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GHANA ELECTRIC VEHICLES BASELINE SURVEY REPORT

2022

ENERGY COMMISSION, GHANA

Ghana Electric Vehicles Baseline Survey Report (2022)

Commissioned by

The Energy Commission under the Drive Electric Initiative (DEI)

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This report aims to establish a baseline for the EV industry in Ghana and to equip public and private sector institutions working in the EV space with the knowledge and tools required to steer progress in the e-mobility space in Ghana, drawing on surveys and research in the sector.

The study was commissioned by the executive secretary and management of the Energy Commission and led by the project coordinator, Ms. Doris Edem Agbevivi.

The report was prepared by Dr. Alfred Ofosu Ahenkorah (Ahenkorah & Partners), Dr. Godwin Kafui Ayetor (KNUST Brew-Hammond Energy Centre), Ms. Doris Edem Agbevivi (Project Coordinator of the Drive Electric Initiative) and Mr. Richard Donkor (Energy Commission).

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EXECUTIVE SUMMARY

Baseline Study

Ghana recognizes that the energy and transportation sectors are key areas in reducing emissions. Consequently, Ghana seeks to transition all its road and rail mobility to electric by 2070. This first electric vehicle baseline study commissioned by the Ghana Energy Commission aims to assist in this focus by providing a clearer picture of the status of electric vehicle adoption in Ghana through the following:

1. Analysis of global and local development of electric vehicles;
2. The total cost of ownership of electric vehicles in Ghana;
3. The emission reduction potential of electric vehicles in Ghana;
4. A nationwide baseline field study to determine barriers to mass adoption of electric vehicles in Ghana;
5. Brief assessment of the Ghana context of the effect of EV adoption on the national grid;
6. Development of an action plan for mass EV adoption.

This data will aid in the implementation of programs and policies to increase equitable electric vehicle access and make data-driven decisions about where the key opportunities and challenges exist. It will further provide a useful snapshot in time to compare the success of programs and policies in the future.

EV Development

The International Energy Agency (IEA) sees vehicle electrification as the major means of reducing carbon footprint in the transport sector. The end-use sector with the biggest reliance on fossil fuels, transportation, accounts for 37% of the carbon dioxide (CO_2) produced thus, to reduce emissions by 64 $MtCO_2e$ by 2030, Ghana has designated transportation as one of its adaptation and resilience areas. Road transportation alone was responsible for 11.11% of Ghana's overall CO_2 emissions in 2016 and has had a cumulative impact of 59.9% from the year 2000, according to the Ghana Environmental Protection Agency.

The global electric car stock share was 1% in 2019 but then accounted for 9% of the global car market in 2021. The global EV stock reached 16.4 million units in 2021 compared to 400 thousand units in 2013 [1]. IEA projects light-duty plug-in electric vehicles (PEVs) to reach 140 million in 2030 although electric two and three-wheelers (E2&3W) are expected to reach 490 million in the same year.

According to the International Trade Centre, about 17,660 PEVs were imported into Ghana between January 2017 and December 2021. Imported motorized E2&3W during this period was 9,431 units with most (98%) of the Battery Electric Vehicles (BEVs) being imported from China. In 2021, the Ghana Revenue Authority (GRA) reported that standard hybrid-electric vehicles (HEVs) have the highest representation (91.5%) followed by BEVs at 5.1%. and plug-in hybrid electric (PHEVs) at 3.3%.

Due to its high electricity access rate (87%), excess capacity in electricity generation (2000 MW), and renewable energy share in our electricity mix (34.65%), Ghana is suitable for the introduction of PEVs. Even with the introduction of 50,000 new standard PEVs per annum in Ghana, the electricity consumption is likely to increase by 600 GWh per year accounting for only 2.6% of the 2022 consumption forecast of 23,578.51 GWh. However, a gradual introduction of PEVs is essential because an overnight increase in peak demand may cause disruptions in the grid. Further grid impact assessment of large-scale EV deployment has been recommended for the long term. The current renewable energy mix allows BEVs to reduce CO_2 emissions by 70%, NO_x emissions by 83%, SO_x emissions by 31%, PM_{10} emissions by 53%, $PM_{2.5}$ by 47%, and Volatile Organic compounds (VOC) by 99%.

The results of the 5-year total cost of ownership as of October 2022 showed that BEV cost per mile exceeds that of internal combustion engine vehicles (ICEV) by 14% - 16% without borrowing costs. It takes 12 years for the BEV to reach cost parity with ICEV. Waiving the current import tariff on BEVs reduces the years of cost parity to 10 years. A disproportionate reduction in borrowing costs in favor of BEVs allows cost parity to be reached in just 5 years. Fortunately, electric two and three-wheelers (E2&3W) reach cost-parity with diesel or petrol 2&3W by the second year of ownership and are already profitable to own in Ghana. The biggest advantage of the BEV is its cost of operation. We found the cost of operating the ICEV was 2.3 times more than the BEV but the cost of fueling the ICEV was 5 times the cost of charging the BEV. Assuming an annual average travel distance of 24,000 km, it will cost $480 to charge the Hyundai Kona Electric compared to $2,535 for the Hyundai Kona ICEV. However, more publicly available charging infrastructure is needed. Ghana has four level 2 charging stations, available to the public but all are located in Accra.

Baseline Field Study

Results of the national baseline field study carried out across the country suggest that a high proportion (89%) of respondents were aware of the existence of electric vehicles. About 53.64% of the respondents will prefer the purchase of an EV over an ICE vehicle. Well-educated and environmentally conscious Ghanaians are more likely to purchase electric vehicles. They will consider the purchase of EVs provided there will be financial savings on forfeiting fuel use, affordable initial cost, available maintenance technicians and well-equipped workshops for EV repair, availability of various EV models on the Ghanaian market, and readily available spare parts among others. While the current world average price for an EV is $36,000 (source) about 54% of potential Ghanaian EV users were only prepared to spend below $20,000 to acquire an EV, 26% were prepared to spend $20,000 to $30,000; 12% were prepared to spend above $30,000 to $40,000 and 8% were prepared to spend above $40,000. Due to the various taxes charged at the point of entry, the initial price of an EV in Ghana further rises by about 30% or more of the manufacturer's suggested retail price after import.

The results of the survey among current EV owners in Ghana indicate that 50% of Ghanaians who own EVs charge their vehicles at home; 17% use public charging stations, and 33% use a combination of home and public charging. Almost 64% of EV drivers indicated that they drive an EV to save money on fuel. The top five (5) preferred brands of EVs among users are Toyota Prius (33%), Tesla Model 3 (28%), Tesla Model Y (26%), Tesla Model S (24%), and Hyundai Kona EV (17%). Almost 46% of EV owners travel between 1km and 50 km per day on errands, 38% travel between 51 km and 100 km, and 8% travel between 101 km and 150 km. This is not different from the average daily distance travelled in Ghana. Generally, most of the respondents do not travel more than 100 km a day even those who use ICE vehicles.

The survey results also indicate that the skills for EV servicing, maintenance and repair are in short supply in Ghana. Only three (3) EV dealerships reported having functional service facilities and well-trained technicians. But many more dealerships are willing to venture into EV maintenance with the appropriate training and support.

Action Plan

In the near term, an action plan has been proposed to aid EV integration in Ghana. The following action measures are recommended:

1. Provide the legal framework and regulation for charging infrastructure and renewable energy integration.
2. Facilitate a well-distributed EV fast-charging network across the country with established standards and regulations to guide the charging market.
3. Conduct grid impact studies of electric vehicle charging stations.
4. Enable implementation of smart charging schemes to limit grid impact.
5. Support EV purchases to reduce the initial upfront cost by waiving import duties on EVs for a period of up to five years or charging equivalent levels of import duties and taxes on EVs as being charged for ICE vehicles, based on engine sizes.
6. Offer financial incentives scheme at lower borrowing rates for EV buyers.
7. Implement a national strategy to recycle/reuse and safely dispose of EV batteries to ensure long-term battery sustainability.
8. Monitor EV growth per category and support EV research to inform policy and decision-making.
9. Provide several avenues for EV skills training by supporting the development of professional short courses, hands-on training certifications and degree programs at all levels of education.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS AND ACRONYMS

IEA	International Energy Agency
CO_2	Carbon dioxide
EV	Electric Vehicle
GRA	Ghana Revenue Authority
BEV	Battery Electric Vehicle
PEV	Plug-in Electric Vehicle
PHEV	Plug-in Hybrid Electric Vehicle
HEV	Hybrid-Electric Vehicle
ICEV	Internal Combustion Engine Vehicle
FCEV	Full Cell Electric Vehicle
NO_X	Nitrogen Oxide
SO_x	Sulphur Oxide
PM_{10}	Particulate Matter 10
$PM_{2.5}$	Particulate Matter 2.5
VOC	Volatile Organic Compounds
NDC	Nationally Determined Contributions
UNFCCC	United Nations Framework Convention on Climate Change
E2 & 3W	Electric two & three-wheelers
NPV	Net Present Value
TCO	Total Cost of Ownership
OEM	Original Equipment Manufacturers
AFID	Alternative Fuel Infrastructure Directive
AC	Alternating Current
DC	Direct Current
CCS	Combined Charging System
SDG	Sustainable Development Goals
HV Battery	High- Voltage Battery
DVLA	Driver Vehicle & Licensing Authority

EPA	Environmental Protection Agency
$MtCO_{2e}$	Metric tons of carbon dioxide
MW	Megawatt
GWh	Gigawatt hour
Km	Kilometer
Gt CO_2	One billion tons of carbon dioxide
kWh	Kilowatt hour
v	Volts
Hz	Hertz
g/km	grams per kilometer

1. Introduction

Ambient air pollution is the leading cause of global disease burden, especially in low and middle-income countries [2]. The burning of fossil fuels especially petrol and diesel, which are sources of ambient air pollution, was responsible for 8.7 million deaths in 2018 [3]. Globally, transport accounts for 37% of Carbon Dioxide (CO_2) from end-use sectors and has the highest reliance on fossil fuels [4]. In 2021, transportation emissions grew by 8% to nearly 7.7 Gt CO_2. Developing and emerging economies accounted for most of the growth in emissions. Transport continues to rely on oil for 91% of its final energy use because of internal combustion engine-powered vehicles, which are the dominant mode of transportation [4]. The Environmental Protection Agency, Ghana (EPA) has identified vehicular exhaust emissions as the single largest contributor among the major sources of air pollution in Ghana [5]. In Ghana, mobile combustion emissions summed up to 7.2MtCO_2e in 2016 [6]. Road transportation alone contributed to 11.11% of Ghana's total CO_2 emissions in 2016 with a cumulative impact of 59.9% since the year 2000.

The International Energy Agency (IEA) in its 10-point plan to reduce oil use, has identified the electrification of road vehicles as the most promising pathway to reducing greenhouse emissions [7]. In its updated Nationally Determined Contributions (NDCs) to the United Nations Framework Convention on Climate Change (UNFCCC), Ghana intends to reduce emissions by 64 MtCO_2e by 2030 [8]. Ghana has named the transportation sector as one of its ten adaptation and resilience areas in its NDCs. According to the National Energy Transition Framework, all road and rail mobility in Ghana will be electricity and hydrogen-fueled by 2070 while off-road ICEV will be phased out by 2040 [9]. The purpose of this study is to conduct a baseline study on the current state of electromobility (e-mobility) in Ghana and develop an action plan to prepare for Ghana's e-mobility transition.

1.1 Objectives

The Energy Commission, as part of its efforts to create responsible and sustainable electricity demand in Ghana, has commissioned a baseline study that will prepare the market condition for the sustainable integration of electric vehicles. To determine the state of preparedness for the e-mobility transition, the following objectives were set:

- Carry out a national field study through a survey, to determine consumer perceptions towards e-mobility transition, barriers to the transition, ownership, and usage.

- Report on the state of E-mobility in Ghana by taking stock of current import data, existing policy, and infrastructure in comparison with the global scenario.
- Carry out a contextual assessment of the total cost of ownership of electric vehicles in Ghana considering various scenarios of import tariffs.
- Determine the effect of EV uptake on the national electricity grid.

1.2 Scope and Methodology

1.2.1 Scope

The Scope of this study is limited to Battery Electric Vehicles (BEVs) and Plug-in Hybrid Electric Vehicles (PHEV). This includes electric two and three-wheelers (E2&3W), light-duty vehicles, compact vehicles, and heavy-duty vehicles.

A thorough review of the global and local development of electric vehicles was carried out. This was complemented by the current capability of electric vehicle technology, charging infrastructure, standards, and regulatory framework. A total cost of ownership spanning saloon cars, pick-ups, and buses was carried out in the Ghanaian context. Results of the national baseline field study were discussed after which the preparedness of the national electricity grid was analyzed. Recommendations were made based on the transition gaps especially on the results of the baseline survey, import data, total cost of ownership, and the readiness of the National Grid for the EV uptake.

1.2.2 Methodology

1.2.2.1 National Baseline Field Study

To elaborate on an understanding of consumer behavior, research usually aims at accounting for influential factors. Several studies have investigated factors that may influence consumer intention to purchase an electric vehicle. Ackaah, [10] used a questionnaire to collect data on factors influencing consumers' intentions to purchase electric vehicles in Ghana. Similarly, Shakeel [11] used the methodology of questionnaires to predict consumer purchase intention for electric vehicles. In this baseline study, questionnaires were administered in eight cities namely Accra, Kumasi, Takoradi, Ho, Koforidua, Sunyani, Techiman, and Tamale for 31 days. These cities were selected due to the regional distribution of vehicles in Ghana as obtained from the Driver and Vehicle Licensing Authority (DVLA). The distribution of the questionnaires was done according to the various stakeholders relevant to the growth of e-mobility. The sectors reached include those shown in Table 1. The questionnaires sort to answer questions on

- Public knowledge of electric vehicles
- Barriers to EV ownership
- Preparedness of service and fuel stations to install charging stations
- Preparedness of vehicle dealers to sell and service EVs
- The user experience of EV owners in Ghana
- Preparedness of Insurance companies
- Preparedness of informal vehicle repairers and workshops

- Table 1:sample sizes used for distribution of questionnaires

Sector	Population (N)	Sample Size (n)
Car Battery Charging workshops (92% CI)	Unknown	70
EVs Dealers	3	3
OMCs	13	13
EV Owners (95% CI)	1,055	290
Hotels (5* to GH) (95% CI)	897	270
Restaurants/Shopping Malls (95% CI)	937	280
Service Stations and fuel outlets (95% CI)	3,653	360
Used Vehicle Dealers (95% CI)	Unknown	200
Vehicle Owners/Prospective/Comm (95% CI)	8,345,414	450
Vehicle Testing Companies (90% CI)	32	32
Vehicle Workshops and Repairers (95% CI)	Unknown	200
Insurance Companies (90% CI)	137	50
EV Public Charging Stations	4	4
Total		**2,230**

The sample size estimation was based on two factors. These were when the population size was known and when the population size was unknown. Yamane sample calculation was used to determine the sample size for all the sectors with known population sizes such as the questionnaire for EV Owners. Yamane sample size determination formula is expressed as follows:

$$n_o = \frac{N}{1+Ne^2} \quad (1)$$

Where $\mathbf{n_o}$ is the Yamane sample size, N is the population size and **e** is determined from the confidence we are seeking from the study.

Cochran's equation to yield a representative sample from the population was used. This was used to determine the sample size for sectors with an unknown population such as Used Vehicle Dealers. The sample size determination according to Cochran is expressed below

$$n_o = \frac{z^2 pq}{e^2} \quad (2)$$

Where **e** is the margin of error, p is the proportion of success, **q = 1-p** is the proportion of failure and $\mathbf{Z^2}$ is the abscissa of the normal curve that cuts off an area **(α)** at the tails. **1- α** gives the desired confidence level, e.g., 95%. This is also termed a critical value which is calculated using Z-table. However, there exist predefined tables of confidence levels with related Z-scores.

1.2.2.2 Total Cost of Ownership

A total cost of ownership (TCO) was conducted for the following vehicles in Table 2. Four comparisons were made for vehicles in the same category.

Table 2:Vehicle specifications

#	Vehicle Type	Distance on a single charge (miles/km)	MPGe	MPG	Initial Price ($)
1	Dongfeng E70-2021	316/508	161	-	20,427
2	Toyota Vitz-2021	-	-	42	8,000
3	Hyundai Kona Electric-2022	258/415	132	-	37,390
4	Hyundai Kona ICE-2022	-	-	27	22,450
5	Ford-150 Lightning-2022	230/370	75	-	51,974
6	Ford-150 ICE-2022	-	-	17	35,885
7	Ford e-Transit Van	196/315	48	-	64,000
8	Ford Transit Van |ICE	-	-	14	41,035

The TCO model includes a one-time purchase cost referred to as the manufacturer-suggested retail price (MSRP) of the vehicle together with its accessories, and all operating costs associated with its use. All future costs were converted into a net present value (NPV) as done by many other researchers [12-14]. The TCO model is calculated as shown in equation (3).

$$TCO = MSRP + TB - TC + \sum_{n=1}^{N} \frac{OC}{(1+i)} - RV \tag{3}$$

Where *TCO* is the total cost of ownership, *MSRP* is the manufacturer's suggested retail price, *TB* is the tax base including the import duty, *TC* is the tax credit applicable to be used in the sensitivity analysis, *n* is the holding year, *N* is the lifetime of vehicle ownership considered, *i* is the bank interest rate, *OC* is the operating cost including fuel/electricity, maintenance and repair costs, and insurance, *RV* is the resale value. The tax base formula used in this study is based on the tax schedule provided by Ghana Revenue Authority (GRA). The details are specified in Table 3 below. While the import duty varies according to engine size from 5% (<1000 cc) to 20% (>3000 cc) for ICEV, that for electric vehicles is kept constant at 20% as specified by the GRA tax base schedule.

Table 3: GRA Tax base Formula for electric vehicles (Source: Ghana Revenue Authority)

#	Tax Code Name	Tax Base Formula	Tariff Rate (%)
1	Import duty	Cost, insurance and freight (CIF)	20
2	Import VAT	CIF+ import duty +NHIL+GETFUND+COVID	12.5
3	ECOWAS levy	CIF	0.5
4	Vehicle examination fee	CIF	1
5	Network charge	Free on Board (FOB)	0.4
6	Network charge VAT	Network charge +Network GETFUND + Network NHIL	12.5
7	Network charge COVID-19 levy	Network charge	1
8	Import NHIL	CIF+ Import duty	2.5
9	Network charge NHIL	Network charge	2.5
10	Special import levy	CIF	2
11	EXIM Levy	CIF	0.75
12	GET fund import levy	CIF+ Import duty	2.5
13	Network charge GET fund levy	Network charge	2.5
14	African union import levy	CIF+ Import duty	0.2
15	COVID-19 health recovery levy	CIF+ Import duty	1

2. Development of Electric Vehicles

2.1 Electric vehicle technology

Electric vehicles have three (3) major classifications namely:

- Hybrid-electric vehicles (HEV)
- Plug-in electric vehicles (PEV)
  - Plug-in hybrid electric vehicles (PHEV)
  - Battery electric vehicles (BEV)
- Fuel cell electric vehicles (FCEV)

HEVs have two means of propulsion: an internal combustion and a traction battery or a combination of both. In a situation where there is provision for the HEV to be charged externally, the terminology PHEV is used. A PHEV requires an external source to be able to charge the high voltage (HV) battery fully, while a standard HEV only relies on the internal combustion engine and regenerative braking to fully charge its battery. PHEV's average driving range on electricity only reached 60 km in 2021. A BEV relies solely on the traction battery as a source of power to propel the vehicle and therefore has no other means of propelling the vehicle.

The average BEV driving range in 2021 was 350 km [1]. Similar to PHEV, BEV requires charging from an external source to be able to fully charge the HV battery. PHEV and BEV are collectively referred to as PEV because both can be charged by an external source. The FCEV is powered by hydrogen via a fuel stack that produces electricity to charge the battery. The average driving range of FCEV is 480 km [1]. Figure 1 represents the various categories of electric vehicles imported into Ghana as supplied by the Ghana Revenue Authority (GRA). Standard hybrid electric vehicles represent the majority with 91.5% followed by PHEV (5.1%) and BEV (3.3%). The initial cost has been an influential factor in this representation as BEV and PHEV initial costs are substantially higher than standard hybrid electric vehicles. The driving range is an essential consideration for consumers and is usually prioritized by EV automakers. Increasing driving range implies bigger batteries at a higher cost. Average world battery prices in 2021 stood at USD 132 per kWh.

In 2021, there were 450 EV models available, 170 of which were electric truck models.

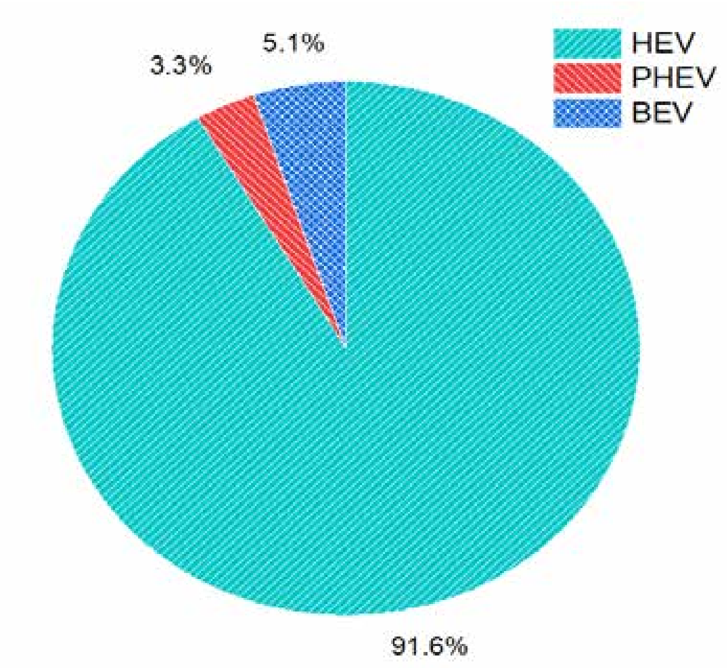

Figure 1: Category of electric vehicles imported into Ghana from 2017 to 2022 (GRA)

2.2 Electric Vehicle as a Solution

Vehicle emissions are further exacerbated by the use of bad-quality fuels which are prevalent in many developing countries [15]. The lack of local refineries implies that most of these countries have to import fuel which further affects exchange rates. E-mobility powered by a dominant renewable energy mix is seen as the solution to global challenges in air quality decline, urbanization, used ICE vehicles, and global warming. To a large extent, this is dependent on the carbon intensity of the National Grid. Some researchers have reported that Ghana's current generation mix allows e-mobility the potential to reduce emissions by at least one-third but a renewable generation share in the electricity mix below 15% is rather detrimental [12, 13, 16]. The transition to e-mobility also allows a reduction of the excess generation capacity of the national grid with its attendant payment of overcapacity charges. It also allows for the potential of opening up the market to renewable energy expansion.

2.3 Electric Vehicle Uptake

2.3.1 Global Electric Vehicle Stock

According to IEA, the global EV stock grew to 16.4 million units in use in 2021 with a car sales share of 9 % [1]. In 2019, the global electric car stock share was 1% [17]. From Figure 2, the Global EV stock comprising cars, vans, buses, and trucks has been increasing by an average of 9% every year. The increase in growth between 2020 and 2021 alone was 60%. The Global EV stock is projected to reach 140 million in 2030. Global electric two/three wheelers are also projected to reach 490 million in 2030.

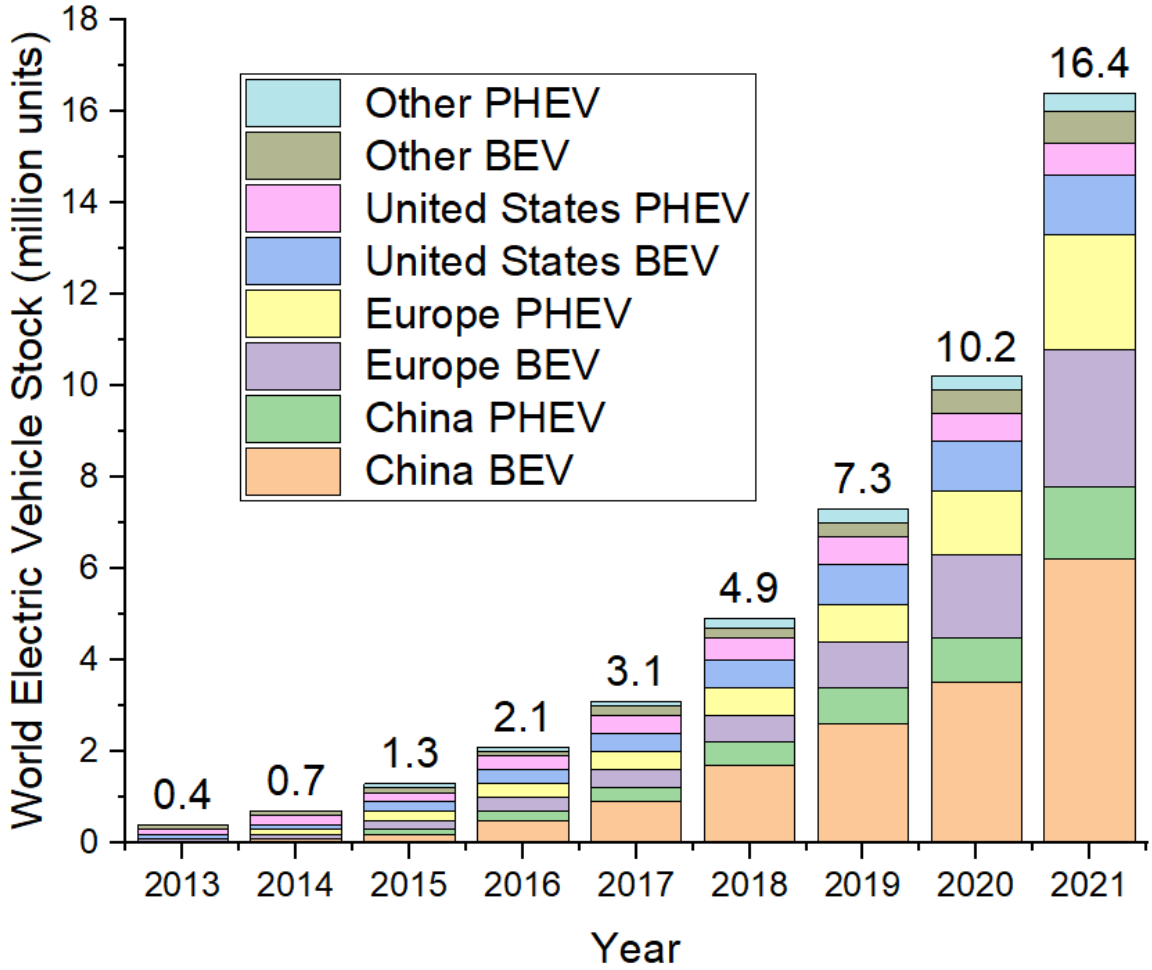

Figure 2: Global electric vehicle stock, 2013–2021 [17]

The projected increase is spurred on by significant fiscal incentives and announced pledges. Measures such as purchase subsidies, and registration tax rebates have been very successful in reducing the price gap with conventional vehicles [1]. Almost all major Original Equipment

Manufacturers (OEMs) in Europe and America have announced electrification plans. Also, the European Union has banned the sale of new internal combustion engine cars (ICE) from 2035 [18].

2.3.2 Ghana's Electric Vehicle Stock

From Figure 3, the International Trade Centre data indicates that a total of 17,660 PEVs were imported into Ghana between 2017 and 2021. Imported motorized E2&3W alone were 9,431 units and represented close to 1% of all motorized 2&3W units imported. The minority segment was heavy-duty PEVs totaling 67 units. The total number of PHEVs constitute 45% while BEVs were 55% of the import. The high number of BEVs is attributed to the motorized E2&3W (96.3%) because only 3.7% of the BEVs were full-size BEVs. China supplied about 98% of all imported PEVs in Ghana followed by Germany (1%) and others.

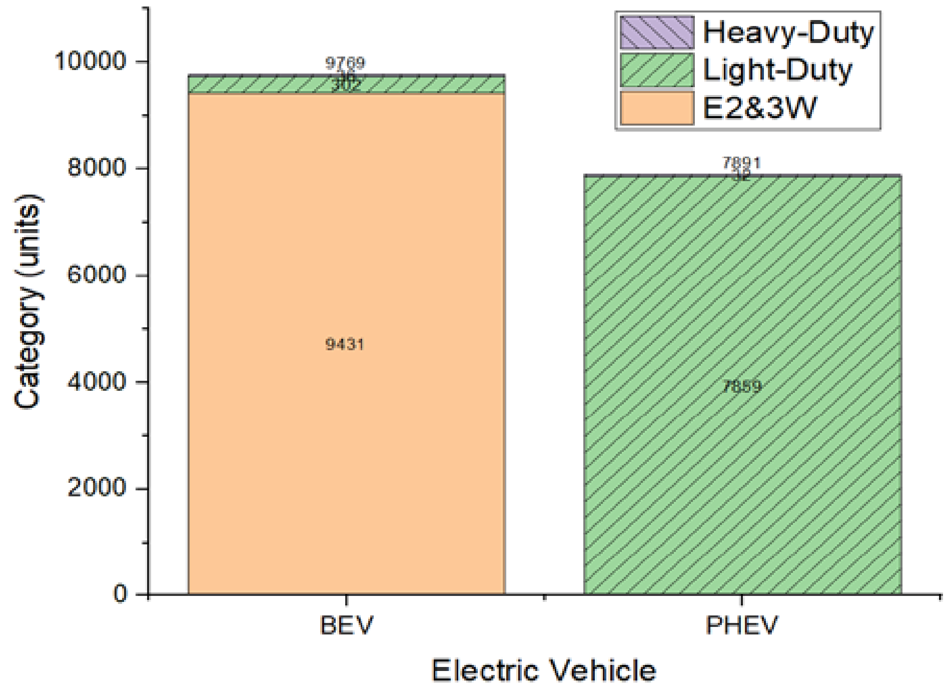

Figure 3: Ghana's electric vehicle import statistics (2017 to 2021) [19]

Figures 4 and 5 show the most popular vehicle models in the respective light-duty BEV and PHEV categories. BEVs from the Chinese EV manufacturer Dongfeng such as IEV 230 and E70 are the most patronized models. This is closely followed by products from the Chinese EV manufacturer Great Wall Motors such as the ORA Black cat. Toyota Camry and Prius hybrids are the most popular hybrid vehicles in Ghana. About 35% of hybrids imported were Camry, 30% were Prius and 10% were RAV 4 hybrids.

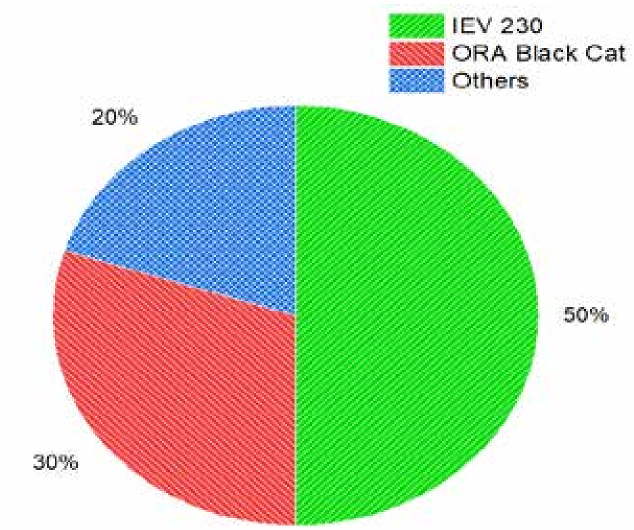

Figure 4: Percentage of BEV models imported into Ghana from 2018 to 2021 (source: GRA)

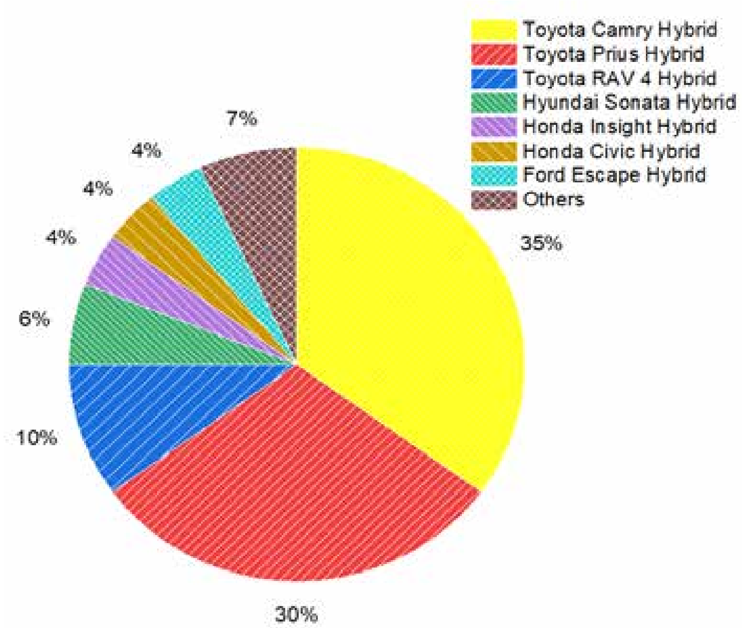

Figure 5: Percentage of hybrid models imported into Ghana between 2018 to 2021(source: GRA)

2.4Charging Infrastructure

2.4.1 Charging Technology

Many studies have suggested that the deployment of adequate charging stations is a precursor to the mass deployment of PEV [20]. A U.S. survey by the Department of Energy revealed that the logistics of where and when to charge an EV is the largest barrier to EV ownership [21]. The

adequacy and number of fast-charging stations are also necessary to avoid range anxiety among consumers. An efficient charging infrastructure that guarantees minimal or no charging time will be eagerly anticipated by potential PEV consumers [22]. The Alternative Fuel Infrastructure Directive (AFID) of the European Union (EC, 2014) recommends a ratio of one publicly accessible charger per ten electric cars [23]. The various state-of-the-art charging technologies are presented in Table 4. There are 3 charging levels namely levels 1, 2, and 3. Levels 1 and 2 are primarily AC charging which requires the use of J1772 or Tesla vehicle connectors to enable charging. Level 1, mostly for home charging, has a maximum of 120 V installation capacity and can take 8 to 16h to charge an average PEV. Level 2 can be installed for home charging or public charging with a charging duration of up to 3h and a power delivery of 12 kW. The single-phase option provides a maximum current flow of 40A at 240 V and the three-phase can supply 80A at 400 V. Level 3 charging is primarily DC fast charging or Tesla supercharging which can charge a vehicle from 0 to 80% in 13 to 20 minutes.

Ghana currently has four public charging stations (level 2) situated in Accra with a fifth one under construction. There is currently no DC public charging station in Ghana. The only DC fast chargers in the country currently are not publicly available but are owned by fleet operators in the country.

Table 4: charging technologies

#	EV Charging	Categories	Connectors	Specifications	Charging duration
1	Charging levels	Level 1 charging (L1)-AC	SAE J1772, Tesla	120V, 16A, 1.9kW	8–16 h
		Level 2 charging (L2)-AC	SAE J1772, Tesla	208 to 400 V, 40–80 A, 12 kW	3h
		Level 3 charging (L3)-DC Fast charging, Tesla Supercharging	CCS combos 1 and 2, ChAdeMO, Tesla DC chargers	200 to 900V, 80A, 50 to 500kW	13–20 min.
2	Charging methods	Conductive charging			
		Inductive charging			
		Battery swap			

2.4.2 EV Charging Infrastructure in Ghana

The four public EV charging stations currently located in Accra can be located at A&C Mall in East Legon, Kempinski Hotel in Accra Central, Palace Mall in Spintex, and Total Energies on the Liberation Road. Two out of the 4 charging stations are owned and maintained by Porsche Ghana, one by Pobad International and one newly launched and established by the Total Energies Marketing Company.

2.4.2.1 POBAD Charging Station

Pobad International EV charging station can be located at the A&C Mall in East Legon with a digital address of GA-170-3611 in Accra. The station as shown in Figure 6, is a level 2 charging station with a capacity of 11kW. It enables type 2 AC charging with a 7 kW battery charge duration of up to 12 hours. Solar PV is the primary source of energy for the charging station’s functioning. Daily, the station can provide charging services for about one vehicle and has the potential to fully charge two vehicles.

Figure 6: POBAD Charging Station Located at the A&C Mall, East Legon

2.4.2.2 Porsche Charging Station located at Palace Mall, Spintex Road

One of Porsche Ghana’s EV charging stations can be located at the Palace Mall on Spintex Road in Accra with a digital address of GZ-232-8323. The station is a level 2 charging station with a capacity of 11 kW as shown in Figure 7. It enables type 2 AC charging with a 7-kW battery charge duration of up to 12 hours. Electricity from the national grid is the primary source of energy for the charging station’s functioning. Daily, the station can provide charging services for about one vehicle and has the potential to fully charge two vehicles.

Figure 7: Porsche Charging Station located at Palace Mall, Spintex Road

2.4.2.3 Porsche Charging Station located at Kempinski Hotel

The second Porsche charging station is located at the Kempinski Hotel located near the Accra International Conference Center, in Accra. The station is a level 2 charging station with a capacity of 11 kW as shown in Figure 8. It enables type 2 AC charging with a 7kW battery charge duration of up to 12 hours. Electricity from the national grid is the primary source of energy for the charging station's functioning. Daily, the station can provide charging services for about one vehicle and has the potential to fully charge two vehicles.

Figure 8: Porsche Charging Station located at Kempinski Hotel

2.4.2.4 Total Energies Charging Station located on the Liberation Road

TotalEnergies launched one of the 4 electric vehicle charging stations installed on Liberation Road located at Total Energies Service Station and fuel outlet in Accra near 37. The station is a level 2 charging station with a capacity of 11 kW as shown in Figure 9. It enables type 2 AC charging with a 7 kW battery charge duration of up to 12 hours. Electricity from the national grid is the primary source of energy for the charging station's functioning. The station can provide daily charging services for about one vehicle and has the potential to fully charge two vehicles.

Figure 9: TotalEnergies Charging Station located Near 37 on the Liberation Road

2.5 Regulatory Framework

Accessible, reliable, and affordable electricity is a prerequisite for efficient charging infrastructure. International regulatory frameworks for EV charging stations and grid integration are governed by guidelines, standards, net metering, and load management requirements. The framework seeks to undertake the following measures

- Provide clear guidelines for the application of metered connections for EV charging stations
- Provide clear guidelines to already existing owners of private charging stations (homes, offices) on the requirements and processes to apply for metered EV connections.
- Provide technical feasibility check to assess the required sanctioned load for the proposed facility
- Respond to queries and carry out site visits concerning EV charging connections

Globally, EV charging standards and protocols ensure the interoperability and compatibility of any Electric Vehicle Supply Equipment (EVSE) with all PEVs. Adequate application of standards minimizes trade barriers for PEVs and their components. As shown in Table 5, the standards govern the EV charger topology, charging connector, charging communication, charging power quality, and charging safety.

Table 5: Electric vehicle charging standards and protocols

Charger topology	Charger Connector	Charging power quality	Charging Safety	Charging communication
IEC 61851-1	IEC 62196-1	IEEE 1547	SAE J2464	SA J2847/J2836
IEC 61851-21	IEC 62196-2	IEC 1000-3-2	IEC 60529	ISO 15118
IEC 61851-22	IEC 62196-3	SAE J2380	IEC 60364-7-722	IEC 61850
IEC 61851-23	SAE J1772	NEC 690	SAE J1766	SAE J2293
IEC 61851-24	IEEE 1901	SAE J2894	ISO 6469-3	OpenADR

High-powered requirements and spatial concentrations synonymous especially with fast charging have the potential to adversely affect the grid [24]. Harmonic distortions due to high loads (18 kWh to 24 kWh) from power electronics are known to occur on many grids during peak hours [25]. The National Electricity Grid Code of Ghana already had power quality standards in place for the grid since 2009. IEEE 519-2014 is recommended for voltage harmonics and flicker while the system frequency is set at 50 Hz [26]. However, Ghana is yet to approve electric vehicle charging standards and protocols.

Passive and active management of EV charging load is essential to maintain the stability of the grid. A passive EV charging management approach is used to influence the charging behaviour of EV users by making charging expensive during peak periods. This time-of-day tariff influences users to charge their vehicles during off-peak periods and helps to maintain the stability of the grid. Active EV charging management involves remotely controlled EV charging that responds to changes in the tariff and power demand [27]. EV charging sessions can start, stop, and charging levels can be increased or decreased automatically. Smart chargers with unique capabilities are needed to implement active charging management.

2.6 Total Cost of Ownership in Ghana

The total cost of ownership (TCO) tool helps to determine the economic disposition towards the different types of powertrains. The TCO model was developed in this study using Ghana's prevailing interest rates, depreciation, inflation, initial cost, cost of fuel/charging, maintenance cost, insurance costs, and cost of importation. The analysis was made based on time-to-cost parity with internal combustion engine vehicles (ICEV) for saloon cars, light trucks, and heavy-duty vehicles.

2.6.1 Saloon Vehicles

In Figure 10, data is given for four saloon vehicles namely the Hyundai Kona Electric, Hyundai Kona ICE, Dongfeng E70 electric, and Toyota Vitz. The 5-year TCO model at varying interest rates indicates that the Toyota Vitz with a cost per mile of $0.475 is the cheapest to own. The Kona Electric cost per mile exceeds Kona ICE by 33% while the E70 electric cost per mile exceeds Vitz ICE by 44%. This is first attributed to the low initial price of Vitz at $8,000 compared to E70 ($21,000) and Kona Electric ($37,390). At a cost per mile of $0.685, the Chinese model Dongfeng E70 electric was the cheapest BEV to own in Ghana. The Kona Electric had a cost per mile of $1,141. The Chinese BEVs provide the biggest prospects for the BEV to reach cost parity with ICEV in Ghana.

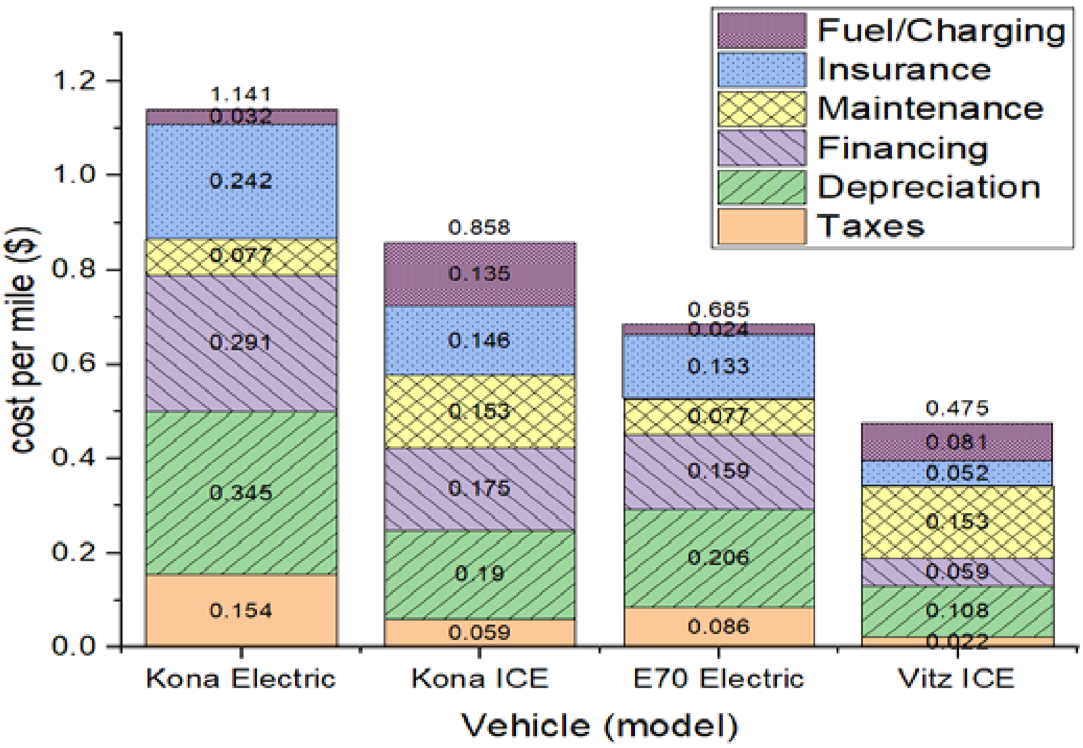

Figure 10: Relative cost per mile of compact BEVs in Ghana assuming a loan interest rate

In Figure 11, the cost per mile is shown for a situation where the buyer obtains the vehicle without a loan. This removes the financial cost as a result of the compound interest. The cost per mile of the E70 Electric exceeds that of the Vitz by only 14% while the Hyundai Kona electric exceeds Kona ICE by 16%. The cost of operating the Vitz in terms of fuel and maintenance was $0.234/mile compared to $0.101/mile for the E70. Thus, the cost of operating the ICEV was 2.3 times more than the BEV. Fueling the ICEV will cost more than five times that of charging the electric vehicle for the same journey. Assuming an annual average travel distance of 24,000 km, it will cost $480 to charge the Hyundai Kona Electric compared to $2,535 for the Hyundai Kona ICEV. The difference in cost of operation further widens whenever there is an increase in fuel cost which is ideal for BEV owners.

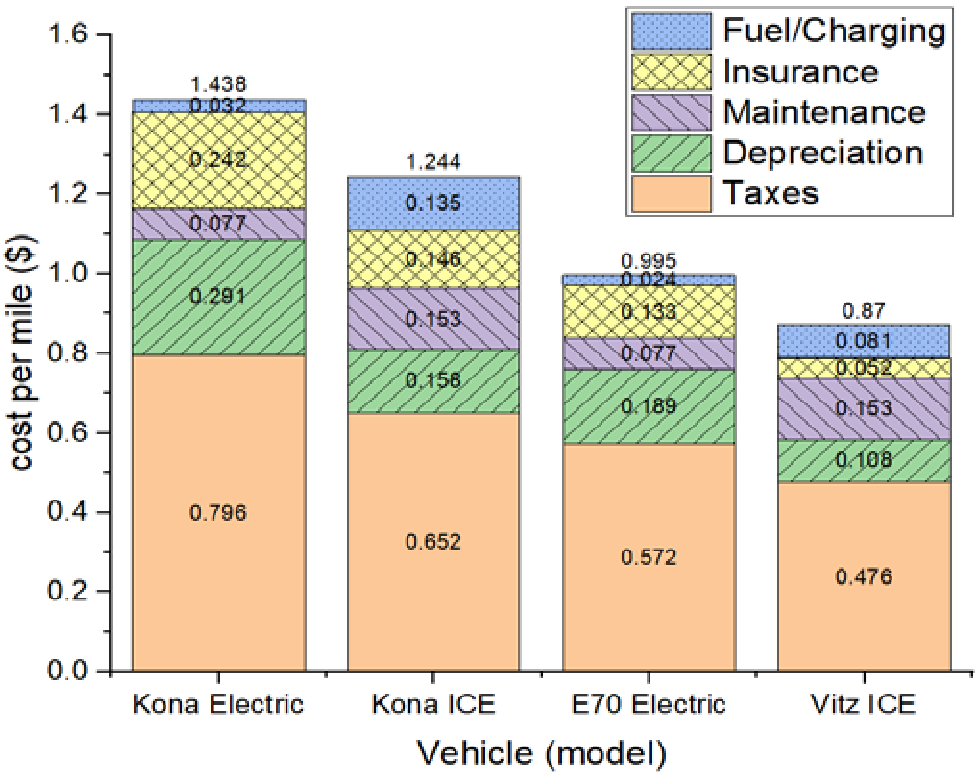

Figure 11: Relative cost per mile of compact BEVs in Ghana without borrowing costs

Figure 12 shows the years to achieve cost parity for the two BEVs compared with the ICEVs. It takes 14 years for the E70 electric to reach cost parity with the Vitz while it takes 16 years for the Kona Electric to reach cost parity with the Kona ICE. This is further reduced to 12 years without borrowing costs as shown in Figure 13. Depreciation, financing cost, insurance cost, and import taxes are the biggest challenges to BEVs reaching cost parity with ICEVs. Together these factors contributed to 85% of the cost of E70 Electric compared to 50% for the Vitz ICE. Figure 14 shows that without borrowing costs, the highest burden in calculating the TCO of an EV owner is the taxes. Given that taxes are a major burden, removing taxes on EVs would reduce the number of years to reach cost parity hence encouraging a deeper penetration of EVs.

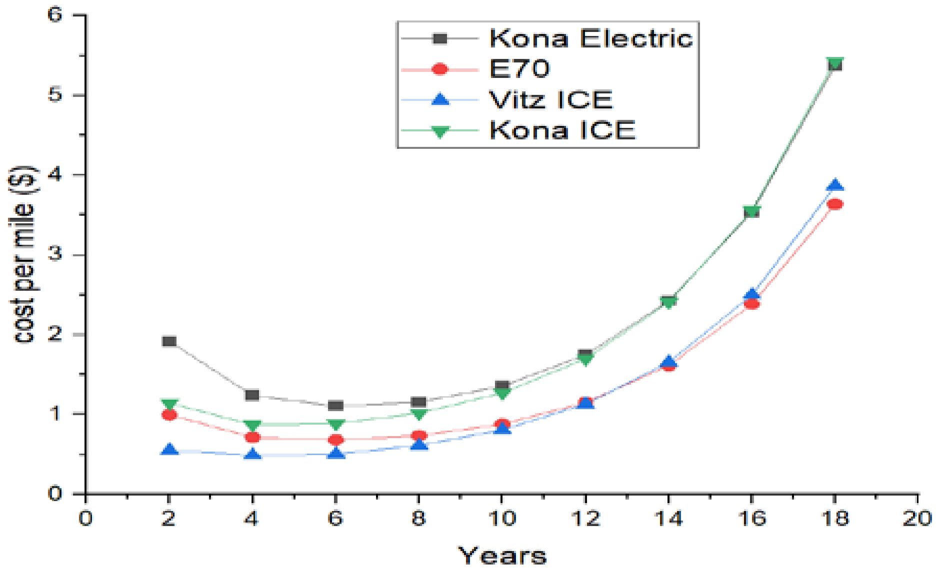

Figure 12: Years to cost parity of compact BEVs in Ghana at borrowing interest rates

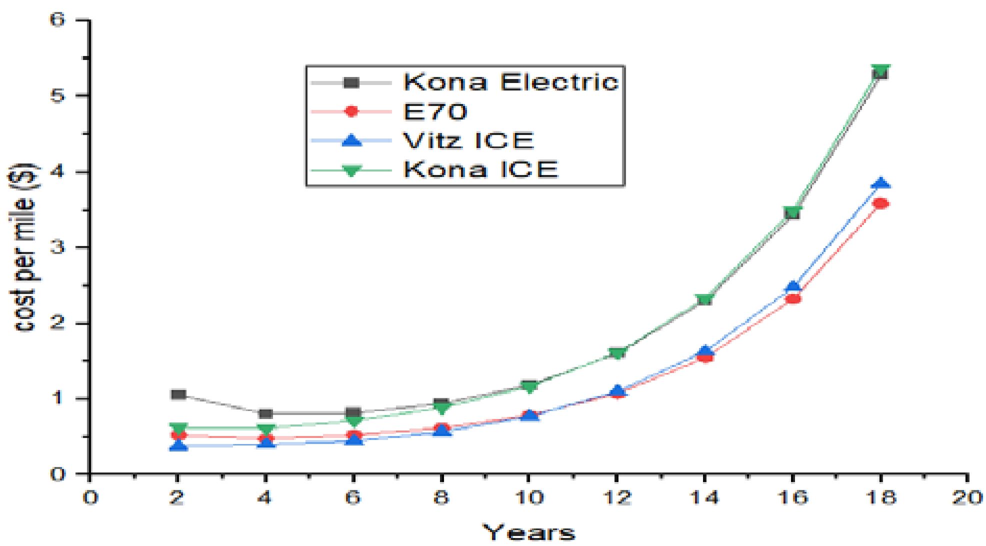

Figure 13: Years to cost parity of compact BEVs in Ghana without borrowing costs

In Figure 13, the years-to-cost parity of BEVs was investigated at different interest rates and zero import tariffs instead of the prevalent 20%. The GRA currently imposes a tariff of 20% on all-electric vehicles imported while other ICEVs attract 5 to 20% depending on the engine capacity. At a 0% import tariff and the prevailing interest rate, it takes Kona Electric 14 years (instead of 16 years) to reach cost parity with the ICEV.

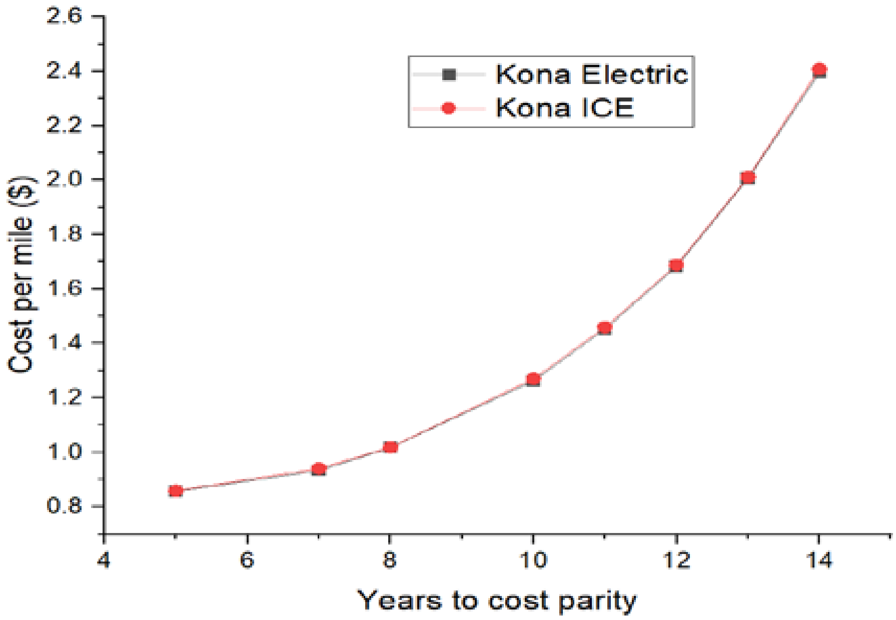

Figure 14: Years to cost parity of compact BEVs in Ghana with zero-rated import tax at different borrowing interest rates

A reduction of the interest rate to 10%, enabled Kona Electric to reach cost parity after only 5 years. However, waiving import tariffs for saloon cars will cost the government close to $9,000 per vehicle. This amount could be paid off through charging costs in less than 3 years considering electricity tariff increase adjustments of 5% a year.

In Figure 15, the model shows that without borrowing costs and at zero import tariff, the years-to-cost-parity will be reached sooner by the 10^{th} year for both the Kona Electric and the E70 Electric.

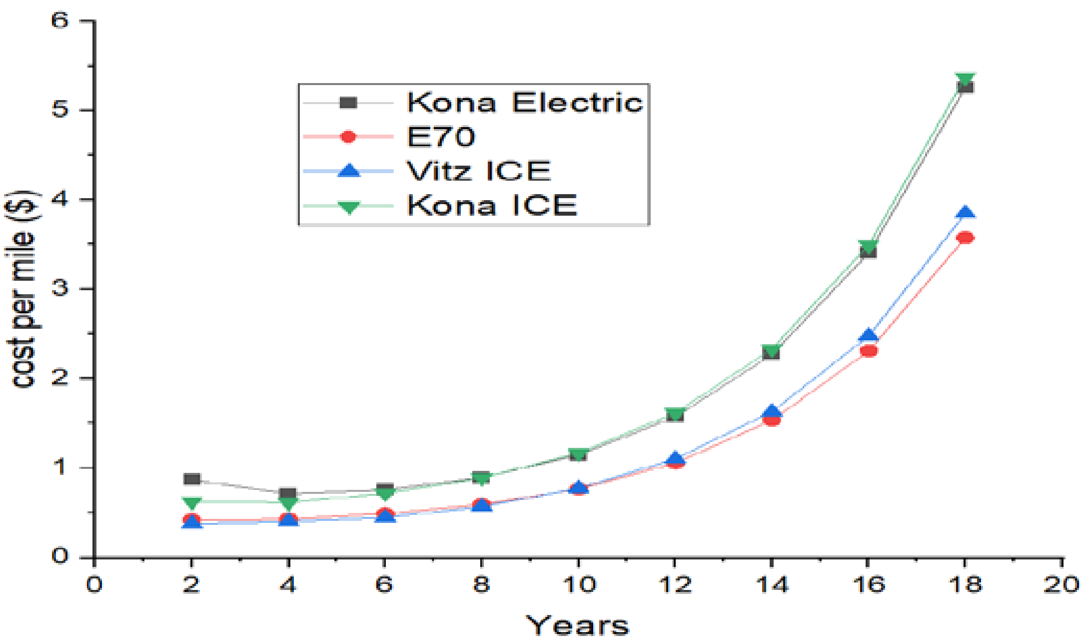

Figure 15: Years-to-cost parity of compact BEVs in Ghana with zero-rated import tax and without borrowing cost

2.6.2 Medium-Duty Vehicle (Bus)

The TCO for the Ford e-transit bus and Ford transit bus ICE is presented in Figure 16. The electric bus TCO exceeds that of the ICE by 9% within the first 5 years. The amount is reduced further to 0.6% for no borrowing cost as shown in Figure 17. The years-to-cost parity is 10 years for the electric bus as shown in Figure 18 but cost parity is reached by the sixth year with no borrowing costs. At zero import tariff, the years-to-cost parity reduces further to 6 years. At a borrowing interest rate of 10% to 20%, it is already cheaper to own an electric bus compared to an ICE for any period as shown in Figure 19. Figure 20 proves that once the import tariff is reduced from 10% to 0% cost-parity will be reached for the Ford e-Transit provided the purchase is done without borrowing at interest.

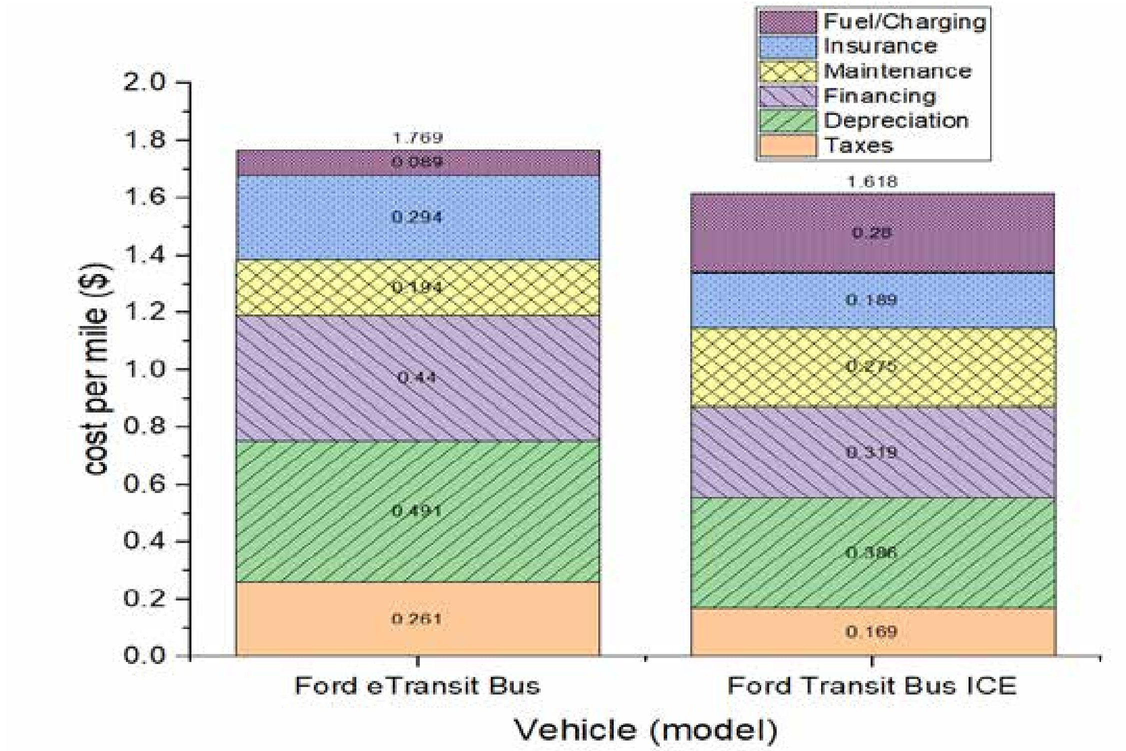

Figure 16: Relative cost per mile of the Ford e-transit bus in Ghana with borrowing cost

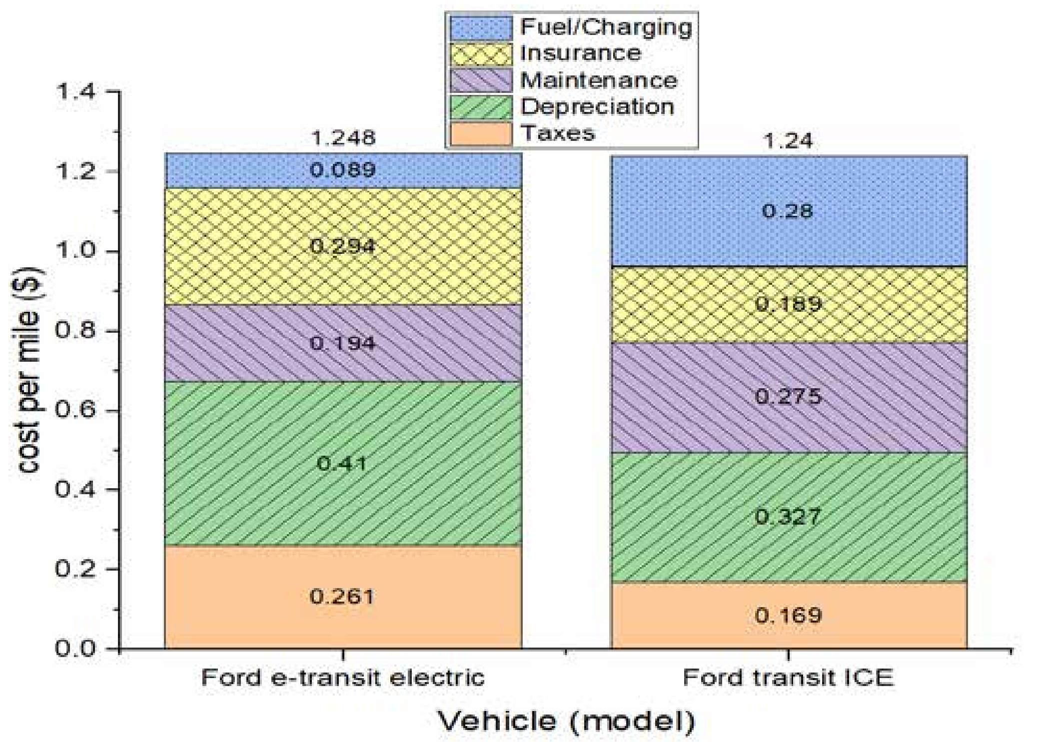

Figure 17: Relative cost per mile of the Ford e-transit bus in Ghana with no borrowing cost

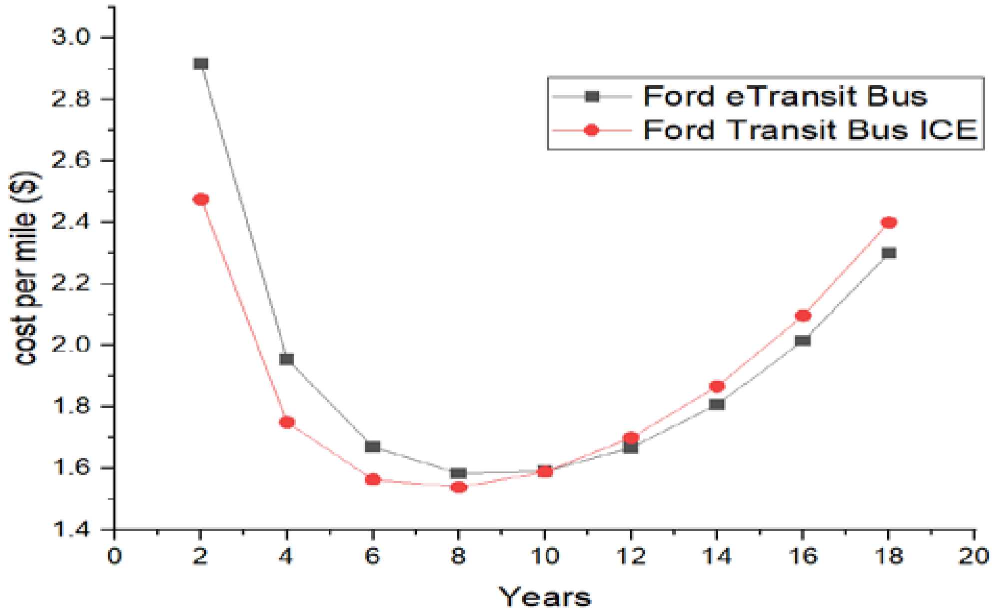

Figure 18: Years to cost parity of the Ford e-transit in Ghana

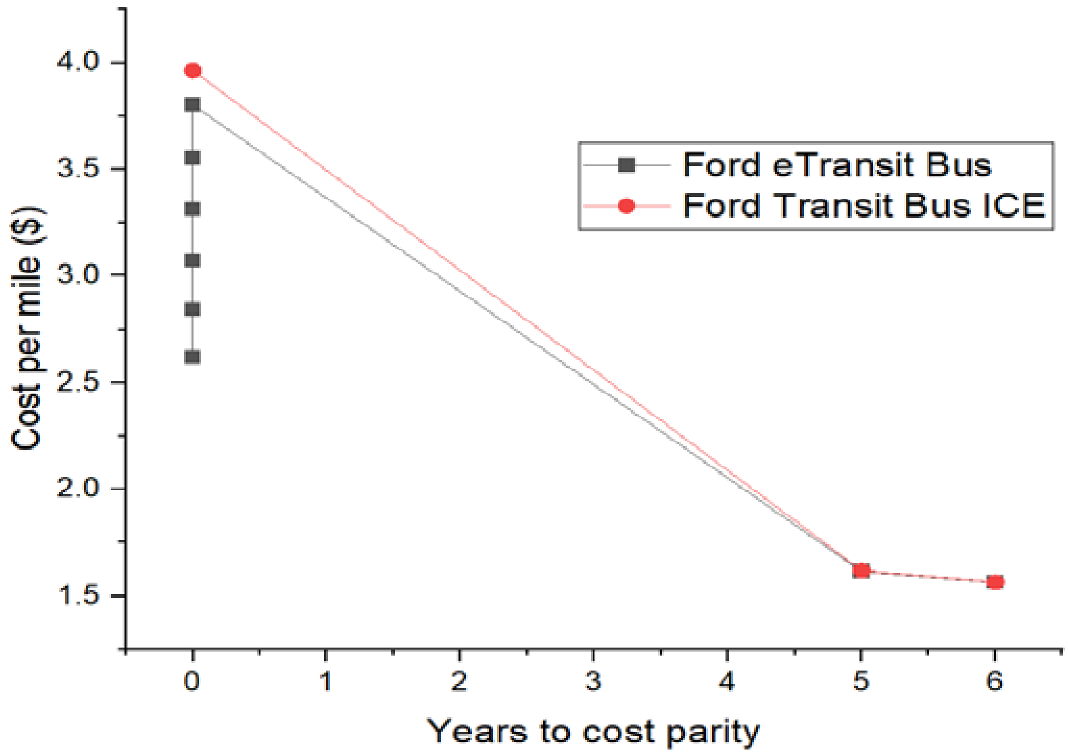

Figure 19: Years to cost parity of the Ford e-transit in Ghana with zero-rated import tax

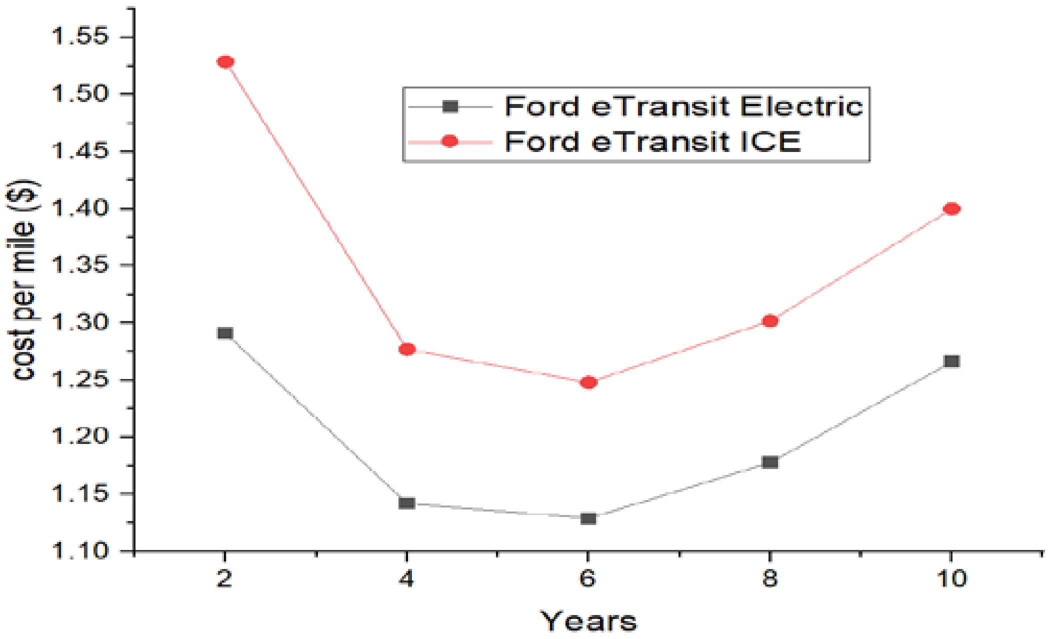

Figure 20: Electric bus reaches cost parity with ICE if the import tariff is zero-rated with no borrowing costs

2.6.3 Two-Wheelers

Figure 21 compares the cost per mile of an electric two-wheeler (e-2W) such as Ather 450+ and a petrol-fueled two-wheeler (petrol-2W) such as TVS Jupiter over five years. In the first year, the cost per mile of the e-2W was $0.7 compared to the petrol-2W of $0.5. Cost parity was reached for the e-2W after the second year of ownership. In the third year, the cost per mile of the e-2W was reduced to $0.24 but that of the petrol-2W was reduced to $0.3. The cost per mile of the petrol-2W is thus 25% higher than the e-2W in the third year which further increased to 68% after the fifth year.

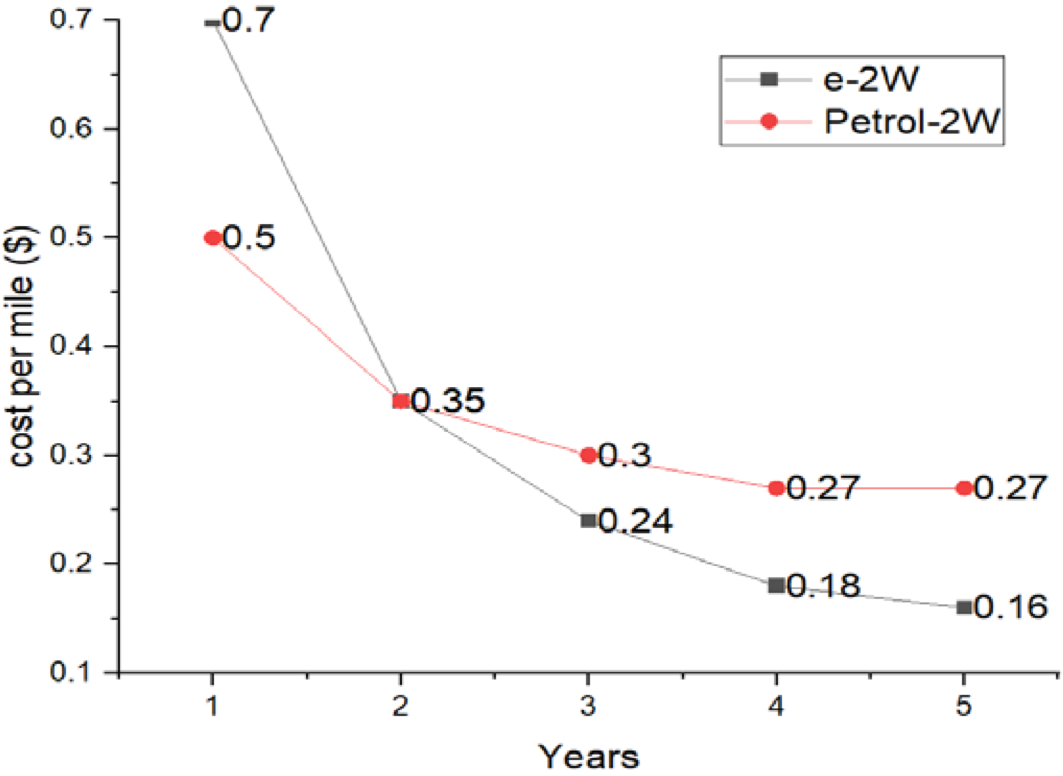

Figure 21: Cost per mile of e-2W and Petrol -2 W

2.6.4 Three-Wheelers

Figure 22 compares the cost per mile of an electric three-wheeler (e-3W), petrol-fueled three-wheeler (petrol-3W) and diesel-fueled three-wheeler (diesel-3W) over five years. Right from the onset, the cost per mile of the e-3W was lower than any of the other alternatives. In year 1, the cost per mile of the e-3W was $0.205 which is less than half that of diesel-3W ($0.457/mile) and petrol-3W ($0.466/mile). However, by the fifth year, the diesel and petrol alternatives were at least 470% more expensive to own compared to the e-3W. Lower operating costs coupled with smaller battery sizes leading to lower battery replacement costs give the e-2&3W a greater advantage over the full-size BEVs. Higher fuel prices compared to the lower cost of charging the e-2&3W is the major advantage over the petrol and diesel 2&3W.

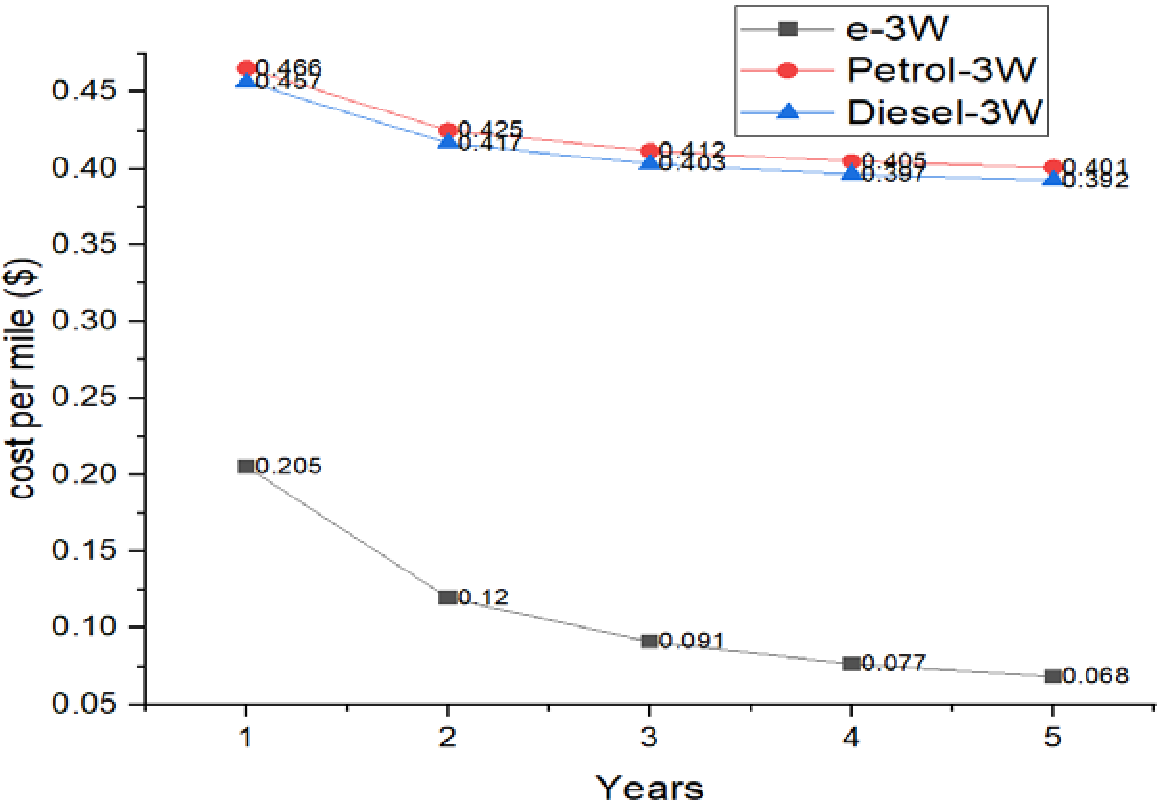

Figure 22: Cost per mile of e-3W, Petrol -3 W and Diesel-3W

3. Emission Reduction Potential of EVs in Ghana

3.1 Fuel Reduction Potential

Figure 23 shows the gallons of fuel that will be avoided annually if electric vehicles replaced similar conventional vehicles. Replacing a single compact ICEV such as a Hyundai gasoline vehicle with a compact BEV such as Hyundai Kona Electric will offset 516 gallons of gasoline a year. The Hyundai Ionic hybrid is capable of saving 86 gallons of gasoline fuel a year. A light-duty electric truck such as a Ford F-150 Lightning will avoid 780 gallons a year compared to the Ford-F150 gasoline pickup. About 1000 gallons of fuel could be avoided every year if a single fuel-based vehicle such as the Ford Transit passenger van is replaced by Ford e-Transit passenger van. Higher-capacity electric vehicles have the highest potential to avoid the use of fuel compared to similar conventional vehicles.

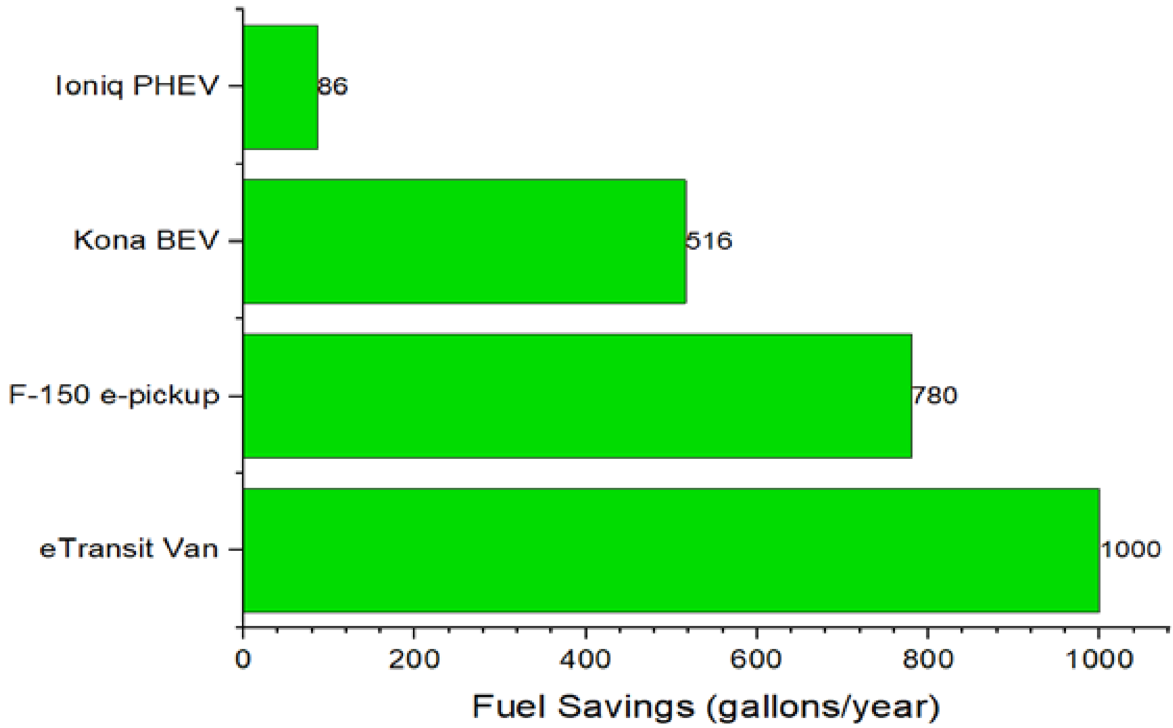

Figure 23: Annual fuel savings of various electric vehicles in Ghana

3.2 Carbon Dioxide Reduction Potential

Greenhouse gases are chemical species that pose a long-term threat to human health by absorbing and trapping the thermal infrared radiation that causes global warming. Carbon dioxide (CO_2) accounts for the vast majority of greenhouse gas emissions on Earth [28]. One of the major occurrences of CO_2 is from fuel combustion in an engine since it is a major product of complete combustion. The emission reduction potential for a transition to electric vehicles is shown in Table 6. Compact BEVs in Ghana have the potential to save 161 g/km of CO_2 representing a 70% of compact ICEV emissions. Electric pick-up trucks have the potential to save 226 g/km while electric vans could save 280g/km. Ghana's registered light and heavy-duty vehicles (excluding motorcycles and tricycles) reached 1,817,302 units in 2019. Replacing 100% of these vehicles with BEV will save at least 3MtCO_2e per annum assuming an annual vehicle trip of 10,000 km.

Ghana commits to implementing unconditional actions that would reduce emissions by 24.6 MtCO_2e by 2030 [8], about 12% of this reduction could be achieved through vehicle electrification.

3.3 Other Vehicle Emissions Reduction Potential

Other vehicle emissions such as nitrogen (NOx), sulfur oxides (SO_x), Particulate Matter (PM_{10} and $PM_{2.5}$), and volatile organic compounds (VOC) are equally detrimental to human health. Nitrogen oxides are the main constituents of photochemical smog and are therefore, responsible for many lung diseases. Sulfur oxide besides being responsible for the formation of acid rain is a strong corrosive oxidizing agent which can damage lung tissue. Compact BEVs have an emission reduction potential of 83% for NO_x, 31% for SO_x, 53% for PM_{10}, 47% for $PM_{2.5}$, and 99% for VOC. This is confirmed by the World Health Organization that air quality guidelines could potentially prevent 1790 deaths annually in the Greater Accra region [5]. This corresponds to an estimated economic burden of approximately US$ 247 million for the city.

Table 6: Emission reduction potential of EV

	Emission Reduction Potential					
	CO_2 (g/km)	NO_x (mg/km)	SO_x (mg/km)	PM_{10} (mg/km)	$PM_{2.5}$ (mg/km)	VOC (mg/km)
Compact BEV	161	132	17	6.2	4	150
Light-duty truck BEV	226	194	18	8.2	5.2	224
Medium-duty BEV	280	344	27	1	2	60
PHEV	131	113	16	5.5	3.5	130

4. Baseline Survey

4.1 EV Ownership and Usage

Out of the total sample size of 14 respondents using PEVs, the data indicates that 57% of respondents drive BEVs, 29% drive HEVs, and 14% drive PHEVS. 71.4% of the vehicles were imported brand-new, 14.3% were imported used, 7.1% were purchased from a local Ghanaian dealer, and 7.1% were obtained from local Ghanaian used-vehicle dealers.

The sample sizes are relatively small for EVs due to the unavailability of data on registered EV owners and data on ownership by categories from DVLA. The authority has started work on compiling the data from its system to be made available to the public for future studies and reference. About 50% of Ghanaians who own EVs charge their vehicles at home, 17% use public charging stations, and 33% use a combination of home and public charging. These charging methods are sufficient for 46% to travel between 1km and 50 km per day on errands, 38% to travel between 51km and 100km, 8% to go between 101km and 150km, and 8% to go between 301km and 400km. About 38% of the respondents travel out of town at least once every week, 8% do so at least once per month and another 8% travel out of town once every other month. However, 46% of the respondents are not frequent travelers. One of the most often reported reasons for switching to an electric vehicle among respondents is the desire to save money (Figure 24). 64% of EV drivers state that they drive an EV to save money on fuel. This advantage is closely followed by the driving experience and technology of electric vehicles (58%). Additionally, driving an electric vehicle is a pleasant and silent experience for some (23 %). The percentage of EV drivers that choose to drive Electric-made vehicles to improve the environment is also noteworthy (43%).

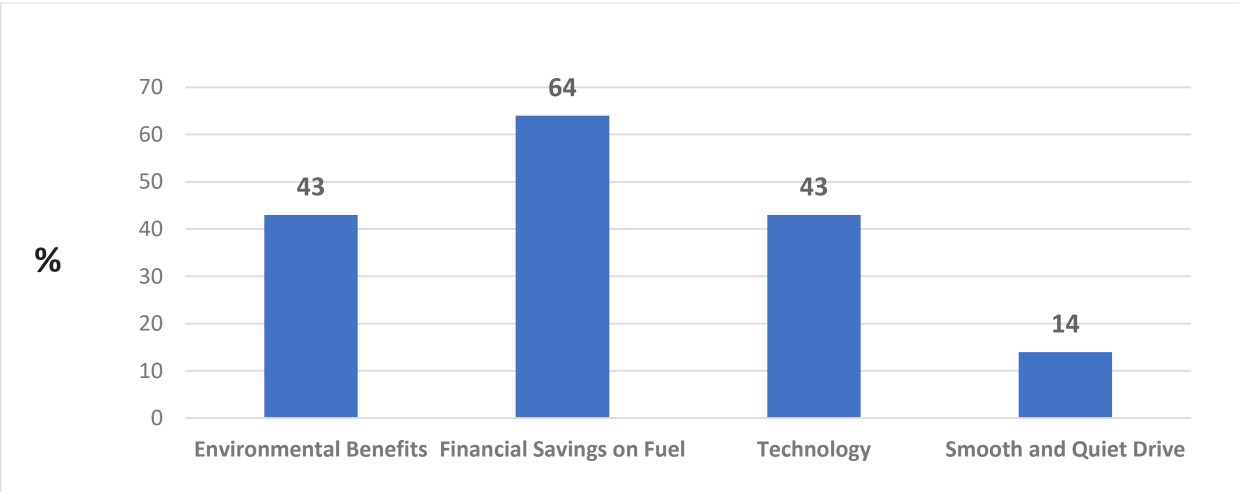

Figure 24: Driving factors among EV users

4.2 EV Users' Perception About Future Acquisitions

The sampled EV drivers can be considered to be very enthusiastic about their switch to EVs. From the captured data, almost all EV users (100 percent) believe that their next car will be an electric vehicle as well. None would switch back to a conventional (fossil fuel-powered) car.

The experience of driving an EV plays a critical role in future vehicle acquisition choices. According to the captured data, there seems to be a slight shift from PHEVs and HEVs towards BEVs among Ghanaian EV users. As depicted by Figure 25, 69% of the EV users will choose BEVs, 23% will choose HEVs and 8% will prefer PHEVs in the future.

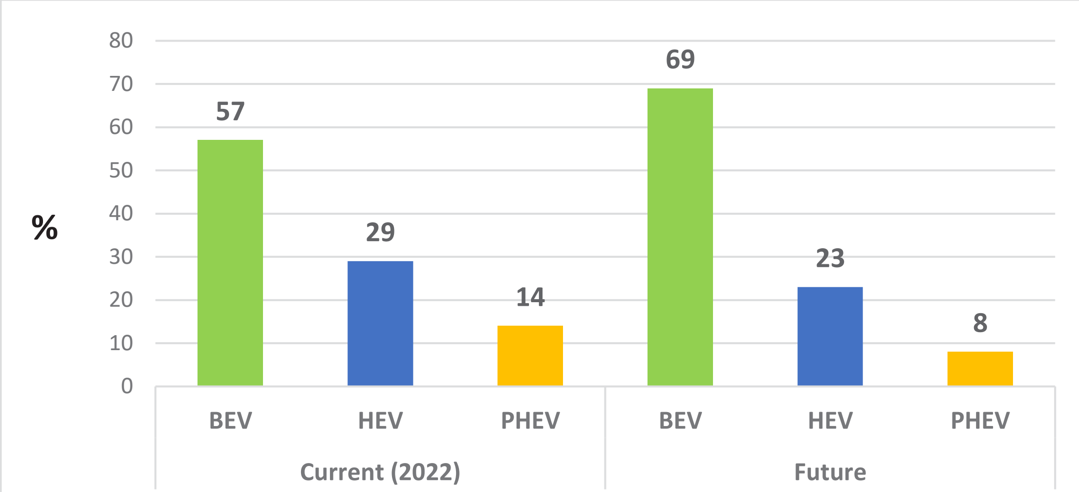

Figure 25: Future EV Types vs. Current EV Types among EV users

The driving forces influencing future EV category choices among EV users include the cost of maintenance and repairs (62%), low running cost (54%), purchasing price (46%), and reliability (38%). 31% of EV users indicated range as being another key factor that will influence a preferred EV category in the future. Factors influencing future EV category choices among EV users are displayed in Figure 26.

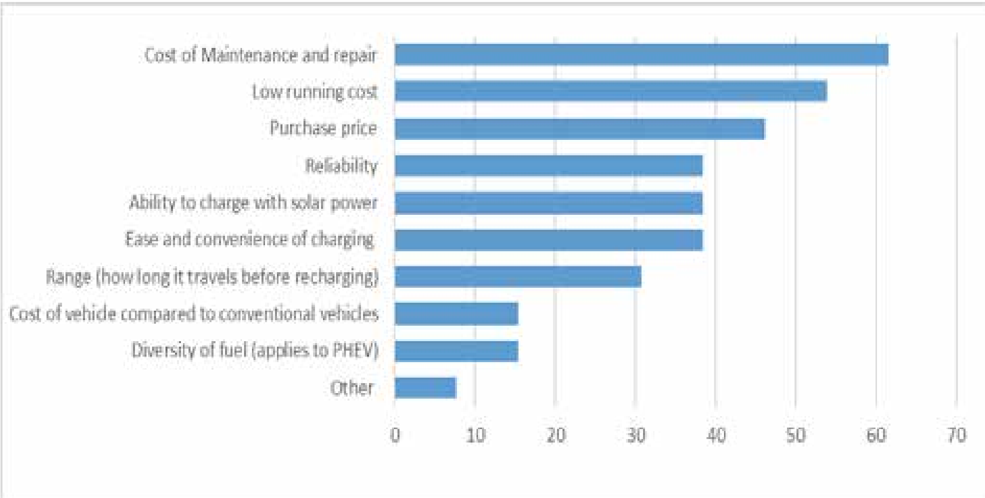

Figure 26: Influential Factors on Future EV Purchase Choices among EV Users

Regarding critical factors that will influence EV users' future automobile acquisition, 57% of the respondents were concerned about the availability of electric vehicles on the Ghanaian market, 50% listed the availability of maintenance and repair workshops with well-trained mechanics and attendants, 43% of respondents would consider the availability of spare parts on the Ghanaian market, the initial cost of an EV, and the convenience of EV charging, to be significant factors. Figure 27 displays the main factors that will influence the future purchase of automobiles among EV users.

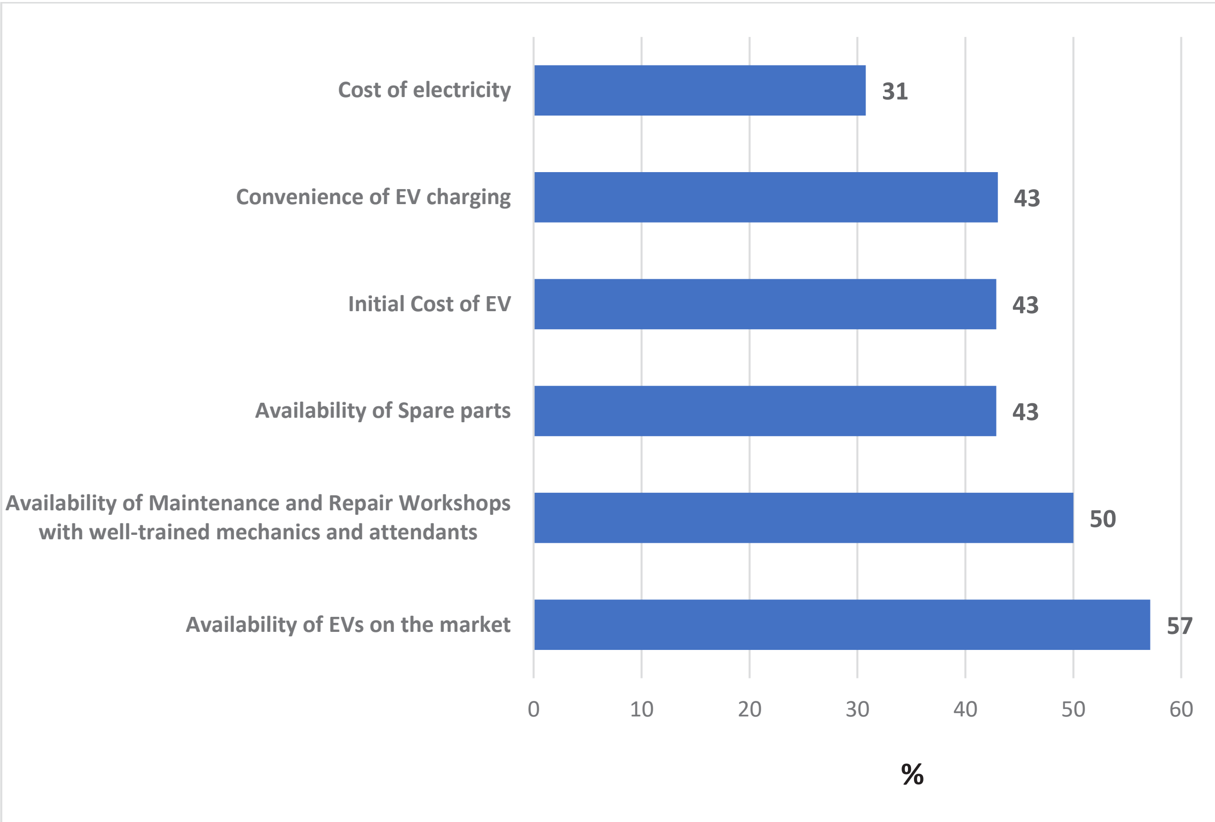

Figure 27: Critical factors influencing EV users' future EV acquisition

4.3 General Perception and Prospects of EV Adoption in Ghana

High benefits offered by EVs, such as environmental benefits, are contingent on consumers' adoption and comprehension of the relevant elements that contribute to the market dissemination of EVs. Among the identified key aspects are economic, technological, political, social, and environmental elements. Some of these issues are driving range anxiety, charging time, price sensitivity, infrastructure (charging stations), personal attributes, government policies, demography, environmental concern and the EV market.

To get an insight into how the Ghanaian market perceives the adoption of EVs, a detailed assessment was undertaken as part of the baseline study to identify the potential elements that influence the

adoption of EVs in Ghana. A total of 605 respondents among the general public in eight (8) regional capitals were interviewed on their perception of EVs.

4.4 Demographic Distribution of Consumers

The data collected as depicted in Table 7 shows that out of the sample of 605, 78% were males and 22% were female. In the data analysis, it was observed that a maximum percentage of respondents, which is 38% belonged to the age group of 31–40 years followed by 33% belonging to the age group 21–30 years and 19% in the age group of 41–50. However, 1% and 8.2% were below 20 years and above 50 years respectively. The educational level of the respondents ranged from basic school to postgraduate education level. A predominant share (41%) of the sample had completed an undergraduate level of education and 24% had completed basic to senior high school. 20% were postgraduates, 12% had Certificate/Diploma or HND and 3% had other forms of qualifications. Regarding the occupation status of the respondents, 76% were salaried workers, while 13% were self-employed. Five percent were students, 2% were commercial drivers, an additional 2% were into other businesses and 1% were unemployed. 43% of the sample size did not own a car of their own, however, 44% of these respondents drive cars and hence could be potential buyers of electric vehicles. About 57% of the sample strength were vehicle owners.

Table 7: Demographic distribution of consumers

Demographic Factor		Percentage of Responses (%)	Demographic Factor		Percentage of Responses (%)
Gender	Male	78	Number of Cars Owned	None	43
	Female	22		One or More	57
Age Group	20 and Below	1	Education	Basic to Senior High	24
	21-30	33		Graduate	41
	31-40	38		Post Graduate	20
	41-50	19		Certificate/Diploma/HND	12
	Above 50	8.2		Other	3
Occupation	Student	5	Aware of Evs	Yes	89
	Unemployed	1		No	11
	Salaried Employee	76	Consider Buying an EV over ICE	Yes	86
	Self employed	13		No	14
	Commercial Driver	2			
	Other	2			

4.5 Factors Influencing Consumers' perception of EV adoption

A high proportion (89%) of respondents were aware of the existence of electric vehicles, as revealed by the data analysis. Data showed that consumers that are well-educated and environmentally conscious are more likely to purchase electric vehicles. 61% of respondents had some type of higher education; thus, it is not unexpected that 86% are interested in acquiring an EV over an internal combustion engine vehicle when certain conditions are met.

The factors indicated by the respondents as necessary to adopt an EV over ICE were numerous. However, from the survey results, the top six factors that potential Ghanaian EV owners would consider before choosing an EV over ICE include environmental concerns, availability of spare parts, availability of EVs on the market, availability of maintenance and well-equipped workshops, the initial cost of EVs and financial savings on fuel, in the order of least to most significant factors to be taken into consideration.

Figure 28 shows the key factors that will influence consumers' adoption of an EV over ICE.

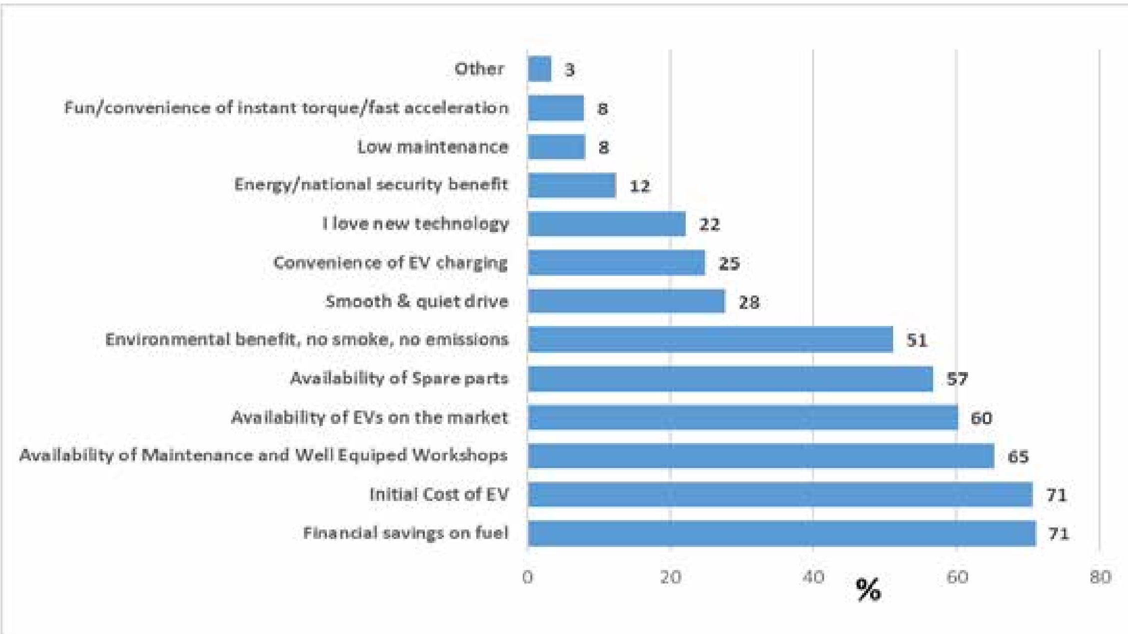

Figure 28: Factors that will influence consumers' adoption of an EV over ICE

4.6 Preferred Types of EVs among Consumers

Out of the 86% of the respondents (520), 38.37% would prefer BEVs, 27.60% will go for PHEV and 26.04% will choose HEV over ICE. This trend indicates that about 53.64% of the respondents will lean toward some form of a hybrid EV over an ICE. Figure 29 shows the share of consumers' preferred EV types.

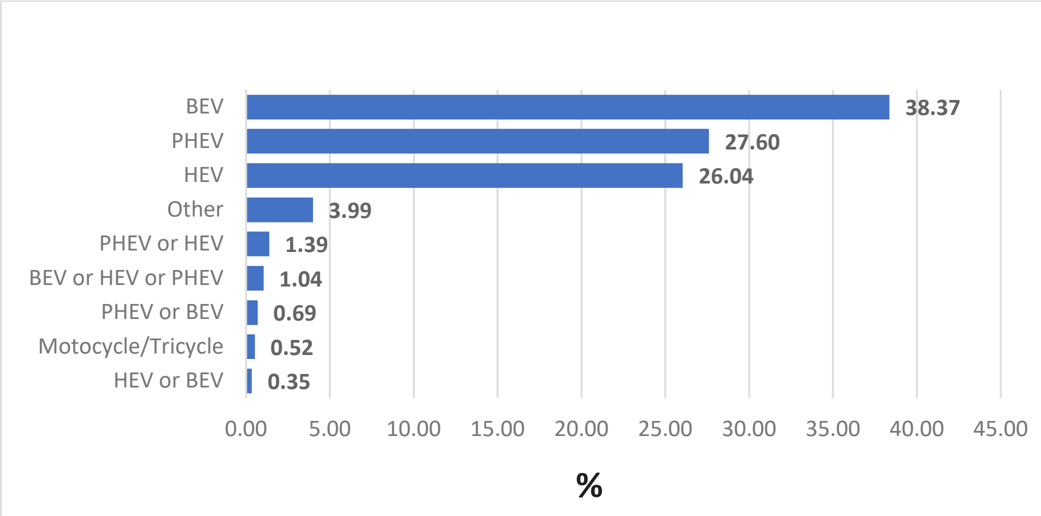

Figure 29: Preferred EV Types Among the respondents

Further, the switching intention of consumers from an ICE to an EV was highlighted by the specific technological and psychological preferences of consumers. Factors influencing preferred types of EVs among consumers include low running cost, purchasing price, reliability, diversity of fuel, and ease and convenience of charging, among others. Figure 30 shows the desired benefits that influence consumers' preferred types of EVs in Ghana.

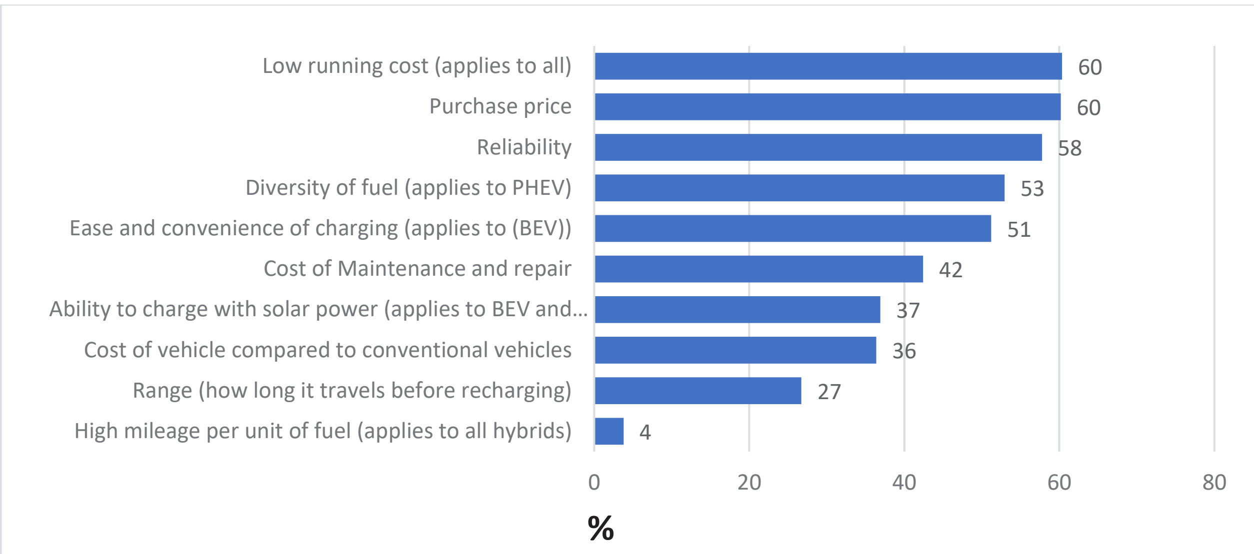

Figure 30: Influential Factors for EVs Types among Consumers

Apart from the desired conditions that influence consumers' preferred type of EVs, the critical factors that influence market penetration of EVs were the cost of electricity (46%) followed by the availability of charging stations (33%) in the country. The issue regarding the availability of reliable EV dealerships was another concern of the consumers (24%). Reliability of the electricity supply (18%) and warranty on the electric vehicles (12%) were the remaining critical issues.

4.7 Preferred Brands of EVs Among Consumers

Survey respondents were quizzed on their preferred brand of EVs they could afford. According to the captured data, the top five (5) preferred brands of EVs among the consumers are the Toyota Prius (33%), Tesla Model 3 (28%), Tesla Model Y (26%), Tesla Model S (24%) and Hyundai Kona EV (17%). An assessment of the amount of money EV users were willing to spend on purchases showed that about 54% of potential EV users were prepared to spend below $20,000 to acquire an EV, 26% were prepared to spend $20,000 to $30,000, 12% were prepared to spend $30,000 to $40,000, and 8% were prepared to spend above $30,000.

4.8 Travel Behavior and Weekly Expenditure on Fuel Among Consumers

The travel preferences and behaviour of a specific population in reaction to various transport options are vital to the adoption of the new options proposed by transport innovators. This can alter the mobility patterns of customers and influence city life. To best satisfy the needs of citizens throughout the implementation of sustainable transportation, it is necessary to comprehend and forecast the behavior of persons under diverse conditions. Based on the captured data, about 87% of the respondents travel not more than 100 km for daily errands and just about 13% make daily errands for more than 100 km as depicted in Figure 31.

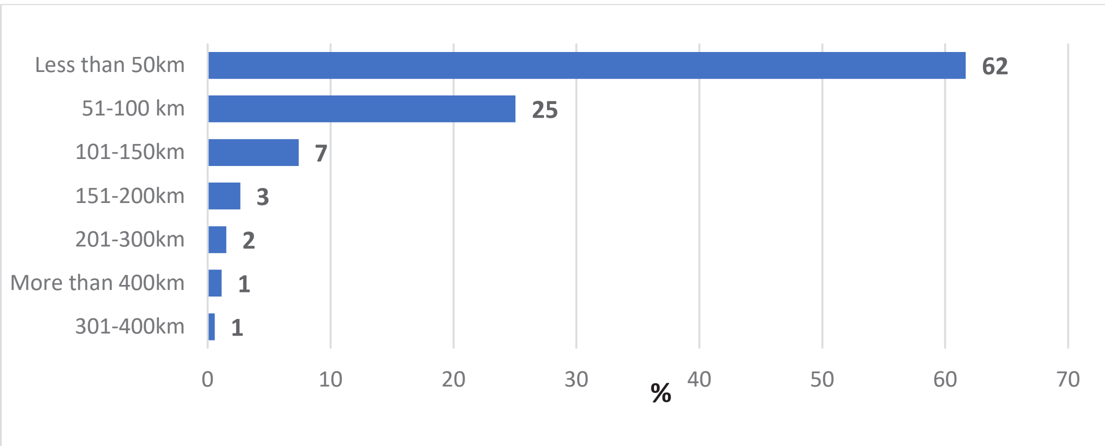

Figure 31: Consumers' Distance Covered for Daily Errands

52.7% of respondents are not frequent out-of-town travelers, whereas 17.1% travel at least once per month. 11.6% of respondents travel once per week, 10.3% travel once per month, 7.9% once every two weeks, and 0.2% once per week. Another 0.2% reported occasional out-of-town travels. According to the survey data, these patterns of travel behaviour among respondents are accompanied by corresponding fuel expenditures. Table 9 displays the average weekly fuel expenditure for consumers who use 4-wheelers and 2–3 wheelers.

Table 8: Consumers' Weekly Fuel Expenses during the survey period. (June -August 2022)

Daily Errands Distance (KM)	4W Vehicles	2–3 W Vehicles
	Average Fuel Use (GHS)	Average Fuel Use (GHS)
Less than 50KM	413	75.25
51–100	551	150
101–150	509	212
151–200	472	
251–300	1,633	
301 or More	738	

4.9 Charging Infrastructure Opportunities

Public charging infrastructure is a prominent policy tool for encouraging the use of electric vehicles (EVs). Locations with more public charging infrastructure have higher rates of EV adoption, and when regions install more public charging stations, EV purchases increase. Many programs aimed at encouraging EV adoption continue to emphasize increased public charging infrastructure and charging speed.

The captured data indicate that the identified potential charging stations investors (used vehicle dealers, vehicle workshops and repairers, Oil Marketing Companies, hotels, restaurants, and service stations and fuel outlets) would consider installing charging stations as part of their core business activities when the demand for EV charging increases. Figure 32 shows the share of each identified potential investor group that is prepared to invest in EV charging infrastructure.

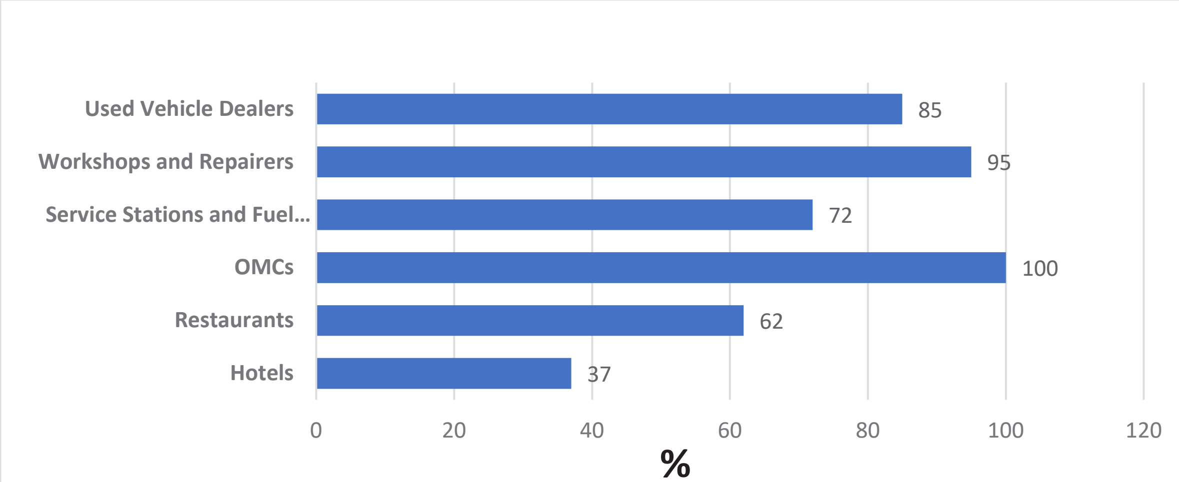

Figure 32: Willingness of Respondents to Invest in Charging Infrastructure

The Energy Commission in the year 2021 invited private participants interested in installing charging stations in the country to submit letters of intent. Available data indicate that over 15 companies have submitted letters of intent to install charging stations. This number further increased after the Commission organized the country's first public charging forum in the first quarter of 2022. Given the number of applications, it is estimated that about 10 more EV charging stations could be installed by the end of the year 2023. Other companies plan to offer DC fast-charging stations that support Combined Charging System (CCS), Chademo, and GB/T while others plan to offer a Pay-as-You-Go EV charging service at residences, workplaces, public places, and along major highway locations.

4.10 EV Maintenance and Repairs

The availability of trained and skilled workers for electric vehicle charging stations and service centres is crucial to the E-mobility adoption agenda and customers' willingness to adopt or switch to EVs. As more customers invest in electric vehicles, more charging stations and service centres will be required, and as a result, more workers will be needed for charging stations and EVs maintenance. Electric motors are significantly easier to maintain than internal combustion engines. Since there is no friction between any moving parts or exchange of liquids and gases, neither lubricant nor exhaust is required. For BEVs, no oil, filter, or exhaust system changes are necessary. Consequently, there are significantly fewer mechanical components to maintain in a battery-powered vehicle than in an internal combustion engine vehicle. HEVs and PHEVs also use the combustion engine less frequently and hence require less maintenance than 100% gasoline or diesel-powered vehicles, but more than BEVs. While it's used less on a hybrid vehicle, the engine still needs to be checked regularly. Hence, maintenance work on the chassis, bodywork, tires, steering, and suspension of all types of EVs is carried out in the normal way, as a check on the air conditioning system, comfort features, and windshield wipers.

However, in many jurisdictions, not all garages or service centres are authorized to carry out maintenance on electric vehicles. Electric vehicles require qualified professionals for checks and any repairs. The high voltages and amperage in the traction system (between 400–700 volts) necessitate a safety procedure so that maintenance can be carried out under the best possible conditions. Even for routine maintenance procedures of EVs in advanced countries, it is strongly recommended that a certified mechanic services an EV. The law requires that these mechanics be certified to work on electrical systems and the qualification must be renewed annually. In this context, one of the most important questions the baseline survey sought to answer was whether or not Ghana has sufficient qualified mechanics and service centers for the mass adoption of electric vehicles.

According to the survey results, only EV dealerships (3) and charging station operators (2) reported having fully functional service facilities and well-trained technicians to handle EV servicing and maintenance. As shown in Figures 33 and 34, service stations and fuel outlets (150) and vehicle workshops (22) offer ICES-related and general EV maintenance services, respectively. Even though more than 90% of these entities were aware of the gradual penetration of electric vehicles (EVs) in Ghana, only 41% reported having the equipment necessary to diagnose and perform routine maintenance of EVs. On the question of whether these entities were prepared to expand their workshops to include EV maintenance, approximately 87% of respondents indicated their willingness to engage in such an endeavour.

Hence, for the mass adoption of electric vehicles (EVs) in Ghana, well-trained and skilled workers for EV charging stations and service centers would be in high demand. Consequently, there is an urgent need for new and existing mechanics to undergo the requisite training and certification processes necessary to maintain and service electric vehicles and charging stations.

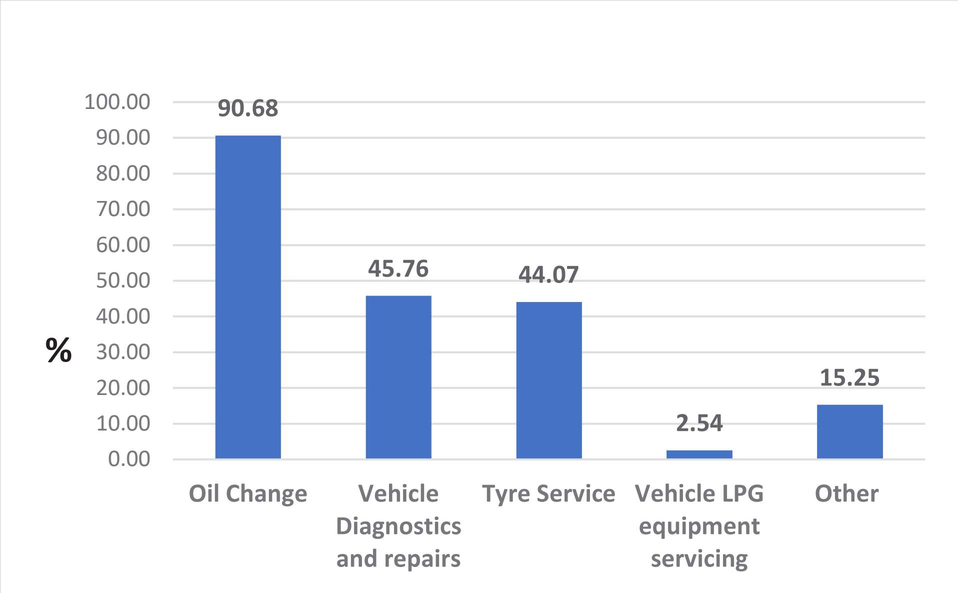

Figure 33: EV maintenance and servicing provided by fuel service stations

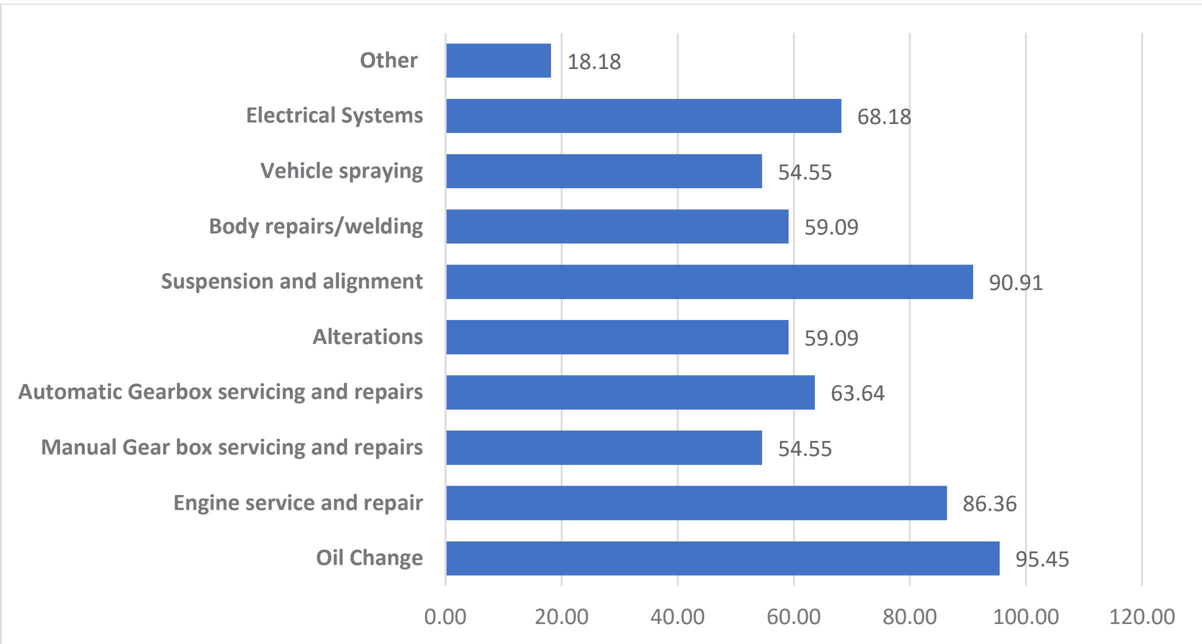

Figure 34: EV maintenance and servicing provided by vehicle workshops and repairers

4.11 EV Inspection and Testing Centers

Regular and periodic vehicle inspections are critical in promoting vehicle safety and reliability, which includes annual checks of the vehicle's safety, roadworthiness, and exhaust emissions. The assessment covers essential components of the vehicle's structure, lighting, body condition, braking and wheel systems amongst others. Due to fewer moving parts, EVs are more reliable than conventional vehicles with internal combustion engines (ICE). However, the absence of these issues creates the false impression that electric vehicles do not require periodic inspections.

Electric vehicles, according to all manufacturers, require routine inspections to ensure safety and reliability. The evaluation also includes important components such as the vehicle's structure, lighting, body condition, braking, and wheel systems. Furthermore, the charging inlet, traction batteries, and power cable systems of electric vehicles must be inspected regularly.

In Ghana, the DVLA is responsible for the development of regulations and assessment criteria for all types of vehicles to ascertain their safety and roadworthiness. The DVLA had no regulations for EV-specific parameters at the time of this baseline study. The representatives of all the 16 vehicle inspection and testing centres surveyed during the baseline survey indicated that they are aware of the market penetration of electric vehicles in Ghana. These facilities inspect and test vehicles by the DVLA's guidelines and inspection criteria. This guideline covers general testing parameters for all types of automobiles, including vehicle structure, lighting, body condition, braking, wheel systems, suspension, emission, and many others. The survey found that all (100%) vehicle inspection and testing facilities were open to expanding their services to include EV-specific parameters assessment once DVLA guidelines were released.

At the time of the baseline study, there were 32 testing centres across the country with 100% being concentrated in the southern and middle belts. There were no testing centres available in the northern belt. The use of EVs and the ability and willingness of the centres to test is premised on the availability of testing centres across the country which is hindered by the uneven distribution of testing centres, especially in the northern sectors.

4.12 Insurance Companies’ Perception About EVs

Numerous factors affect the cost of auto insurance, such as the make and model of the vehicle, the country, and the owner's driving habits. The insurance provider and the amount of coverage selected by the vehicle owner are also significant factors. When insuring electric vehicles, insurers must consider the research and history of electric vehicles, as well as their potential risks and expenses.

Obtaining insurance for EVs essentially boils down to the cost of claims for electric vehicles and specific components that are more expensive to repair or replace than their non-electric counterparts. Additionally, depending on the location, it may be difficult to find a mechanic or repair shop equipped to service electric vehicles. This can add to the cost of claims and increase auto insurance premiums. However, a rise in rates is not guaranteed if a prospective user switches to an electric vehicle. For some drivers, the cost of insurance does not differ between an EV and a conventional vehicle.

During the baseline survey, thirteen insurance companies were questioned to determine the market readiness of insuring EVs in Ghana as well as their perceptions about EVs.

The findings indicate that all the surveyed insurance companies in Ghana were aware of the presence of electric vehicles on the market. However, approximately 31% do not provide comprehensive coverage for electric vehicle owners, and 15% do not insure EVs at all. Third-party insurance coverage for electric vehicle owners is offered by approximately 67% of insurance providers, while approximately 69% offer comprehensive insurance coverage. On the types of EVs that are insured in Ghana, 70% of the companies insure hybrid, 50% insure plug-in-Hybrid and 40% insure BEVs.

Insurance companies that do not currently insure EVs cited the limited availability of EVs in Ghana, the high cost of parts replacement, and the novelty of the technology in the country as some of the relevant reasons. However, approximately 92% of insurance companies were willing to invest in EV charging station insurance.

5. EV Uptake Scenarios

5.1 Do we have enough electricity to power EVs in Ghana?

Electricity generation in the country continues to increase with a current state of excess capacity gap widening over the years (Figure 35). The current installed generation capacity of the country stands at 5,481 MW with a generation mix of hydro and thermal generation fuelled mainly by gas. The generation mix as of 2021 stood at approximately 34.65% from renewables against 65.3% from thermal. (Energy Statistics, 2021). Electricity generation almost doubled from 11,200 GWh in 2011, to 22,051 GWh in 2021, representing an annual average growth rate of 7%. The total electricity generated in 2021 comprised 7,643 GWh from renewable sources and 14,408 GWh from thermal generation.

It is projected that generation will increase to 23,578.57 comprising 7, 578.53 GWh of renewable sources and 16,000.04 GWh from thermal. (GRIDCO, 2022 supply plan). The peak demand for the year 2021 was 3,246.0 MW representing an increase of 5% from 2021. The 2021 peak represents an increase of 156.0 MW over the 2020 peak of 3,089.5 MW (growth of 5.0%). With a projected peak demand of 3,545 MW and a projected dependable generation capacity of 4,618 MW, the country has enough generation to cover our short-term needs.

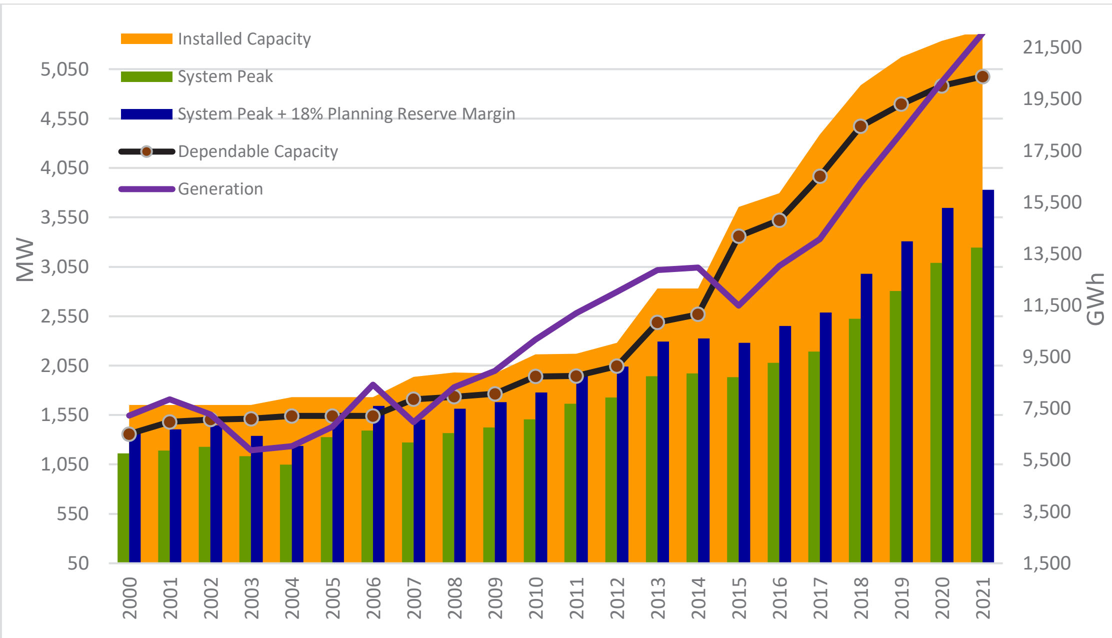

Figure 35: Ghana's energy capacity (source: Energy Commission, National Energy Statistics)

5.1.1 Electricity Access

The energy access rate for the country as of 2022, stood at 88.5%; an increase of about 1.5% from the 2021 national population access rate of 87% (Figure 36). Ghana is committed to achieving a universal access rate by 2025 in line with SDG targets. This will in turn create a conducive environment for EV users across the country. The achievement of the universal access rate will make way for more investment in distribution and transmission networks to solve intermittent power issues. In some parts of the country mostly the Northern areas, there are increased cases of low voltage and intermittent power outages which could pose a challenge to the penetration of EVs.

Figure 36: Ghana's 2021 Population Electricity Access Map @ 87% access rate (Source: 2022 National Energy Statistics)

5.2 Electricity Supply and Demand for EVs

5.2.1 Types of Chargers

The available charger (connectors) is broadly divided into AC and DC chargers. Tables 10 and 11 show the available charger and power output.

Table 9: Available Chargers and their outputs

AC (Slow Charging) Connectors

Charger	Power, kW
IEC 60309	3 - 3.7
Type 2 (IEC 62196) Single Phase	7.4
Type 2 (IEC 62196) three-phase	22 - 50

Table 10: DC (fast charging) connectors

Charger	Power, kW
GB/T Connector	250
CHAdeMO connector	62.5 - 400
CCS1 and CCS2 connector	350

5.2.2 Impact of EVs on the capacity of the national Grid and Electricity consumption

The peak demand on the domestic system over one week in January 2022 is shown in Figure 37.

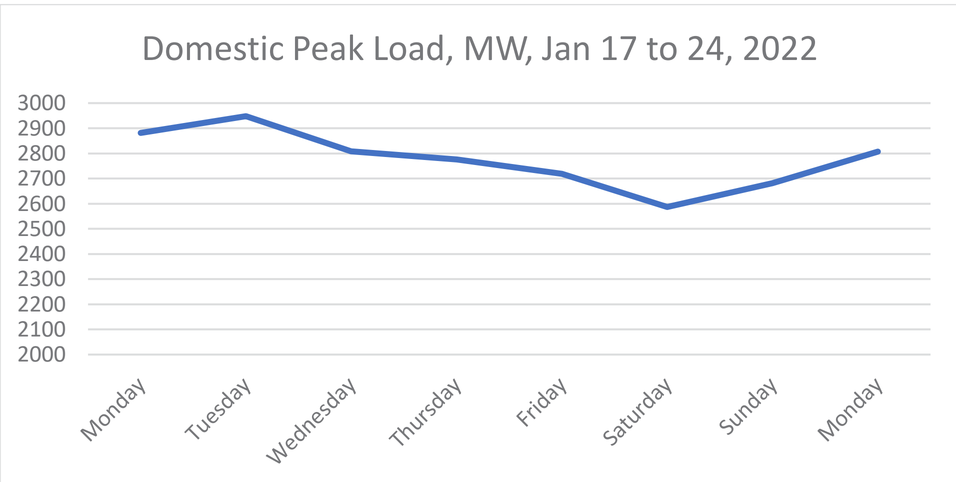

Figure 37: Peak Domestic Demand, MW in January 2022

In January 2022, the peak occurred at the times shown in Table 12

Table 11: Peak loads in Jan 2022

Date	Day of the week	Peak Load, MW	Time
17- Jan	Monday	2,882	7:45 p.m.
18- Jan	Tuesday	2,948	9:02 p.m.
19- Jan	Wednesday	2,808	8:00 p.m.
20- Jan	Thursday	2,776	8:42 p.m.
21- Jan	Friday	2,719	8:15 p.m.
22- Jan	Saturday	2,587	7:30 p.m.
23- Jan	Sunday	2,681	7:45 p.m.
24- Jan	Monday	2,807	8:49 p.m.

From the data, the peak demand periods occur in the evenings, between 7 p.m. and 9:30 p.m. According to data obtained from the DVLA, about 3 million vehicles had been registered in Ghana as of January 2022 and about 130,000 new vehicles are registered every year. If government provides incentives for EVs, and 50,000 new vehicles are BEVs that require charging, then the electricity demand will increase by 350 MW each year assuming that all the EVs would charge at the same time and within the 7 p.m. to 9 p.m. period using the 7 kW connector. With an excess capacity of over 2,000 MW, it will take 5 years to use up the excess due to EV charging alone. However, not all vehicles will charge at the same time and the demand is not expected to increase so quickly. It is rather expected (from the experience from other countries) that 80% of EV users will be charged at home, using the 7.0 kW charger or the 22 kW-three phase connectors.

Depending on incentives provided by the government, EV ownership and usage could vary over the years. Assuming that 50,000 EVs will be registered every year for the next 10 years, there would be 500,000 EVs in the country by the end of 2032. Bigger or faster chargers would be expected to be used in commercial charging stations along highways, car parks, restaurants, etc. The installed capacity of the Ghana grid is 5531 MW (GRIDCO Demand Forecast 2022). The effect of EVs on grid electricity demand based on the above assumptions would be an annual increase of 350 MW. The distance each car in Ghana travels per year is estimated at between 10,000 km and 60,000 km, with the higher figure being for commercial vehicles. An EV will consume between 0.15 kWh and 0.2 kWh per km [13]. So for 10,000 km, the electricity consumed will be between 1,500 kWh and 2,000 kWh on average for private vehicles. For commercial vehicles (taxis and passenger minibuses), that travel 200 km per day, the estimated annual consumption is between 9,000 kWh and 12,000 kWh, based on 300 working days per year. Using the high distances, and with 50,000 vehicles added per year, the electricity consumption shall increase by 600 GWh per year, which is only 2.6% of the 2022 consumption forecast of 23,578.51 GWh.

Table 12: Increase in electricity demand due to EVs

Year	Total Demand due to EV	Increment
Year 1	350	350
Year 2	700	350
Year 3	1150	350
Year 4	1500	350
Year 5	1850	350

In 5 years, the consumption by electric vehicles is expected to hit 3,000 GWh or 12.7% of 2022 forecast consumption (Figure 38).

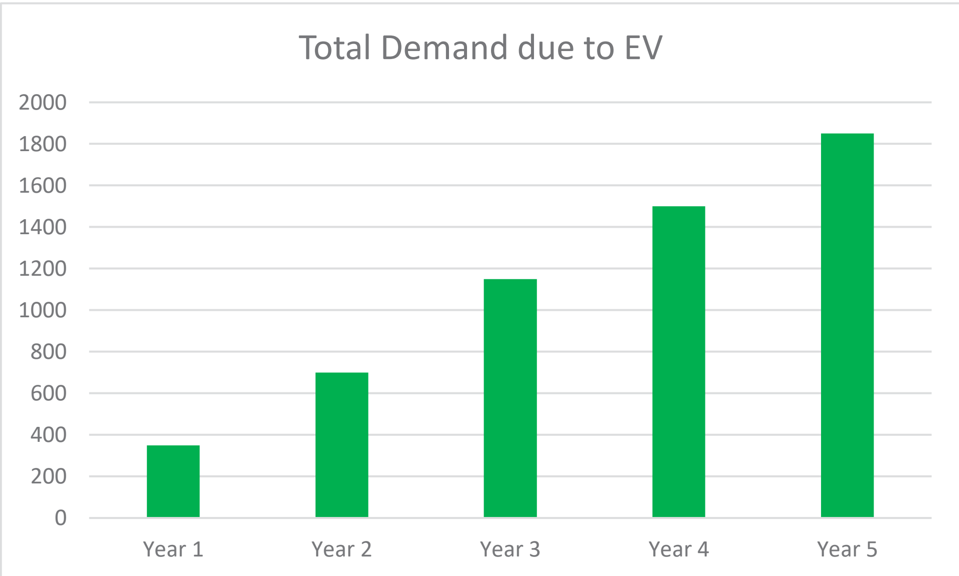

Figure 38: Increase in Demand for Electricity as a result of EVs

This consumption can be accommodated within the current installed capacity but will require more before 2027, which is far enough to accommodate planning. After all, the transition to EV isn't going to happen overnight. With most EVs having a range of at least 320 km (200 miles) the average distance covered by the majority of vehicles in Ghana is 100 km per day. This implies that EVs won't need charging more than twice a week or even once every week or two. The important consideration is to balance the load because if too many EVs are charging at once, there could be a problem with grid stability. To forestall demand increases at the same time it is recommended to:

1. incentivize charging during off-peak periods such as at night, or after 10 p.m., or make peak charging more expensive.
2. provide an option to reduce charging power rates locally, while providing the ability to prioritize where necessary – such as emergency services workers.

The EVs that will be introduced would be new cars, leaving the vast majority of cars on the road fossil fuel powered. A gradual introduction is essential because an overnight change will cause not only disruptions in the grid but is also not economically feasible. Electric vehicles can be introduced and promoted without significant impact on the national grid. There will be no immediate need for additional power plants until after 2027.

6. Barriers to EV adoption in Ghana

6.1 Educational Awareness and Gaps in knowledge and expertise

There is a huge gap in terms of awareness of the benefits of e-vehicles and that is evident in how most Ghanaians react to the idea of owning an EV. Although there is a heavy burden of the initial cost of acquisition, there is the need to educate port authorities, vehicle licensing authorities, etc. on how to handle EVs. First-hand interactions with individuals and companies show a huge awareness gap. Salim (pseudonym) imported a Plug-in Hybrid in May 2019 and had this to say:

"I bought a Mitsubishi Outlander, 2018 PHEV, and when I got to the port, the official seeing two fuel outlets decided to charge me twice the price for import clearance on the vehicle. It took hours of negotiations to come to terms with the official and even then, I paid a higher amount than I would have paid on an ICE of the same make and model." Lydia, a sole proprietor interested in buying an EV called to ask; "How do they register our vehicles at the Vehicles and Licensing Authority? How about the duties? I want to be very sure before I buy my vehicle.

The regional EV baseline survey results revealed a significant awareness gap among respondents. Even though 89% were aware of EVs in general, approximately 27% were unaware of the various types of EVs and their specifications. As a result, approximately 38% of respondents lacked

sufficient information about EVs to make a choice. Some, among those interviewed, kept repeating "I have never heard of electric vehicles" or "I have heard of them on social media but have no idea there are any such vehicles in Ghana." The above first-hand remarks give a sense of confusion among individuals and companies due to the educational and awareness gap in the system. The Energy Commission under the Drive Electric Initiative (DEI-Gh) in September 2021, organized Ghana's first e-mobility conference and exhibition and also organized Ghana's first public charging forum in March 2021 all geared towards awareness creation both for users and charging station operators.

6.2 The Initial Cost of EVs

The perceived high price of EVs and battery replacement is another factor hindering the penetration of EVs. Although their prices have plummeted in the past few years and are even projected to reduce further in the next few years to match those of similar non-electric vehicles given the projected future demand for these vehicles, there is still the perceived high cost which is drawing people away. From an average price of over $75,000 in 2010, prices have dropped to $36,000 for a 2020 Tesla model 3, about $28,000 for a 2022 Toyota Prius Prime Plug-In Hybrid, about $24,000 for a 2022 KIA Niro Hybrid, $27,000 for a 2020 Ford Fusion hybrid, etc. These prices will continue to drop even further as some governments continue to provide or extend fiscal incentives to make EVs more competitive on a cost-of-ownership basis (IEA 2021 Global EV). It, therefore, comes as no surprise that several other renowned studies forecast the fall of EV prices more quickly than originally predicted. However, the lack of fiscal incentives for EVs to buffer purchase prices and the lack of charging infrastructure are contributory factors to low EV sales shares in Ghana. Hopefully, this challenge will become a thing of the past given the locally assembled vehicles and other foreign companies planning on assembling hybrid vehicles in the country.

6.3 Battery Technology

The current lifespan of batteries is also another hindrance to acquiring EVs. People are not motivated by the idea of changing their batteries after 10–12 years. The main components of EVs are the high-voltage (HV) battery and the electric traction motion [13] with the life expectancy of the vehicle being tied to the life expectancy of these components. With further drops in lithium prices and other battery revolutions, the prices of EVs and battery life expectancy will improve, making EVs more attractive. Although EV batteries can be used for 10–20 years either in the vehicle

or for second-life purposes, the Ghanaian market is not active and developed for second-life battery applications.

6.4 Incentives.

The penetration of electric vehicles all around the world has been driven by one or more Government driven incentives mainly due to the high initial cost of these vehicles. EVs in the absence of incentives are not cost-competitive. There are currently no incentives for EV users in Ghana. EV importers pay Customs duties of 20%, irrespective of the size and capacity of the EV, in addition to all the other taxes at the port. Talks have begun between the relevant institutions being led by the Energy Commission to either have monetary incentives or non-monetary ones to help ease the initial cost burden on the EV user. In the United Kingdom, the purchase subsidy covers 25% of the purchase price of EVs irrespective of their CO_2 emissions albeit with an upper limit of £5000. In the US, there is a federal tax credit of up to $7,500. All electric and plug-in hybrid cars purchased in or after 2010 may be eligible for a federal income tax credit of up to $7,500. Given the role of incentives in ensuring the penetration of EVs, the following proposal was laid before the relevant Ministries by the Energy Commission while negotiations are still ongoing.

1. A full exemption on import duties for all BEVs and a 50% tax exemption for PHEVs are to be reviewed in 2030.
2. The following non-monetary incentives to encourage EV users:
    - Free zero-emission DVLA car registration
    - Toll-free charges on the highways
    - Designated parking in public spaces
3. Waiver of duties and Levies on EV Equipment and spares to be reviewed in 2030.

6.5 Charging Infrastructure Deployment

Charging Infrastructure is critical for the successful penetration of electric vehicles in any jurisdiction. It has been observed across many jurisdictions that people prefer charging their vehicles at home in their driveways or garages, however, long-distance journeys and range anxiety among users necessitate the deployment of charging infrastructure across the country. The Energy Commission has been spearheading activities under its Drive Electric Initiative to promote charging infrastructure across the country by working on standards and regulations while encouraging private sector participation. The organization of Ghana’s first public charging forum was to introduce current and potential charging station operators including oil marketing operators in Ghana to the charging market for collaboration, discuss best practices around the world and analyze the business potential of charging station operation and the crucial role of energy in e-mobility.

Today, Ghana can boast of 4 public charging stations, two (2) of which are owned and operated by Porsche, Ghana, one (1) owned and operated by POBAD International in partnership with ECG Ghana, and one (1) recently launched by the TotalEnergies Marketing Company. Over 10 companies have reached out to the Energy Commission to build charging stations at various locations in the country.

6.6 Policy Measures and Action Plan

Table 13: Policy measures and action plan

Standards for charging stations are required to streamline the sector: formalize national charging standards for regular and fast charging in agreement with the industry based on international standards, and adapt local electrical installation norms to safely incorporate EV charging installation requirements.	Energy Commission Ghana Standards Authority	Clear legal framework on EV charging, to open the market for charging infrastructure and facilitate third parties' investment in charging infrastructure.
Prepare new regulations or amend existing regulations to enable vehicle charging from the grid and vehicle-to-grid exchanges, formalize "charging services" as a regulated service to EV drivers to provide a clear legal framework for EV charging.	Energy Commission	Increased effectiveness and interoperability of the charging network.
Formalize a financial incentive mechanism to support businesses involved in charging station installation to deploy an initial minimum fast charging network (interoperable, open standards, and 99% reliable).	Ministry of Finance GIPC	The realization of a minimum fast charging network to support EV adoption.
Formalize the checklist for import, registration, and fitness test for new and reconditioned EVs.	GRA Ministry of Transport DVLA	Assure the safety and quality of vehicles on the road. Assured availability of affordable reconditioned EVs
Implement the international HS code for EV registration at the port	GRA	Assured smooth import processes and data collection enhanced
Recategorize ICE and EV engine and battery capacities to align for tax purposes	GRA, Energy Commission	Streamlined taxes
Separate DVLA registration of PHEV from BEV. Encourage the establishment of vehicle testing centres across the northern belt of the country	DVLA Ministry of Transport	Monitoring EV growth per category to inform policy and decision-making Encourage the even uptake of EVs across the country
Require EV car importers to guarantee the battery for a minimum of 8 years for new or 5 years for used electric vehicles and take back battery for 2nd life use or recycling.	Ministry of Transport Energy Commission EPA, Ghana Association of importers and Garages	Create an environmentally friendly use for batteries that will ensure long-term battery sustainability.

6.6 Policy Measures and Action Plan

Table 13: Policy measures and action plan

Develop a national battery plan to address EV battery pack fates, support a second-life battery market, and ensure battery recycling.	Ministry of Transport EPA Energy Commission	Create an environmentally friendly use for batteries that will ensure long-term battery sustainability.
Request the implementation of a battery tracking system for the traceability of batteries, enabling the identification of owners of discarded batteries	Ministry of Transport Energy Commission EPA	Create an environmentally friendly use for batteries that will ensure long-term battery sustainability.
Classify batteries both from motorbikes and vehicles viable for second-life applications as raw materials and not waste, and classify repurposed batteries as new products	Ministry of Transport Energy Commission EPA"	Create an environmentally friendly use for batteries that will ensure long-term battery sustainability.
Provide 'green' loans for e-taxi (BEV) purchases and commercial fleet owners	Ministry of Finance Financial Institutions Donor organizations	Support EV purchases to reduce the initial upfront cost and drive penetration and increased entrepreneurship
Provide financial EV incentives for buyers to increase penetration	Ministry of Finance Ministry of Energy Energy Commission Ministry of Transport	Support EV purchase to reduce the initial upfront cost and drive penetration
Set up a platform for training on EVs for: i) emergency services (firefighters, police, ambulance, etc.) ii) maintenance (including the ’informal sector) iii) Port officials iv) vehicle licensing officials	Energy Commission Ministry of Transport Academia, International Donors	Ensured road safety for electric vehicles. Reliable maintenance for electric vehicles. Smooth registration and importation processes
Expand platform for training on maintenance of electric vehicles with installation and maintenance of solar EV charging systems	Energy Commission Ministry of Transport DVLA, Ghana Association of importers and Garages	Ensured road safety for electric vehicles. Reliable maintenance of electric vehicles and solar charging

6.6 Policy Measures and Action Plan

Table 13: Policy measures and action plan

Implement a Time of Use tariff (double rate) for EV charging during peak hours.	PURC Distribution utilities	Prevention of additional peak load on the electricity grid.
Make smart chargers the minimum performance standard through legislation	Energy Commission Distribution utilities	Enabled implementation of future smart charging schemes to limit grid impact
Large-scale EV integration grid impact study and long-term strategy development.	Energy Commission GRIDCo Academia International Donors	Insight into the impact of future large-scale EV charging, and development of long-term grid integration strategy
Modify the Ghana building code for residential and office buildings to include mandatory conduits for electrical installation for future EV charging at parking spaces.	Energy Commission Ministry of Works and Housing	Ensured future-proofing of buildings at little cost to the project developer.
Develop a charging allocation map for cities	Ministry of Works and Housing, Land use and Spatial Planning Authority	To ensure well-distributed EV charging across the country
Monitor new charging and battery stations to meet minimum safety and fire test requirements	Energy Commission Ghana Fire Service	To ensure safety of charging stations

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