batteries at various designated stations for a fee. However, all the ten battery swap stations are

in Accra. Since this model only works for areas with battery swap stations, more stations are needed in Accra and other regions. There has been a surge in the use of conventional three-wheelers for public transport nationwide. If mobility-as-a-service is offered for electric tricycles, then battery-as-a-service for them will provide an excellent opportunity. Presently, this service is not available in Ghana.

The battery swap model is increasingly becoming popular for electric four-wheeled vehicles, including light-duty and heavy-duty vehicles in China. The Chinese EV company Nio offers swappable batteries for its vehicles, reducing the initial price [55]. The model presents an opportunity for Ghanaian charging station operators to reduce the initial price of the vehicles they sell, provide another revenue means, and significantly reduce charging time to five minutes. While there are opportunities to install public charging stations in Ghana, the limited number of electric vehicles does not justify this. Instead, there is high demand for home charging stations as every electric vehicle owner prefers to own a private one. It is essential for charging station providers to specialize in providing, installing, and repairing home charging stations. There are currently no highway charging stations in Ghana. There is an opportunity to offer mobile charging stations to electric vehicle owners who like to travel far distances. The fast DC mobile charging stations could be plugged into any three-phase meter to charge the vehicle anywhere.

7.3. Mobility as a Service

The cost of operation of electric vehicles is known to be far less than conventional vehicles. Switching conventional mobility to electric could reduce energy costs alone by 60% in Ghana [31], which makes it very appropriate for a ride-hailing business model that operates by establishing a platform business model, a two-sided market that links the service provider and end-user via a modern digital platform (usually a smartphone application). Taufic Taya Transport and Logistics company has started using electric mobility in its fleet, but there are more opportunities for ride-hailing. Recently, the government of Ghana called on mobility apps such as Bolt Ghana to invest in this space [56]. Mobility-as-a-service could also be extended to car-sharing and ride-sharing. Car-sharing operates as a short-term rental model, allowing users to rent vehicles hourly, per-kilometer, or hybrid. The platform supporting this model streamlines transactions, provides insurance, and equips vehicles with technology for easy access. By offering flexibility and access without long-term ownership, car-sharing is a practical alternative to traditional car ownership. Ride-sharing is a software or network-based car-sharing model where the car-sharing company only offers its mobile application to car owners without owning their own car fleet.

7.4. Maintenance and Recycling

Repair-as-a-service for electric vehicles in Ghana is absent, mainly presenting an excellent opportunity for green SMEs. Informal artisans service most vehicles with inadequate knowledge and tools to service electric vehicles. Some electric vehicle companies in Ghana only sell vehicles with no repair provision. Some electric vehicle owners have had to ship their cars abroad to service them due to a lack of skilled labor. Electric vehicle servicing includes software updates, battery health checks, and repairs specific to electric drivetrains. Revenue streams can be established through service fees, maintenance plans, and collaborations with EV manufacturers to operate authorized service centers. Additionally, selling specific components can be a profitable venture.

Battery recycling in electric vehicles is another opportunity yet to be explored. Battery recycling is recovering valuable materials and components from used batteries. Batteries that cannot be repaired will be destined for landfills if not recycled. Recycling batteries recover valuable metals like lithium, cobalt, and nickel from used batteries. The recovered materials can be repurposed to produce new batteries, fostering a circular economy for battery components. This approach may help lower the production costs of new batteries and reduce reliance on foreign stources for essential battery materials. As the number of EVs on the road grows, so will the need for efficient and sustainable battery recycling. The increasing number of electric vehicles on the road will drive a growing demand for battery recycling.

7.5. Assembly and Component Manufacturing

Generally, SMEs have been absent in vehicle manufacturing in Ghana. Component manufacturing of vehicle parts is non-existent. Considering the number of taxes imposed on imported parts, the best way out will be to manufacture these components locally. Opportunities exist primarily in the manufacturing and distributing of affordable electric two and three-wheelers. Two and three-wheelers are already in high demand. Providing affordable alternatives in electric two- and three-wheelers that require no fuel usage can lead to significant patronage and income streams.

7.6. Electricity as a Service

The disaffection for the frequent power outages, quality of electricity, and tariff mean charging station and battery swapping operators are looking for alternatives. Preferably, renewable energy integration, such as solar electricity, is the most popular option. Charging station operators are increasingly planning to incorporate solar and wind electricity to support their business. There are opportunities for entrepreneurs to provide solar and wind services. Providers of affordable services for solar electricity are in high demand. Entrepreneurs could focus on acquiring the accessories and installation of reliable solar charging stations. Another prospect to consider is the advent of green hydrogen to extend electricity production through the night and rainy days.

7.7. Technical Training and Skills Training

Technical training programs are lacking to equip existing and new technicians in EV repair and maintenance. Ghana has vocational institutions and technical universities not equipped to train electric vehicle technicians. Traditionally, vehicle repair is done through informal apprenticeship because no formal journeyman approach to skills training is accepted nationwide. Entrepreneurs can set up EV training centers and offer apprenticeship opportunities for students to pursue internships in E-mobility companies.

7.8. Electric Vehicle Technology and Software Solutions

Most vehicle and charging station breakdowns have been attributed to software-related issues. This is evidenced by the regular charging stations and vehicle breakdowns in the Ghanaian e-mobility sector. Additionally, software solutions through apps that could enhance the EV experience through charging station locations and tracking vehicle performance are needed. Significant can be generated through app subscriptions, consulting services, and licensing software to fleet operators.

8. Conclusions and Recommendations

8.1. Summary of Findings

The study aims to determine Ghana's current infrastructure and technological requirements for scaling electric mobility (e-mobility). The approach involved gathering insights from e-mobility initiatives implemented in other regions. Assessing government policy documents and regulations provided insights into Ghana's e-mobility sector. A field study was conducted through interviews and site visits to identify barriers and propose policy reforms to support e-mobility growth.

The study results show that about 38% of the total emissions in 2021 were attributed to transport alone. Government policy seeks to mitigate transport emissions through a shift to freight transport from road to rail, electric buses, restricted use of used vehicles, and construction of new bicycle lanes. Despite the growing interest in e-mobility, Ghana's roads host few electric vehicles. By the end of 2021, approximately 17,660 electric vehicles had been imported, mainly consisting of electric two- and three-wheelers. Due to the high cost of electric vehicles, only Ghanaians with high education and environmental awareness were more inclined to buy electric automobiles.

The Ghana electric vehicle policy recommends phasing out of internal combustion engine vehicles by 2045, when it expects electric vehicle penetration to be 70%. The policy does not explicitly state the transition targets for the various vehicle categories, such as electric two and three-wheelers and trucks. The energy plan of all the energy policies reviewed differs so significantly that it is difficult to conclude what energy source is intended for electrification by 2045.

Several electric mobility companies in Ghana offer services for selling, repairing, and charging electric vehicles. However, very few public charging stations exist, numbering seven (7) and having only one fast charging station. The results of the field study indicate that the high initial cost of electric vehicles, charging infrastructure, and spare parts account for 40% of the challenges. Following this are the cost of finance (24%), operation and maintenance (11.5%), availability of public charging infrastructure (12%), power quality of electricity (7.8%), and technological awareness (4.7%). In Ghana, the average price of a new electric vehicle is three times that of an equivalent conventional vehicle, and it takes 11 to 20 years for electric vehicles to reach cost-parity with conventional vehicles. The 2024 budget announced a waiver of import duty for electric vehicles for public transportation. In practice, this waiver has been limited to commercial buses. Also, none of the e-mobility companies interviewed, including those who import commercial electric buses, admitted benefitting from this reprieve. Instead, electric vehicles are subjected to an import tax of 20%, while most conventional vehicles attract as low as 5%.

E-mobility companies have faced significant challenges in securing financing for purchasing electric vehicles and installing charging stations. The primary reasons for this challenge are the depreciating Ghana cedi, high borrowing costs, and the absence of green loan options. The significant skills gap in electric vehicle maintenance and charging stations has been identified as the main reason for the lack of effective operation and maintenance. Most e-mobility companies' source of training is outside the country.

8.2. Recommendations

1. A comprehensive incentive scheme for e-mobility businesses, all-electric vehicle categories, charging stations, and their respective components are required to enable the e-mobility industry in Ghana. The package should cater to purchase, operational, construction, and tariff incentives. The incentive scheme should reduce the price parity to within 30% instead of the current 66%.

2. Special incentives should be given for installing public charging stations. Extra incentives should be given to charging stations that rely on a renewable grid independent of the national grid. Incentives should incorporate the import of solar panels, batteries, and charging station equipment.

3. The requirement for electric vehicle assembly plants to benefit from the Ghana Automotive Development Policy should be relaxed by reducing the required number of units to 200 units a year. The e-mobility industry is nascent and will not be able to compete with conventional vehicles without a significant advantage.

4. Accessible green loans with interest rates below 10% should be available to e-mobility providers. The e-mobility companies are start-ups and do not have the historical records to prove viability as required by traditional banks. The government could serve as a guarantor for such loans to remove the burden of proof.

5. Strategically locating public electric vehicle charging stations (EVCSs) plays a vital role in promoting the adoption of electric vehicles (EVs) and alleviating range anxiety. Electric vehicle adoption tends to accelerate after many EVCSs have been established in key areas. Site selection for EVCSs is typically influenced by traffic and population density, access to electricity, and grid reliability.

6. Charging stations must be equipped with voltage transformers, voltage stabilizers, residual current devices, and current transformer meters to protect the vehicles they charge and the charging station.
7. Highway charging stations should be required to have at least 120 kW of capacity to provide rapid charging for commuters.
8. There should be collaborations with supermarkets, malls, hotels, restaurants, public parks, and rest stops to install public fast charging stations.

9. A national journeyman skills program for electric vehicles and charging station repair, installation, and maintenance should be administered. The Energy Commission wiring program should be upgraded to accommodate charging station installation and maintenance. KNUST's electric vehicle technician program should be supported and administered nationwide.

10. E-mobility start-ups should employ people who can help them win grants and green funding to expand their business and incorporate a marketing and public relations team that will place them in a better position to attract funding and increase clientele

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