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Upscaling E-Mobility for Sustainable Transport System in Kenya

Amaya Aura Linda and Delphina Dali Mzozo

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Abstract

The shift from fossil fuel powered to electric vehicles is gradually taking shape in Kenya's transport system. The electrification of the road transport system provides a solution to growing carbon emissions from the sector. Kenya has identified electric vehicles as a decarbonization technology to achieve the net zero carbon emissions target by 2050. The study employed the futures approach to define the drivers likely to have the greatest impact in the future of e-mobility. The study established that climate change (environmental sustainability) is the most influential factor in reshaping the future of e-mobility. This will not only reduce greenhouse gas emissions and air pollution but also foster innovation and economic growth in the green technology sector. Similarly, the conversion of existing Internal combustion engine vehicles (ICEs) to electric vehicles (EVs) by replacing the internal combustion engine and its components with an electric motor and EV battery is a possible alternative to the adoption of electric mobility. Government Incentives including reduced import duties and importation fees, VAT and purchase tax exemptions, rebates, and fees for higher emission vehicles, boost the affordability of EVs. In addition, charging infrastructure that is convenient, affordable, and is a pre-requisite for electric mobility growth. The ideal growth pathway for e-mobility would require a combination of both environmental sustainability goals and targeted government interventions including providing public charging infrastructure and incentives. To achieve environmental sustainability, there is a need to develop comprehensive guidelines and policies for the sustainable lifecycle management of EVs, focusing on ethical sourcing of materials, recycling, and disposal. It is also important for vehicle manufacturers and assemblers to undertake research and design on the potential conversion of ICEs to EVs and its viability. The government needs to employ targeted incentives for consumers across different income levels to address the affordability barrier. In addition, there is a need for adequate assessment of EV market trends to inform the phasing down of incentives. It is imperative for charging infrastructure to integrate technology like smart charging to monitor energy needs and grid stability hence meeting the growing electricity demand.

Abbreviations and Acronyms

EV	Electric vehicles
GDP	Gross Domestic Product
GHG	Greenhouse Gas
ICEs	Internal Combustion Engines
KAM	Kenya Association of Manufacturers
KNBS	Kenya National Bureau of Statistics
MtCO2e	Metric tonnes of carbon (IV) oxide emissions
4IR	Fourth Industrial Revolution
STEEP	Social, Technological, Economical, Environmental and Political
VAT	Value Added Tax

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1. Introduction

Electric mobility (E-mobility) is the utilization of electric power for different kinds of transportation. This includes motorcycles, trains, ships, ferries, and other seagoing vessels, this also applies to automobiles, buses, trucks, and off-road vehicles (KIPPRA, 2023). E-mobility is gaining momentum as a means for sustainable transport. By using E-mobility, the world shifts transport energy consumption from fossil fuels that release greenhouse gases into the atmosphere to electrical power sources. This aims at achieving a cleaner, healthier, and more affordable future (Ghasemian et al., 2020)

The advantages of E-mobility extend across various scales, from the global to personal level. On a global scale, the electrification of transportation plays a crucial role in mitigating climate change by diminishing greenhouse gas emissions (Ghasemian et al., 2020). The potential of E-mobility is likely to have a higher impact on passenger and private vehicles, which are an essential part of everyone's life. Presently, a large proportion of vehicles use fossil fuel and their exhaust fumes are a major source of emissions (Kumar et al., 2020). Given that transportation presently contributes to approximately 30 per cent of the world's final energy demand, the potential for decarbonization is immense. Meeting the goals set by the Paris Agreement necessitates the inevitable shift towards electrifying both public and private transportation on land and at sea.

Growing concerns about environmental sustainability are driving the development of sustainable, economical, and clean vehicles for transportation (Ayetor et al., 2023). Various factors such as global warming, rising emissions, climate change, and increased energy consumption have prompted nations worldwide to take decisive action to curb, manage, and reverse the adverse trends affecting the climate, environment, and ultimately the planet's future (Energy and Petroleum Regulatory Authority, 2023). Apart from the environmental sustainability advantage of E-mobility, over-reliance on fossil fuels is not sustainable. The global over-reliance on oil as the main energy source for vehicles has significant economic and political implications, and as the world's oil reserves run out, the situation will undoubtedly worsen (Ghasemian et al., 2020). Many new, progressively complex design challenges are presented by EVs that are not present in conventional automotive technologies or transportation systems. The automotive sector is allocating substantial resources to advance the development of electric vehicles, aiming to comply with rigorous regulations on efficiency, performance, safety, and environmental conservation (Kumar et al., 2020). Electric vehicles (EVs) is a generic name for cars, buses, two-wheelers, and three-wheelers powered by electricity.

An eco-friendly, effective, and clean transportation system is made possible by electric vehicles powered by alternative renewable energy sources and equipped with high-efficiency electric motors and controllers. Furthermore, renewable energy sources such as water, wind, and solar energy may be used to generate electricity for EV (Ayetor et al., 2023). Notably, Kenya's energy mix is highly conducive to supporting E-mobility, with nearly 89.6 per cent of the country's energy derived from renewable sources (Kenya National Bureau of Statistics, 2024). The transport sector contributes significantly to the development of a country. In Kenya, the transport sector's contribution to Gross Domestic

Product (GDP) has increased at an annual average rate of 13.3 per cent in comparison to 11.8 per cent of the overall economy over the period 2002-2022. In 2021/2022, the sector contributed 11.4 per cent of the country's GDP (Ministry of Roads and Transport, 2024). In addition, transport accounts for 9.65 per cent of total household expenditures (KIPPRA, 2023).

Consequently, the transport sector, especially road transportation, stands as a significant contributor to greenhouse gas (GHG) emissions in Kenya contributing about 18 per cent of the GHG. This is primarily attributed to the prevalent use of fossil fuels in vehicle propulsion systems. As such, the government aims to implement a low-carbon and efficient transportation system as a mitigation measure (Ministry of Environment and Forestry, 2020). One of the strategic initiatives is the decarbonization of the transport sector through a shift from fossil fuel-powered to electric-powered vehicles. This is to accelerate the shift towards E-mobility as a sustainable transport alternative to the current mobility model that is characterized by imported second-hand fossil fuel vehicles (KIPPRA, 2023). Therefore, an increased emphasis on electrifying the transportation sector has the potential to play a pivotal role in attaining Kenya's goal of reducing emissions by 3.46 MtCO2e, relative to the established baseline by 2030. To achieve this, annual carbon emissions from the transport sector need to be limited to not more than 0.4 MtCO2e per year on average (Republic of Kenya, 2023).

In 2022, total domestic transport sector emissions in Kenya amounted to 12.60 MtCO2e with road transport accounting for 98 per cent of the sectoral emissions (Republic of Kenya, 2023). In addition, road transport and retail pump outlets are the highest consumers of domestic petroleum, using about 3665.6 thousand tonnes (72%) of fuel sales in 2023 (KNBS, 2024). As of 2020, the number of registered vehicles and motorcycles in Kenya was 4, 588,770 (KAM, 2020; KNBS, 2023). Whilst Kenya has made significant progress in the shift to E-mobility, only 3753 electric vehicles were registered as of 2023. Uptake of E-mobility is, however, hampered by several factors including high purchasing costs, inadequate charging infrastructure, and high cost of electricity (Ayetor, Mashele and Monigaba,2023). Failure to address these barriers is likely to slow the uptake of E-mobility in the transport sector, hence allowing continued use of fossil-powered vehicles. Projections indicate that fossil fuel use will be the leading cause of greenhouse gas emissions in Kenya by 2030 under the Business-as-Usual Scenario (Ministry of Environment and Forestry, 2020).

Electric mobility transition seeks to achieve a low-emission transport sector hence mitigating climate change. Kenya has committed to reduce greenhouse gas emissions by 32 per cent by 2030 as a pathway to achieve sustainable development and meet its international obligations on climate change (Ministry of Environment and Forestry, 2020). Kenya's decarbonization of the transport sector is a key climate change mitigation strategy in line with its long-term emission reduction targets. As such, several mitigation measures in the transport sector were put in place to achieve its 2030 goal. One of the targets is to increase the adoption of E-mobility by having an annual 5.0 per cent share of registered vehicles being electric (Ministry of Energy, 2020). While the goal of achieving sustainable transport has been defined, there is limited information on the crucial drivers of change, which are likely to have the most significant impact on E-mobility in the future. Therefore, this study will help identify and inform action on the most important growth pathways of the E-mobility ecosystem to achieve low emissions and a sustainable transport system in Kenya. Specific objectives of the study include to: examine the drivers and barriers to E-mobility adoption in Kenya; and exploring the growth pathways to encourage E-mobility transition in Kenya.

The rest of the chapters are organized as follows: Chapter 2 gives an overview of the E-mobility industry, Chapter 3 presents the literature review, Chapter 4 discusses the methodological approaches, results are presented in Chapter 5 while Chapter 6 provides the conclusion and recommendations.

2. E-mobility Industry

This section gives the status of various indicators of E-mobility including the growth trends of EVs, sector emissions, infrastructure, electricity, local manufacturing potential, government incentives and policy and legal framework.

2.1 Trends in the E-mobility Industry in Kenya

E-mobility in Kenya is more than a technological advancement but a commitment to a more sustainable and environmentally conscious future. Significant progress has been made in the uptake of electric vehicles in Kenya. There was a substantial increase in the percentage share of electric vehicles from 0.04 per cent in 2019 to 1.62 per cent in 2023. Table 2.1 shows the trend in EV registrations as of December 2023.

Table 2.1: Trend in EV registrations as of December 2023

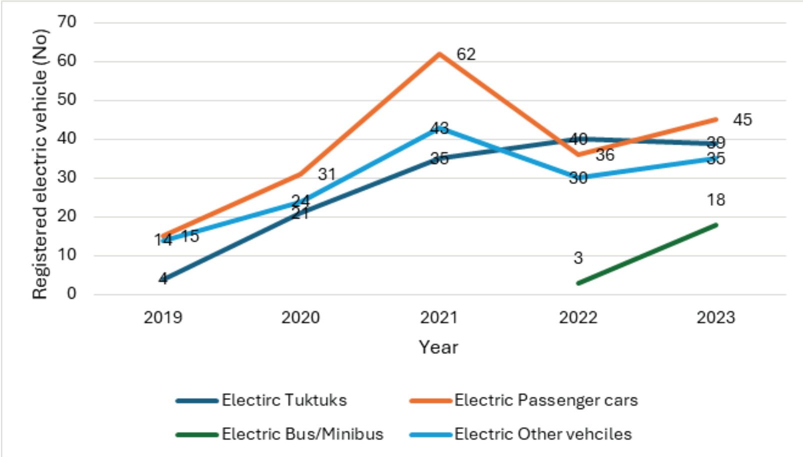
Year	Total no. of registered vehicles	Total no. of registered EVs	Per cent share of EVs	Change (per cent)
2018	297,289	65	0.02	
2019	328,551	129	0.04	98
2020	339,813	106	0.03	-17.8
2021	407,462	284	0.07	167.9
2022	285,009	475	0.17	67.25
2023	165,913	2,694	1.62	467.15

Data source: EPRA, 2024

The increase in registered EVs may be attributed to government initiatives such as the introduction of the E-mobility tariff, the reduction of excise duty on EVs from 20 per cent to 10 per cent, and the exemption of fully electric cars from Value Added Tax (VAT) (EPRA, 2024).

The EV landscape in Kenya is characterized by electric two-wheelers, three-heelers, cars, and buses.

Figure 2.1: Trend in electric vehicles by type

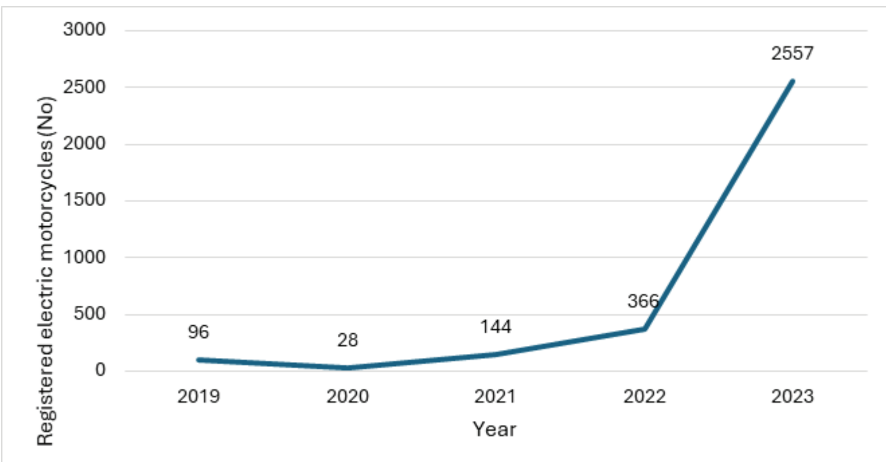


Data source: National Transport and Safety Authority

2.1.1 Electric two-wheelers

Advancements in technology in the motorcycle industry have led to the emergence of electric motorcycles and bicycles. In Kenya, the number of electric motorcycles has increased exponentially as shown in Figure 2.2. New opportunities arise in the adoption of electric bicycles with both commuter and cargo bicycle options offering delivery services hence an important component in E-commerce. Both electric motorcycles and bicycles provide a potential alternative to high-emission fossil fuel powered motorcycles.

Figure 2.2: Trend in electric motorcycles



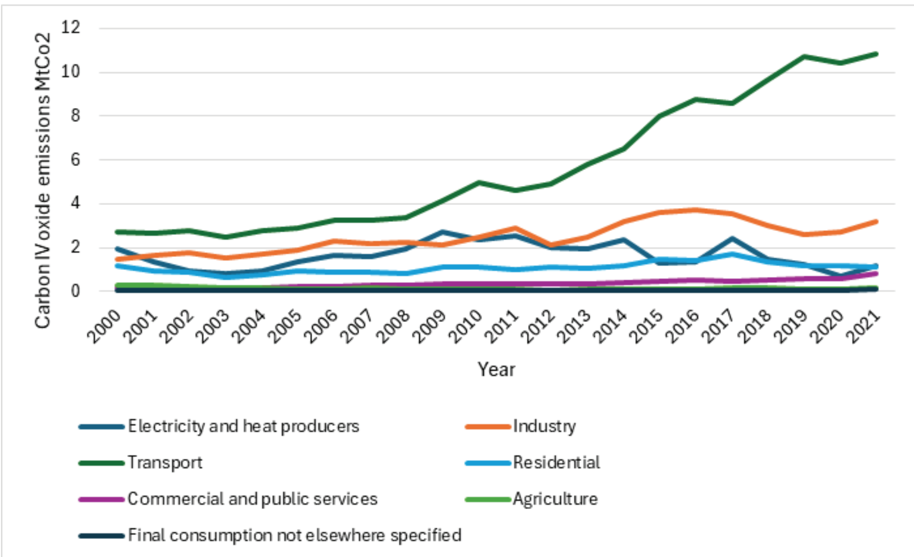
Data source: National Transport and Safety Authority

2.2 Greenhouse Gas Emissions

Carbon IV Oxide gases from internal combustion engine (ICE) vehicles due to burning fossil fuels contribute a significant amount of emissions. Conversely, electric vehicles do not have a tailpipe (exhaust) emissions hence providing a cleaner alternative to ICE vehicles. Existing data shows that the transport sector is the largest contributor to greenhouse gas emissions with increasing trend over time in Kenya as shown in Figure 2.3 below. Air pollution from burning fossil fuel negatively impacts public health hence increasing the disease burden. Integration of EVs into the transport sector is expected to reduce vehicles related emissions.

Nevertheless, the existing EVs production technology especially the extraction of mineral resources and energy used leads to considerable amounts of emissions and environmental degradation (Parajuly et al.,2020). This is a growing concern about EVs despite their capability of reducing emissions associated with fossil fuel used in transport. Therefore, adequate attention needs to be paid to the EV production carbon footprint to ensure lower lifecycle emissions of EVs compared to ICEs.

Figure 2.3: Carbon IV oxide emissions by sector (2000-2021)



Data source: International Energy Agency

2.3 Infrastructure

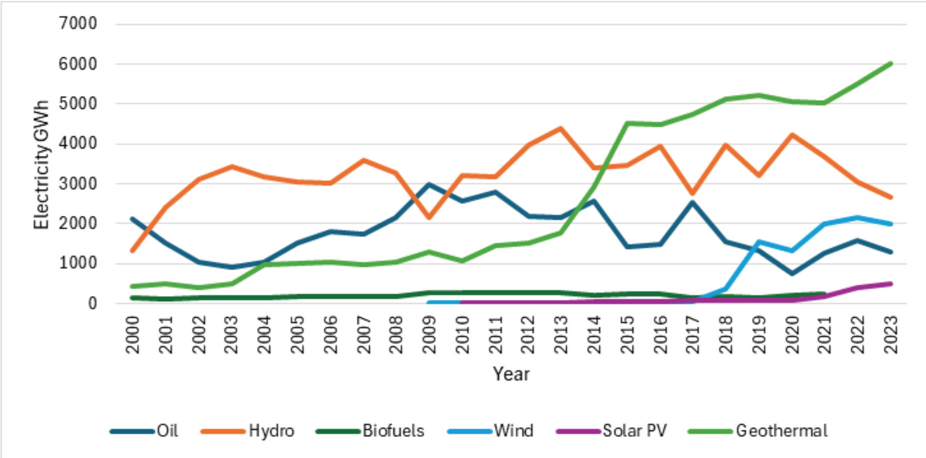
Transition to E-mobility increases the demand for an electric vehicle charging infrastructure, especially fast charging stations. This also encompasses battery swapping infrastructure for swapping and charging batteries. The Bottom-Up Economic Transformation Agenda envisages the construction of 1000 electric vehicle charging stations. The government envisions that there will be 700 charging stations in urban areas and 300 along highways. It is envisaged that one (1) charging station will be established in a grid of 3km by 3km, one (1) charging station at every 25km on highways, and one (1) fast charging station every 100km. Public charging and battery swapping will be offered as a commercial service. Charging electric vehicles is achievable through various methods which include wallbox chargers – specially designed, wall-mounted units for charging electric vehicles, providing a convenient and efficient way to power up at home or work; in-house electrical installations – a method that utilizes sockets specifically designed for charging purposes within homes or buildings, ensuring safe and reliable charging infrastructure for electric vehicle owners; and charging stations – dedicated installations specifically for electric vehicles, offering convenient public charging options for drivers on the go.

As of the end of March 2022, the number of EV charging stations in Kenya was estimated at 27, according to Kenya Power (2023) report. Despite the increasing number of charging stations, there is limited information on the total number of stations available throughout the country. This gap in data highlights the need for more comprehensive tracking and reporting on the expansion of EV charging infrastructure in Kenya. Upscaling of charging infrastructure is key to meeting the growing number of EVs, which in turn increases the need for electricity hence impacting the grid infrastructure. Therefore, balancing the grid capacity and power demand is necessary to sustain the operation of EVs. It is also crucial for the charging infrastructure to be convenient, reliable, and transparent in pricing. Resources may be required to upgrade the existing electricity distribution infrastructure to accommodate the growing number of charging stations. Equally, the use of solar-powered charging infrastructure is a complementary measure that can be explored.

2.4 Electricity

A successful transition to sustainable transport requires clean energy. Kenya's energy mix is mainly from renewable sources, which accounted for 89.6 per cent of electricity generation in 2023 as shown in Figure 2.4. This creates an enabling environment for them to transition to E-mobility. Reduction of carbon emissions from the electricity generation sector is crucial to ensuring the electric vehicles ecosystem is sustainable.

Figure 2.4: Electricity generation sources



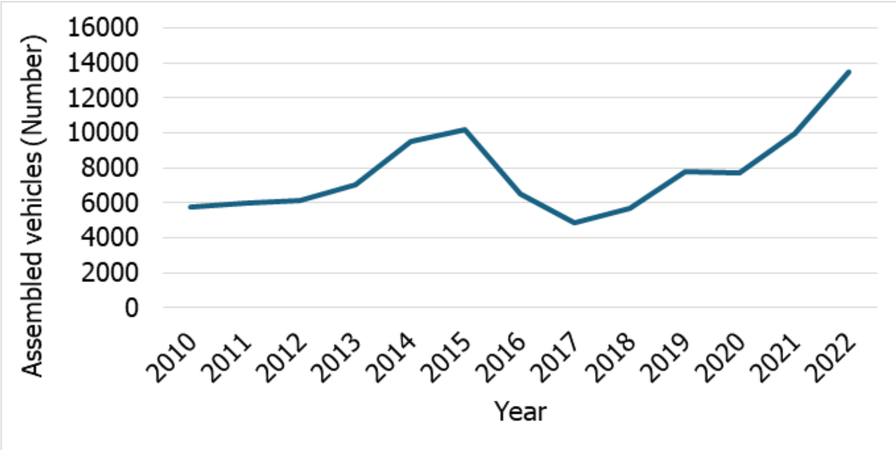
Data source: International Energy Agency

To ensure affordability in charging electric vehicles, Kenya Power Company has established a time-of-use tariff to encourage the E-mobility transition. Time-of-use tariff charges different rates at different times of the day based on changing electricity demand (Africa E-mobility Alliance, 2023). The E-mobility tariff is Ksh 16 (peak hours) and Ksh8 (off-peak hours) for energy consumption of between 200 to 1500KWh per month.

2.5 Local Manufacturing

The automotive industry is a significant contributor to Kenya's economic growth. The industry is primarily involved in the assembly, retail, and distribution of motor vehicles and is grouped into five main sub-sectors namely: motor vehicle assemblers, trailer assemblers, motorcycle assemblers, parts and components manufacturers, and body builder's sub-sectors (Kenya Association of Manufacturers, 2020). However, the current motor vehicle manufacturing industry is faced with various challenges including access to affordable finance, taxation, market access, and weak research and development (RandD) (Shibia, 2022). The number of locally assembled vehicles has been growing as shown in Figure 2.5.

Figure 2.5: Production of assembled vehicles (2010-2022)



Data source: KNBS

EV manufacturing in Kenya is still in its early phase and has attracted the private sector. Vehicles locally assembled are free from 25 per cent import charge and 25 per cent excise charge. (Africa E-mobility Alliance, 2023). Kenya Vehicle Manufacturers and Associated Vehicle Assemblers have partnered with electric vehicle companies to assemble electric vehicles in Kenya. BasiGo entered a new partnership with Associated Vehicle Assemblers Limited to assemble over 1,000 electric buses in the next three years (Africa Renewable Energy Manufacturing Initiative, 2024). The E-mobility industry holds great potential to offer employment in different sectors including setting up and running charging infrastructure, assembling, maintenance, and within the circular value chain (KIPPRA, 2023).

2.6 Types of Vehicles

Various types of electric vehicles exist, ranging from fully electric to partially electric models. For instance, battery electric vehicles (BEVs) rely solely on batteries to store electrical energy, which powers their motors. Charging BEVs involves plugging the vehicle into an electric power source, categorizing them as fully electric vehicles.

Hybrid electric vehicles (HEVs) are powered by both an internal combustion engine and an electric motor that uses energy stored in a battery. The battery in HEVs is charged through regenerative braking and the internal combustion engine, thus eliminating the need for external charging.

Plug-in hybrid electric vehicles (PHEVs) also feature an internal combustion engine and an electric motor that uses energy stored in a battery. However, unlike HEVs, PHEVs can be plugged into an electric power source for charging, providing flexibility in their power sources. On the other hand, fuel cell vehicles generate electricity onboard by using hydrogen as a fuel source (Republic of Kenya, 2021).

2.7 Government Incentives

The Government has put in place various fiscal and non-fiscal incentives to promote the adoption of e-mobility. In particular, the Finance Act of 2019 reduced the excise duties on all electric vehicles (EVs) from 20 per cent to 10 per cent. This fiscal policy measure aims to promote the adoption of electric vehicles within the country and represents a significant step toward addressing the affordability barrier of electric vehicles for the public by reducing taxes.

The Finance Act of 2023 amended the VAT Act of 2013 to include several items in the list of zero-rated goods: electric bicycles, solar and lithium-ion batteries, and electric buses under tariff heading 87.02. Additionally, the 2023 Act amended the Excise Duty Act of 2015, exempting electric motorcycles from the Ksh 12,952.83 per unit rate. The excise duty for 100 per cent electric vehicles remains at 10 per cent.

In addition to these fiscal measures, the government introduced a non-fiscal incentive where all-electric vehicles will have unique green number plates, further encouraging the adoption of environmentally friendly transportation options.

2.8 Policies and Legal Framework

Table 2.2: Policy and legal framework

Policy and legal framework	Gaps	Recommendations
1. The National E-mobility Policy of 2024 seeks to promote local manufacturing and assembly of electric vehicles, and develop and enhance e-mobility infrastructural and technical capacity.	There have been challenges, especially in terms of the distance an electric vehicle or motorbike can cover per charge and the time for fast charging, which is about two (2) hours.	The manufacturers or researchers can come up with ways to increase the distance covered by a single charge from 200 kilometres to 500 kilometres. This will help people to easily embrace E-mobility. The time for charging can be reduced by providing battery-swapping services at the charging stations. The government can find a way to enable the Garissa Solar Power Plant, which is the largest in East and Central Africa, to be used as a sustainable energy source.

Policy and legal framework	Gaps	Recommendations
2. The National Climate Change Action Plan (NCCAP) for 2018-2022 Identifies the reduction of transport emissions as a key mitigation strategy against climate change. It includes pilot projects on electric vehicles to promote emission reduction.	Capacity development of a climate-proof. transportation infrastructure	The government needs to increase generation capacity for captive renewable energy and climate-proofed energy infrastructure; develop affordable, safe, and efficient public transport; and encourage low-carbon technologies in the aviation and maritime sectors.
3. The Kenya National Energy Efficiency and Conservation Strategy for 2020 It sets a goal of achieving a 5 per cent increase in the adoption of electric/hybrid vehicles by 2025.	While the strategy outlines ambitious goals and policies, there is a lack of clear implementation and enforcement mechanisms to ensure compliance and accountability by 2025. The strategy does not sufficiently address the financial aspects of implementing energy efficiency measures, including funding sources and financial incentives for EVs	The government can consider developing detailed implementation plans with specific timelines, responsibilities, and monitoring frameworks. Establish a robust enforcement mechanism with penalties for non-compliance and incentives for adherence. Creating a dedicated energy efficiency fund supported by public and private sectors. Introduce financial incentives such as tax breaks, subsidies, free parking for EVs, and low-interest loans to encourage investment in energy-efficient technologies
4. The BETA Agenda seeks to roll out electric vehicle charging infrastructure in all urban areas and along the highways. The agenda also aims to provide financial and tax incentives for public service vehicles and commercial transporters to convert to electric vehicles.	There is an absence of a comprehensive and integrated policy framework to guide the rollout of electric vehicle (EV) charging infrastructure and the transition to EVs. The agenda does not provide detailed plans for the location, capacity, and types of charging stations needed in urban areas and along highways.	Develop a cohesive national policy that outlines clear objectives, guidelines, and responsibilities for all stakeholders involved in the EV ecosystem, including government agencies, private sector players, and consumers. Conduct a comprehensive feasibility study to identify optimal locations for charging stations, considering factors such as population density, traffic patterns, and existing infrastructure.

Policy and legal framework	**Gaps**	**Recommendations**
5. National Building Code 2022 highlights the need for charging and battery-swapping infrastructure. It mandates the allocation of parking spaces for EV charging in commercial buildings.	There are no clear incentives or subsidies for property developers and building owners to install EV charging infrastructure.The code does not emphasize the integration of renewable energy sources with EV charging infrastructure.	Introduce financial incentives, such as tax credits, grants, and subsidies, to encourage developers to include EV charging infrastructure in their building projects. These incentives could help offset the initial costs and make it more attractive for developers to comply with the mandate. Encourage the use of renewable energy for EV charging stations by providing incentives for solar panels, wind turbines, and other renewable energy technologies. This could reduce the carbon footprint of EV charging and promote sustainable energy use.
6. Electric Vehicle charging and battery swapping infrastructure guidelines 2023 provides key considerations when setting up, designing, installing, and operating electric vehicle charging points and stations.	The guideline does not provide detailed safety and security protocols to protect users and infrastructure The guideline does not adequately address the environmental impacts and sustainability aspects of EV charging and battery swapping infrastructure. There is insufficient emphasis on the need for training and certification programs for technicians and engineers.	Develop stringent safety standards for the installation and operation of charging stations, including fire safety measures, protection against electrical hazards, and cybersecurity protocols to protect against data breaches and vandalism. Implement environmental impact assessments for new installations and encourage the use of sustainable materials and practices in the construction and operation of charging stations. Establish comprehensive training and certification programs for professionals involved in the installation, maintenance, and operation of EV charging and battery swapping infrastructure. Partner with educational institutions and industry bodies to create standardized curricula.

3. Literature Review

3.1 Theoretical Framework

3.1.1 Diffusion of Innovation Theory

The theory highlights how new ideas spread across the population (Kaminski, 2011). Rogers (1983), the proposer of this theory, defines diffusion as "the process by which an innovation is communicated through certain channels over time among the members of a social system" and innovation is "an idea, practice, or object that is perceived as new by an individual or another unit of adoption". The theory classifies innovation adopters into five categories (innovators, early adopters, early majority, late majority and laggards) based on adoption of technology and their influence on the diffusion process (Kaminski, 2011). The theory recommends streamlining the adoption process to meet the unique needs of each category. The innovation adoption process involves 5 stages that is the knowledge, persuasion, decision, implementation, and conformity stages. Further the theory describes relative advantage, compatibility, complexity, trialability and observability as key characteristics of an innovation (Rogers 1983; Kiwanuka, 2015).

The diffusion of innovation theory will be employed in this study to examine the acceptance and adoption of E-mobility in Kenya in line with sustainable transportation goals.

Value-Belief-Norm Theory of Environmentalism

The value-Belief-Norm(VBN) theory by Stern describes how personal values and beliefs can drive individuals change of attitudes to new objects due to impact on their values. It explains how environmentally conscious personal beliefs and norms can influence a person's behavior towards environmental sustainability choices (Stern et al ,1999). The theory has also been applied in the transport sector to forecast how personal attitudes and behavior influence choices of modes of transport (Lind et al., 2015). In this regard, the VBN theory will be used to assess the influence of environmentally conscious E-mobility transition in Kenya.

3.2 Empirical literature

3.21 Pathways of e-mobility

Initiatives are in place to cut carbon emissions and promote sustainability in the face of climate change. A case in point is decarbonization of the transport sector. As the shift to E-mobility is gaining momentum, the history of electric vehicles dates back to early 19th Century and their production peaked in 1912 (Lulia and Lorand, 2022). The electric cars were designed to replace the horsedrawn vehicles. The market for electric vehicles grew due to their lack of noise and emissions. However, technological advancements in the Internal combustion engines vehicles coupled with low fuel prices shrank the electric vehicles market (Lulia and Lorand, 2022). The Internal Combustion Engine vehicles dominated the market for about 3 decades until the early 1970's when there was an increase in global fuel prices impacting the global economy. At the same time, there was a growing concern on emissions resulting from fossil fuel combustion (Ajanovic, Haas and Schrodl, 2021). In Early 1990s there was a growing interest in electric vehicles. Development of electric and hybrid vehicles grew due to the strengthened emission regulations. This led to growth of electric vehicles industry expanding the markets across the world including Kenya.

The Paris global climate agreement of 2015 is a legally binding treaty adopted by 196 Parties at the Conference of Parties (COP 21) of the United Nations Framework Convention on Climate Change (Salman et al., 2022). The agreement aims to strengthen the global response to the threat of climate change by reducing global greenhouse gas emissions, which would effectively limit global temperature rise to 1.5° Celsius. Other measures are geared toward adaptation, financing, education, and technological collaboration to achieve some of the sustainable development goals. The Paris Agreement has been signed by all 54 African countries and intended nationally determined contributions have been submitted (Salman et al., 2022). The nationally determined contributions framework is a legally binding review architecture in which countries make pledges, the impact of which is evaluated regularly in an international evaluation exercise (Stua et al., 2022). So far, 53 African countries have submitted their nationally determined contributions to reduce 550 Mt of Carbon dioxide emissions by 2030 (International Energy Agency, 2022). This carbon dioxide emission reduction target represents approximately 40 Per cent of Africa's current emissions.

Africa currently contributes only 3.8 Per cent of global carbon dioxide emissions, compared to 23 Per cent from China, 19 Per cent from the United States of America, and 13 Per cent for the European Union, but Africa is the most vulnerable to climate change (Disclosure Insight Action, 2020). Transportation accounts for 40 Per cent of Africa's carbon dioxide emissions on average (Ayetor et al., 2021). The burning of fossil fuels used for vehicular applications leads to the emission of greenhouse gases. Electric vehicles have been known to be three times more efficient than internal combustion engine vehicles (Glitman et al., 2019). They present a significant opportunity to decarbonize transportation to meet the requirement of various sustainable development goals (Naidja et al., 2018). As a result, sustainable development goals 3.9 and 7.2, which aim to reduce air pollution and improve renewable energy in the energy mix, respectively, promote electric vehicles powered by renewable energy sources. Africa Agenda 2063 transformation framework aims to achieve an Environmentally sustainable and climate resilient economies and communities through various initiatives including upscaling renewable energy. It emphasizes the need for all urban mass transport to operate on renewable and low emissions fuel by 2063.

Despite the various benefits of using an electric vehicle, global adoption has been slow. In 2021, electric vehicles accounted for nearly 10 Per cent of global car sales, with 16.5 million vehicles in use (International Energy Agency (IEA), 2022).

Africa has the lowest market share for electric vehicles due to many challenges. The high purchase price and limited range reduce motivation to purchase electric vehicles. Especially in Africa, where low purchasing power is a significant factor for Africa's low motorization rate (Ayetor et al., 2021). Monetary and non-monetary government incentives are known to be the major impetus for any increase in electric vehicle adoption (Corradi et al., 2023). Norway is the country with the highest per capita share of electric vehicles in the world with a BEV vehicle stock share of 12 per cent in 2020 (Koch et al., 2022); they achieved primarily through economic incentives. On the contrary, some African countries tax electric vehicles more than conventional vehicles (Ayetor et al., 2021).

Limited battery range, long charging time, and the need for charging infrastructure affect electric vehicles' perceived reliability compared to conventional vehicles. Especially in Africa where a vast majority of the population has no access to electricity. Around 600 million Africans, the majority of whom live in Sub-Saharan Africa, do not have access to electricity (IEA, 2022) . A radical approach for a transition to electric vehicles without any pragmatic provision for energy security is likely to negatively affect most people in Africa who are without access to electricity. Even if range anxiety and high purchase costs are overcome, social conformity and experience with electric vehicle use, which is associated with electric vehicle acceptance, will be another challenge (Ayetor et al., 2023). The lack of knowledge about the electric vehicle experience of consumers fosters myths that exaggerate the disadvantages of electric vehicles.

3.2.2 Drivers of e-mobility

Transition to e-mobility is mainly driven by the need to decarbonize the transport sector which is a key contribute to greenhouse gas emissions across the world. A sustainable transport system is the ability of a transport system to minimize its impacts on the environment, meeting the E-mobility needs of a society while securing mobility needs of future generations (Rodrigue, 2020).

European Union Transition to E-mobility was driven by its long-term emission reduction targets which aims to cut Green House Gases emissions by at least 80 Per cent by 2050 (Biresselioglu et al., 2018). Climate change is identified as the solid driver for the shift to E-mobility (Ciftci et al., 2022).

Further, this is enabled by other factors including technology, electric vehicle charging systems and financial capability. Growth of E-mobility will also be driven by demandwith customers preferring electric vehicles to conventional fossil fuel powered vehicles (Ciftci et al., 2022).

However, this transition is impacted upon by socio economic factors, individual attitudes, demographic factors and social influence. Whilst environmental goal might be the vital driver for e-mobility, other factors including economic, technical, personal and demographic factors need to be taken into consideration (Biresselioglu et al, 2018). This is notable in Africa including Kenya, where factors like cost parity, electric access and quality, infrastructure, manufacturing are important drivers that could cause a significant shift to E-mobility (Ayetor et al.,2023).

In Kenya, besides the climate change mitigation potential of E-mobility, the shift to renewable energy sources and reduced operational cost of the electric vehicles are some of the incentives that would drive the transition. This is enabled by supporting secondary aspects including employment opportunities, lack of noise, restructured urban planning system, startup industry and availability of international funding (Ayetor et al.,2023).

3.2.3 Best practices in E-mobility

Different countries have established growth strategies to accelerate E-mobility transition in line with their transport systems goals. While the growth rate is different for each country, several lessons can be drawn from the targeted interventions put in place.

Norway is a global leader in transition to Electric Vehicles. As of 2022, the country had the highest share of all EVs which constituted about 80 Per cent of passenger vehicle sales in 2022 as compared to about 1.0 per cent in 2010. The growth in sales is attributed to the gradual roll up of incentives from early 1990's (Qorban et al., 2024). Norway waives import duties and car registration taxes for electric vehicles. The total cost of ownership including purchasing, maintenance and charging costs for EVs is lower as compared to ICEs. The country has recorded a highest public fast charges per capita in the world including the right to charge for residents of buildings and provides grants for housing companies to install their own chargers. Non-monetary incentives such as free parking in cities, exemptions or reductions in road tolls, access to priority bus lanes (Koch et al., 2022).

China is one of the leading manufacturer and supplier of lithium-ion batteries (LIB) for Electric Vehicles. LIBs are an important component for energy storage of EVs. This has been largely driven by the country's regulations which provide subsidies to Electric Vehicles which source batteries from China (Liu et al., 2021). China has developed several standards for electric batteries and batteries related components and systems including specifications for battery recycling, action plan to promote the development of automotive power battery industry, strengthen safety of new vehicles, and Energy Vehicle Industry Development Plan (2021-2035). However, Greenhouse Gas (GHG) emissions associated with production of lithium-ion battery production is still a major concern. Research and design in battery manufacturing companies aim at exploring new materials and technologies to improve the performance and capacities of the batteries (Prevete, 2018).

Germany, Europe's largest car market, has been a key actor in electric vehicle adoption. About 20 Per cent of vehicle produced in Germany were EVs in 2021. The auto mobile industry has set ambitious electric car production targets hence driving the shift in E-mobility (Kunle and Minke, 2022). The government offers subsidies for the purchase of new and young used electric vehicles. The government has established market incentive including temporary purchase incentives, the expansion of the charging infrastructure, and the purchase of electric vehicles by public authorities. A purchase grant, known as the environmental bonus, is paid towards new vehicles. In addition, there is a target that at least 20 Per cent of the Federation's vehicle fleet should consist of electric vehicles (Ball et al., 2021).

Morocco is the leading car exporter in Africa. Morocco's auto industry now accounts for 22 percent of the country's gross domestic product and $14 billion in exports. The country has a production capacity of 40,000 electric cars per year. It also boasts of high renewable energy mix which provides a lower cost of electricity. An industry zone specializing on E-mobility has also been established which includes the production of rechargeable batteries, electric vehicles, and hybrids; the installation of charging infrastructure in the private and public sectors; and the recycling of vehicles and batteries (Hofmeyer, 2022).

The International Energy Agency (IEA) has developed a four-phase framework for grid integration of EVs. The framework highlights how increase in EV electricity load impacts the flexibility of a grid system. Several interventions can be employed including establishment of databases for charging points, separate metering for EVs, time of use tariffs, forecasting of EV availability, real time metering infrastructure and grid standardization protocols (IEA, 2022).

The transition to E-mobility is gaining global momentum and different countries are at different stages of implementation. Kenya can learn and tailor some of the intervention especially on manufacturing of EVs to expand the E-mobility industry in Kenya.

4. Methodology

This study utilized foresight methods to explore the future of electric vehicle adoption in Kenya's transport sector. Semiquantitative techniques, which use mathematical principles to quantify subjective, rational judgments and expert viewpoints, such as cross-impact analysis and the Delphi method, were employed. Specifically, this study applied cross-impact analysis as a semiquantitative method. Through a review of existing literature on electric mobility and a stakeholder consultative workshop, 22 drivers were identified. These drivers were then categorized into five groups within the Social, Technological, Economic, Environmental, and Political (STEEP) framework.

4.1 Drivers and Barriers to E-mobility adoption in Kenya

To examine drivers and barriers to e-mobility, horizon scanning was conducted using a systematic literature review and a Delphi questionnaire to identify 22 drivers. These indicators were categorized using the Social, Technological, Economic, Environmental and Political (STEEP) framework (Table 4.1). This framework aided in broadening our perspective while scanning for key drivers.

Table 4.1: Drivers of change identified from the literature and classified using the STEEP framework

Drivers	Variables	Indicators
Social	Demographic change Consumer preference/ behaviour Public health Skills	Population growth rate Proportion of consumers owning EV Level of air and noise pollution Number of relevant courses offered
Technological	Renewable energy sources EV charging infrastructure EV batteries design Conversion of ICE vehicles to electric vehicles Energy efficiency	Proportion of renewable energy sources Number of charging points Number of batteries swapping points Proportion of efficiency
Economical	Cost of ownership Government incentives Financial shocks Energy markets Energy efficiency Cost of Electricity Electric Vehicles startups	Total cost of ownership Number of electric vehicles sold Total cost of energy saved Total cost of charging Number of Startups

Environmental	Climate Change Noise pollution Recyclability	Total Greenhouse Gas emissions Noise levels
Political	Global governance Policies and regulations Public Private partnerships (PPP)	Number of policies developed. Number of PPP

4.1.1 Systematic literature review

In responding to Objective 1, the study employed systematic literature review to define the drivers and barriers to E-mobility adoption. Systematic literature review is a step-by-step method of collecting, analyzing, combining, and presenting findings from research studies on a research topic of interest (Pati and Lorusso, 2018). The research studies reviewed include journal articles, books and conference proceedings. Several steps were followed: -

Step1: Defining Research questions (RQ)

The following research questions guided the review;

RQ1: What are the drivers of E-mobility adoption?

RQ2: What are the barriers to E-mobility adoption?

Step 2: Selecting digital libraries; channels for literature review

The description of digital libraries used to access materials on e-mobility and sustainable transport was done.

Systematic review was then undertaken by selecting peer-reviewed published literature from the Elseiver (which encompasses Scopus and Science direct) and IEEE electronic database.

The keywords used in search include: “Drivers and E-mobility”, “Drivers and electric vehicles”, “Barriers and electric vehicles”, “Barriers and E-mobility”.

Step 3: Screening for Inclusion and exclusion

After compilation of the literature, screening of each published article was done to identify which should be included for analysis. This was done in two stages; First articles were included based on the review of abstracts and refined quality assessment based on a full text review. Criteria for inclusion/exclusion was defined.

Criteria for inclusion

Studies published later than 2010, peer-reviewed scientific journals, books and articles from conferences.

Criteria for exclusion

Articles prior 2010, Articles not accessible in specific databases, Studies not relevant to research questions. A total of 25 journal articles were reviewed.

Step 4: Assessing quality

Full text of these studies was then obtained to assess their effectiveness to be used in preparing the pool of studies for data extraction and synthesis.

The quality of study was identified by making a scrutiny of the sequence from the data collection method to the data analysis, results interpretation, and conclusions.

Step 5: Extracting Drivers and barriers

Drivers and barriers of E-mobility were extracted and filled in the data extraction form.

Step 6: Analysis and synthesis of drivers

Analysis and synthesis of drivers was done by categorizing drivers and barriers based on social, technological economic environmental and political (STEEP) analysis and mapped.

4.2 A Scenario analysis approach to explore the growth pathways to encourage Electric mobility adoption in future

Scenario Development was done in defining the growth pathways for e-mobility in Kenya. Scenario development has become an integral component of strategic transport planning. Scenarios are developed to enable an exploration of different futures, in turn improving transport systems (Lyons et al., 2021). Also, Scenario processes usually involve experts and stakeholders hence the diversity of participants has an impact on the quality of the participatory process (Lyons et al., 2021).

First, interviews were conducted where a total of 33 Stakeholders were engaged. Their composition is as shown in table 4. The stakeholders were asked to rank the identified drivers based on their impact on e-mobility adoption. Based on the rankings, the impact of each driver on another mapped and active and passive sum for each driver obtained. The sums were then mapped using the Micmac tool to show their dependency on other factors as well as their impact on E-mobility growth. As a result, an impact-dependency matrix was generated. Based on this matrix, the drivers of change with high systemic impact were used to develop scenarios that would inform the E-mobility growth pathways. The main drivers were combined on a scenario cross. Each driver was captured on one axis. The axes were then crossed to create a framework used to explore possible scenarios for the future. The axes of the cross represent a continuum of possibilities ranging between two extremes. Four main scenarios were developed and used to define futures that will foster the switch to electric vehicles.

Table 4.2: Stakeholder classification

Stakeholder category	**Sample size 33(%)**
Consumers/users	9(27.2)
EV manufacturers/assemblers	3(9.1)
Experts/researchers	8(24.2)
Government officers	5(15.2)
Civil society/advocacy	3(9.1)
E-mobility partners	2(6.1)
Financers	2(6.1)
Other	1(3.0)
Total	**33(100)**

5. Results

This section outlines the results from the analysis of the drivers for adoption of E-mobility in Kenya. It also presents an illustration of drivers and barriers reported from systematic literature review, the interactions between drivers of change, a map on the level of influence towards E-mobility and description of scenarios.

5.1 Drivers and barriers to E-mobility

Analysis and synthesis of drivers was done by categorizing drivers and barriers based on Social, Technological Economic Environmental and Political (STEEP) analysis and mapped as shown in the Table 5.1.

Table 5.1: Drivers of E-mobility

	Driver of E-mobility	Number of Papers
Social	Consumer preference	4
	Skills relevant to E-mobility	4
	Public health	3
	Demographic	2
Technological	Charging infrastructure	13
	Battery technology	9
	Energy efficiency	5
	Renewable energy sources	5
	Conversion of ICE to EV	1
Economical	Incentives	10
	Cost of purchase	6
	EV Startup markets/business models	5
	Energy markets	3
	Cost of electricity	2
	Finance	1
Environmental	Climate change	10
	Noise pollution	2
	Recyclability	1
Political	Regulations and policy framework	9
	Global/regional governance	2
	Public private partnerships	2

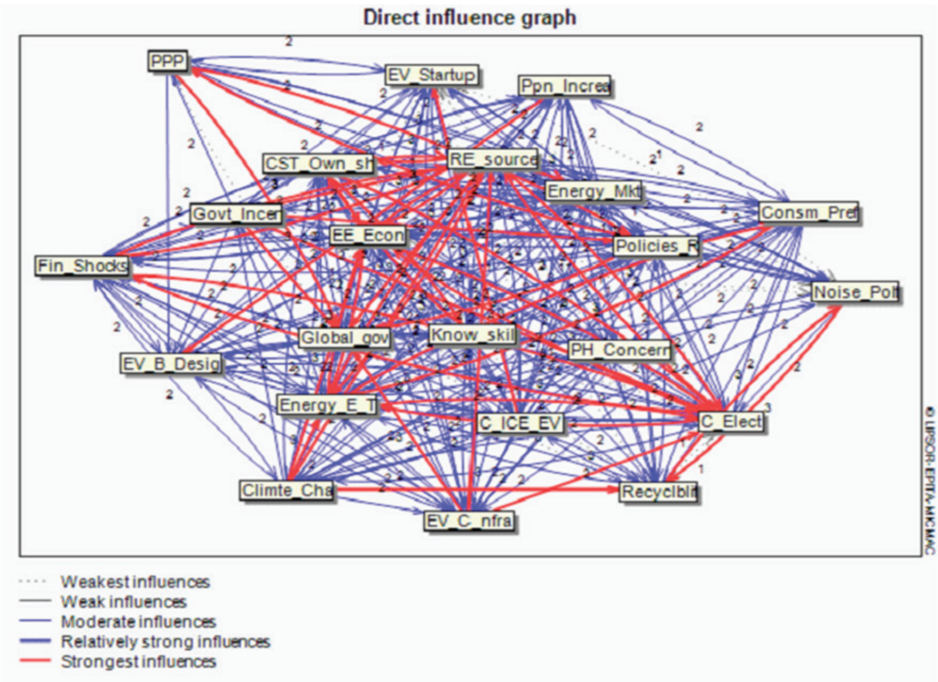
From the reviewed literature, the top drivers likely to shape the future of E-mobility were identified as Charging Infrastructure, Climate Change, Incentives and policy and regulation framework. The total cost of EV ownership was identified as a major hindrance to E-mobility adoption.

5.2 Cross Impact Analysis on the adoption of E-mobility

The Delphi questionnaire was used to establish the direct relationship between the drivers of E-mobility identified. Active and passive sums for each driver were then generated from the ranking of the relationships and mapped in a cross-impact matrix. The resulting data was then analyzed in the Micmac tool and generated a direct influence graph as shown in Figure 6 and four quadrant graph in Figure 5.1.

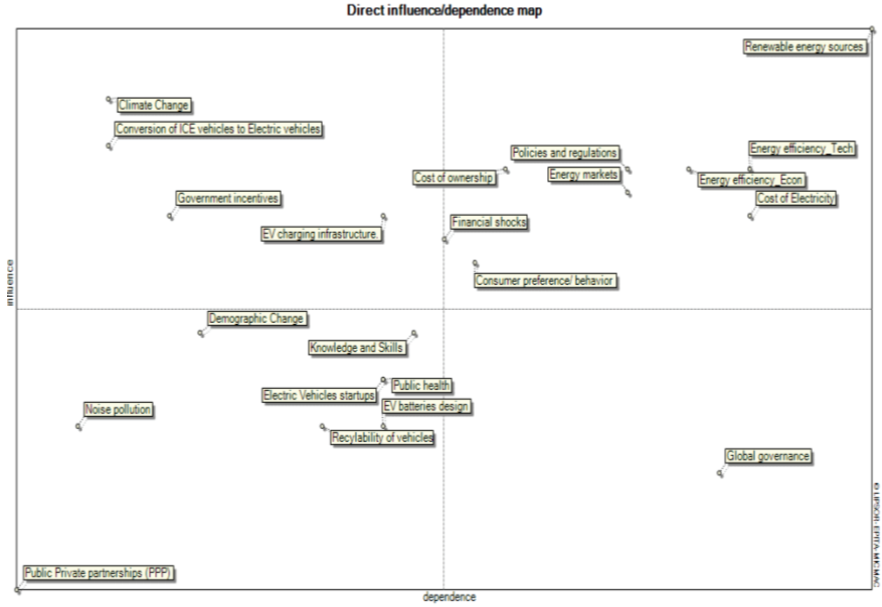
Direct influence graph shows how one driver influences the other drivers. The driver with more arrows pointing towards is highly influenced by other drivers, while the driver with more arrows originating from it highly influences the other drivers.

Figure 5.1: Direct influence graph



The Impact dependency analysis generated a map with four equal quadrants as shown in Figure 5.2. The distribution of drivers within each quadrant shows the varying levels of influence towards upscaling of E-mobility.

Figure 5.2: Direct influence/dependence graph for adoption of E-mobility in the transport sector in Kenya



The representation of the quadrants is as follows:

Driving forces in (Upper left corner of the matrix)

The most important driving forces are the factors that have the highest influence and the least dependency, which are in the upper left corner of the matrix. They have only one possible projection/ have stable trends.

Climate change (environmental sustainability) the most influential factor in reshaping the future of e-mobility. Similarly, conversion of ICE vehicles to Electric vehicles, incentives and charging infrastructure act as a driving force in adoption and growth of E-mobility adoption. This agrees with results from systematic review which show charging infrastructure, climate change and incentives as highest drivers of E-mobility. While conversion of ICE to EVs was not majorly mentioned in the literature, its an important factor in Kenya's E-mobility future.

Relay factors (Upper right corner of the matrix)

Factors in Quadrant 2 are called relay factors. Relay factors are both highly influential and highly dependent on other factors and thus represent unstable and emergent outcomes within E-mobility space. Relay factors play an important role in the future of E-mobility if the driving forces they depend on have a significant change. They include cost of ownership, policies and regulations, energy efficiency, energy markets, cost of electricity, consumer preference behaviour, financial shocks, energy markets and renewable energy sources.

Autonomous factors (Lower left corner of the matrix)

The factors on quadrants 3 represent the autonomous factors. These factors have little influence or dependence on the other factors. Among autonomous factors within Quadrant III, public private partnerships have no influence on e-mobility adoption, while knowledge and skills are the most effective ones in terms of influencing e-mobility adoption.

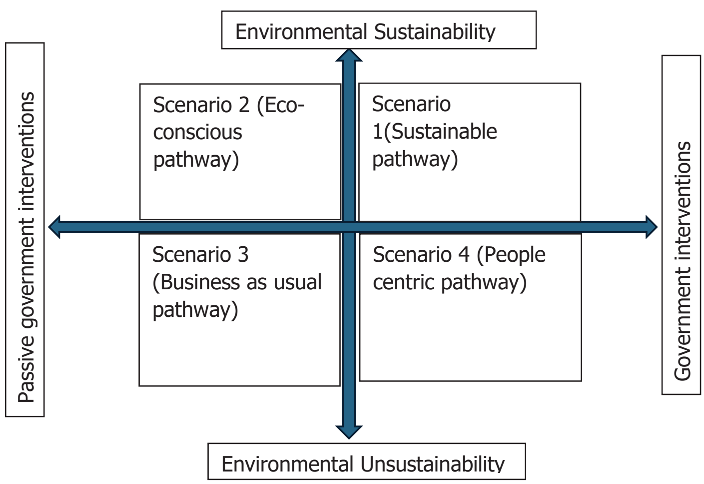
Result factors (Lower right corner of the matrix)

These factors have low influence, and their dependence is sensitive to other factors. Based on this quadrant, global governance is the most important result factor with low influence and high dependence. This implies that global governance does not play a leading role in the future of e-mobility ecosystem and has a lower impact as compared with environmental sustainability in quadrant 1.

5.3 E-mobility Scenarios

To have different representations of the future, Scenarios need to be clearly distinctive. A 2 by 2 matrix combines the most important drivers to create four scenarios (Ramirez and Wilkinson, 2014). The key driving forces of E-mobility identified under quadrant 1 in the direct influence map were then used to develop the scenarios. Scenarios constructed provide a range of alternate possible futures that will inform strategic decision making in the transport system. The drivers were summarized into two broad distinct categories, Environmental sustainability and government initiatives. Climate change and conversion of ICE vehicles to electric vehicles were combined as they both drive at achieving environmental sustainability by reducing emissions. Also, charging infrastructure and incentives were grouped as government interventions since they both create an enabling environment for E-mobility growth. Figure 5.3 depicts how the combination of environmental sustainability and gqaovernment interventions define the scenarios.

Figure 5.3: E-mobility scenarios



Scenario 1(Sustainable pathway)

The scenario is characterized by growing government interventions coupled with the need for environmentally sustainable transport system that will motivate shift towards electric vehicles. Electric vehicles will benefit from both monetary and non-monetary incentives. Evolution of incentives will take into account the EV market growth. This could include incentives for production, purchase or even imports of EVs. Financial incentives cover all consumers of different income groups. As a result, the total cost of ownership of EVs (including purchase, maintenance and running costs) is lesser compared to ICEs. The adoption of EVs will grow substantially across public and private fleets. This is likely to grow EV demand and supply by creating an enabling environment for EV industry. Infrastructure to support Multi modal integration including cars, two and three wheelers and even walking will be established. Also, there will be increased accessibility to public charging infrastructure with nationwide coverage. The growth of EV industry such as local manufacturing will foster economic growth and create job opportunities. High capacity and low-cost battery designs are developed improving on range coverage and efficiency. The scenario will also be characterized by lower road transport related emissions due to growing number of vehicles with zero to limited tail pipe emissions. There will be improved air quality and reduced pollution related public health concerns. Growth in circular economy model by establishing recycling technologies and end of life vehicle tracking systems will be realized. Optimal use of resources either through recycling or reuse of used ICE vehicles, EVs and EV batteries will be prioritized. The grid capacity will support increased demand for electricity due to high number of EVs. Renewable energy sources will power the electric grid hence reduced reliance on fossil fuels imports.

However, critical factors need to be addressed in this scenario. The roll out of incentives is uncertain and phasing them down as sales expand out could slow down the adoption rate of EVs. While the public charging system is offered as a service, regulation is key to ensure cost of charging is affordable to all categories of consumers. Carbon footprint from EV production will grow. Growth in production of EVs will increase extraction of mineral resources which may create environmental impacts such as emissions, water pollution and environmental degradation exercabating climate change burden. EVs and associated batteries design need to promote circularity to ensure material recovery for production of new vehicles and batteries hence cutting on demand for new resources. Sustainability of material resources to support the growing E-mobility industry need to be considered.

Scenario 2 (Eco-conscious pathway)

In this scenario, ICE Vehicles are still competitive with EVs hence most people may still prefer fossil fuel vehicles. There is limited availability of affordable EV options. The cost of ownership is more favourable to two-wheelers and three-wheelers as compared to larger vehicles. More cycling and walking is encouraged to limit use of vehicles. High capacity and efficient battery design are available but are costly. However, environmental sustainability targets are well defined. EVs are promoted as an act of environmental consciousness. Recycling technologies will be developed to encourage circular economic model. EVs may be largely owned by environmental enthusiasts. Nevertheless, motorists will experience range anxiety due to limited charging infrastructure. Hybrid vehicles may be new entrants into the market. Regulatory measures that will enable the clean vehicle industry to thrive will be reinforced such as developing tail pipe emissions standards for ICE vehicles. The incentives are unstable hence slowing down the uptake of EVs. Renewable Energy will be the main source for powering electric grid. The electricity prices are relatively high. Public health concerns from noise and air pollution will still be critical.

Scenario 3 (Business as usual pathway)

In this scenario, there is limited government interventions and less ambitious environmental sustainability targets. The cost gap between the EVs and ICEs is high. The number of ICEs grows due to increasing population. The automobile market is still dominated by ICEs and consumers reject EVs due to limited awareness. Fossil fuels is the main source of energy to power mobility. This may also be characterized by high fuel prices due to increasing demand and scramble for the limited reserves. As a result, emissions from the transport sector are expected to increase beyond the targeted limits. There will also be increased number of premature deaths associated with air pollution. Less efficient battery designs will be in use hence not economically viable. There is a liner economy model of production of vehicles hence most of them are dumped after end of use. The limited skill sets to support EV industry its growth. The local EVs industry will struggle due to inadequate enabling interventions for their business models to grow.

However, this scenario may also realize a technological advancement to more efficient and cheaper combustion engine vehicles alternatives which could compete with EVs.

Scenario 4 (People centric pathway)

In this scenario, people are educated on the benefits of interventions put in place such as incentives or charging infrastructure However, there are limited environmental sustainability targets to cut on emissions and promote circularity. The interventions put in place are not equally focused on addressing resource sustainability issues such as end of life vehicle management and recycling. As such, recycling is costly and complex. Production and end of use of EVs contribute significantly to emissions. On the other hand, the government sets out incentives for both public and private vehicles to compensate for high EVs prices and infrastructure to attract change in consumer preference. The government also ensures availability and affordability of charging infrastructure. EVs including cars, buses, two and three wheelers become more mainstream. Consumer uptake will mainly depend on costs of purchase. Hybrid charging stations may be prevalent where existing petrol stations incorporate charging points for EVs. There is thriving EV startups due to the enabling environment created. Growth in Ev fleets among government institutions and business entities like ride services will also be realized. Renewable energy sources will be preferred but push for technological advancement may also see the utilization of alternative fuels like hydrogen to power vehicles.

6. Conclusion and Policy Recommendations

6.1 Conclusion

The study aimed to develop scenarios so to envision the plausible futures of a sustainable transport system in Kenya. The study established that Climate Change, Conversion of ICE to EVs, Charging Infrastructure and Incentives were the most important drivers on future of E-mobility as a sustainable transport system.

E-mobility growth will be achieved by balancing transport environmental sustainability targets and government interventions. Four exploratory scenarios were developed namely, sustainable pathway, eco-conscious pathway, business as usual pathway and people centric pathway.

The desirable future of transiting to electric mobility will not only reduce greenhouse gas emissions and air pollution but also foster innovation and economic growth in the green technology sector. This means that the sustainability aspects of E-mobility growth will not only focus on the reducing tail pipe emissions from the transport sector however Life cycle analysis of the EVs.

By converting existing internal combustion engines (ICE) to EVs as a possible alternative pathway to adoption of Electric mobility. This can complement the efforts to increase the proportion of having new vehicle sales being electric. Adequate planning of EV charging infrastructure is a requirement for the widespread adoption of e-mobility. Incentives and availability of public charging infrastructure will be key enablers in growth of E-mobility.

6.2 Policy Recommendations

To foster sustainable growth in E-mobility industry, the government in partnership with stakeholders may formulate an Energy Vehicle Industry Development Plan. Also, the government may develop comprehensive guidelines and policies for the sustainable lifecycle management of EVs, focusing on ethical sourcing of materials, recycling, and disposal. This could include standards for electric batteries and batteries related components and systems including specifications for battery recycling. The Ministry of Transport may come up with an effective database to enable tracking and collection of disposed and End of Life vehicles.

Vehicle manufacturers and assemblers may invest in Research and Development (RandD) on Conversion of ICE vehicles to Electric Vehicles. In addition, research on possible sustainable alternative material resources for production of EVs may be prioritized. This will be key in the development of efficient, sustainable and cost effective EVs. Partnerships between educational institutions and industry bodies in creating standardized curricula will help to bridge the gap on the skills demand in this technical area.

The government may employ targeted incentives for manufacturers, importers and consumers of electric vehicles across different income levels to address the affordability barrier. Equally, the sustainability of these incentives need to be considered so as to allow E-mobility growth after the incentives are phased down. Assessment of EV market trends will be critical to inform the phasing down of incentives. These could include phasing down incentives when the cost parity is reduced, incentives may be strategically targeted on electric vehicle models with higher electric range capacity. In addition, regulatory framework, charging infrastructure, and enabling policy are critical in the transition to E-mobility as the incentives phase out.

Given the growing trend in EV uptake, energy providers may assess the impact of E-mobility on the energy sector. This will allow seamless integration of EV charging into the local electricity distribution networks to meet the grid capacity demand. Investing in solar powered charging infrastructure can reduce dependency on the grid. While the development of public charging infrastructure needs to keep pace with EV sales, having less stations will cause inconvenience while have more stations will be uneconomical. Charging infrastructure providers may integrate technology like smart charging to monitor energy needs and grid stability. It may be more relevant to consider the charging capacity per EV for each station rather than the number of EV to Charging Infrastructure ratio.

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Appendix 1: Mapping of Drivers

Driver of E-mobility	Number of papers	Authors
Charging infrastructure	13	Geronikolos, I., and Potoglou, D. (2021); Tsoi, K. H., et al. (2022). Ball, C. S., et al. (2021); Ota, Y., et al(2023); Panagakos, G., et al (2023); Dijk, M., Orsato, R. J., and Kemp, R. (2013); Pamidimukkala, A et al. (2024); Thorgeirsson, A. et al. (2020); Bedogni, L., et al. (2015); Rajashekara, K. (2013); Desai, A., and Patel, C. R. (2023); Ajanovic, A., et al. (2021); Yong, T., and Park, C. (2017)
Climate change	10	Sánchez-Braza, A., Cansino, J. M., and Lerma, E. (2014); Geronikolos, I., and Potoglou, D. (2021); Tsoi, K. H., et al. (2022); Ahn, H., and Park, E. (2024); Panagakos, G., et al (2023); Rosa, C. B., et al(2023); Dijk, M., Orsato, R. J., and Kemp, R. (2013); Pamidimukkala, A et al. (2024); Ajanovic, A., et al. (2021); Yong, T., and Park, C. (2017)
Incentives	10	Sánchez-Braza, Cansino, J. M., and Lerma, E. (2014); Geronikolos, I., and Potoglou, D. (2021); Chaianong, A.,et al. (2024); Tsoi, K. H., et al(2022); Ball, C. S., et al. (2021); Panagakos, G., et al (2023); Rosa, C. B., et al(2023); Pamidimukkala, A et al. (2024); Ajanovic, A., et al. (2021);Yong, T., and Park, C. (2017)
Battery technology	9	Barakat, et al. (2024); Chaianong, A.,et al. (2024); Augenstein, K. (2015); Ali, Z. M., et al. (2023); Thorgeirsson, A. et al. (2020); Bedogni, L., et al. (2015); Rajashekara, K. (2013); Desai, A., and Patel, C. R. (2023); Yong, T., and Park, C. (2017)
Regulations and policy framework	9	Chaianong, A.,et al. (2024); Tsoi, K. H., et al. (2022); Ball, C. S., et al (2021); Dixon, J., et al(2023); Rosa, C. B., et al. (2023); Dijk, M., Orsato, R. J., and Kemp, R. (2013); Mahdavian, A., et al. (2021); Ajanovic, A., et al. (2021); Yong, T., and Park, C. (2017)
Cost of purchase	6	Greyson, K. A., et al. (2021); Rajashekara, K. (2013); Yong, T., and Park, C. (2017); Dijk, M., Orsato, R. J., and Kemp, R. (2013); Sánchez-Braza, Cansino, J. M., and Lerma, E. (2014); Geronikolos, I., and Potoglou, D. (2021)
Renewable Energy sources	5	Barakat, et al. (2024); Tsoi, K. H., et al(2022); Dijk, M., Orsato, R. J., and Kemp, R. (2013); Ajanovic, A., et al. (2021); Ball, C. S., et al. (2021)
EV markets/ business models	5	Tsoi, K. H., et al(2022); Ball, C. S., et al (2021); Dixon, J., et al(2023); Dijk, M., Orsato, R. J., and Kemp, R. (2013); Desai, A., and Patel, C. R. (2023)
Energy efficiency	5	Greyson, K. A., et al. (2021); Ali, Z. M., et al. (2023); Panagakos, G., et al. (2023); Pamidimukkala, A et al. (2024); Thorgeirsson, A. et al. (2020)

Driver of E-mobility	Number of papers	Authors
Skills relevant to E-mobility	4	Sánchez-Braza, A., Cansino, J. M., and Lerma, E. (2014); Ball, C. S., et al. (2021); Yong, T., and Park, C. (2017); Patel, C. R. (2023)
Consumer preference	4	Ball, C. S., et al. (2021); Ahn, H., and Park, E. (2024); Panagakos, G., et al (2023)., Mahdavian, A., et al(2021).
Energy markets	3	Barakat, et al. (2024); Geronikolos, I., and Potoglou, D. (2021); Dijk, M., Orsato, R. J., and Kemp, R. (2013)
Public health	3	Tsoi, K. H., et al. (2023), Cansino, J. M., and Lerma, E. (2014), Lee, K., and Sener, I. N. (2023).
Global/ regional Governance	2	Tsoi, K. H., et al(2022); Dixon, J., et al. (2023)
PPP	2	Sánchez-Braza, A., Cansino, J. M., and Lerma, E. (2014); Lee, K., and Sener, I. N. (2023)
Electricity cost	2	Ajanovic, A., et al. (2021); Yong, T., and Park, C. (2017)
Demographic	2	Sánchez-Braza, A., Cansino, J. M., and Lerma, E. (2014); Geronikolos, I., and Potoglou, D. (2021)
Noise pollution	2	Tsoi, K. H., et al. (2023); Panagakos, G., et al. (2023)
Conversion of ICE to EV	1	Chaianong, A.,et al. (2024)
Finance	1	Dixon, J., et al. (2023)
Recyclability	1	Chaianong, A.,et al. (2024)

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