REVIEW OF ELECTRIC VEHICLE CHARGING & BATTERY SWAPPING INFRASTRUCTURE IN KENYA AND INTERNATIONAL BEST PRACTICES

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATION

A	Amperes
AC	Alternating Current
BEV	Battery Electric Vehicles
BSI	British Standards Institution
BSS	Battery Swapping Station
CCS	Combined Charging System
CHADEMO	CHArge de Move
CPO	Charge Point Operator
CS	Charging Station
DC	Direct Current
DHI	Department of Heavy Industries
DIN	German Institute for Standardisation
EMC	Electromagnetic Compatibility
EN	Europäische Norm
EOI	Expression of Interest
EPRA	Energy Petroleum and Regulatory Authority
ETD	Electro technical Division
EU	European Union
EV	Electric Vehicles
EVCS	Electric Vehicle Charging System
EVSE	Electric Vehicle Supply Equipment
FAME	Faster Adoption and Manufacturing of Hybrid & Electric Vehicles
GB/T	Guobiao Standards
GBP	Great Britain Pound
GHG	Green House Gases
HEV	Hybrid Electric Vehicle
IC-CPD	In Cord – Control and Protection Device
ICE	Internal Combustion Vehicles
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IP	Ingress Protection
ISO	International Organization for Standardization

KEBS	Kenya Bureau of Standards
KPLC	Kenya Power and Lighting Company
KWh	Kilowatt - hour
LDV	Light Duty Vehicle
LPG	Liquid Petroleum Gas
MF-WPT	Magnetic Field – Wireless Power Transfer
MOP	Ministry of Power
MW	Megawatt
NaMATA	Nairobi Metropolitan Area Transport Authority
NCCAP	National Climate Change Action Plan
NEMMP	National Electric Mobility Mission Plan
NSB	National Standards Bodies
NSTDA	National Science and Technology Development Agency
NTSA	National Transport and Safety Authority
OEM	Original Equipment Manufacturer
OPSD	Over Pressure Safety Device
PCS	Public Charging Station
PHEV	Plug In Hybrid Electric Vehicles
PPP	Private and Public Partnerships
PRCD	Portable Residual Current Device
PV	Photovoltaic
PWM	Pulse Width Modulation
RCBO	Residual Current Breaker with Over-Current
RDC - DD	Residual Direct Current – Disconnecting Device
RESS	Rechargeable Energy Storage System
RFID	Radio Frequency Identification
SAE	Society of Automotive Engineers
SC	Sub-Committee
SDoT	State Department of Transport
TC	Technical Committee
TC	Technical Committee
UNEP	United Nations Environmental Program
USA	United States of America
V	Volts
WPT	Wireless Power Transfer

Acknowledgement

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EXECUTIVE SUMMARY

Background

Technology switch, from internal combustion engines to Electric mobility (e-mobility), is viewed as an attractive option for emission reduction in the transport sector for Kenya and the entire world. This intervention offers more than just emission reductions. It provides opportunities in investment, employment, research, and innovation. It is essential for countries to come up with policies, standards, programs, infrastructure and plans to improve uptake of the e-mobility solutions.

> Kenya is at the introductory stage of e-mobility, with the presence of electric vehicles standing at less than 1% of the total number of vehicles in the country. In a bid to enhance emission reduction, the Kenyan Government targets to increase electric vehicles by 5% of the total number of imported cars annually by 2025. This deployment can only be successful if guided by a conducive environment consisting of policies, standards, regulations, government support, fiscal and non-fiscal incentives. Participation of development partners like the United Nations Environment Program (UNEP) is central to this success.

UNEP is implementing a No and Low Emission project aimed at improving air quality and mitigation of climate change effects. Amongst others, electric mobility adoption was identified as one of the key outcomes needed to achieve the objective of the project. UNEP provides support in policy development and strategies to various countries. Kenya is part of the beneficiaries of the support through, among others, development of frameworks for adoption of electric vehicles (EV).

For accelerated deployment of EVs, investment in charging methods need to be addressed. To expedite 4-wheelers e-mobility growth in Kenya, motorist need to be assured of adequate and reliable charging infrastructure. Similarly, for 2 & 3 wheelers, charging infrastructure in the form of battery swapping stations (BSS) should be readily available/ accessible to reduce range anxiety and promote mass adoption of 2 & 3 wheelers. The goal of this study is to promote electric mobility by improving the understanding of the current local status vis-a-vis international best practice of both charging infrastructure and battery swapping. Presented in this report are the results of the study. The report focuses on two, three, and four-wheeler vehicles.

Aim and approach

The aim of this study was to analyse the current status of charging and battery swapping infrastructure in Kenya, and the international best practices of both systems. This aim was achieved through study of existing technologies, standards, and the policy environment in Kenya for charging and battery swapping systems and examination of international best practice for charging and battery swapping. The study analysed different countries such as India, South Africa, Philippines, USA, China, Norway, Netherlands, Rwanda and Thailand, as examples of best practice in both charging and battery swapping.

The experiences from these countries provide Kenya with good reference examples which can be adopted in the country.

Key Findings

Public charging infrastructure in the form of charging stations (CS) and BSS have already been deployed in the country. Future plans to increase the number of both CS and BSS are underway by different electric mobility companies. Presently, there exists no regulations to guide the setting up of the infrastructure. Moreover, there exists no Kenyan standard on either CS or BSS. Investors are presently installing different types of charging plugs, sockets and battery swapping stations. There is need to prevent market chaos, investment risk as well as promote public safety. This can be met through development of standards and policies, which will offer guidance to market players.

China has the largest EV market share in the world at 14% and promotes development of charging networks through standards and providing funding. Local Governments by-laws in China provide for allocation of charging spaces in residential areas and commercial parking spots. USA follows at 4.5%, the second largest EV market. This is attributed to policies that promote market incentives. USA provides significant investments in charging infrastructure in public areas to boost EV's in the country. Netherlands has one of the densest charging networks in the world, at 19.3 charging stations per 100km. Netherlands has successfully deployed charging stations along the entire length of a major highway. Furthermore, the country is promoting interoperability of EV charging infrastructure by the use of a single card for payment (e-roaming). This is a major step towards eliminating payment hurdles and further boosting EV uptake.

Developing countries have also made major strides in electric mobility. The Philippine Government has developed policies on the use of EVs and the establishment of EVCS. As Kenya shares similar dynamics to Philippines, such policies can be replicated in Kenya to guide the industry. Similarly, India has one of the largest electric 2&3 wheeler markets. The Indian Government has successfully allocated special tariffs for the supply of electricity for public charging stations. In Africa, South Africa has the largest number of vehicle manufacturing companies. The country is advancing development of policies on e-mobility for EV production. It has also proposed that EV batteries with less than 80% capacity to be re-used in renewable energy storage as a 2nd life use. This initiative promotes recycling of EV batteries and further reduces e-waste.

Opibus Electric bikes in their warehouse in Nairobi Kenya

INTRODUCTION

The National Climate Change Action Plan (NCCAP) 2018-2022 identifies the opportunity to reduce 60% of two-wheeler (2W) emissions through transitioning to electric motor- cycles but does not state any strategic targets. The National Energy Efficiency and Conservation Strategy has an e-mobility objective – to increase adoption of e-mobility. It aims to increase the share of EVs to 5% of the total annually imported vehicles by 2025. This will be achieved by implementing fiscal incentives for EVs and regulatory actions such as revision of the Building Code to mandate inclusion of charging stations in public buildings and new estates.

5%

Increase in EV's imported by 2025

In Kenya, the EV charging infrastructure is at its introductory stage and is mainly uncoordinated. There are few operational EVs and charging stations. Development has so far been driven by the private sector and national targets and incentives for deployment of the charging infrastructure are yet to be formulated. The adoption of EVs in the country is however suboptimal. Charging infrastructure is one of the areas that has not fully developed.

In addition to lack of charging stations, standards for EV chargers and connectors have not been developed and companies in EV charging business have been promoting their own EV chargers, resulting in a proliferation of different chargers that are incompatible. This will result in reduced accessibility of charging infrastructure which ultimately turns off people from adopting EVs. Moreover, this lack of a regulatory framework contributes to risks perceived by possible investors in EV charging infrastructure. The business case for deploying a network of charging stations becomes more daunting, because the prospective investor will have to account for all the different types of chargers or risk narrowing his customer base to only the ones with a matching EV connector/plug. Standardization of EV charging equipment can help solve this, thus accelerating the development of the charging infrastructure and uptake of EVs in Kenya.

Background

The United Nations Environment Programme (UNEP) is implementing a **No and Low Emission** project aimed at improving air quality and mitigation of climate change effects. Amongst others, electric mobility adoption was identified as one of the key outcomes needed to achieve the objective of the project. UNEP provides support in policy development and strategies to various countries. Kenya is one of the beneficiaries.

The transition to more efficient and less carbon transport is one of the key targets of Kenya's current climate policies. The transport sector is a significant source of greenhouse gas (GHG) emission, accounting for about 13% of the total GHG emissions in 2015 in the world. According to the Nationally Determined contributions NDC document that Kenya submitted to United Nations Convention on Climate Change UNFCC in December 2020, transport will account for 4.7 MtCO2e out of 86.5 MtCO2e, the total emission reduction potential in 2030.

From studies (Notter, et al., 2018), e-mobility has the second highest mitigation potential for transport emissions in Kenya. This is mainly because more than 86% of Kenya's electric generation mix is renewable (Kenya National Bureau of Statistics , 2021). Moreover, Kenya has a huge renewable energy potential and the reduction of prices of renewable energy technologies has made EVs viable because charging can be scheduled to coincide with the availability of the renewable energy resource therefore avoiding the need for energy storage.

Despite the advantages highlighted herein, e-mobility is yet to take off optimally in Kenya. Figure 1 presents the distribution of different types of vehicles in Kenya as at 2020.

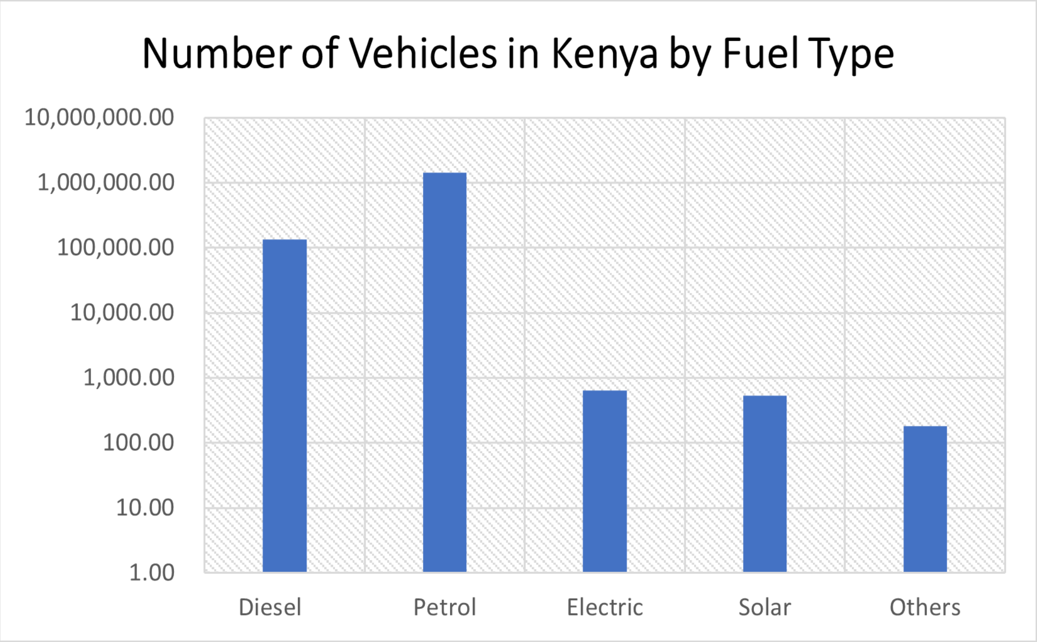


Figure 1 Number of vehicles in Kenya by type of fuel (Source: NTSA, 2020)

Internal combustion engine (ICE) vehicles are the dominant player. Petrol powered vehicles account for 91.37% of all vehicles in Kenya. Diesel powered vehicles follow at 8.54% and EVs at 0.041%. EVs in this category are full electric vehicles only and do not include hybrid vehicles. The hybrid vehicles are classified as ICEs in Kenya. The solar powered vehicles account for 0.034% and are two and three wheelers. Other vehicles powered by other technologies account for 0.012% - these vehicles are mainly LPG powered vehicles that are becoming popular among public transport vehicles.

A contributing intervention towards facilitation of uptake of EVs is the deployment of charging infrastructure. Availability of charging infrastructure is seen as a precursor to increased adoption of EVs. A comprehensive charging infrastructure is seen as a cure to the so-called range anxiety. EV users need assurance that they will recharge their vehicles when their car batteries run low and have a similar experience as they would normally have at a fossil fuel station. In Kenya, there are currently few operational EV charging stations (EVCS). The EV infrastructure market is in its introductory stage and policy intervention is needed to kick start the market and prevent early-stage market chaos. For example, mandated standards for EVCS can be used to address compatibility and interoperability issues.

Solar PV sector in Kenya offers a successful example of policy intervention to prevent early-stage market chaos. Energy and Petroleum Regulatory Authority (EPRA) has been implementing the Energy (Solar Photovoltaic Systems) Regulations, 2012. These regulations provide for licensing of all persons involved in the manufacture, importation, distribution, promotion, sale, design or installation of any solar (PV) systems, collection of data on solar PV systems installed in the country, ensuring the manufacture, design, installation, repair and maintenance of solar PV systems is done as per the relevant Kenyan Standards and fair business practices in the Solar PV industry. Since the implementation of these policies, the solar PV industry has grown significantly, as indicated by the growth in installed capacity and licensed players, in Figures 2 and 3.

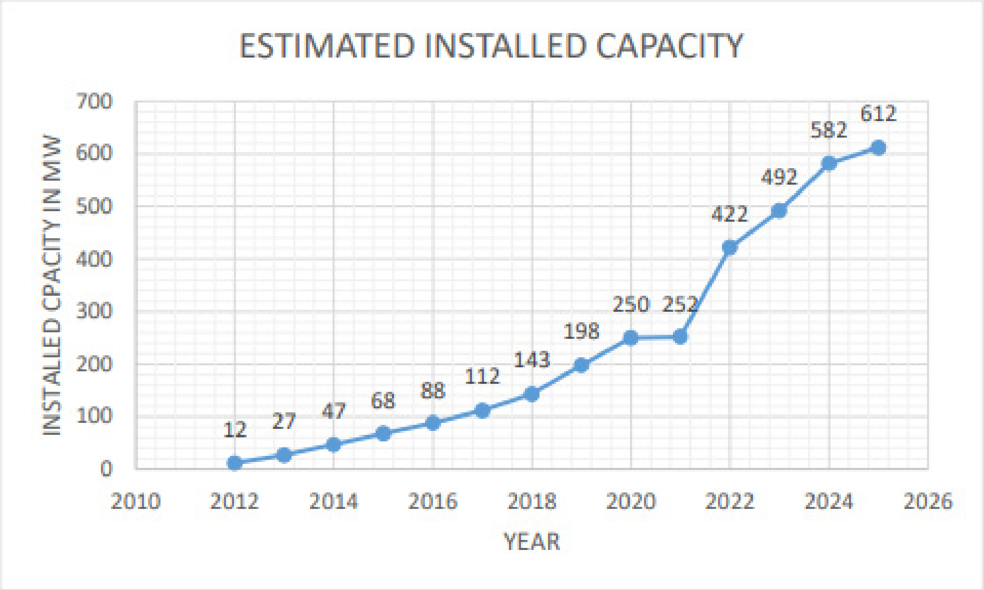


Figure 2 Solar PV Generation Systems Installed Capacity

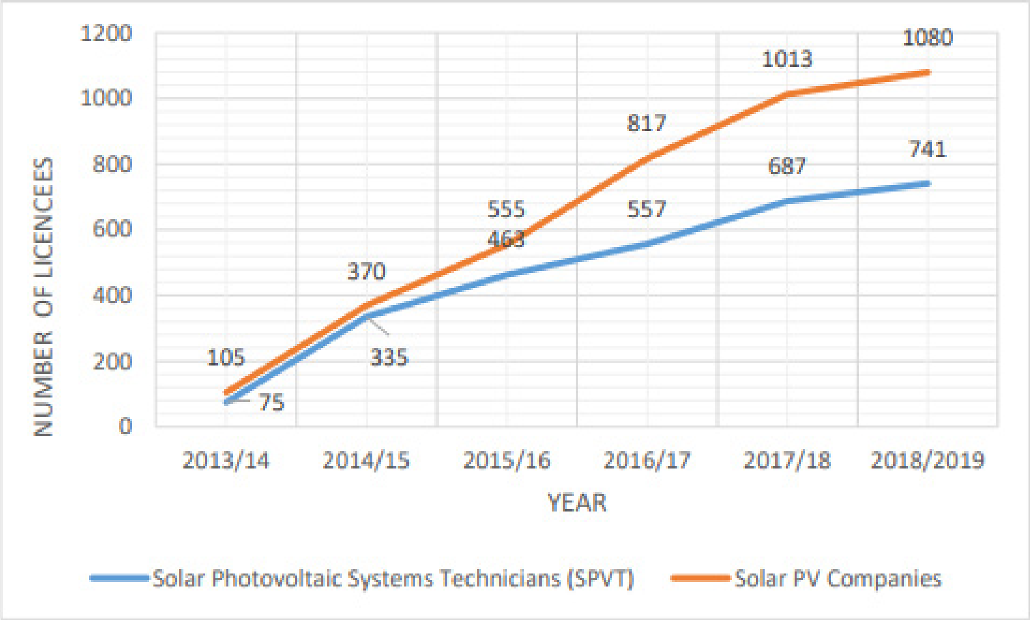


Figure 3 Growth in the number of licensed Solar PV Technicians and Companies

The installed capacity of PV systems (both grid and off-grid systems) in Kenya has grown from an estimated 12MW in 2012 to 250MW in 2020 while the number of licensed technicians and companies has grown by over 700 and 900 respectively. The solar industry growth success can thus be attributed to policy interventions. The E-mobility sector can also benefit similarly with the introduction of policy measures at the intoductory growth stage.

Objective

The objective of this study was to analyse the current status of charging and battery swapping infrastructure in Kenya, international best practices of both systems, highlight key issues likely to be of concern to policy makers in Kenya and give recommendations .

Scope

Electric mobility can be defined as use of EVs – vehicles that use an electric propulsion system. The propulsion system consists of an energy storage device, a power converter and an electric motor together with the related controls. It includes electric two, three and four-wheeler vehicles (e-2W, e-3W & e-4W). Electric four-wheeler can be classed as: plug in hybrid vehicles (PHEV), hybrid electric vehicles (HEV) and battery electric vehicles (BEV). BEVs only use a rechargeable battery to power the electric motors whereas PHEVs include an all-electric powertrain together with an ICE. Together, BEVs and PHEVs are classified as plug in EVs (PEVs) since they can be recharged using an external electricity source. This study details charging infrastructure including battery swapping systems that are crucial for increased uptake of e-2Ws, e-3Ws and PEVs.

The analysis covers the current status of charging infrastructure and battery swapping systems in Kenya as well as international best practices for both systems. This includes existing technologies, policy environment and standardization issues. Metering systems, pricing schemes, business models and readiness of the electricity distribution network to the integration of EVs are not part of this study.

The International best practices highlight case studies of countries at different levels of charging infrastructure development – introductory and growth stages. No country has reached the maturity stage. Case studies of countries at introductory stage analysed in this study are: India, Thailand, Philippines, South Africa and Rwanda. Case studies of countries at growth stage analysed in this study are: Norway, USA, Netherlands and China.

How to read this Report

Firstly, the report presents a general overview of charging infrastructure including classification, charging modes, EV connectors and thereafter discusses the current status of EV charging infrastructure in Kenya. Secondly, an overview of status of standards related to charging infrastructure in Kenya and at the international level is introduced followed by policy environment in Kenya. Thirdly, case studies of best practices in charging infrastructure are discussed. There after it presents an overview of battery swapping systems and the status of battery swapping in Kenya. Case studies of best practices in battery swapping are also covered. Finally, an outline of the conclusion and policy recommendations to accelerate growth of charging infrastructure and battery swapping systems in Kenya.

CHARGING INFRASTRUCTURE

Figure 3.1 Electric Vehicle charging

General Overview of EV charging

This section presents a general overview of vehicle charging infrastructure also known as Electric Vehicle Supply Equipment (EVSE). EVSE control enables charging authorization, information recording, exchange for network management and data privacy and security.

The section reviews different charging levels/models and connector types.

Charging methods vary depending on the user requirement and location. The EVSE also vary depending on the country and the EV models in that specific region.

Charging infrastructure networks ensure that the user needs are met. Thus, different types of infrastructure are available for different user needs.

1. Private Charging- This is "at home" charging that is not accessible to the public.
2. Public charging- Charging available for the general public at designated public areas. May be public-public charging on the streets/highways, or public-private charging in private commercial areas accessible to the public such as shopping malls.
3. Long distance fast charging- This charging is based on fast charging needed during long distance travels along the highways.

Classification of Electric vehicle charging

Electric vehicle charging can be classified according to the charging technology applicable. Figure 4 presents this classification.

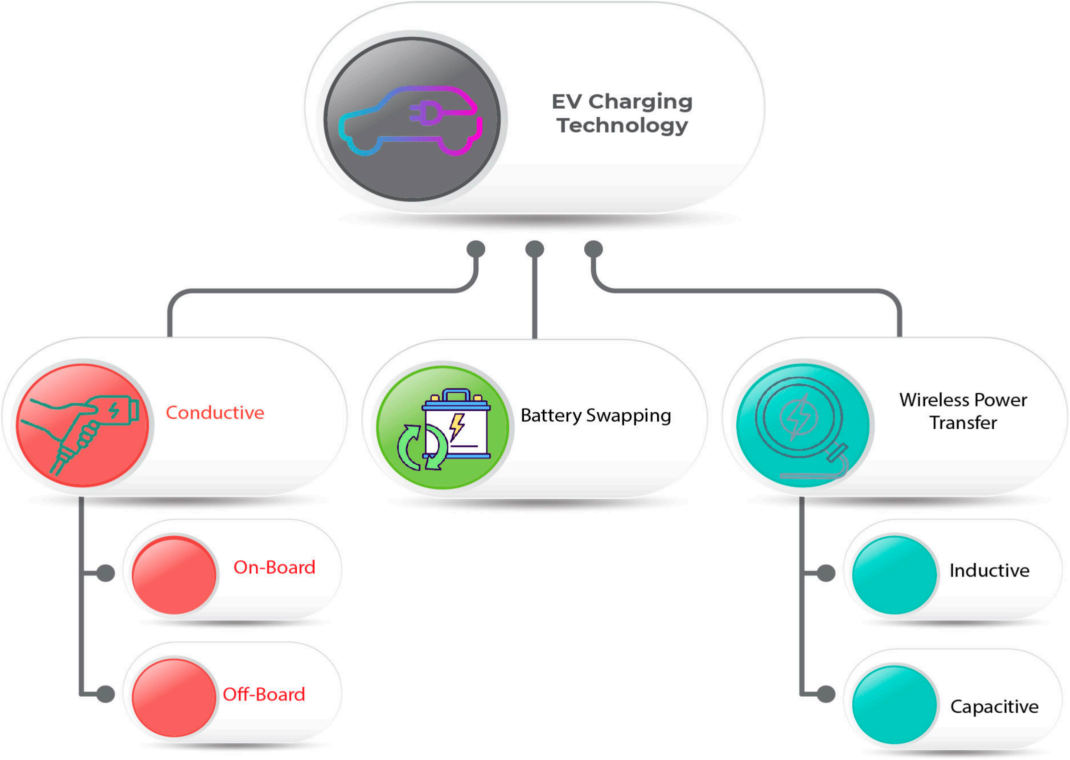


Figure 4 Classification of Electric Vehicle charging

Electric Vehicle charging can be classified into three main categories (see Figure 4): Conductive, wireless power transfer (WPT) and battery swapping. Conductive charging market is greater than non-conductive (WPT) mode of charging. Conductive charging is further classified into on board and off board charging which are the main modes used around the world. Wireless power Transfer covers inductive and capacitive modes of charging which are not commonly used in EV charging.

A detailed discussion of the configurations in Figure 4 are presented in subsequent subsections.

Conductive Charging

EV conductive charging is currently the commonly used charging technology. It involves the supply of Direct Current (DC) to the battery pack of the EV. Alternating Current (AC) or DC power is used in conductive charging to charge the vehicle from supply equipment. In either case, a converter is used to provide the required amount of power to the battery.

Conductive charging can be further classified into:

i. On board Charging
   This involves supply of AC power to an "on-board" converter which in turn converts to DC power for charging the battery. On-board charging charges the EV at moderate rates.
ii. Off-board charging
   Involves directly supplying the DC power to the EV battery by bypassing the on board converter. The battery in this case charges faster.

These arrangements are presented in Figure 5.

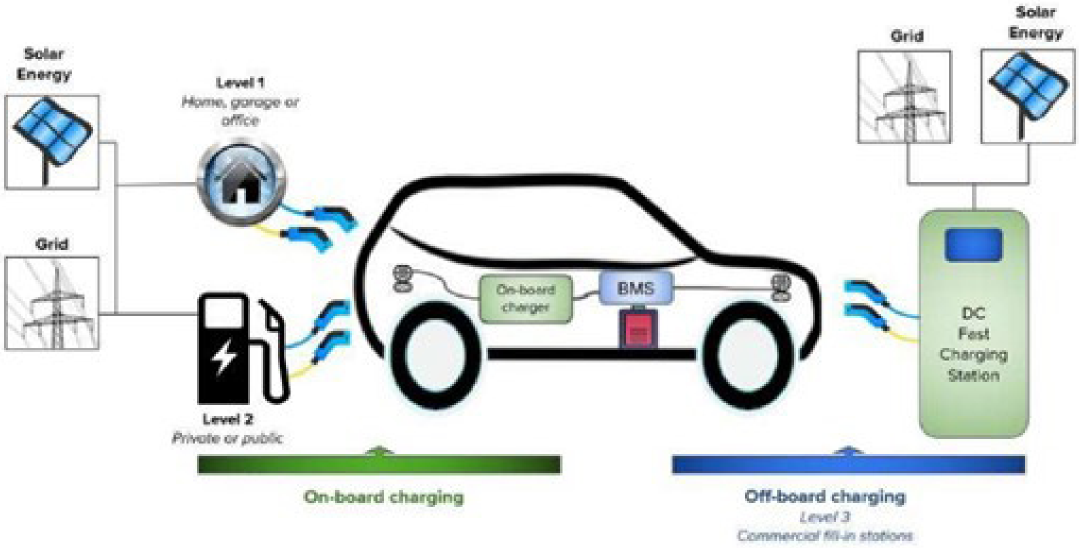


Figure 5 On and off board charging (India Institute of Technology, 2021)

Wireless Power Transfer (WPT)

This mode of EV charging does not include any physical connection between EV and EVSE. The following are two main types of WPT technologies.

i. Inductive WPT (see figure 6)- The technology employs a transmitter and receiver side power electronic systems for power transfer. A high frequency inverter is contained in the transmitter side and is coupled to the receiver side by a magnetic coil. (Mohamed et al., 2017)

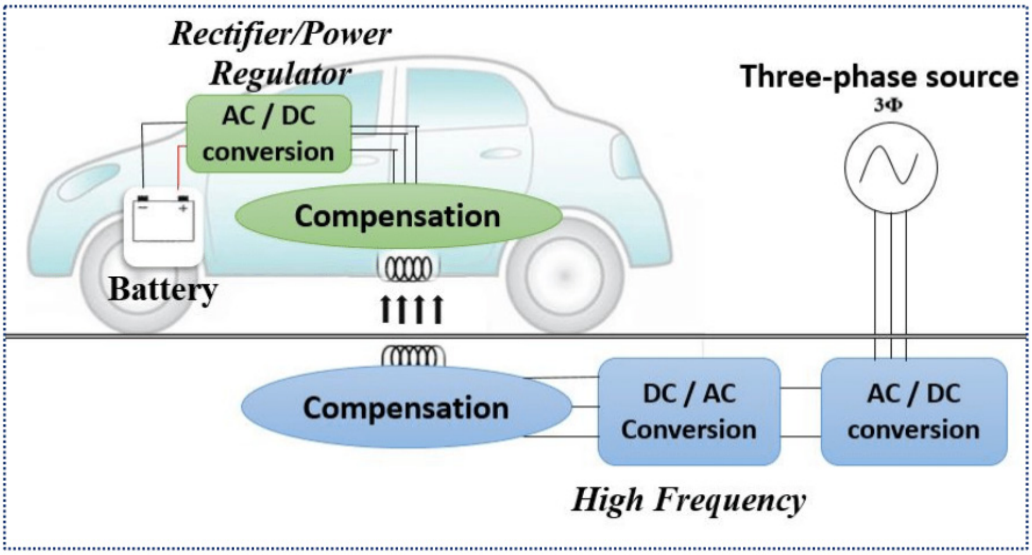


Figure 6 Inductive wireless power transfer (Mohamed, et al., 2017)

ii. Capacitive WPT (see figure 7)- It eliminates the need for electromagnetic shielding. This is advantageous over inductive WPT. It is less expensive due to the absence of ferrite, allowing use of high frequency resulting in smaller size of the charging system. However, this use of high frequency translates to design challenges. Electromagnetic safety also is an issue with capacitive WPT with high power transfer density at high efficiency. (Lu, et al., 2017)

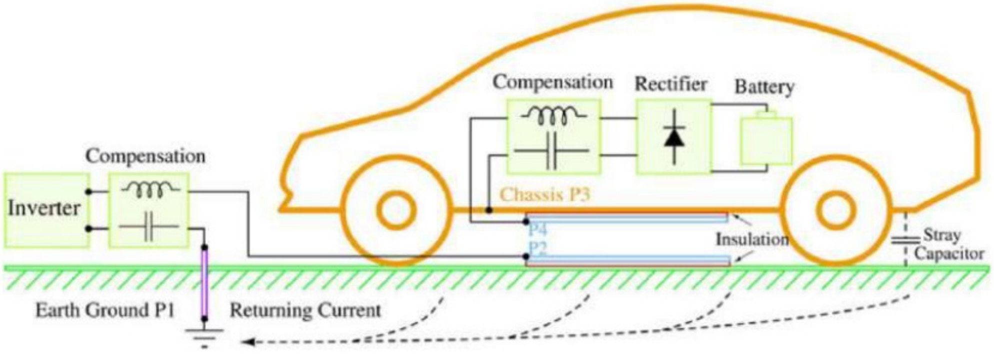
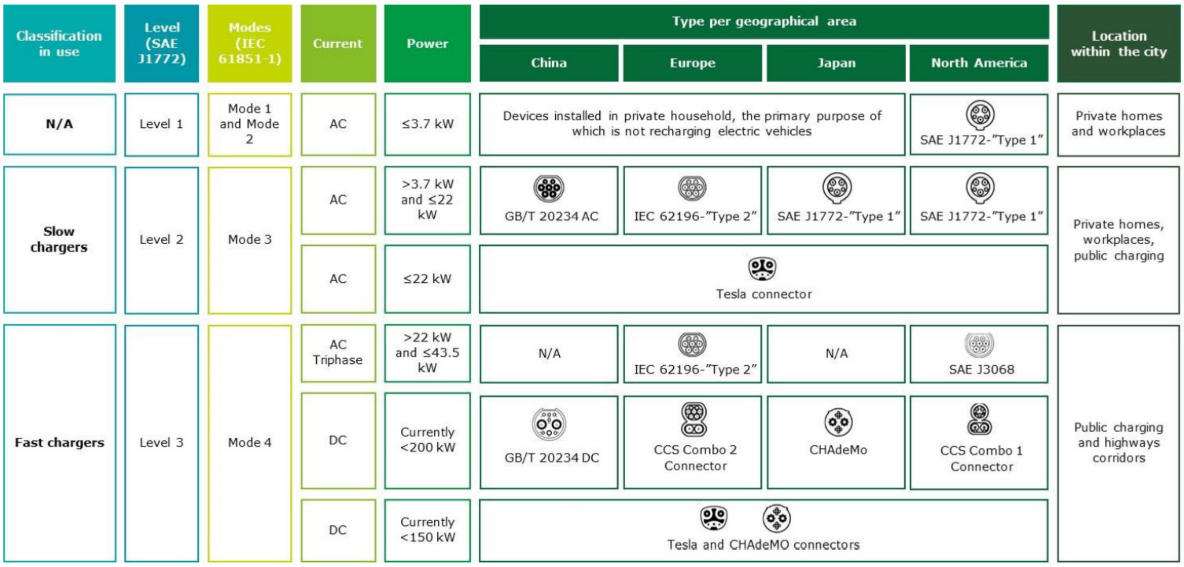


Figure 7 Capacitive wireless power transfer (Lu, et al., 2017)

Descriptors of EVSE

Generally there are three accepted descriptors for electric vehicle supply equipment: Mode, Level and type. Figure 8 shows a comparative analysis of the different descriptors for EVSE. These three descriptors are detailed in the subsequent sections.



Classification in use	Level (SAE J1772)	Modes (IEC 61851-1)	Current	Power	Type per geographical area				Location within the city
					China	Europe	Japan	North America	
N/A	Level 1	Mode 1 and Mode 2	AC	≤3.7 kW	Devices installed in private household, the primary purpose of which is not recharging electric vehicles			SAE J1772-"Type 1"	Private homes and workplaces
Slow chargers	Level 2	Mode 3	AC	>3.7 kW and ≤22 kW	GB/T 20234 AC	IEC 62196-"Type 2"	SAE J1772-"Type 1"	SAE J1772-"Type 1"	Private homes, workplaces, public charging
			AC	≤22 kW	Tesla connector				
Fast chargers	Level 3	Mode 4	AC Triphase	>22 kW and ≤43.5 kW	N/A	IEC 62196-"Type 2"	N/A	SAE J3068	Public charging and highways corridors
			DC	Currently <200 kW	GB/T 20234 DC	CCS Combo 2 Connector	CHAdeMo	CCS Combo 1 Connector	
			DC	Currently <150 kW	Tesla and CHAdeMO connectors				

Figure 8 Classification of the main types of chargers (Alberto, et al., 2021)

Modes of Electric Vehicle Charging Systems

EV conductive charging is classified into four different modes. Each different mode specifies how an EV is connected to different types of charging points. Figure 9 shows the different types of modes and their associated connectors.

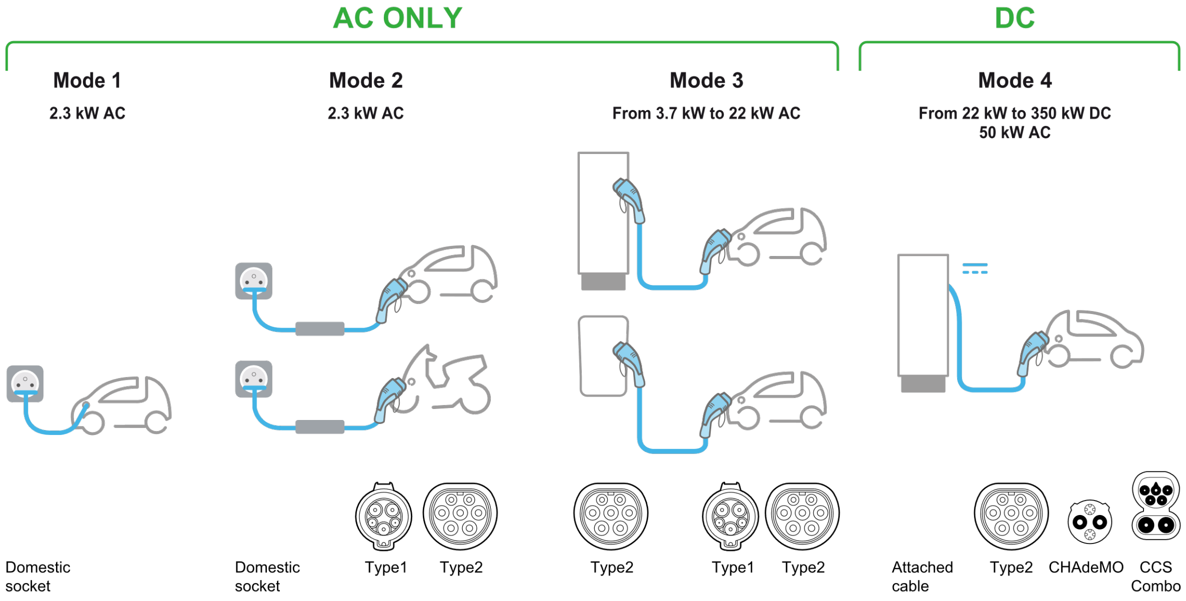


Figure 9 Four electric vehicle charging modes (Schneider Electric, 2021).

Mode 1

This is a connection mode between an EV and standard AC supply socket outlet. It is also referred to as dumb charging because there is no communication between EV and EVSE. Typically, the rated values should not exceed 16A and 250V AC for single phase and 16A and 480V AC for three phase. This type of charging is not recommended. Some national codes, for example in USA and UK, prohibit it.

Mode 2

This is a connection mode between an EV and standard AC supply socket outlet utilizing an AC EVSE with a plug and cable. The EVSE has inbuilt protection against electric shock and control capability and is classically used for home charging. The connection cable is usually provided together with the EV. Normally, the rated values should not exceed 32A and 250V AC for single phase and 32A and 480V AC for three phase.

Mode 3

This is a connection mode between an EV and AC EVSE, which is permanently connected to an AC mains supply network (charging station). The charging cable in this mode allows communication between the EV and charging equipment. This mode enables a control pilot function between the AC EVSE and EV. It is typically used for public/ commercial charging. This mode is specifically designed and recommended for electric vehicle charging.

Mode 4

This is a connection mode between an EV and DC EVSE which is supplied by an AC or DC supply network. This mode bypasses the onboard charger by delivering DC straight to the battery pack. The supply equipment may be permanently connected or through a cable and plug connection to the supply network.

Electric Vehicle Charging Levels

Level 1 delivers basic charging which can be done from the standard AC supply socket. This level is limited to 120V and 1.8 kW.

Level 2 delivers a maximum output of 19.2kW at a maximum current of 80A. The level is applicable to homes with three phase power of 11kW at 16A current, while single-phase power source need to supply around 48A. The level has a voltage range of 208V to 240V.

Level 3 provides upto 1000VDC with a power output of over 350kW. The level has a capability of reaching 500A in future. This level is applicable to TESLA supercharger for TESLA EVs.

Electric Vehicle Connectors

Conductive charging of EVs employs different types of connectors to plug the electric cable to the vehicle inlet. The following are the commonly used connectors in EV charging.

Type 1 connector (SAE J1772)

Type 1

This connector is used with AC charging stations, and can deliver between 3 -7.4 kW for single phase at 32A maximum current. The connector has 3 large pins, for phase, neutral and ground with two smaller ones which act as communication points with the EV.
Countries Used: USA & Japan, but also EU accepted.

Type 2 connector

Type 2

This connector is used with AC charging stations, and can deliver between 3 -43 kW for single phase at 16A maximum current, and 63A for three phase. It is similar to type 1 with additional two more pins for 3-phase charging.
Countries Used: European countries

CHAdeMO (CHArge de Move)

CHAdeMo

This connector is used with DC charging stations, and can deliver up-to 62.5 kW at 125A maximum current
Countries Used: Japan, USA

Combined Charging system (CCS) Combo 2

Combo 2

This connector is designed for DC fast charging, with both AC and DC charging capability of up-to 350 kW
Countries Used: European countries

Status of charging infrastructure in Kenya

Location

As at the end of March 2022, there are about 29 public charging points in the country. Table 1 summarizes existing charging points in the country. All the charging stations are within Nairobi and most of them (over 82%) are in shopping malls and public parking spaces (see Figure 11). The rest are located semi-public parking and petrol stations. However, Opibus and NaMaTa plan to introduce charging stations at public service vehicle terminals and on selected points along major highways. Shopping malls provide a safe environment for charging station operators and owners, as their equipment is safe from theft, damage and vandalism due to round-the-clock security. Malls also provide an opportunity for EV owners to charge vehicles for long hours as they shop. This is also an added benefit to the charging station operators as it results in revenue increase.

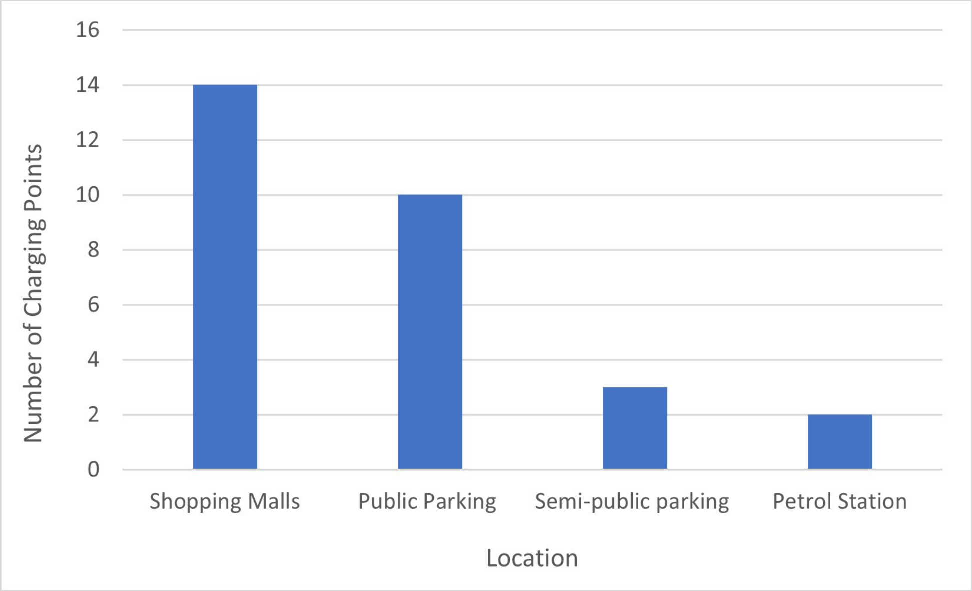


Figure 10 Location of public charging points

Charging Level

All the charging points installed in the country are Level 2 (AC charging) though Opibus plans to install the first DC charger (Level 3) by end of 2022. The Level 2 charging stations operate in mode 3. As shown in Figure 11, about 80% of the installed chargers are slow AC chargers (power rating less than 22 kW) while the remaining 20% are fast AC chargers (power rating greater than 22 kW). The chargers serve the passenger car EV segment. Electric two wheelers are connected directly to normal mains socket outlet. This is safe so long as the maximum rated current of the charger does not exceed 10 A. As at writing of this report, no chargers serving electric buses (e-buses) have been installed. However, Opibus and BasiGo are at advanced stages of setting up charging stations for e-buses.

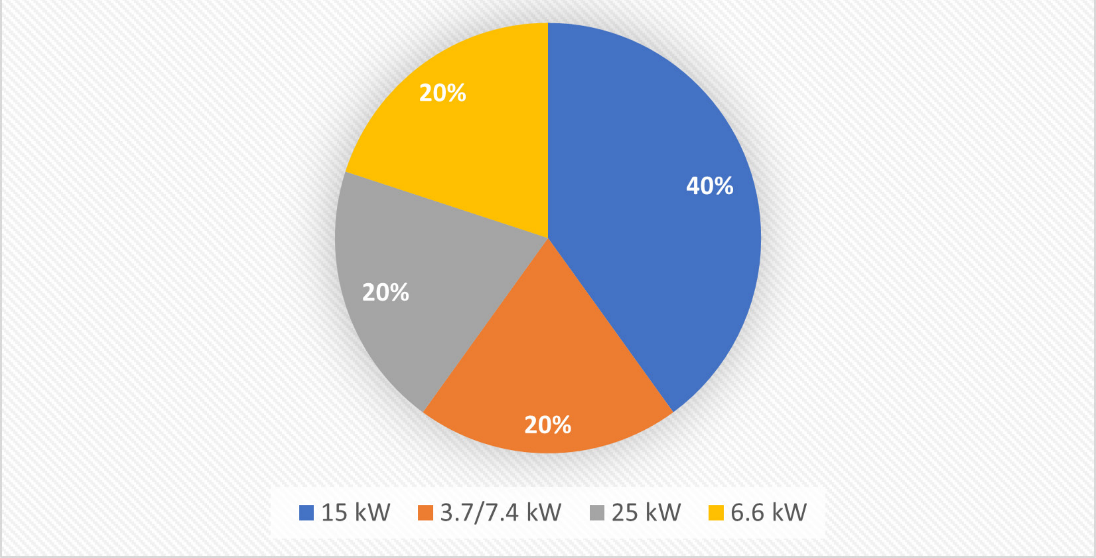


Figure 11 Public charging points by power rating

Connector Types and Charging Cables

Two-thirds of the charging points provide charging cables, whereas at the remaining third users need to have their own cables.

Type 2 connector is the most prevalent connector used, whereas Opibus plans to use the CCS2 connector at its proposed Level 3 charging points. Some charging stations provide Type 1 to Type 2 adaptors to accommodate EVs with Type 1 inlets. CCS2 connector has several advantages, including: it combines both AC and DC charging capability in a single connector, has a higher power rating, meaning it can charge the EV at a faster rate. In addition, many manufacturers promote it across the globe.

As at the end of March 2022, there were no charging stations with CHAdeMO connectors in the country even though the Nissan Leaf brand of car is the most common EV car in Kenya. The Nissan Leaf uses two charging standards for its inlets—Type 2 (AC charging) and CHAdeMO (DC charging).

> *"As there are no mandated standards for EV charging connectors in Kenya, with entry of more players into the charging infrastructure market, it is possible that every company will promote its own charger, resulting in the proliferation of different chargers that might be incompatible. This will cause reduced accessibility of charging infrastructure, ultimately turning off people from adopting EVs.'"*

Payment Methods

The most common mode of payment at the charge points is the use of Radio Frequency Identification (RFID) cards. RFID cards are used at charging points owned by NopeaRide. At ChargeNet charging points, one can use the mobile money (M-Pesa) payment option.

The major challenge with the use of the cards is the lack of interoperability of the cards at stations operated by different charging point operators.

As it stands, with no standardized payment method, new entrants into the EV charging market will implement their own RFID cards, meaning users of charge stations will be required to have a different card for each different charging point operator in the market. This is a bottleneck towards the expansion of charging infrastructure and uptake of EVs in Kenya.

> *"Currently, there is no special electricity tariff for EVs and charge point operators are billed using standard rates"*

Special EV Tariff

Currently, there is no special electricity tariff for EVs and charge point operators are billed using the standard rates depending on the electricity tariff they are contracted to.

Charging stations earn their revenue by dispensing electricity, which might not form a basis for a viable business. One way of making the business more lucrative is the introduction of special tariffs for EVs.

This way, more players can be motivated to enter the EV charging market. In addition, there is no guidance on charging fees that charging point operators should impose on their customers. Different billing criterion is used at the charging stations, as detailed below:

+ Variable/consumption-based billing where the EV users are billed per kWh consumed. This billing method is used at all the NopeaRide charging points.
+ Time based billing where the EV users are billed at cost per minute charge. This billing method is used at ChargeNet charging points.

Permitting and Licensing Process

The permitting and licensing process for setting up an EV charging station is long and arduous, making it difficult to set up public charging infrastructure.

This process involves first acquiring (by lease agreement or buying it outright) the parcel of land where the charging station will be installed.

Thereafter, the CPO then assesses the space and the power requirements and seeks approvals from the following entities: Ministry of Planning, NCA, County government (business permits), NEMA, EPRA, KPLC and KRA.

Once all the approvals are granted, the CPO procures and installs the EVSE. At the moment, no guidance is available on the documentation (including exemptions) required by each entity. This may lead to unnecessary back and forth between the developer and the agencies. This results in delays and costs that they can avoid. Therefore, it is important that the licensing and permitting process be streamlined to remove unnecessary administrative hurdles.

Summary of existing charging stations in Kenya.

Charging Station	Location	Description of charging station	
Holy Family Basilica basement[1]	Central Business District, Nairobi	**Characteristics:** The charge point is rated 7.4 kW, single phase AC power, operating under mode 3 charging with a type 2 charger. There is one charger per floor and each charger has two charging points , in each of the 4 underground basement floors. The points are to be used primarily used for public charging. There is a provision for an additional charger per floor. Total Number of Charge Point: 8 Level of Charging: Level 2	
Nopea Charging stations	Sarit Centre, Thika Road Mall & The Hub mall, Two rivers mall	Characteristics: There are three charge points in each of the stations in every mall. Two are a single-phase AC charger rated at 15 kW with a Type 1 charger. The other one is a three phase AC charger rated at 25 kW with a Type 2 charger. All operating under mode 3 charging. The 25kW rated is a fast AC charger. The points are primarily used for private charging. Billing: billed per kWh Payment method: Radio Frequency Identification (RFID) cards Total Number of Charge Point: 12 Level of Charging: Level 2	
Knights and Apps (Drive Electric)	Great Jubilee Center, Karen	**Characteristics:** The charger is rated at 7.4 kW, single phase AC power, operating under mode 3 charging with a type 2 socket. There are three chargers each with one charging point. The points are primarily used for private charging. **Total Number of Charge Point**: 3 **Level of Charging**: Level 2	

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[1] Not operational as at the time of writing this report.

Lites Infrastructure Company	Charging station in CBD (Haile Selassie Avenue)	Characteristics: The charge point is a ground mounted pedestal charger rated at 7.2 kW (32A), single phase AC power, operating under mode 3 charging with two type 2 sockets. There is one charge point at the station. The point is primarily used for public charging. **Total Number of Charge Point**: 2 **Level of Charging**: Level 2.	
Opibus	[2]Charger locations: Thika Bus Station (Kiambu county), at Green Park Terminus, Marble Arch both in Nairobi Central Business District for buses	**Characteristics:** The charger is rated at 180 kW (200A) DC output power. It is a fast charger, operating under mode 4 charging with a CCS2 charger. The points will be primarily used for public charging. **Total Number of Charge Point**: 6 **Level of Charging**: Level 3	
Charge Net charging station (Mayleen Corporation)	ABC Mall Westlands, Be Energy Racecourse, Hass Petrol Station Kasarani, The Acrh Place Nyangumi Rd.	Characteristics: The charge point is rated 6.6 kW, single phase AC power, operating under mode 3 charging with a type 2 & 1 charger. At each station, there is one charging point. The points are primarily used for public charging. Billing: users are billed per minute. KES 4 per minute for type 1 charger and KES 7 per minute for type 2 charger. Payment: through mobile money (M-Pesa) **Total Number of Charge Point**: 4 **Level of Charging**: Level 2.	

Table 1 EV Charging Systems in Kenya

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[2] *At the time of writing this report, these chargers are yet to be installed at these locations.*

Standardization

Charging Infrastructure International standardization

Standardization of charging infrastructure has been geared towards addressing different aspects of EV plugs, communication, the mechanisms used for security as well as pulse-width modulation (PWM) protocols. This has been done by several international standardization bodies such as IEC (International Electrotechnical Commission), ISO (International Organization for Standardization), IEEE (Institute of Electrical and Electronics Engineers) as well as regional standardization bodies such as European Standards (EN), national standards bodies such as British standards Institute (BSI).

IEC EV charging standards

IEC has developed standards covering e-mobility under IEC Technical Committee (TC) 69: Electrical power/energy transfer systems for electrically propelled road vehicles and industrial trucks. The committee has developed IEC 61851 series which has multiple documents covering Electric Vehicle Charging station (EVCS). The standard defines different charging modes and has been adopted by all EVCS manufacturers. In addition, the following TCs and subcommittees (SCs) have contributed to development of EVCS and battery swapping by developing standards covering plugs, electric cables, protection devices and LV switchgear and control gear assemblies:

i. IEC TC 23 Electrical accessories
   a) SC 23H Plugs, socket outlets and couplers for industrial and similar applications and for electric vehicles
   b) SC 23E Circuit breakers and similar equipment for household use
ii. IEC TC 121/SC 121B Low voltage switchgear and control gear assemblies
iii. IEC TC 20 Electric Cables
iv. IEC TC 64 - Electrical installations and protection against electric shock

Figure 12 gives an overview of IEC standards on EV charging infrastructure developed by the above mentioned TCs.

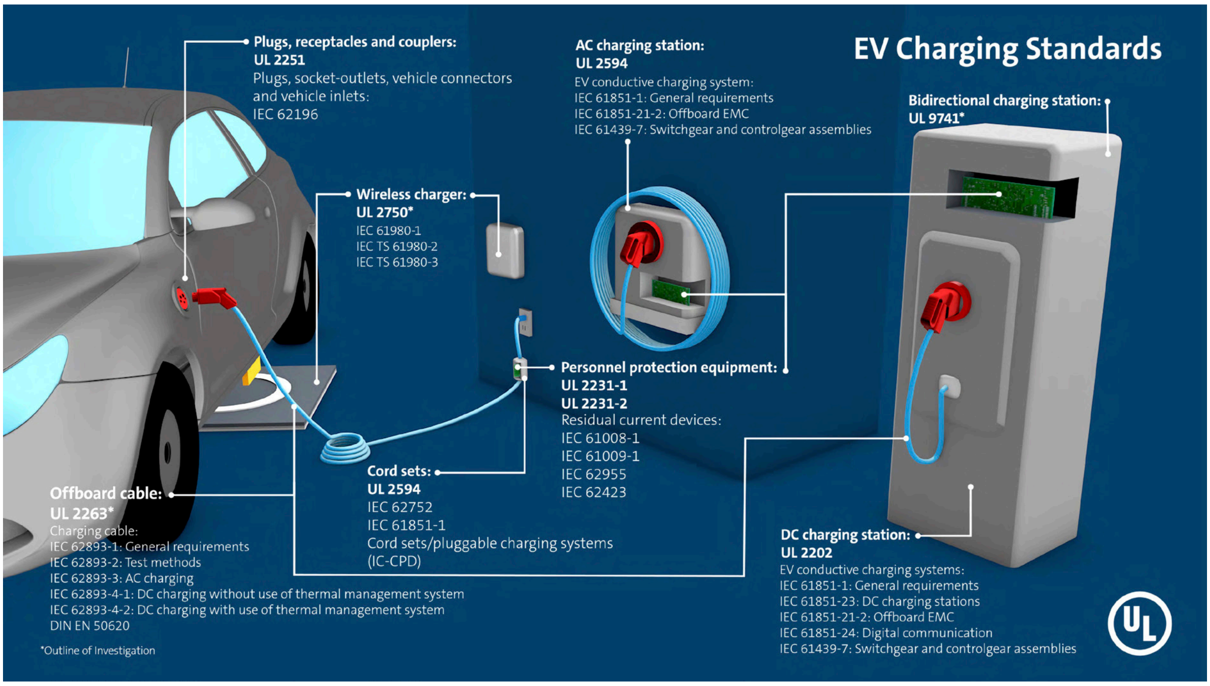


Figure 12 Charging infrastructure standards (UL, 2021)

The IEC standards for EV conductive charging systems cover the following aspects:

- System (IEC 61851-1, 23)
- Plugs/connectors (IEC 62196- 1,2,3 & IEC 60309 -1)
- Communication protocols (IEC 61851 - 24)
- Electromagnetic compatibility (IEC 61851 – 21 – 1, 21 -2)
- Supply Equipment Protection (IEC 61851 – 25, IEC 62955, IEC 62752)
- EV Charging Cables (IEC 62893)
- Switchgear and Control Gear Assemblies (IEC 61439-7)
- EV Installation Requirements (IEC 60364 – 7 -722)

The above standards are elaborated in tables 2 and 3. Table 4 gives an overview of IEC standards for EV WPT systems whereas ANNEX I gives an overview of other IEC standards relating to other aspects of electric mobility.

i. IEC 61851 Series: Electric vehicle conductive charging system standards

The series covers electrical, mechanical electromagnetic compatibility, communications, and performance requirements for EVSE used for electric vehicle charging as shown in table 2 below.

Standard	Title	Summary and Scope
EV Conductive charging system		
IEC 61851-1	Electric vehicle conductive charging system - Part 1: General requirements	Part 1 of the standard gives general requirements for provision of electric power to electric vehicles. The requirements are specific for electric supply equipment used for charging road vehicles, rated 1000V AC or 1500V DC for output as well. All road vehicles with a rechargeable energy storage system are covered in this standard including plug-in hybrid electric vehicles (PHEV). Several aspects such as safety, connection specifications and operating conditions of the supply equipment are covered. The standard further classifies the four charging modes used in electric vehicle supply equipment. Functional requirements provided in the four charging modes are specified in the standard. These control pilot functions are to be provided by the EV supply equipment, which include; i. Protective conductor continuous continuity checking ii. Confirmation of proper connection between the EV and EVSE iii. Power supply energization & de-energization to the EV iv. Interruption of energy supply in case EV draws current above maximum allowable current. Other requirements such as protection against electric shock and communication are highlighted in the standard.
IEC 61851:21-1	Electric vehicle on-board charger EMC requirements for conductive connection to AC/DC supply	Part 21-1 covers the electromagnetic compatibility (EMC) requirements when electric vehicles are connected to a power supply in any of the four charging modes. It however only covers on board charging units tested on the complete EV or on the charging system. Only electromagnetic compatibility tests are addressed in the standard.

IEC 61851:21-2	Electric vehicle requirements for conductive connection to an AC/DC supply - EMC requirements for off board electric vehicle charging systems	Part 21-2 covers electromagnetic compatibility (EMC) requirements for off board charging units which supply power to EVs using conductive power transfer. The standard covers power supply from EVSE in all four modes of charging. Similarly, to part 21-1, this part only addresses electromagnetic compatibility tests with the exclusion of other electrical tests.
IEC 61851:23	DC electric vehicle charging station	This standard specifies requirements for direct current (DC) charging stations used for conductive power transfer to EVs. The standard is applicable to charging mode 4. The general requirements for communication control between EV and EV supply equipment are also highlighted in this part. Protection against electric shock in the standard is also covered under single fault condition. However due to the dynamic nature of electric vehicle charging requirements, not all combinations of electric shock protection have been covered in the standard. Other requirements regarding this have been captured in ISO 17409:2015.
IEC 61851:24	Digital communication between a d.c. EV charging station and an electric vehicle for control of d.c. charging	This part of the series covers digital communication between the EV and EV charging station. It applies to DC stations hence used in conjunction with part 23 of the series. The standard covers charging mode 4 for dc conductive charging. The standard does not apply to high voltage ac supply equipment's.
IEC 61851:25	DC EV supply equipment where protection relies on electrical separation	This part covers DC EVSE requirements where there exists an electrical separation protecting the secondary circuit from the primary circuit. The supply equipment has a rated voltage of up to 480V AC or 600V DC and a rated output voltage of 120V DC, with maximum current limit of 100A DC. Other aspects that are included in the standard, include operating conditions, specifications and requirements between EV and EVSE.

Table 2 Electric vehicle conductive charging system standards

ii. EV charging standards covering plugs, sockets and switchgear

Table 3 gives a highlight of other key IEC standards in relation to electric vehicle charging.

Standard	*Title*	*Summary and Scope*
EV Plugs & Sockets		
IEC 62196 series: Part 1,2,3,3-1	Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of electric vehicles	The series of standards specify inputs and tests for plugs, socket outlets, vehicle connectors and vehicle inlets for conductive charging of electric vehicles.
IEC 60309-1:2021	Plugs, fixed or portable socket-outlets and appliance inlets for industrial purposes - Part 1: General requirements	The standard covers charging inlets, sockets and EV plugs (connector guns), for outdoor use. The operating voltage should not exceed 1000V DC or 1000VAC, with a rated current not exceeding 800A.
EV Charging cables		
IEC 62893 series: Part 1,2,3,4-1,4-2	Charging cables for electric vehicles for rated voltages up to and including 0.6/1kV	This series specifies dimensions, tests and construction of cables used for power supply between electric vehicles and charging stations. Cables included have a rated voltage up to and including 0.6/1kV and 1500V DC. These cables are applicable for use for charging mode 1-4.
EV Protection		
IEC 62955:2018	Residual direct current detecting device (RDC-DD) to be used for mode 3 charging of electric vehicles	This standard applies to residual current detecting devices used for protection of AC EV charging stations for mode 3. The voltage should not exceed 440V and current should not exceed 125A.
IEC 62752:2018	In-cable control and protection device for mode 2 charging of electric road vehicles (IC-CPD)	The standard covers in cable control and protection devices (IC-CPDs) for EVs mode 2 charging.

Switchgear		
IEC 61439-7:2018	Low-voltage switchgear and control gear assemblies - Part 7: Assemblies for specific applications such as marinas, camping sites, market squares, electric vehicle charging stations	This standard covers low voltage switchgear and control gear assemblies of electric vehicle charging stations (EVCS). The rated voltage should not exceed 1000V AC or 1500V DC.
EV Installation requirements		
IEC 60364-7-722:2018	Low-voltage electrical installations - Part 7-722: Requirements for special installations or locations - Supplies for electric vehicles	This standard applies to electric circuits meant for energy supply to electric vehicles as well as circuits meant for electricity feedback from electric vehicles.

Table 3 IEC standards on plugs, sockets and switchgear used in EV charging

iii. IEC 61980 series: Electric vehicle wireless power transfer (WPT) systems

The series of standards covers wireless charging of electric road vehicles at standard supply voltages up to 1 000 V AC and up to 1 500 V DC as shown in table 4 below.

Standard	*Title*	*Summary and Scope*
EV wireless power transfer (WPT) systems		
IEC 61980-1	Electric vehicle wireless power transfer (WPT) systems - Part 1: General requirements	This standard covers the supply devices used to charge EVs wirelessly using standard supply voltages. Aspects that are included in the standard, include operating conditions, specifications and requirements between EV and EVSE. Aspects such as electromagnetic compatibility of the supply equipment are covered.
IEC 61980-2	Specific requirements for communication between electric road vehicle (EV) and infrastructure	This standard covers communication between the EV and EVSE which enables wireless control of charging. However safety aspects in relation to maintenance is not covered in this standard.
IEC 61980-3	Specific requirements for the magnetic field wireless power transfer systems	This part gives specifications for magnetic field wireless power transfer (MF-WPT) of power from EVSE to EVs. The characteristics and operating conditions as well as electrical safety are highlighted. In addition, communication for safety requirements by the MF-WPT have been also captured in the standard.

Table 4 Electric vehicle wireless power transfer (WPT) systems

Other IEC standards referenced in EV charging standards and covering other aspects of electric mobility are as presented in Annex I.

ISO EV charging standards

At ISO, standards covering safety specifications, test procedures and electrical specifications have been developed for both light duty vehicles and 2 & 3 wheelers. These standards have been developed by ISO/TC 22/SC 37 Electrically propelled vehicles. ISO standards for EV charging systems cover the following aspects:

- Communication protocols (ISO 15118)
- Electromagnetic compatibility (ISO 11451 -2, ISO 11452 -2 & 4)
- Safety and Interoperability Requirements (ISO 17409, ISO 19363, ISO 18246)

The above standards are elaborated in table 5 and 6.

Table 5 shows the ISO standards that cover charging systems for electric vehicles.

Standard	*Title*	*Summary and Scope*
ISO 17409:2020	Electrically propelled road vehicles-conductive power transfer-Safety requirements	These standard covers safety requirements for conductive connection of EVs to EVCS. The four charging modes are covered under this standard as highlighted in IEC 61851-1. On board sections of EV power supply units also apply to this standard. Power control functions used to connect EVS to eternal circuits are as well covered.
ISO 18246:2015	Electrically propelled mopeds and motorcycles — Safety requirements for conductive connection to an external electric power supply	ISO 18246:2015 specifies safety requirements for conductive connection to an external electric power supply of electrically propelled mopeds and motorcycles. It applies only to on-board charging systems between the plug or vehicle couplers and RESS circuits.
ISO 19363:2020	Electrically propelled road vehicles-magnetic field wireless power transfer-safety and interoperability requirements	This standard gives requirements for EV supply equipment that allows magnetic field wireless power transfer (MF-WPT) of power to EVs. Passenger cars and light duty vehicles are covered by this specification. The characteristics and operating conditions as well as electrical safety are highlighted. In addition, test procedures, EV device ground clearance and efficiency of power transfer have been addressed.

ISO 15118-1,2, 3,4, 5,8,9, 20, 21,	Road vehicles — Vehicle to grid communication interface	This document, specifies terms and definitions, general requirements and use cases for conductive and wireless HLC between the EVCC and the SECC. This document is applicable to HLC involved in conductive and wireless power transfer technologies in the context of manual or automatic connection devices. This document is also applicable to energy transfer either from EV supply equipment to charge the EV battery or from EV battery to EV supply equipment in order to supply energy to home, to loads or to the grid. This document provides a general overview and a common understanding of aspects influencing identification, association, charge or discharge control and optimisation, payment, load levelling, cybersecurity and privacy. It offers an interoperable EV-EV supply equipment interface to all e-mobility actors beyond SECC.

Table 5 ISO Standards for EVCS

Other ISO standards

Additional ISO standards under ISO/TC 22/SC 37 Electrically propelled vehicles covering other aspects of electromobility are captured in table 6 below;

Standard	*Title*	*Summary and Scope*
Hybrid electric road vehicles		
ISO 20762:2018	Electrically propelled road vehicles — Determination of power for propulsion of hybrid electric vehicle	This standard specifies measurement methods for the maximum system propulsion power of hybrid-electric vehicles (HEV). The standard applies only to the vehicles with the following characteristics: — HEVs with an internal combustion engine (ICE) and one or more electric motors powered by one or more rechargeable energy storage systems (RESS) for propulsion; — vehicles classified as passenger cars or light duty trucks.
Fuel Cell Vehicles		
ISO/TR 11954:2008	Fuel cell road vehicles — Maximum speed measurement	The standard describes test procedures for measuring the maximum road speed of fuel cell passenger cars and light duty trucks which use compressed hydrogen and which are not externally chargeable, in accordance with national or regional standards or legal requirements.

Electrically propelled road vehicles		
ISO 21498-1:2021	Electrically propelled road vehicles — Electrical specifications and tests for voltage class B systems and components — Part 1: Voltage sub-classes and characteristics	This standard applies to voltage class B electric propulsion systems and connected auxiliary electric systems of electrically propelled road vehicles. Additionally, it applies to electric circuits and components in these systems. It also provides specifications of voltage sub-classes related to DC electric circuits. It also provides specifications of characteristics which are relevant for design and operation of systems and components for the voltage sub-classes.
ISO 21498-2:2021	Electrically propelled road vehicles — Electrical specifications and tests for voltage class B systems and components — Part 2: Electrical tests for components	The standard applies to voltage class B electric propulsion systems and connected auxiliary electric systems of electrically propelled road vehicles. It applies to electric circuits and components in these systems. It focuses on the characteristics at the DC voltage class B terminals of these components as specified in ISO 21498-1. It describes testing methods, test conditions and test requirements for components exposed to electrical behaviour caused by operation of electric loads and power sources.
ISO 21782-1:2019	Electrically propelled road vehicles — Test specification for electric propulsion components — Part 1: General test conditions and definitions	The standard specifies the test procedures for performance and operating load for voltage class B electric propulsion components (motor, inverter, DC/DC converter) and their combinations (motor system) of electrically propelled road vehicles.
ISO 21782-2:2019	Electrically propelled road vehicles — Test specification for electric propulsion components — Part 2: Performance testing of the motor system	The standard specifies the performance tests for the motor system designed as a voltage class B electric propulsion system for electrically propelled road vehicles.
ISO 21782-3:2019	Electrically propelled road vehicles — Test specification for electric propulsion components — Part 3: Performance testing of the motor and the inverter	The standard specifies performance tests for the motor and the inverter designed as a voltage class B electric propulsion system for electrically propelled road vehicles.
ISO 21782-4:2021	Electrically propelled road vehicles — Test specification for electric propulsion components — Part 4: Performance testing of the DC/DC converter	The standard specifies performance tests and each evaluation for the DC/DC converter in the voltage class B electric propulsion system of electrically propelled road vehicles.

ISO 21782-5:2021	Electrically propelled road vehicles — Test specification for electric propulsion components — Part 5: Operating load testing of the motor system	The standard specifies operating load tests and test criteria for the motor system designed as a voltage class B electric propulsion system for electrically propelled road vehicles.
ISO 21782-6:2019	Electrically propelled road vehicles — Test specification for electric propulsion components — Part 6: Operating load testing of motor and inverter	The standard specifies operating load tests and test criteria for motor and inverter designed as a voltage class B electric propulsion system for electrically propelled road vehicles.
ISO 21782-7:2021	Electrically propelled road vehicles — Test specification for electric propulsion components — Part 7: Operating load testing of the DC/DC converter	The standard specifies the operating load test and test criteria for the DC/DC converter designed as a voltage class B electric propulsion system of electrically propelled road vehicles.

Table 6 ISO EV charging standards

In addition, the ISO standards presented in Annex II have been developed by ISO/TC 22/SC 37 and similarly adopted by Kenya.

IEEE Standards

Other international standardization institutions such as the Institute of Electrical and Electronics Engineers (IEEE) has developed the following standard on electric vehicle charging.

Standard	*Title*	*Summary and Scope*
IEEE 2030.1.1-2021	IEEE Approved Draft Standard Technical Specifications of a DC Quick and Bi-directional Charger for Use with Electric Vehicles	The standard covers conductive direct current charging for rapid charging of EVs from power source.

Table 7 IEEE EV charging standard

Standardization at National level

National Standardizing Bodies (NSBs) have also developed specifications covering charging infrastructure and in other areas of E-mobility in general. NSBs such as the Standardization Administration of China as well as Deutsches Institut für Normung (DIN) standards have already developed specifications for charging infrastructure of EVs. As per the Standardization Administration of China, Guobiao (GB) standards are mandatory whereas GB/T standards are recommended. Standards for electric vehicle charging in China are prefixed GB/T, indicating that they are not mandatory. Society of Automotive Engineers (SAE) International a United States based professional organization has also developed standards in the sector.

Figure 13 summarizes SAE International standards on charging infrastructure, they cover the following EV characteristics, and they are further elaborated in Table 8:

- EV Charging Safety
- EV/Fuel Cell Safety
- Energy Transfer Systems
- EV Charging and Grid Communications

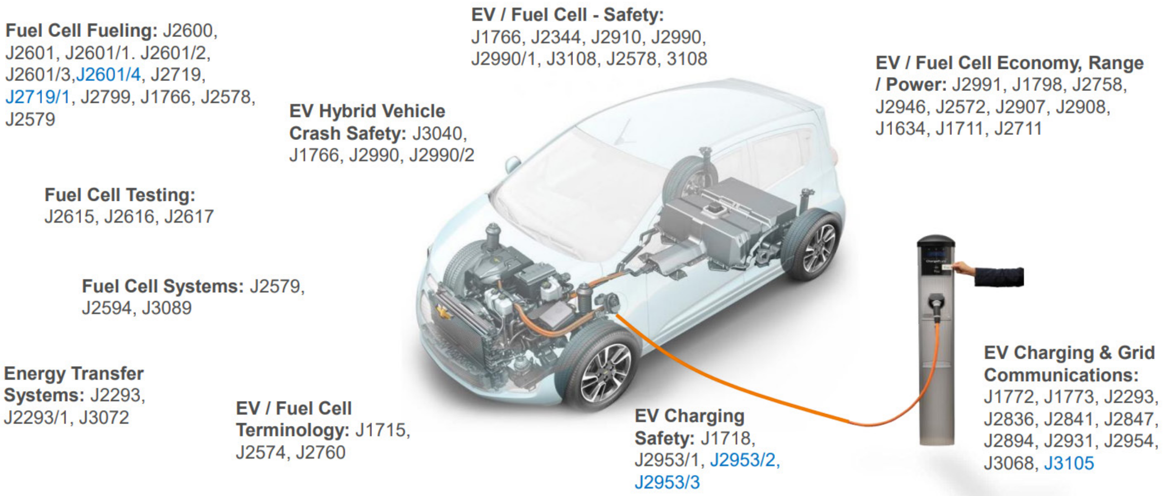


Figure 13 SAE EV charging standards (Wilson, 2021)

Table 8 captures SAE and China GB standards.

Standard	Title	*Summary and Scope*
SAE J2293/1	Energy transfer system for electric vehicles Part 1: Functional requirements and system architectures	This standard specifies requirements of off board EV supply equipment used to transfer power to an EV. The document ensures interoperability of the EV and EVSE by giving requirements of the EV energy transfer system. The standard defines three different system architectures used in coupling energy transfer systems for EVs. The architectures include; i. Conductive AC coupling ii. Inductive coupling iii. Conductive DC coupling

SAE J2293/2	Energy transfer system for electric vehicles Part 2: Communication requirements and network architecture	This part of the series of standards specifies physical requirements used in power transfer and communication between the EV and EVSE.
SAE J1772	SAE Electric Vehicle and plug in hybrid electric vehicle conductive charge coupler	The standard gives physical and electrical requirements of EVSE for conductive charging of EVs. Plug in hybrid Vehicles (PHEVs) are also covered in this document, with their functional and performance characteristics outlined. The design for the DC and AC chargers are specified as well as the rating of the system. The following classification specifies the current and voltage values for the three levels of charging as highlighted in the standard. i. Level 1: 120V, 16A, 1.92KW ii. Level 2: 240V, 80A, 19.2KW iii. Level 3: 200-600V, 400A, 240KW
SAE J1773	SAE Electric Vehicle inductively coupled charging	This standard applies to inductive charging levels 1 and 2. It gives specifications for power transfer at frequencies higher than power line frequency. It only applies to manual connection and software controlled inductive charging.
SAE J2954	Wireless power transfer for light duty plug in/Electric vehicles and alignment methodology	The standard establishes requirements for wireless power transfer systems for light duty vehicle charging. Specifications such as electromagnetic compatibility, interoperability, safety and testing of the WPT systems have also been covered in the standard.
GB/T 20234	Connection set for conductive charging of electric vehicles	This Guobaio (GB/T) standard provides requirements for the charging accessories, plug, socket and connector for conductive charging of electric vehicles. Testing methods have been highlighted in the standard at 690V AC, 250A and 1000V DC, 400A. The standard therefore covers both DC and AC charging.

Table 8 SAE and China GB standards

Kenyan Standards

Kenya has developed 24 electric vehicle standards. The standards specify requirements for performance, safety and testing of electric motorcycles, mopeds, and electrically propelled road vehicles. The developed standards are adoptions from ISO, where Kenya is a full member. Electrically propelled road vehicles take up 14 of the standards, 4 standards cover mopeds and motorcycles while 3 on Hybrid electric vehicles and 3 more on Fuel Cell vehicles.

However, amongst all the e-mobility standards adopted in Kenya, none covers charging infrastructure between EV and EVSE.

Table 9 highlights current Kenyan standards on emobility and issues addressed.

Standard	*Title*	*Summary and Scope*
Electrically propelled Road Vehicles		
KS ISO 6469-1:2019	Electrically propelled road vehicles-Safety specifications -Part 1: Rechargeable energy storage system (RESS)	This standard specifies safety requirements for rechargeable energy storage systems (RESS) of electrically propelled road vehicles for protection. Test procedures for safety are included in the document.
KS ISO 6469-2:2018	Electrically propelled road vehicles-Safety specifications -Part 2: Vehicle operational safety means and protection against failures.	This standard specifies requirements for operational safety specific to electrically propelled road vehicles, for the protection of persons inside and outside the vehicle.
KS ISO 6469-3:2018	Electrically propelled road vehicles-Safety specifications -Part 3: Electrical safety	This standard specifies electrical safety requirements for voltage class B electric circuits of electric propulsion systems and conductively connected auxiliary electric systems of electrically propelled road vehicles.
KS ISO 6469-4:2015	Electrically propelled road vehicles-Safety specifications -Part 4: Post crash electrical safety.	This standard specifies safety requirements for the electric propulsion systems and conductively connected auxiliary electric systems of EVs for the protection of persons inside and outside the vehicle after a crash.
KS ISO/TR 8713:2012	Electrically propelled road vehicles-Vocabulary.	This Technical Report outlines a vocabulary of terms and the related definitions used in electrically propelled road vehicles.

KS ISO 17409:2015	Electrically propelled road vehicles-Connection to an external electric power supply-Safety requirement.	This standard specifies electric safety requirements for conductive connections of electrically propelled road vehicles to an external electric power supply using a plug or vehicle inlet. It applies to electrically propelled road vehicles with voltage class B electric circuits. This standard may be applied to electric motorcycles and mopeds if no dedicated standards for these vehicles exist. It applies only to vehicle power supply circuits and dedicated power supply control functions used for the connection of the vehicle to an external electric power supply.
KS ISO/ PAS16898:2012	Electrically propelled road vehicles-Dimensions and designation of secondary lithium-ion cells.	This standard specifies the designation systems, shapes and dimensions of secondary lithium-ion cells for the integration into battery packs that are used in electric vehicles. It also specifies the systems used in electrically propelled road vehicles including the position of the terminals and any overpressure safety device (OPSD).
KS ISO 8714:2002	Electric road vehicles-Reference energy consumption and range-Test procedures for passenger cars and light commercial vehicles.	This standard describes the test procedures for passenger cars and light commercial vehicles. The standard is limited to a scope of vehicles that have a total mass of 3500kg and a maximum speed greater than 70km/h. The test procedures consist of four steps - initial charging of traction batteries, application of the designated test sequence, and the measurement of the reference range and consumption at the mains, charging of the traction battery and measurement of the consumption at the mains and calculation of the reference energy consumption.
KS ISO 8715:2001	Electric road vehicles-Road operating characteristics.	This standard specifies the procedures for measuring the road performance of purely electrically propelled passenger cars and commercial vehicles. The maximum authorized total mass of the vehicles is 3500 kg. The road performance comprises road operating characteristics such as speed, acceleration and hill climbing ability.

KS ISOPAS 19363:2017	Electrically propelled road vehicles-Magnetic field wireless power transfer-Safety and interoperability requirements.	This standard outlines the safety and interoperability requirements for magnetic field wireless power transfer in electric vehicles. It defines the requirements and operation of the on-board vehicle equipment that allows magnetic field wireless power transfer (MF-WPT).
KS ISO/ PAS19295:2016	Electrically propelled road vehicles-Specification of voltage sub-classes for voltage class B.	This standard specifies the voltage sub-classes for road vehicles that are classified as voltage class B. Class B voltage is a classification of an electrical component or circuit with a maximum operating voltage of between 30Vac (rms) to 1000Vac (rms) or between 60Vdc to 1500Vdc.
KS ISO 12405-4:2018	Electrically propelled road vehicles-Test specification for lithium-ion traction battery packs and systems-Part 4: Performance testing	This standard specifies the test procedures for lithium ion battery packs and systems. The test procedures are limited to the basic characteristics of performance, reliability and electrical functionality for the battery packs and systems for either high-power or high-energy application. High power battery pack applications are in HEV. High energy battery pack applications are in battery electric vehicles (BEV) and plug-in hybrid electric vehicles (PHEV).
KS ISO 15031-6: 2015	Road vehicles - Communication between vehicle and external equipment for emissions-related diagnostics Part 6: Diagnostic trouble code definitions	This standard specifies the uniformity for standardized Diagnostic Trouble Codes (DTC) that electrical and electronic On-Board Diagnostic (OBD) systems of motor vehicles are required to report when malfunctions are detected. DTC are codes that are used by vehicle manufacturers to diagnose problems in vehicles.
KS ISO 18300:2016	Electrically propelled vehicles-Test specifications for lithium-ion battery systems combined with lead-acid battery or capacitor.	This standard describes the test specifications or lithium ion battery packs that are combined with lead acid batteries or electric double layer capacitors that are used in voltage class A systems. Voltage class A systems are systems that have a maximum operating voltage that is less than 30Vac (rms) or 60Vdc.
Mopeds and Motorcycles		

KS ISO 13063:2012	Electrically propelled mopeds and motorcycles-Safety specifications.	This standard specifies requirements for functional safety means, protection against electric shock and the on-board rechargeable energy storage systems intended for the propulsion of any kind of electrically propelled mopeds and motorcycles when used in normal conditions.
KS ISO/TR 13062:2015	Electric mopeds and motorcycles-Terminology and classification	This standard covers the terms and definitions used for electric mopeds and motorcycles.
KS ISO 13064-1:2012	Battery-electric mopeds and motorcycles-Performance-Part 1: Reference energy consumption and range.	Part 1 of this standard specifies test procedures for measuring the reference energy consumption and reference range of electric motorcycles and mopeds with traction batteries as the only power source for vehicle propulsion. Test conditions such as vehicle conditions, atmospheric conditions, rider and riding position, and road conditions are both specified to guide the test procedure.
KS ISO 13064-2:2012	Battery-Electric mopeds and motorcycles-Performance-Part 2: Road operating characteristics.	Specifies the procedures for measuring the road performance of electric motorcycles and mopeds with only traction batteries as power source for vehicle propulsion.
Hybrid Electric Vehicles		
KS ISO 23274-1:2013	Hybrid-electric road vehicles-Exhaust emissions and fuel consumption measurements-Part 1: Non-externally chargeable vehicles	This standard specifies test procedures for measuring the exhaust emissions, electric energy and fuel consumption of hybrid-electric vehicles.
KS ISO 23274-2:2012	Hybrid-electric road vehicles- exhaust emissions and fuel consumption measurements part 2: externally chargeable vehicles	Part 2 of the standard specifies the procedures for measuring the exhaust emissions, electric energy and fuel consumption of hybrid-electric vehicles that are recharged externally. European, North American and Japanese test procedures are referred to in this standard.

KS ISO/TR 11955:2008	Hybrid-electric road vehicles-Guidelines for charge balance measurement.	This technical report describes the procedures of charge balance measurement to ensure necessary and sufficient accuracy of a fuel consumption test on HEV with batteries. The charge balance of a RESS is measured during a fuel consumption test of non-externally chargeable HEV so as to determine the effect of energy change on fuel consumption.
Fuel Cell Vehicles		
KS ISO 23273:2013	Fuel cell road vehicles — Safety specifications — Protection against hydrogen hazards for vehicles fuelled with compressed hydrogen	ISO 23273:2013 specifies the essential requirements for fuel cell vehicles (FCV) with respect to the protection of persons and the environment inside and outside the vehicle against hydrogen-related hazards. It applies only to such FCV where compressed hydrogen is used as fuel for the fuel cell system. ISO 23273:2013 does not apply to manufacturing, maintenance, and repair. The requirements of ISO 23273:2013 address both normal operating (fault-free) and single-fault conditions of the vehicles.
KS ISO/TR 11954:2008	Fuel cell road vehicles — Maximum speed measurement	ISO/TR 11954:2008 describes test procedures for measuring the maximum road speed of fuel cell passenger cars and light duty trucks which use compressed hydrogen and which are not externally chargeable, in accordance with national or regional standards or legal requirements.
KS ISO 21087:2019	Gas analysis — Analytical methods for hydrogen fuel — Proton exchange membrane (PEM) fuel cell applications for road vehicles	This standard specifies the validation protocol of analytical methods used for ensuring the quality of the gaseous hydrogen (H2) at hydrogen distribution bases and hydrogen fuelling stations for road vehicles using proton exchange membrane (PEM) fuel cells. It also gives recommendations on the calculation of an uncertainty budget for the amount fraction. The standard is established mainly for analysis done in laboratories after the sampling of hydrogen either at hydrogen distribution bases or at hydrogen refuelling stations.

Table 9 Kenyan Electric mobility standards

Policy environment

Policy is an essential intervention tool needed by countries to boost uptake of EVs. Globally, different policy measures have been used by countries to spur the uptake of light duty vehicles (LDV). Countries such as US, China, Norway implemented measures such as subsidies in purchase and tax rebates in motor vehicle registration. These efforts were geared towards reducing the price difference between commercial vehicles and EVs. Countries that lead globally in EV uptake have undertaken a mix of three types of policy measures to boost EV uptake.

The Figure 14 represents different types of policy measures used globally in promoting EV uptake. (Lieven, 2015)

POLICY MEASURES

FISCAL MEASURES	TRAFFIC REGULATIONS	CHARGING INFRASTRUCTURE
Direct subsidy for the purchase of Electric vehicles. Exemption for road tax	Use of bus fast lanes for free. Free parking of EV buses in city centres.	Charging at workplace. Charging at public parking. Charging at highways

Figure 14 Global policy measures for EV

1

Fiscal measures

Monetary measures have time limits or include a cap on the number of eligible beneficiaries. Countries such as the United Kingdom have limited grants up to GBP 5000 for EVs for a maximum of 50,000 vehicles. The time limit on this grant was up to 2017. This was aimed at making EVs accessible to a wider range of people.

2

Traffic regulations

This policy measure is less expensive in its implementation. It involves adding regulations to already existing ones to accommodate EV parking and use of bus lanes for electric buses. The measure over time may lead to congestion hence become less attractive over a period.

3

Charging Infrastructure

This policy measure involves investment in infrastructure of charging facilities. The measure is expensive as compared to the other policy measures. Since Governments cannot invest in charging stations at company premises, subsidies and tax abatements in conjunction with policy can support development of stations at such places. A less expensive measure would be to investment in charging infrastructure on major highways by the Governments. The measure over time is more attractive as the charging networks provide sufficient capacity for an increasing number of EVs.

General EV Policies in Kenya

National Climate Change Action Plan (NCCAP) 2018-2022

Kenya's National Climate Change Action Plan (NCCAP) 2018-2022 identifies energy and transport as a way of climate proofing infrastructure, among others. This policy identifies actions to be taken by Kenya in supporting the development of E-mobility. The NCCAP 2018-2022, capacity development supports EV charging by exploration of infrastructure needs for electric mobility. Table 10 below highlights different actions captured in NCCAP 2018-2022 aimed at creating an enabling environment for e-mobility.

Action	*Expected Result by 30th June 2023*	*Measure (Mitigation/Adaptation)*
Developing an affordable, safe and efficient public transport system	1. Use of electric hybrid buses and incentives to be provided for their use. 2. Electrification of Standard Gauge Railway from Nairobi to Mombasa.	Mitigation
Enabling technology	1. Domestic technology development for electric modes of transport encouraged. 2. Research on use of renewable energy for powering different modes of transport undertaken.	Enabling
Enabling capacity development	1. Awareness built on the fuel economy and electric mobility options including exploring infrastructure needs for electric mobility.	Enabling
Enabling policy and regulation	Standards for electric cars and 2-wheelers developed and adopted by 2019.	Enabling

Table 10 NCCAP 2018-2022 EV action plans

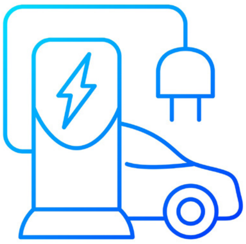
Finance Act 2019

The finance act of 2019 proposed the reduction of excise duty for electric vehicles from 20% to 10%. This action point in the policy directly supports the growth of the e-mobility sector as a monetary policy measure. However, there is a need to include fiscal policy considerations for charging infrastructure such as reduction of energy tariffs for charge point operators. This measure would result in an increase in deployment of charging stations.

Kenya National Energy Efficiency and Conservation Strategy 2020

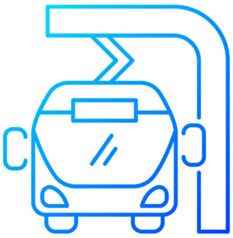
The Kenya National Energy Efficiency and conservation strategy targets an increase of number of electric vehicles by 5% of the total number of imported cars annually, by 2025. To achieve the proposed target, as per the strategy, regulatory and fiscal policy measures will be employed. The strategy calls for lowering of the import duty for electric vehicles, bicycles and tuk-tuks. In addition, the strategy envisages a revision of the building code to incorporate charging infrastructure in new estates and public buildings. Lastly, the strategy plans to raise awareness on vehicle energy efficiency through e-mobility.

Electric Vehicle Standards



The Kenya Bureau of Standards has already developed electric mobility standards. They specify testing procedures, performance, product specifications and safety requirements. The standards are highlighted in the Kenyan Standards section.

Other policies



Other policies such as the Integrated National Transport Policy (2009) are currently under review. The revision of this document is likely to include provisions for electric mobility and charging infrastructure.

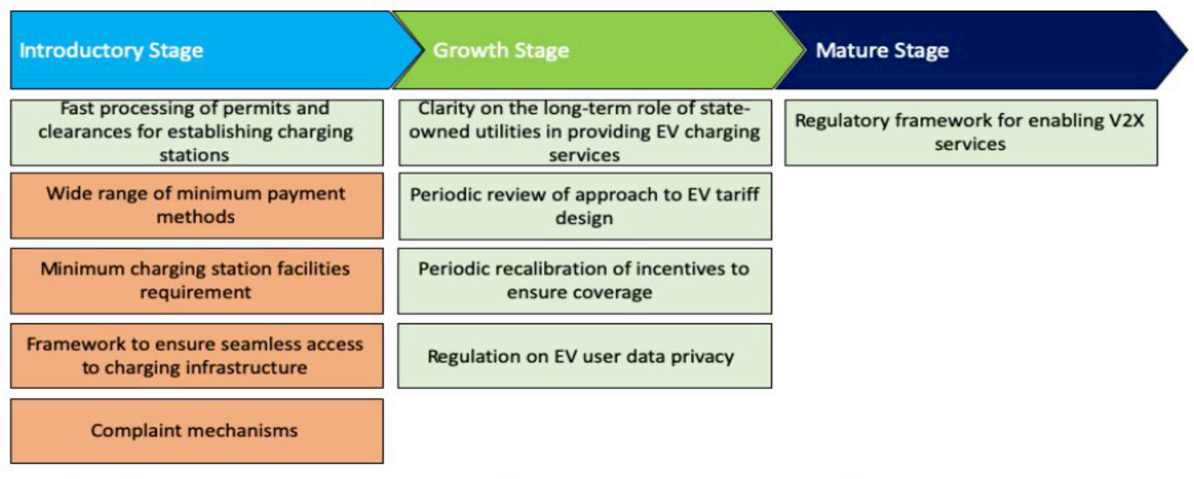
At the county level, a draft of the Nairobi climate change action plan mentions the intention of electrification of the Bus Rapid Transit (BRT) corridor. The BRT is proposed to be primarily used by electric buses procured under public private partnerships (PPPs) (Kimuyu, 2021).

Furthermore, at the county level, Kisumu has developed the Kisumu Sustainable Mobility Plan which has proposals to transition to a fully electric fleet of buses by 2030. This will be achieved by incentives for car taxis, boda-bodas as well as tuk-tuks to electrify these 2,3 and 4 wheelers by 2025 (Kisumu County Government, 2020).

Gaps in charging infrastructure policies

Currently, there exist no policies that regulate nor support framework for development of charging infrastructure in Kenya.

Figure 15 presents charging infrastructure deployment policies to enable different market development stages.



Introductory Stage	Growth Stage	Mature Stage
Fast processing of permits and clearances for establishing charging stations	Clarity on the long-term role of state-owned utilities in providing EV charging services	Regulatory framework for enabling V2X services
Wide range of minimum payment methods	Periodic review of approach to EV tariff design	
Minimum charging station facilities requirement	Periodic recalibration of incentives to ensure coverage	
Framework to ensure seamless access to charging infrastructure	Regulation on EV user data privacy	
Complaint mechanisms		

Figure 15 Charging infrastructure deployment policies (Bhagwat, 2020)

Kenya is currently at the introductory stage, whereby for the industry to move to the growth stage a number of factors need to be undertaken as highlighted in Figure 15. The summary is key in identifying policy considerations at each stage of market growth.

Government Stakeholders and their role in EV uptake

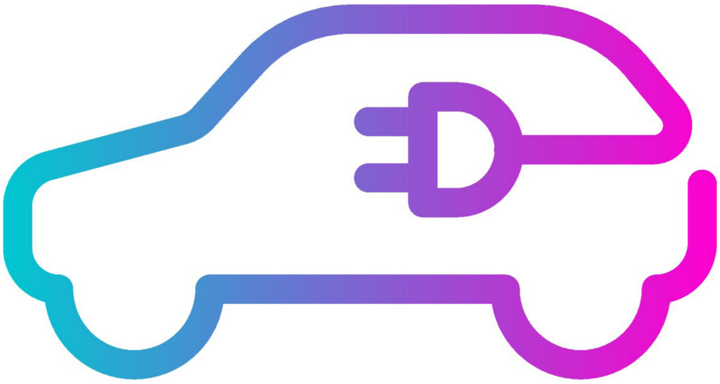
Notable stakeholders in the EV industry in Kenya that would influence the uptake of EVs in Kenya include:

- Kenya Bureau of Standards (KEBS)
- Kenya Power and Lighting Company (KPLC)
- Energy and Regulatory Authority (EPRA)
- National Transport and Safety Authority (NTSA)
- Ministry of Energy
- Ministry of Transport, Infrastructure Housing, Urban Development and Public Works
- Ministry of Environment and Forestry
- National Treasury
- Ministry of Industrialization
- County Governments

Institution	Role
Kenya Bureau of Standards (KEBS)	This is the government agency that provides standards, metrology and conformity assessment to the public. Its main roles are to provision of the country's quality infrastructure for facilitation of trade, to support Kenya's industries, and ensuring sustainability of production systems. Currently, KEBS is at the forefront of ensuring adoption of EVs in Kenya and has already created a Technical Committee (TC) for Electric Mobility. The aim of the TC is to develop Kenyan standards that will help to regulate the EV industry.
Energy Petroleum and Regulatory Authority (EPRA)	EPRA is established as the successor to the Energy Regulatory Commission (ERC) under the Energy Act, 2019 with a mandate to regulate the energy sector. Part of their mandate is to regulate generation, importation, exportation, transmission, distribution, supply and use of electrical energy with the exception of licensing of nuclear facilities. Given that EVs are powered by electricity from various energy generation systems and the charging infrastructure is connected to electricity distribution infrastructure, part of the EV industry will fall under EPRA's mandate.
Kenya Power (KPLC)	This is the main electricity distribution utility company in Kenya. KPLC owns and maintains the majority of the electricity distribution infrastructure in the country. For a successful adoption of EVs in Kenya, the electricity distribution network needs to be ready to handle EV charging infrastructure. This is Kenya Power's main role in the development of EVs in Kenya. KPLC has made a pledge to install electric vehicle charging infrastructure in major towns in Kenya.
National Transport and Regulation Authority (NTSA)	NTSA is a statutory body established by the National Transport and Safety Authority Act (2012) to register motor vehicles, license transport systems, inspect motor vehicles, road safety, driver testing and to some extent traffic law enhancement. NTSA will be key in developing and adopting a vehicle classification system for EVs, inspect EVs, test EV drivers and registering existing EVs in the country. It is the role of the government to develop and adopt policies that will lead to the adoption of EVs.

Ministry of Energy **Ministry of Energy**	The Ministry is in charged with the mandate to develop and implement policies that create an enabling environment for efficient operation and growth of Kenya's energy sector. The Ministry sets strategic directions to facilitate the growth of the sector while providing long term vision for all sector players. It is the role of the Ministry of Energy to develop directions that will facilitate the growth of the EV industry.
State Department of Transport (SDoT) **STATE DEPARTMENT OF TRANSPORT**	The SDoT is one of the five functional State Departments under the Ministry of Transport, Infrastructure, Housing, Urban Development and Public Work. The main roles of the SDoT are; to strengthen institutional framework for infrastructure development and accelerating the speed of completion of sector priority projects; to develop and enforce regulations and standards to ensure safe, secure and efficient transport and infrastructure systems; to undertake research and development for efficient transport and infrastructure systems; and to expand, modernize and maintain integrated, safe and efficient transport network. As at the writing of this report, the State Department of Transport had advertised for consultancy services for development of a National Electric Mobility policy for Kenya.
Ministry of Environment and Forestry **MINISTRY OF ENVIRONMENT & FORESTRY**	The Ministry of Environment and Forestry is mandated to undertake National Environment Policy and Management, Forestry development policy and management, Development of re-afforestation and agro-forestry, Restoration of strategic water towers, Protection and conservation of Natural environment, Pollution control, Lake Victoria management program, Restoration of Lake Naivasha basin, Kenya Meteorological department, Kenya meteorological training, Conservation and protection of wetlands and Climate change affairs. The role of this ministry in the EV sector is the development of policies to combating climate change, therefore encouraging the uptake of EVs.

Ministry of Industrialization Republic of Kenya Ministry of Industrialization, Trade and Enterprise Development	The mandate of the Ministry is to promote Industrialization through: Industrial Policy and Planning; SME Policy; SME Financing Policy; SME/ Biashara Financing Policy; Buy Kenya – Build Kenya Policy and Strategy; To Promote Standardization in Industry and Quality Control; Promotion and Development of Micro and Small Enterprises; To Promote and Facilitate Domestic and Foreign Investments; Promotion and Oversight of the Development of Special Economic Zones and Industrial Parks; Kenya Property Rights Policy (Patents, Trade Marks, Service Marks, and Innovation); Promotion of Value Addition and Agro-Processing; Textile Sector Development; Business Innovation and Incubation; Promotion and Development of the Cottage Industry; Oversight and Regulation of the Scrap Metal Industry and Industrial Training and Capacity Development. The role of this ministry in the EV sector is the development of the automotive policy to support motor-vehicle and motorcycle manufacturing in Kenya. This policy can be critical in supporting manufacturing and assembly of EVs in Kenya by unlocking the industry potential across the entire EV value chain and related sectors of the economy.
County Governments The Council of Governors 48 Governments, 1 Nation	Counties are responsible for Transport matters within their devolved units including parking. They are crucial in designating some parking slots for installation of charging infrastructure. This can be part of 1% of county budget which they resolved to be set aside to address climate change. In Nairobi, the County Assembly passed Nairobi Transport Act (2020) whose section 63 provides powers for CEC to designate specific areas within the city as low emission zones where fossil fuel based vehicles will not be allowed.



National Treasury REPUBLIC OF KENYA **The National Treasury & Planning** The National Treasury	The National Treasury and Planning is mandated by law to; Strengthen financial and fiscal relations between the National Government and County Governments and support for county governments in performing their functions; Issue guidelines on the preparation of county development planning; Prepare the annual legislative proposals on intergovernmental fiscal transfers; Provide logistical support to intergovernmental institutions overseeing intergovernmental fiscal relations; Coordinate the development and implementation of financial recovery plans for County Governments that are in financial distress; Build capacity of County Governments on public finance management matters for efficient, effective and transparent financial management as well as planning, monitoring and evaluation; and, Administer the Equalization Fund. The role of this ministry in the EV sector is to propose monetary policies aimed at reducing financial costs incurred by investors and consumers of E-mobility products. The Ministry in 2019, proposed the Finance act of 2019 which reduced the excise duty for electric vehicles from 20% to 10%

Table 11 Notable stakeholders in the EV industry in Kenya

INTERNATIONAL BEST PRACTICES BEST PRACTICES FOR CHARGING INFRASTRUCTURE

Rationale for policy intervention

Availability of EV charging infrastructure is seen as a precursor to increased adoption of EVs. Widespread EV charging infrastructure is seen as a cure to the so-called range anxiety. EV users need assurance that they will be able to recharge their vehicles when their car batteries run low and still have the experience they always get at a fossil fuel station. However, the business case for EV charging infrastructure is dependent on EV adoption. Without charging stations the demand for EVs would not increase whereas without the critical mass of EVs on road charging stations would be under-utilized. McKinsey's EV consumer survey of buyers in China, Germany, and the United States revealed that not having enough access to an efficient charging network is the third most significant barrier to purchasing EVs. The causality dilemma of whether EVs or charging infrastructure needs to come first has been much debated (Gnann, et al., 2015) though experience from around the world shows that the requisite momentum has to arrive from either side. A probable approach is to use incentives (fiscal and non-fiscal) to kick start the charging infrastructure market.

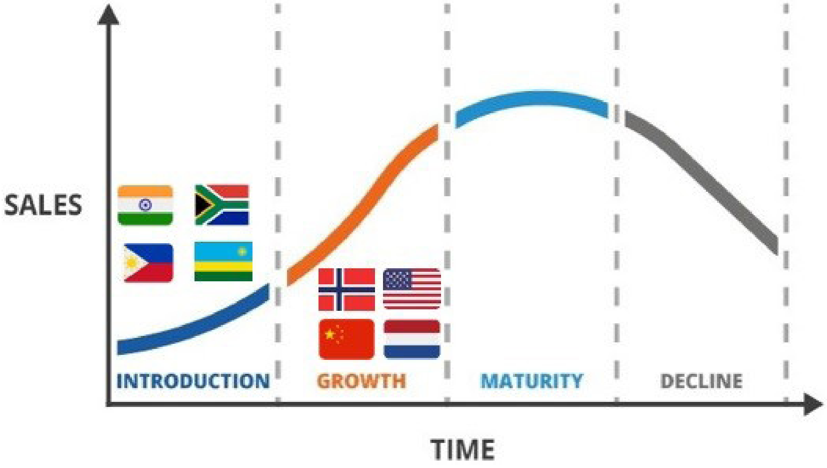


Figure 16 Stages of EV market development

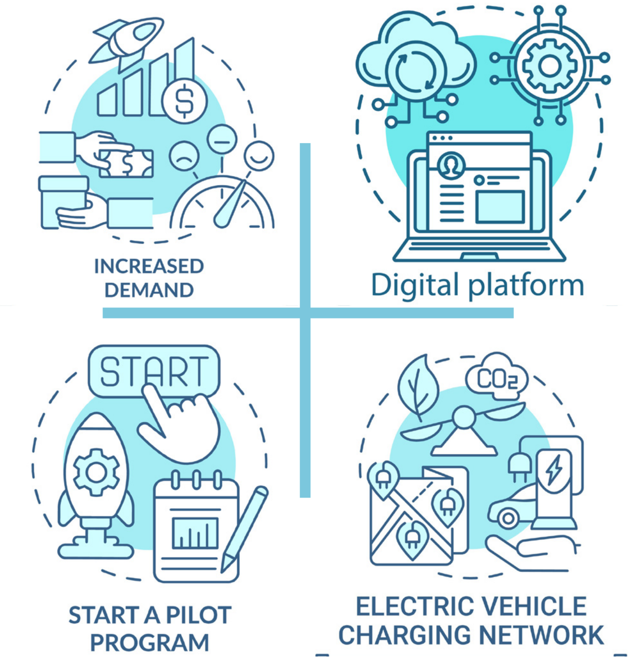
In the following sections, we will review how some countries have implemented various incentives (fiscal and non-fiscal) to help kick start their charging infrastructure market. As presented in Figure 16, we have considered countries at different stages of EV infrastructure development and care has been taken to also include countries that can be classed as developing.

India

Policies and Regulations Supporting EV Charging Infrastructure Deployment

The key EV policy document in India is the National Electric Mobility Mission Plan (NEMMP, 2020), which was launched in 2013, with targets set for year 2020. NEMMP 2020 provides a roadmap and vision for accelerated adoption of EVs and aims to promote EV technology in India through demand creation by offering fiscal incentives to EV buyers and manufacturers, developing charging infrastructure and providing funds for research and development. The fiscal incentives were designed with an ambitious target of having hybrid and electric vehicles account for 14-16% of all new vehicle sales by 2020. The scheme grants rebates of up to $300 for eligible models from 11 original equipment manufacturers (OEM).

As part of the NEMMP 2020, the Government of India approved 'Faster Adoption and Manufacturing of Electric & Hybrid Vehicles in India' (FAME India) in April, 2015. FAME has four main focus areas namely: demand creation; technology platform; pilot project; and charging infrastructure. Under this scheme, the Government of India has set aside approximately USD 1.33 billion for both demand and supply side subsidies. Other incentives under the scheme include green number plates, custom duty exemption, tax reduction on EVs to 5% and exempting EVs from road tax among others.



500
Charging Stations Developed

Under charging infrastructure, the Government of India has developed about 500 charging stations in cities like Bangalore, Chandigarh, Jaipur and NCR of Delhi. The Department of Heavy Industry has also been tasked with making three expressways (Delhi-Chandigarh, Delhi-Jaipur and Mumbai-Pune Expressways) fully electric vehicle friendly by establishing charging stations at regular intervals. So far, Delhi – Chandigarh highway has been declared as the first expressway in India to be E-vehicle friendly. Moreover, the Department of Heavy Industry has issued an Expression of Interest (EOI) inviting proposals for deployment of 7000 charging stations in municipalities across India. (Government of India, 2019)

Table 8 presents a summary of other policies and regulations relevant to EV charging infrastructure in India.

Policy Instrument	*Measures*
Ministry of Power (MOP) Charging Infrastructure Guidelines and Standards.	+ De-licensed setting up of Public Charging Stations (PCS). Any entity can set up PCS provided the station meets the technical and performance standards prescribed by MOP. + Details the minimum requirements for public charging infrastructure. These include the minimum number of charger connectors: CHadeMo, CCS, Type 2 AC, Bharat AC-001 and Bharat DC-001 + Guidance on location of PCS i.e., the density and distance between two PCS. At least one PCS to be available in a 3km x 3 km grid. One PCS every 25 km on both sides of a highway. At least one fast charging station every 100 km on both sides of the highway. + Tariff for supply of electricity for PCS. Separate metering for PCS. MOP mandated the state electricity regulatory commission to fix EV tariff that is not more than the average cost of supply plus 15%. + All stations are required to have an exclusive transformer together with associated substation equipment.
Capital subsidies on EVSE	+ Offered at state levels - Andhra Pradesh, Maharashtra, Bihar, Punjab and Madhya Pradesh provide 25% capital subsidies for a fixed number of PCS. The maximum amount is capped at different levels in different states. + Delhi offers an unspecified capital subsidy for installing PCS. It also offers 100% grant up to It is the only state to offer financial incentives for private charging equipment, with a 100% grant up to USD 80 per charging point for the first 30,000 private charging points.
Concessional land provision	+ Delhi, Uttar Pradesh and Punjab will provide land to charging service operators (CSOs) at concessional rental rates, while Madhya Pradesh offers a "rental holiday" for three years to CSOs selected to operate EV charging in a public-private.
Concessional tariffs for EV charging	+ Concessional EV tariffs are meant to reduce the cost of electricity procurement for EV charging, resulting in lower charging costs for consumers. + The EV tariffs in different states range between 5-11 US cents/kWh.

Table 12 Policies and Regulations Relevant to EV Charging Infrastructure in India

Status of EV Charging Standards in India

Bureau of Indian Standards (BIS) is the body mandated to develop national standards in India. BIS has set up various technical committees (TCs) that develop standards within their respective scopes among which is Committee of Electrotechnical Division (ETD) 51, which is responsible for preparing Indian Standards (IS) for EVCS.

IS 17017 series of standards are the main standards for India that set the requirements for EVCS and related equipment. The IS 17017 series of standards have been derived and adapted from the IEC 61851 series of standards. IEC 61851 series covers the mechanical, electrical, communications, EMC and performance requirements for EV supply equipment used to charge EVs, including light EVs. India has also adopted ISO 15118 series of standards (IS/ISO 15118 series). ISO 15118 series gives requirements for digital communication between the EV, EVCS and the utility grid. These communications standards are needed to ensure interoperability of information transfer between the EV, EVCS and the utility grid.

The Department of Heavy Industries (DHI) and Automotive Industry Standards (AIS) have also prepared and published relevant standards to EVCS. In 2017, DHI developed the Bharat Charger AC-001 (AC Charging system) and DC-001 (DC Charging system). AC-001 and DC-001 were adopted from Chinese (GB/T) standards with slight modifications in ambient temperature requirements to suit the Indian climatic conditions. AIS has also developed AIS 138-1 and AIS 138-2 for testing EVCS. AIS 138-1 and AIS 138-2 were adapted from IEC 61851 series.

IS:17017-1 published by BIS in August 2018 recommends both CCS-2 and CHAdeMO. Bharat EV Charger AC001 & DC001 support some EVs operating in India and BIS has agreed to maintain them as well though they are expected wither away as new vehicles with fast charging DC capability come into the market. So, for now CCS-2, CHAdeMO and the Bharat chargers will coexist. A list of standards and aspects covered that have been published is given in Table 13.

SL No.	Standard	Aspects covered and status
1	IS 17017-Part 1:2018 and Bharat Charger AC -001	Give general requirements for Electric Vehicle Conductive Charging System.
2	IS 17017: Part 21: Sec 1:2019 and AIS 138 (Part 1)	Defines electromagnetic compatibility (EMC) requirements for on-board charger or AC EVCS.
3	IS 17017: Part 21: Sec 2:2019 and AIS 138 (Part 2)	Defines electromagnetic compatibility (EMC) requirements for off- board charger or DC EVCS
4	IS 17017-Part 23* and Bharat Charger DC-001	IS 17017-Part 23 will be adapted from IEC 61851-23 and will give requirements for DC EVSE.
5	IS 17017-Part 24*	Defines requirements for control communication between DC EVSE and EV

6	IS 17017-Part 2: Sec 1*	Specifies general requirements for plugs, socket-outlets, vehicle connectors, vehicle inlets and cable assemblies as described in IEC 61851-1. The standard will be adapted from IEC 62196-1.
7	IS 17017-Part 2: Sec 2:2020	Specifies dimensional compatibility and interchangeability requirements for a.c. plugs, socket-outlets, vehicle connectors, vehicle inlets and cable assemblies as described in IEC 61851-1. The standard has been adapted from IEC 62196-2.
8	IS 17017-Part 2: Sec 3	Specifies dimensional compatibility and interchangeability requirements for d.c. plugs, socket-outlets, vehicle connectors, vehicle inlets and cable assemblies as described in IEC 61851-1. The standard has been adapted from IEC 62196-3.
9	IS/ISO 15118 series	Gives requirements for digital communication between the EV, EVCS and the utility grid. A total of 8 standards under this series have been directly adopted from the ISO 15118 series.
10	CEA Regulations, 2019 (Measures relating to Safety and Electric Supply) and (Technical Standards for Connectivity to the Grid)	Voltage change, frequency variations, power factor, harmonics measurements, flicker, DC injection, V2G process, the safety of EVCS. IS 17017 (Part 5) will be prepared by BIS in near future regarding grid connectivity and EVCS networks. Power quality standard requirements as per IEEE 519-2014.
11	IS 14700-6-2, IS 14700–6-3, and IS 14700-3-12	EMC testing for emission, immunity, and harmonic measurements

* Not published yet

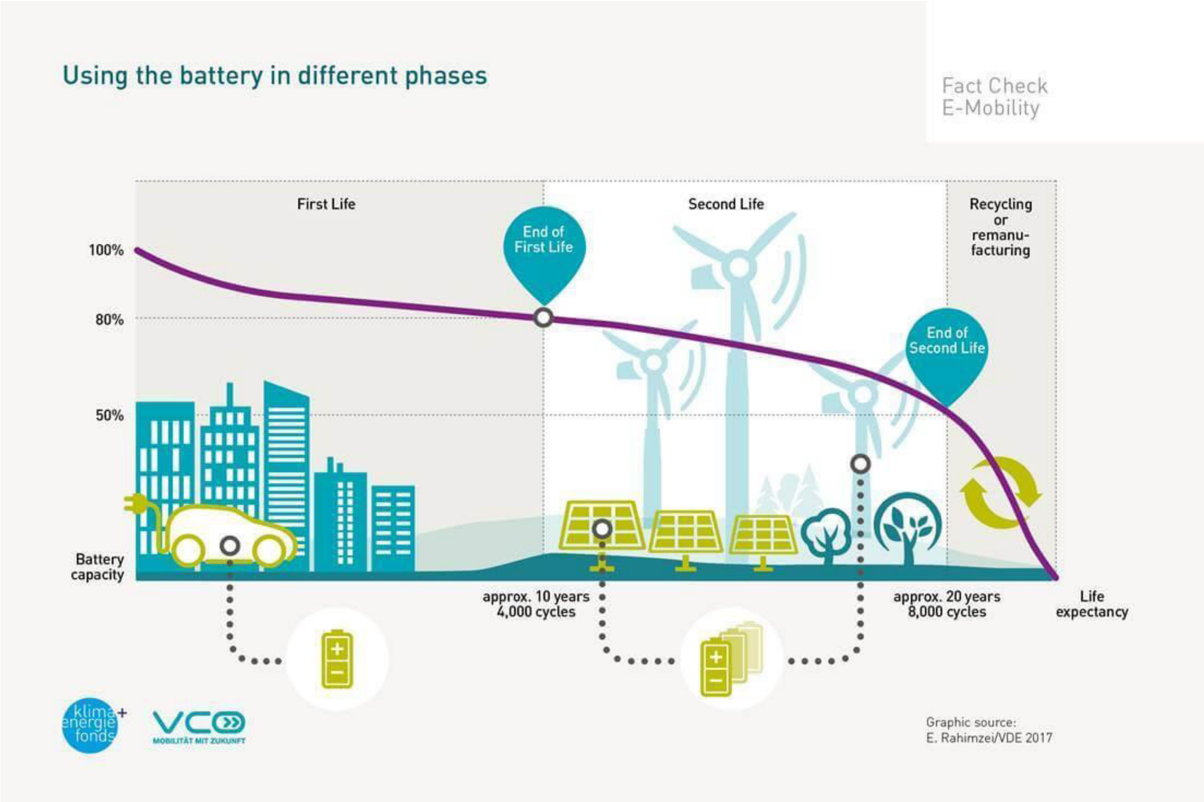
Table 13 List of Indian Standards Relevant to EVCS

South Africa

Policies and Regulations Supporting EV Charging Infrastructure Deployment

Long-term vision for the transport sector in South Africa is guided by the Green Transport Strategy for South Africa: 2018-2050. It calls for the replacement of fossil fuels by vehicle technologies with low or zero tailpipe emissions, such as electric and fuel cell vehicles. It gives provision for incentives (tax rebates, subsidies and non-financial incentives) for the EV sector. The proposed policy on e-mobility (Government of South Africa, 2021) offers a road map for production of EVs in South Africa and proposes subsidies for both EV manufacturers and buyers. It proposes lower- or zero-rated duty for identified unique EV components including EVSEs. There is also a commitment to expand the EV charging infrastructure to incentivize customers to switch to EVs. According to the draft policy on e-mobility, charging network roll out will follow common standards stipulated by South Africa Bureau of Standards.

There is also an interesting proposal with regards to 2nd life of EV batteries – repurpose them to supply homes with electricity to mitigate against power outages and a better balance of energy demand and supply-cycles. At less than 80% state of health, an EV battery is not suitable for use for traction purposes (see Figure 17) and this marks the end of first-life and beginning of second-life. At second life, the battery can be repurposed for renewable energy storage. At less than 50% state of health, the second life comes to and end and the battery can thus be recycled or remanufactured.



Graphic source:
E. Rahimzei/VDE 2017

Figure 17 EV Batteries 2nd Life (Fischhaber, et al., 2016)

Status of EV Charging Standards in South Africa

In general, all EV conductive charging equipment supplied and installed in South Africa must adhere to latest versions of the following IEC standards that have been adopted as South Africa Standards:

- IEC 62196 (All Parts);
- IEC 61851 (All Parts).

The manufacturer of EV conductive equipment must also obtain a National Regulator for Compulsory Specifications (NRCS) Regulator's Certificate of Compliance (RCC).

Defining the roles of various Government agencies. It requires that all regulations related to EVs and establishment of charging stations allow for equitable and non-discriminatory private sector participation.

Assigns the Department of Energy (DOE) as the primary agency for promotion of adoption of EVs and the development of charging infrastructure. DOE, in coordination with other agencies, will harmonize existing policies and disseminate harmonized regulations and standards on use, operation and maintenance of charging stations. This will include accreditation of charging station providers and ensuring compliance with Philippine Electrical Code and relevant standards.

Gives guidance on permits for EV charging stations installations.

Provides for fiscal incentives for manufacture and assembly of EVs, charging stations and related components. This includes VAT exemption on purchase of EVs and charging equipment.

Provides for non-fiscal incentives for EV users such as expedited registration of motor vehicles and issuance of special type of number plate.

Financial assistance – the central bank of Philippines will encourage financial institutions to lend a certain percentage of their portfolio to EV infrastructure businesses.

Proposed electric vehicle supply guidelines stipulate that all public facing Direct Current (DC) fast charging stations must be dual CHAdeMO and Combined Charging System 2 (CCS2). This is to allow EVs from all vehicle manufacturers with DC fast charging capabilities to be able to charge at the charging station. In case the charging station operator chooses also to include an Alternating Current (AC) fast charging outlet in addition to the dual DC charging plug standards, this AC outlet must be of a Type 2 socket only. Figure 18 depicts CHAdemo and CCS2 EV connectors stipulated by the proposed guidelines.

Figure 18 DC Charging plug standards

For public facing Alternating Current (AC) charging stations, the guidelines require that these be equipped with Type 2 sockets only. This will allow EVs from all manufacturers to use the station, with each vehicle owner required to only carry either a (Type 1 to Type 2) or a (Type 2 to Type 2) Mode 3 public charging cable. Figure 19 depicts Type 2, Type 1 to Type 2 and Type 2 to Type 2 EV charging cables stipulated by the proposed guidelines.

Figure 19 AC charging plug standards

A list of standards and aspects covered that have been published is given in Table 14.

SL No.	Standard	Aspects covered and status
1	SANS 61851-1:2018	Give general requirements for Electric Vehicle Conductive Charging System.
2	SANS 61851-22:2014	Gives requirements for AC electric vehicle charging stations
3	SANS 61851-21-2:2020	Defines electromagnetic compatibility (EMC) requirements for off- board charging system or DC EVCS
4	SANS 61851-21-1:2020	Defines electromagnetic compatibility (EMC) requirements for on- board charging system or AC EVCS
5	SANS 61851-23:2015	Gives requirements for DC charging station.
6	SANS 61851-24:2015	Defines requirements for control communication between DC charging station and EV
7	SANS 62196-1:2015	Specifies general requirements for plugs, socket-outlets, vehicle connectors, vehicle inlets and cable assemblies.
8	SATS 62196-3-1:2020	Specifies requirements for vehicle connectors, vehicle inlets and cable assemblies for DC charging intended to be used with a thermal management system.
9	SANS 62196-2:2018	Specifies dimensional compatibility and interchangeability requirements for a.c. plugs, socket-outlets, vehicle connectors, vehicle inlets and cable assemblies
10	SANS 62196-3:2015	Specifies dimensional compatibility and interchangeability requirements for d.c. plugs, socket-outlets, vehicle connectors, vehicle inlets and cable assemblies.

Table 14 List of South Africa Standards Relevant to EVCS

❱ Philippines

Policies and Regulations Supporting EV Charging Infrastructure Deployment

When it comes to EV charging infrastructure, the key policy document in the Philippines is the proposed Senate Bill No. 1382 - Act Providing the National Energy Policy and Regulatory Framework for the Use of Electric Vehicles and the Establishment of Electric Charging Stations (Senate of the Philippines, 2020). The bill aims to decarbonize the transport sector in the Philippines, among other things. Key issues addressed by the Senate Bill No. 1382 include:

The Department of Energy (DOE) issued EVCS policy guidelines in July 2021 (Republic of Philippines, 2021). The EVCS policy guidelines address the following issues:

- Set installation standards and permitting protocols for EVCS.
- Set safety requirements for EVCS. EVCS are required to comply with the Building Code of the Philippines and the Philippine Electrical Code.
- Classification of EVCS. Five categories are given – Mode 1, 2, 3 & 4; Battery Swapping Stations. Though no requirements are given for the type of connector to be used for each mode.
- EVCS Energy Label and Marking Requirements
- Endorsement to the Board of Investments (Under the Department of Trade and Industry) to be provided of fiscal incentives under the Omnibus Investment Code. Under this code EVCS businesses can receive an income tax holiday of between 3-6 years and capital equipment costs of up to USD 10,000.

Under The 2020 Investment Priority Plan, charging/refueling stations are listed as one of the preferred activities for investments in the Philippines hence they can receive incentives from the Board of Investments. More importantly, the DOE plans to deploy up to 5000 EV charging stations by 2027.

Status of EV Charging Standards in Philippines

The country has adopted fairly comprehensive standards on on-board and off-board charging equipment and practices. However, standards on wireless charging and vehicles to grid have not been defined.

In general, all EV conductive charging equipment supplied and installed in Philippines must adhere to the following IEC that have been adopted as Philippine Standards:

- IEC 62196 (Part 1,2 &3);
- IEC 61851 (Part 1, 21-1, 21-2, 22, 23 & 24).
- IEC 62752:2016

The list of other applicable standards is given in Table 15.

SL No.	Standard	Aspects covered and status
1	PNS IEC 61851-1:2019	Give general requirements for Electric Vehicle Conductive Charging System.
2	PNS IEC 61851-22:2012	Gives requirements for AC electric vehicle charging stations
3	PNS 61851-21-2:2018	Defines electromagnetic compatibility (EMC) requirements for off- board charging system or DC EVCS
4	PNS IEC 61851-21-1:2018	Defines electromagnetic compatibility (EMC) requirements for on- board charging system or AC EVCS
5	PNS IEC 61851-23:2018	Gives requirements for DC charging station.
6	PNS IEC 61851-24:2018	Defines requirements for control communication between DC charging station and EV
7	PNS IEC 62196-1:2019	Specifies general requirements for plugs, socket-outlets, vehicle connectors, vehicle inlets and cable assemblies.
8	PNS IEC 62196-3:2019	Specifies dimensional compatibility and interchangeability requirements for d.c. plugs, socket-outlets, vehicle connectors, vehicle inlets and cable assemblies
9	PNS IEC 62196-2:2018	Specifies dimensional compatibility and interchangeability requirements for a.c. plugs, socket-outlets, vehicle connectors, vehicle inlets and cable assemblies
10	PNS ISO 17409:2018	Specifies electric safety requirements for conductive connection of electrically propelled road vehicles to external electric circuits.
11	PNS ISO 11898-1:2019	Specifies the characteristics of setting up an interchange of digital information between modules implementing the controller area network (CAN) data link layer. Controller area network is a serial communication protocol, which supports distributed real-time control and multiplexing for use within road vehicles and other control applications.
12	PNS ISO 15118 series	Gives requirements for digital communication between the EV, EVCS and the utility grid. Parts 1,2, 3, 4, 5 & 8 have been adopted.
13	PNS IEC 62752:2016	Defines requirements for in -cable control and protection device to be used for mode -2 charging.

Table 15 List of Philippine Standards Relevant to EVCS

❱ USA

Policies and Regulations Supporting EV Charging Infrastructure Deployment

USA is the second largest EV market, after China, accounting for about 4.5% (Lambert, 2022) of the total EVs in the world. This significant EV market development can be attributed to Federal and State policies that stipulate both fiscal and non-fiscal incentives. Looking to further ramp up the number of EVs on its roads, the USA plans to increase the number of its DC fast chargers. The driver is the belief among analysts and academics that a fast-charging infrastructure is essential to large-scale adoption of EVs. According to the US Department of Energy, there are about 4,900 fast charging stations (inclusive of AC fast charging stations) in the USA. However, this is about to change if the infrastructure bill proposed by President Joe Biden is approved. The plan is to invest $15 billion to install at least 500,000 public chargers by 2030. The objective is to accelerate the deployment of a mix of chargers in apartment buildings, public parking and fast charging along the nation's highways. This will be achieved through a combination of grant and incentive programs for state governments and the private sector (White House, 2021).

Table 16 presents a summary of other policies and regulations relevant to EV charging infrastructure in the USA.

Policy Instrument	*Measures*
Tax credits to owners of EVCS (US DOE, 2019)	+ 30% tax credit of the of the cost of purchasing and installing an EVCS (up to a maximum of USD 1000)
Federal loan guarantees	+ up to USD 4.5 billion has been set aside for the development of EV charging infrastructure along identified EV corridors.
Designated EV corridors	+ Federal Highway Administration (FHWA) has designated EV corridors approximately 95000 km of national highways in 48 states plus DC. + Plan to install EVCS every 80 km on these EV corridors. Signage to help EV owners to easily identify the EVCS.
Charging space allocation	+ Required charging space in new parking lots
California Calgreen Code	+ Specifies minimum facilities to be provided at an EVCS. + The Code specifies wiring practices, labelling, EV charging, space dimensions, and markings and accessibility.

Table 16 Policies and Regulations Relevant to EV Charging Infrastructure in USA

Status of EV Charging Standards in USA

Three categories of EV chargers are available in the USA:

- Level 1 Chargers - Fitted with SAE J1772 connector
- Level 2 Chargers - Fitted with SAE J1772 connector
- DC Fast Chargers - Fitted with CCS or SAE Combo, CHAdeMO or Tesla connectors

SAE J1772 is the de facto standard for level 2 chargers. A de facto standard for fast charging stations is also emerging. CCS is becoming dominant. Nissan Leafs, the first EV car in the US market have been using CHAdeMO but Nissan has announced that for the North America market they are moving to CCS. In addition, Tesla is about to offer an adapter that makes it possible for Tesla EVs to use CCS charging stations. It is also feasible that Tesla may decide to add CCS charging stations at their supercharger sites.

Charging communication protocols are necessary to optimize charging for the needs of the user (to detect state of charge, battery voltage and safety) and for the grid. CHAdeMO use a communication protocol known as Controller Area Network (CAN), while CCS works with the Power Line Communication (PLC) protocol. Open communications protocols, such as the Open Charge Point Protocol (OCPP) developed by the Open Charging Alliance, are becoming increasingly popular in the USA.

Table 17 presents a list of US standards for EV charging.

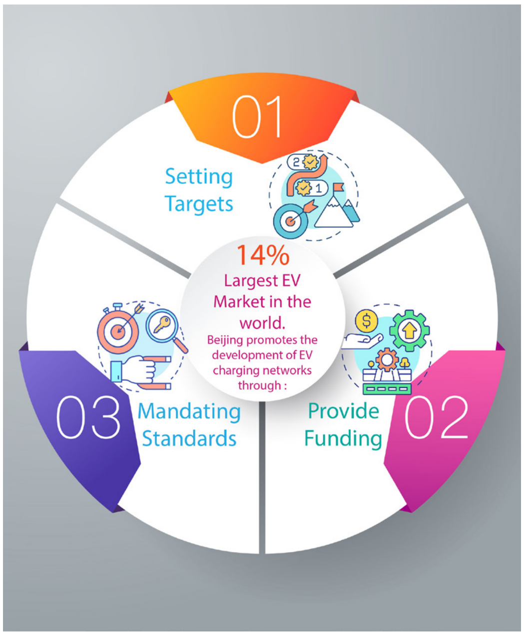
SL No.	Standard	Aspects covered and status
1	ANSI/UL 2594	Specifies safety requirements for on-board EV supply equipment or AC EVCS.
2	ANSI/UL 2202	Specifies safety requirements for off-board EV supply equipment or DC EVCS
3	ANSI/UL 62	Specifies safety requirements for EV cables.
4	ANSI/UL 2251	Defines safety requirements for EV connectors.
5	ANSI/UL 2231-1	Defines general requirements for personnel protection systems in EV supply equipment.
6	ANSI/UL 2231-2	Specifies particular requirements for protection devices for use in charging systems.
7	UL 2750	Specifies safety requirements for wireless power transfer equipment for EVs.
8	SAE J2954	Specifies requirements for the design of the wireless power transfer system for EVs. It covers interoperability and efficiency issues.

Table 17 List of US Standards Relevant to EVCS

❱ China

Policies and Regulations Supporting EV Charging Infrastructure Deployment

China has the largest EV market in the world at 14% (Lambert, 2022) and innovative companies like BYD are becoming major global EV players. To achieve further growth in the sector, the Central Government in Beijing promotes the development of EV charging networks through setting targets, providing funding and mandating standards. Many provincial and local governments also promote development of EV charging networks by providing financial incentives, mandating residential building owners to allocate EV charging spaces and requiring that a certain percentage of commercial parking spots have EV charging. The main policy documents are presented in Table 18. Figure 20 illustrates typical process flow for deployment of an EVCS in China.



Policy Instrument	*Measures*
Guidance on Accelerating the Construction of Electric Vehicle Charging Infrastructure	+ Sets target to provide for charging + infrastructure sufficient for 5 million EVs by 2020. + All new residential buildings post-2015 are required to be EVSE equipped. + 10% of parking spaces in large public buildings to be available for EV charging. + at least one public charging station for every 2,000 EVs. + The guidance also calls for public-private partnerships to develop charging infrastructure at shopping malls and major parking facilities.
Guidelines for Developing Electric Vehicle Charging Infrastructure (2015–2020)	+ The guidelines call for at least 120,000 EV charging stations and 4.8 million EV charging posts by 2020. + Divide China into three regions with varying degrees of EV infrastructure promotion and call for establishing a grid of EV-charging-enabled highways covering the most populous coastal provinces of East China. (See figure 21)

National standards for EV charging interfaces and communications protocols.	+ In January 2016 the National Energy Administration released a notice summarizing five revised national standards for electric vehicle charging interfaces and communications protocols. + The standards were issued in late 2015 by the National Standards Committee, + the Ministry of Industry and Information Technology and others.
Five-Year Plan for New EV Infrastructure Incentive Policies	All provinces mandated to increase support for charging infrastructure development and to establish a reporting system for EV charging infrastructure construction with monthly reports on the number of charging facilities.
Notice on Accelerating Residential EV Charging Infrastructure Construction	Setting out standards and procedures for residential charging as well as designating the Jing-Jin-Ji, Yangtze River Delta and Pearl River Delta regions as demonstration zones for residential charging infrastructure development
Notice on EV Charging Policy	+ clarifies EV charging rates for three classes of customers. + residential customers pay the residential rate. + dedicated central EV charging and battery swap stations pay the large industrial customer rate, except they are exempt from the basic charge (demand charge). + government offices, public parking lots and other businesses pay the commercial and small/medium industrial (C&I) rate.
Regional policies	+ The city of Shenzhen offers purchasers of EVs subsidies of up to RMB 20,000 for vehicle insurance and installation of charging equipment. + Over 30 other cities offer some form of subsidy for home or public EV charging. + Guangzhou has adopted a requirement that new buildings must have 18% of parking spots either equipped with EV charging or enabled for future installation. + In 2017 the Beijing municipal government began mandating that all parking spots in new residential developments set aside space for EV chargers, with new government or state-owned enterprise buildings required to install chargers at 25% of parking spots.

Table 18 Policies and Regulations Relevant to EV Charging Infrastructure in China

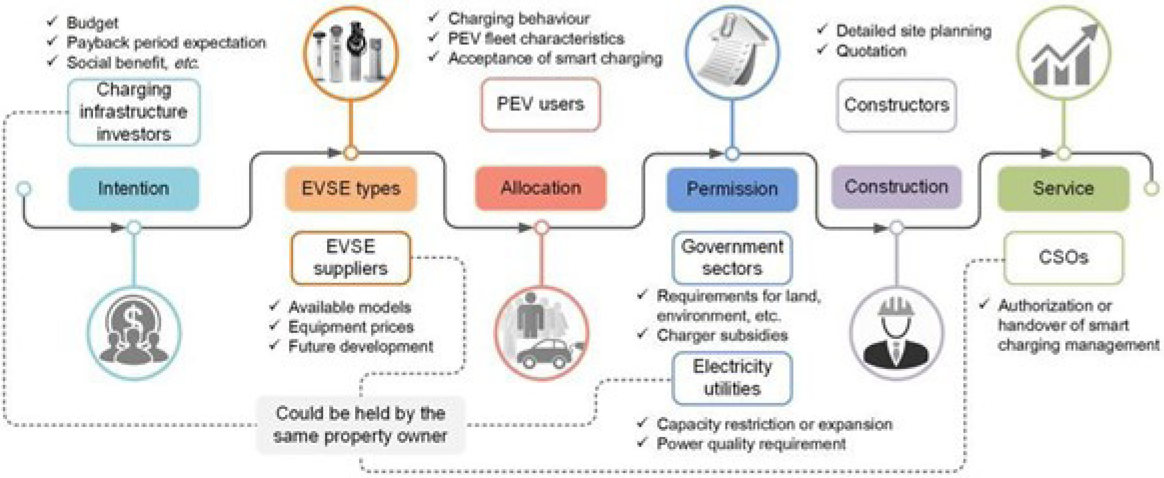


Figure 20 Typical process flow for deployment of EVCS in China (Ji & Huang, 2018)

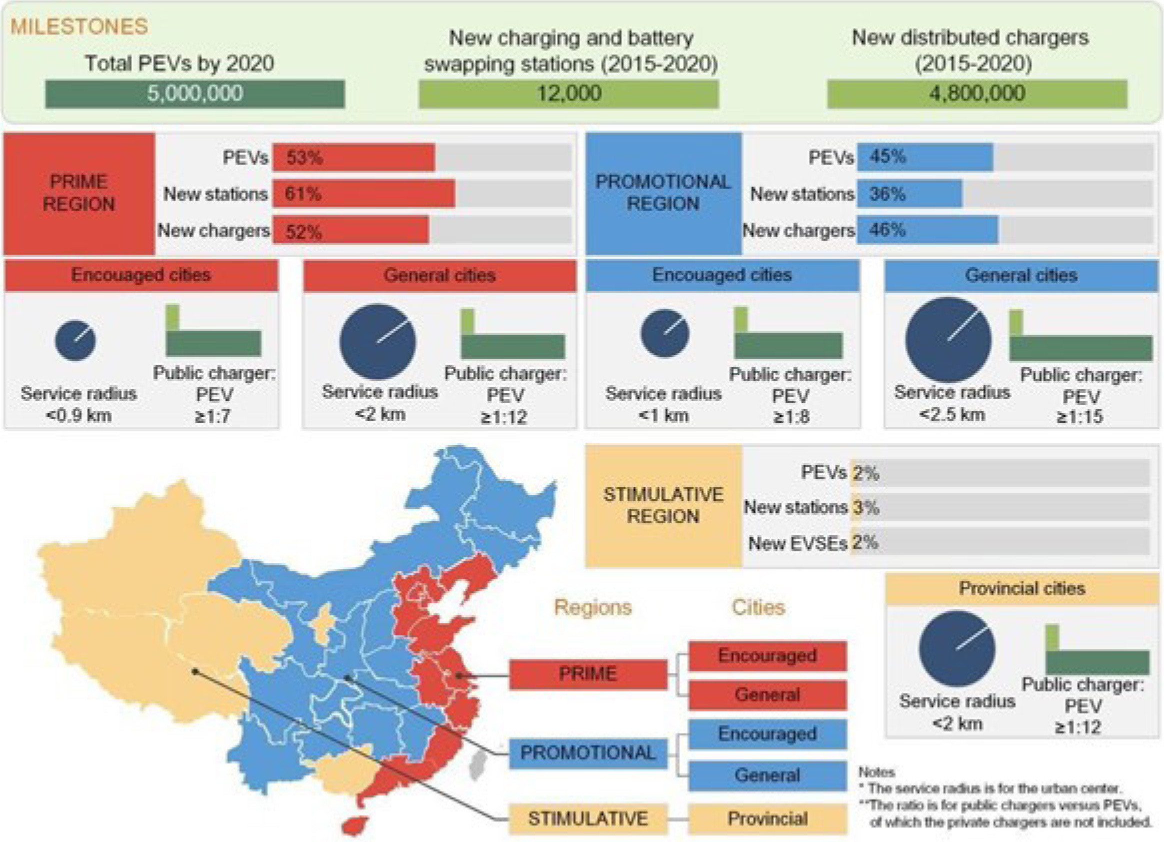


Figure 21 China's planned regional charging infrastructure by 2020 (Ji & Huang, 2018)

Status of EV Charging Standards in China

The Standardization Administration of China (SAC) is the entity responsible for developing national standards in China. The Standardization Administration of China and together with other relevant regulators have published a series of national standards on key EV components such as batteries and charging infrastructure among others as shown below:

- Conductive charging system – GB/T 18487 series. The scope corresponds to that IEC 61851 series of standards.
- Interface (EV charging connectors) – GB/T 20234 series. The scope corresponds to that IEC 62196 series of standards.
- Communication – GB/T 27930 -2015. The scope corresponds to that ISO 15118 series of standards. GB/T 27930 is based on the SAE J1939 network protocol and uses the CAN bus with a point-to-point connection between the charger and the battery management system (BMS).
- Wireless charging system - GB / T 38775 series of standards.

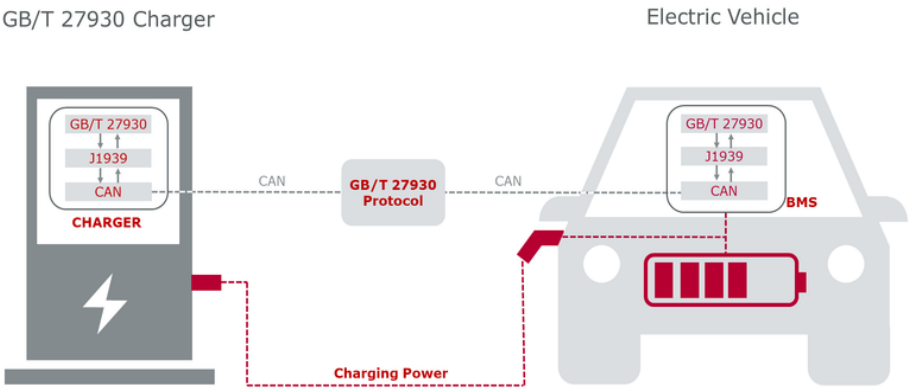


Figure 22 Figure 21 GB/T 27930: A cable charging standard based on SAE J1939

Figure 23 GB/T 20234.3-2015 Compliant DC fast charging port (Ji & Huang, 2018)

SL No.	Standard	Aspects covered and status
1	GB/T 18487-1-2015	Specifies general requirements for EV conductive charging system.
2	GB/T 18487-2-2017	Specifies requirements EMC requirements for off-board EV supply equipment.
3	GB/T 18487-3-2001	Specifies requirements (safety and performance) for AC/DC charging stations.
4	GB/T 27930-2015	Defines communication protocols between off-board conductive charger and battery management system of an EV.
5	GB/T 20234.1-2015	Specifies general requirements for connection set for conductive charging of electric vehicles.
6	GB/T 20234.2-2011	Specifies requirements for AC charging couplers for conductive charging of EVs.
7	GB/T 20234.3-2015	Specifies requirements for DC charging couplers for conductive charging of EVs.
8	GB/T 38775.1-2020	Specifies general requirements for wireless power transfer system for EVs.
9	GB/T 38775.2-2020	Specifies the communication protocols between on-board EV charger and wireless power transfer device
10	GB/T 38775.3-2020	Specifies specific requirements for wireless power transfer system for EVs.
11	GB/T 38775.4-2020	Specifies EMC limits for wireless power transfer for EVs.
12	GB/T 29317-2021	Defines the terms and definitions related to charging and battery swap facilities for electric vehicles
13	GB/T 28569-2012	Specifies the technical requirements of electric energy metering for electric vehicle AC charging spots, as well as electric energy metering device's configuration and installation requirements, test methods and inspection rules.
14	GB/T 29318-2012	Specifies the configuration installation requirements, technical requirements, test methods and inspection rules of the DC electric energy metering device for the electric vehicle off-board charger.
15	GB/T 29316-2012	Specifies power quality requirements for EVSE

NB: GB is a national standard and T represents recommended (to the contrary of mandatory).

Table 19 List of Chinese Standards Relevant to EVCS

❯ Netherlands

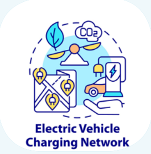
EV Policies and Regulations Supporting EV Charging Infrastructure Deployment

The Netherlands has one of the densest charging networks in the world at 19.3 charging stations per 100km (McCarthy, 2022) and has successfully deployed charging stations along the entire length of a major highway. As of 1st January 2020, there were about 49520 public charging points and 1,252 fast charging points (see Figure 24).

> *"The policy of the Dutch government is towards the market model with the aim of stimulating profitable business models."*

Public parking facilities are only provided if necessary and EV charging infrastructure should be developed on private premises, home facilities or semi-public facilities such as parking lots in shopping malls. However, early deployment of charging infrastructure was facilitated by ElaadNL, an initiative set up by seven grid operators in the country. The Netherlands is also an interesting case study for interoperability of EV charging infrastructure – the so-called e-roaming. EV car owners can charge at any charging facility using a single card (ID). The Netherlands achieved this by instituting regulations that require all public charging stations to use a single ID.

The key policy document is the National Charging Infrastructure Agenda, part of the Climate Agreement. It is a widely supported multi-year policy agenda with the ambitions and actions for creating a charging infrastructure network in the Netherlands. It takes an integrated approach to meet future charging needs and aims to create the following:



\+ A network with high coverage of charging infrastructure;

\+ Strategic & data driven placement of public charging infrastructure;

\+ Accessible information such as location and availability of charging point and charge rates;

\+ A good balance for types of charging infrastructure for all modalities;

\+ Future-proof charging infrastructure and smart charging to prevent capacity overload on the electricity grid.

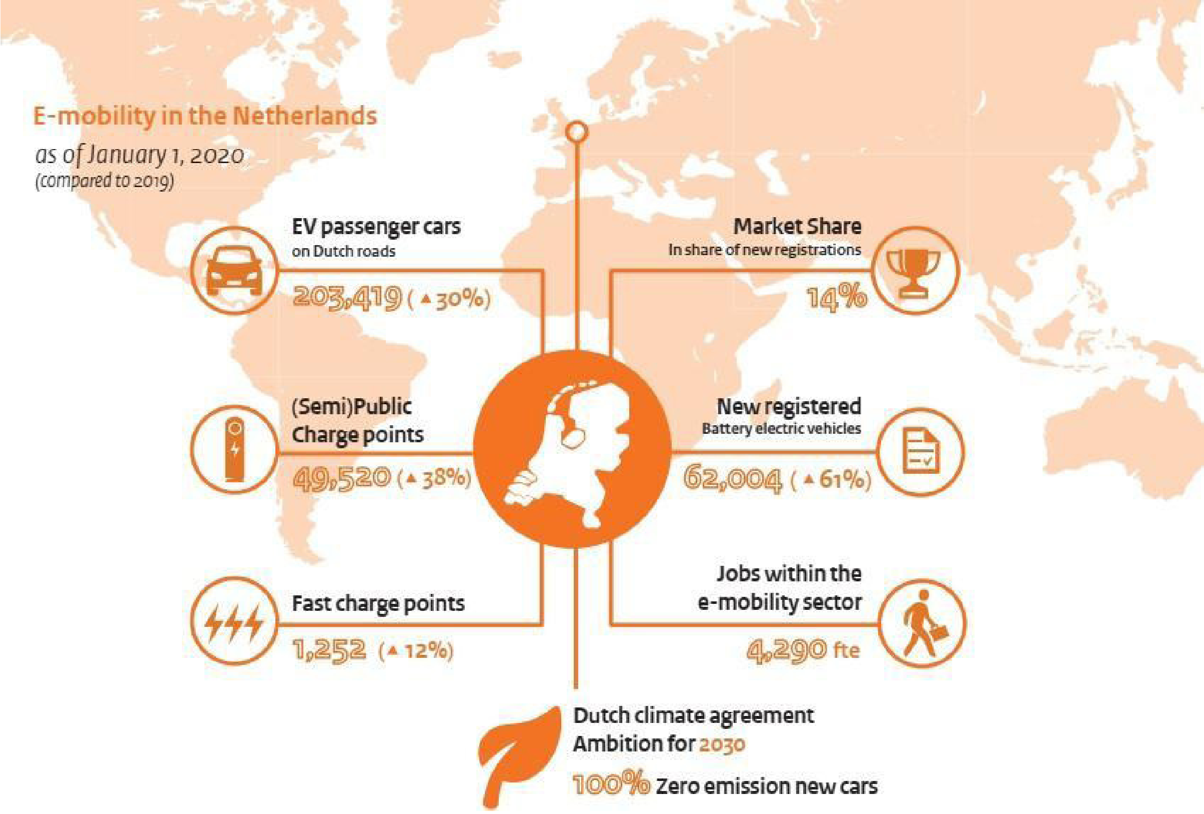


Figure 24 E-mobility in Netherlands (Netherlands Enterprise Agency, 2020)

Other policy documents are presented in Table 20.

Policy Instrument	Measures
EV charging definitions and explanation	Developed by the Netherlands Enterprise Agency, it aims to give clear definitions and explanations on relevant aspects of EV charging. It is available to the public and receives regular content updates.
Publicly Accessible Electric Charging Infrastructure Green Deal	Dutch government commitment to eliminate uncertainty regarding organization of public charging infrastructure and promote roll out of publicly accessible charging infrastructure.
Environmental Investment Tax Scheme (MIA) for charging infrastructure	Provides tax incentives for businesses to make investments in environmentally friendly technologies including EV charging infrastructure.
Electricity tax breaks for public EV charging infrastructure	In the Netherlands, the first 10,000 kWh units of electricity consumed are taxed at a higher rate than subsequent consumption. However, EV charging station operators pay the rate normally paid after the first 10 000 kWh for all electricity consumption up to 50,000 kWh.

Open Charge Point Protocol (OCPP)	An open protocol used for connections between charging station operators and service providers. This protocol facilitates automated roaming for EV drivers across several EV charging networks, allowing them to charge on several networks using a single card.
Dutch Guidelines (B117)	These guidelines mandate EV charging station operators to accept any valid charging card from an e-Mobility Service Provider for access and payment.
Directive 2014/94/EU on the deployment of alternative fuels infrastructure	Requires EU member states to establish a policy framework for EV charging infrastructure including targets and incentives for establishing public charging stations. Defines technical specification for charging points. It requires normal charging points for EVs to be equipped with at least socket outlets or connectors of type 2 as defined in EN 62196-2 (IEC 62196-2). High power a.c charging points for EVs are required to have at least type 2 connectors. DC high power charging points to be equipped with at least CCS Combo 2 as defined by EN 62196-3 (IEC 62196-3). Labeling of EVs and EV charging stations has to be done as per the specification given in EN 177186:2019

Table 20 Policies and Regulations Relevant to EV Charging Infrastructure in Netherlands

Status of EV Charging Standards in the Netherlands

The country has developed a number of standards on on-board and off-board charging equipment, EV connectors/plugs, and EV and EV charging station labeling. Standardization has been executed to ensure compatibility of charging infrastructure, avoid technological lock-ins and enable competition. The standards have been developed to ensure compatibility between different charging stations and EV service providers. Compatibility is necessary to execute the market model advocated by the Dutch government that involves many competing companies.

Communication compatibility standards are flexible (only prescribe performance requirements), which is beneficial to innovation in the charging infrastructure sector. Stability of the Dutch EV charging infrastructure is guaranteed by mandating a fixed design for the socket of charging stations (Type 2 for AC charging stations and CCS Combo 2 for DC fast charging) and by creating a roaming model (see Figure 25) for EV service providers by convention.

Specifications for charging stations are mandated by Directive 2014/94/EU (see Table 20). Standardization of charging connectors/plugs early on in the development of the market has avoided the situation of multiple standards being used by players in different markets for a long period.

In addition, it has provided greater certainty to investors. Adoption of a standardized communication protocol (see Table 20) between charging stations and service providers has allowed e-roaming to be implemented. The e-roaming allows charging stations operated by different providers accessible for a broad range of clients. The list of standards related to EVCS in the Netherlands is given in Table 21.

The e-roaming model in the Netherlands works in the following steps:

1. EV driver gets a contract from a service provider and gets a RFID card with a unique RFID identification number which is coupled to a contract identification number (standard contract ID).
2. *The service provider sends the RFID card number to a central interoperability register (CIR) where it is stored together with the service provider identity.*
3. *The EV driver can enable a charging station by using the RFID card. The charging station verifies if the RFID card is stored in the CIR.*
4. *The car can be connected with the charging station with a Type 2 or CSS connection cable. The charging station communicates with the car using the Mode 3 or 4 protocol and the car starts to charge.*
5. *The charging station operator controls the charging station either directly or through EVSE software. The OCPP defines the minimum functions a charging station is capable of for example that the RFID is approved or the energy consumed by the EV.*
6. *Charging station operators can collect RFID card numbers that are registered by service providers from the CIR database.*
7. *If the charging station operator and service provider are different, settlement take place using the standard protocol Charge Data Record which is coupled to a Standard Contract ID.*

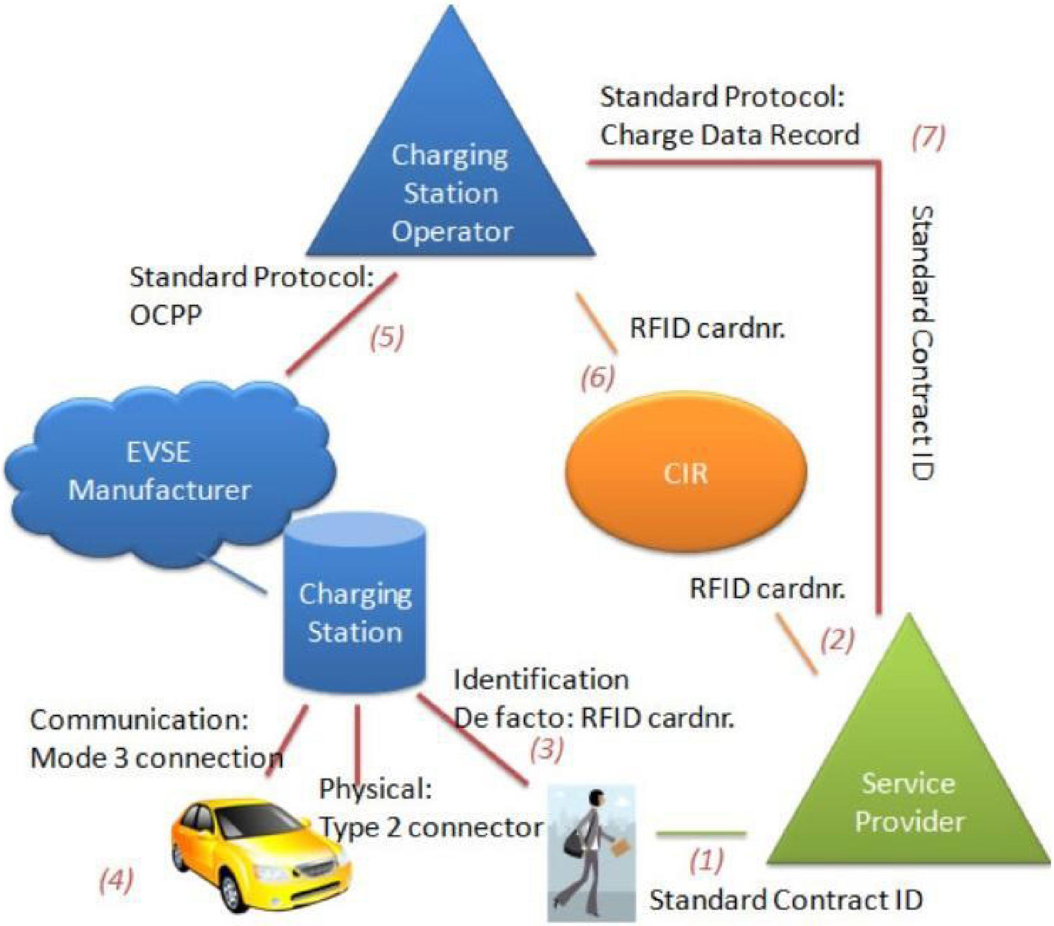
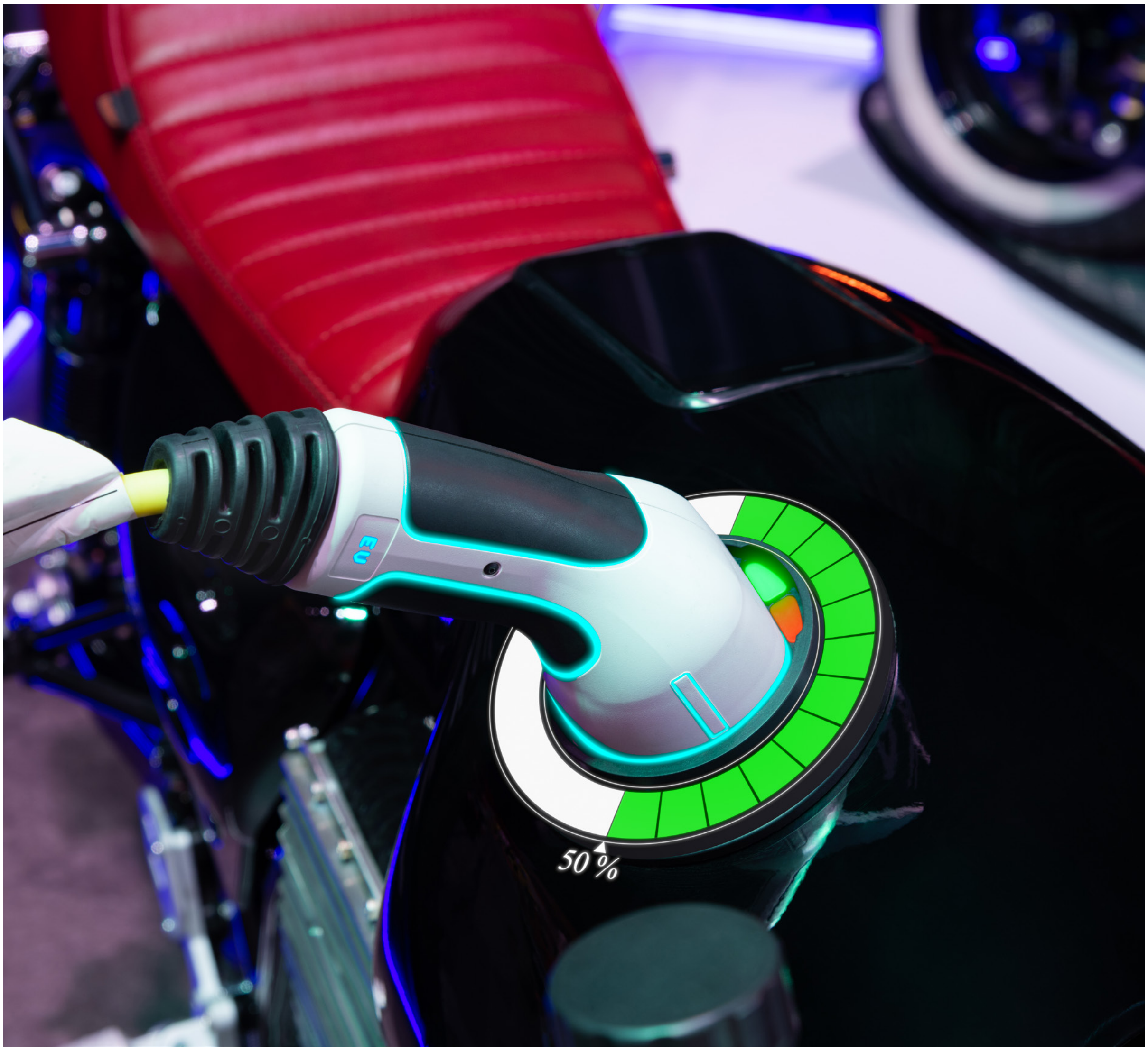


Figure 25 Interface standards for the current market model (Source: C.I, 2012)

SL No.	Standard	Aspects covered and status
1	NEN-EN-IEC 61851-1:2019	Give general requirements for Electric Vehicle Conductive Charging System.
2	NEN-EN-IEC 61851-22:2002	Gives requirements for AC electric vehicle charging stations
3	NEN-EN-IEC 61851-21-2:2021	Defines electromagnetic compatibility (EMC) requirements for off- board charging system or DC EVCS
4	NEN-EN-IEC 61851-21-1:2017	Defines electromagnetic compatibility (EMC) requirements for on- board charging system or AC EVCS
5	NEN-EN-IEC 61851-23:2014	Gives requirements for DC charging station.
6	NEN-EN-IEC 61851-24:2014	Defines requirements for control communication between DC charging station and EV
7	NEN-EN-IEC 61851-25:2021	Gives requirements for DC charging stations where protection relies on electrical separation.

8	NEN-EN-IEC 62196-1:2014	Specifies general requirements for plugs, socket-outlets, vehicle connectors, vehicle inlets and cable assemblies.
9	NEN-EN-IEC 62196-2:2017	Specifies dimensional compatibility and interchangeability requirements for a.c. plugs, socket-outlets, vehicle connectors, vehicle inlets and cable assemblies
10	NEN-EN-IEC 62196-3:2014	Specifies dimensional compatibility and interchangeability requirements for d.c. plugs, socket-outlets, vehicle connectors, vehicle inlets and cable assemblies.
11	NEN-EN 17186:2019	Defines requirements for labels for EVs and EV charging stations. For example, EV charging station label (identifier) gives compatibility information with either plug of the cable assembly or the vehicle inlet in case of attached cable configuration.

Table 21 List of Standards Relevant to EVCS in the Netherlands

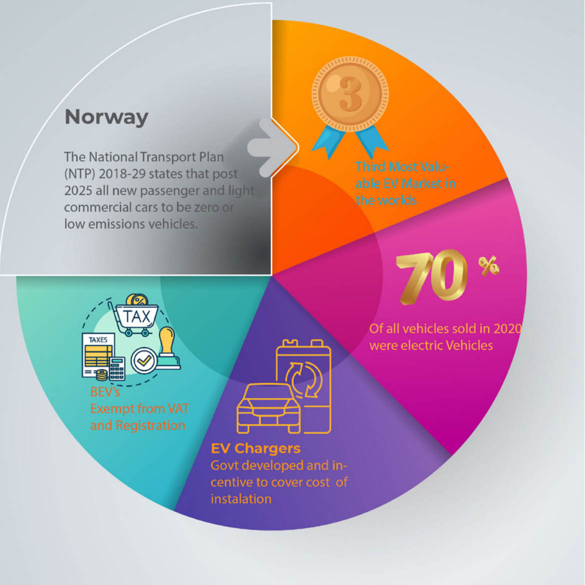


❯ Norway

Policies and Regulations Supporting Deployment of EV Charging Infrastructure

Norway is the third most valuable market for EVs in the world despite its small size. In 2020, electric vehicles (PHEV and BEV) accounted for more than 70% of all the vehicles sold in Norway. As of December 2020, the number of EVs accounted for about 12% of the total fleet of passenger cars in Norway.

The National Transport Plan (NTP) 2018-29 states that post 2025 all new passenger and light commercial cars to be zero or low emissions vehicles. Key driver for increased adoption of EVs has been government incentives – the Norwegian government has made it easier for people to choose EVs through provision of fiscal and non-fiscal incentives. In Norway, BEVs are exempt from VAT and registration tax which combined can add up to 100% of the net price of the vehicle (European Union, 2018).



Moreover, the government developed an incentive to cover the cost of installation of EV chargers and established a state enterprise, Enova, to deploy charging stations in Norway's motorways.

Enova was established in 2001 and is financed through government funding, in addition to a USD 0.001/kWh tax on electricity to consumers. It has established an incentive scheme to deploy publicly accessible fast chargers at least every 50 km on the highway network.

As of December 2020, there were about 17000 chargers, of which around 5300 are classified as fast chargers (see figure 26). At the same time, the number EVs in Norway was just under half a million meaning Norway has a comparatively low ratio of publicly available chargers per electric car (Wagner, 2020). This is mainly because home charging is the most prevalent form of charging in Norway as 70 per cent of Norwegians can be able to charge their vehicles at home – 80% of BEV owners charge their vehicles at home.

In terms of national EV infrastructure, the Norwegian government has already established fast-charging stations every 50km on all main road (Schulz & Rode, 2022). Policies and regulations supporting deployment of EV charging infrastructure in Norway are presented in Table 22.

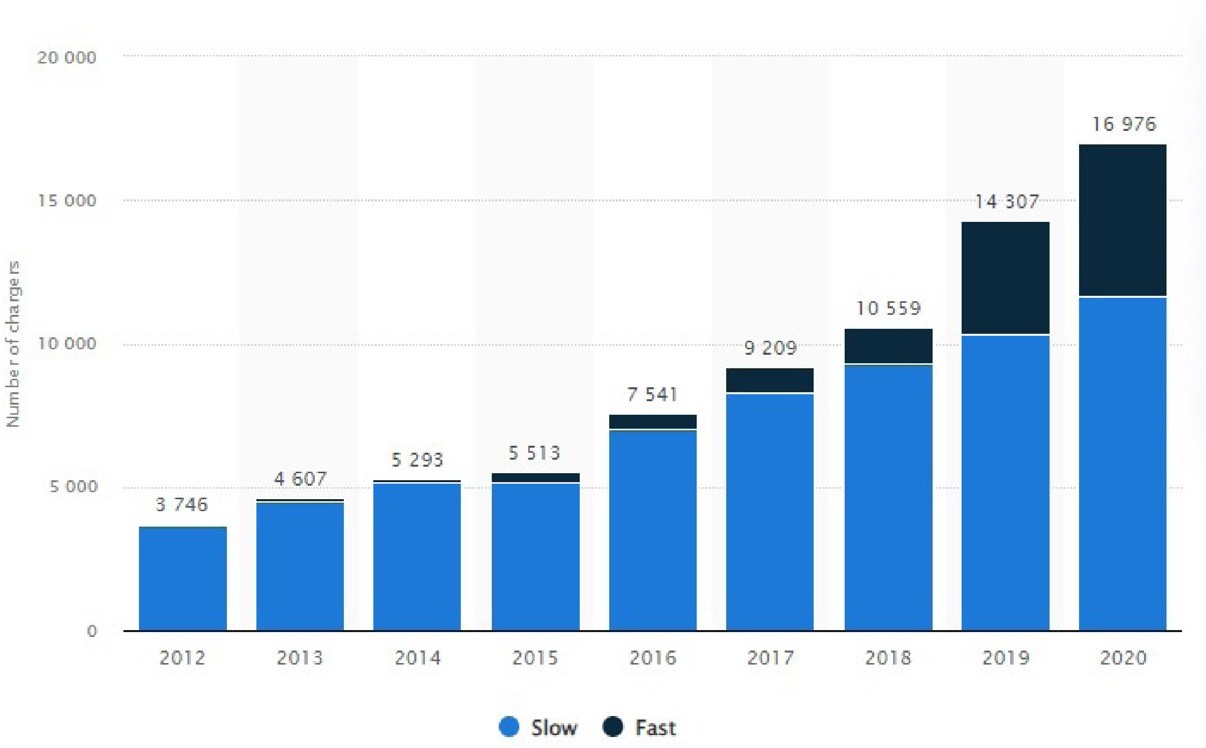


Figure 26 Number of publicly accessible fast and slow electric vehicle chargers in Norway (Source: Statista (Wagner, 2020)

Policy Instrument	Measures
Financial stimulus package (2009-2010) (Lorentzen, et al., 2017)	+ Norway's first governmental support scheme for public charging infrastructure. Instituted after the 2008 financial crisis. It catered for slow chargers. + Funded 100 % of the installation cost for normal chargers, up to US$ 3380 per charging point. + The total support amounted to US$ 5.6 million and the scheme resulted in around 1800 charging points installed across the country.
Enova financial support scheme for fast chargers (IEA, 2018)	+ Aims to cover the Norwegian main roads with fast charging stations every 50 km (around 7500 km road network) + 100 % of installations costs for EV charging operators + The road network is split into several smaller segments, and operators compete for public funding. All the stations are owned and/or operated by charging operators. + To reduce the risk for charging stations being out of order and reduce charging queues all locations must have at least two multi standard fast chargers (CHAdeMO and CCS Combo 2) in addition to two 22 kW Type 2 points.

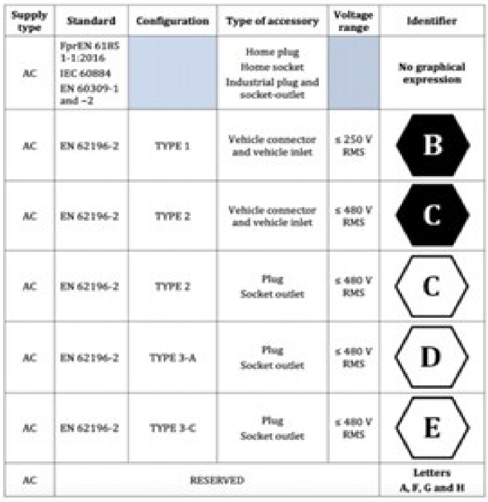
National database for charging stations (NOBIL)	+ Joint effort between the governmental entity Enova and the Norwegian EV Association. + Open, publicly owned database that allows everyone to build services using standardized data free of charge. + Provide EV users with up-to date information about the charging infrastructure + Data is used by several in-car navigations systems in addition to charging maps and apps.
Regulation on the requirements for EVSE in new buildings and parking lots. (IEA, 2018)	+ Came into force on 1st January 2018. + Requires parking lots and parking areas of new buildings to allocate a minimum of 6% to EVs
Building regulation EVSE Oslo (IEA, 2019)	+ Oslo adopted a measure in 2017 to strengthen the availability of private charging infrastructure. + This regulation mandates that new buildings must have at least 50% of the parking facilities equipped for electric car charging. + The grid capacity must also be designed to charge at 3.6 kW all of the vehicles in the building without any need for smart charging to prevent local power shortages.
EVSE Grants for Housing Associations (Wall Box , 2021)	+ **Oslo:** An EVSE grant for a maximum of 20% of the cost of EVSE purchase and installation, up to €450 per charging point and €91,000 per housing association + **Skedsmo:** An EVSE grant for a maximum of 20% of the cost of EVSE purchase and installation, as well as the cost of professional consultation, up to €450 per charging point and €23,000 per housing association. + **Asker:** An EVSE grant for a maximum of 50% of the cost of EVSE purchase and installation, up to €450 per charging point and €4,500 per housing association.

Table 22 Policies and regulations supporting deployment of EV charging infrastructure in Norway.

Status of EV Charging Standards in Norway

To aid interoperability Norway has mandated standards for publicly accessible charging stations. All publicly accessible charging stations must have at least two multi standard fast chargers (CHAdeMO and CCS Combo 2) in addition to two 22 kW Type 2 points. NOBIL, an open and publicly owned database for EV charging stations, provides EV users with up-to-date information about the charging infrastructure. It is used by several in-car navigation systems in addition to charging maps and apps. No standardized payment system is in place yet (Lorentzen, et al., 2017).

A new labeling system for EV charging stations came into force on 20th March 2021 in the European Economic Area, made compulsory by Directive 2014/94/EU, which addresses the deployment of alternative fuel infrastructure. The labels must comply with the requirements set out in standard EN 17186:2019 and be applied both to vehicles and to the charging points. The label is a hexagonal mark containing a letter indicating the connector type. The label ensures that each connector and plug should be plugged into the vehicle's inlet or station's socket-outlet bearing the same identifier (see Figures 27 & 28).



Supply type	Standard	Configuration	Type of accessory	Voltage range	Identifier
AC	FprEN 6185 1-1:2016 IEC 60884 EN 60309-1 and -2		Home plug Home socket Industrial plug and socket-outlet		No graphical expression
AC	EN 62196-2	TYPE 1	Vehicle connector and vehicle inlet	≤ 250 V RMS	B
AC	EN 62196-2	TYPE 2	Vehicle connector and vehicle inlet	≤ 480 V RMS	C
AC	EN 62196-2	TYPE 2	Plug Socket outlet	≤ 480 V RMS	C
AC	EN 62196-2	TYPE 3-A	Plug Socket outlet	≤ 480 V RMS	D
AC	EN 62196-2	TYPE 3-C	Plug Socket outlet	≤ 480 V RMS	E
AC	RESERVED				Letters A, F, G and H

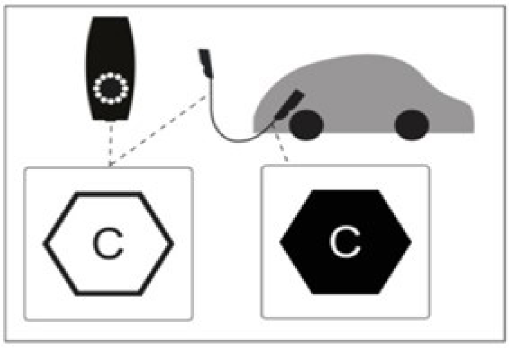
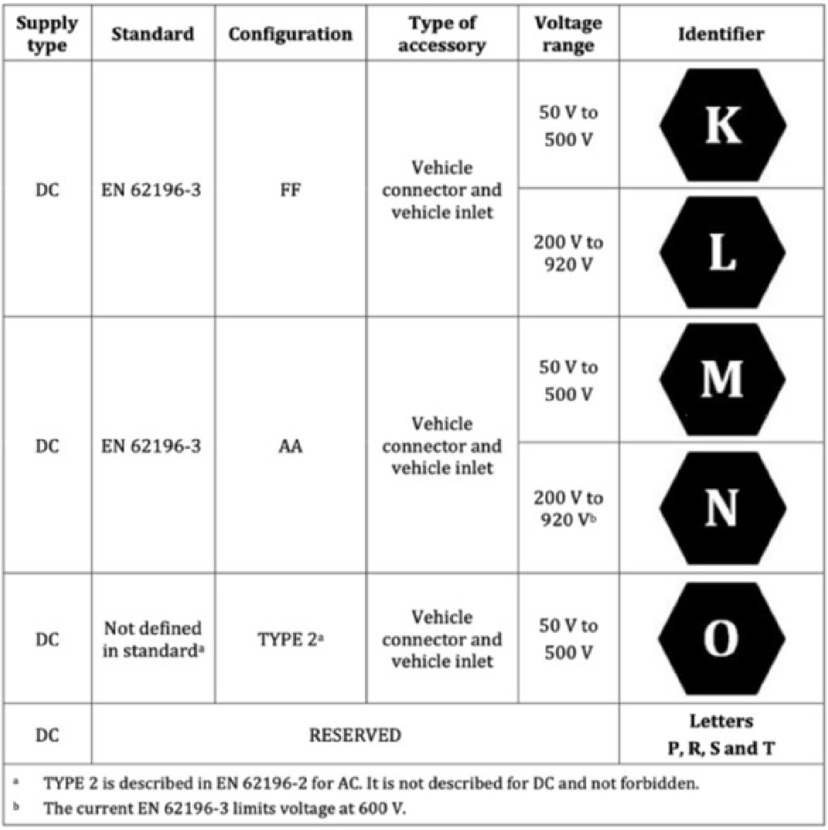


Figure 27 AC Connectors and Identifiers (Source: EN 17186:2019)



Supply type	Standard	Configuration	Type of accessory	Voltage range	Identifier
DC	EN 62196-3	FF	Vehicle connector and vehicle inlet	50 V to 500 V	K
				200 V to 920 V	L
DC	EN 62196-3	AA	Vehicle connector and vehicle inlet	50 V to 500 V	M
				200 V to 920 V[b]	N
DC	Not defined in standard[a]	TYPE 2[a]	Vehicle connector and vehicle inlet	50 V to 500 V	O
DC	RESERVED				Letters P, R, S and T

[a] TYPE 2 is described in EN 62196-2 for AC. It is not described for DC and not forbidden.
[b] The current EN 62196-3 limits voltage at 600 V.

Figure 28 DC Connectors and Identifiers (Source: EN 17186:2019)

❱ Rwanda

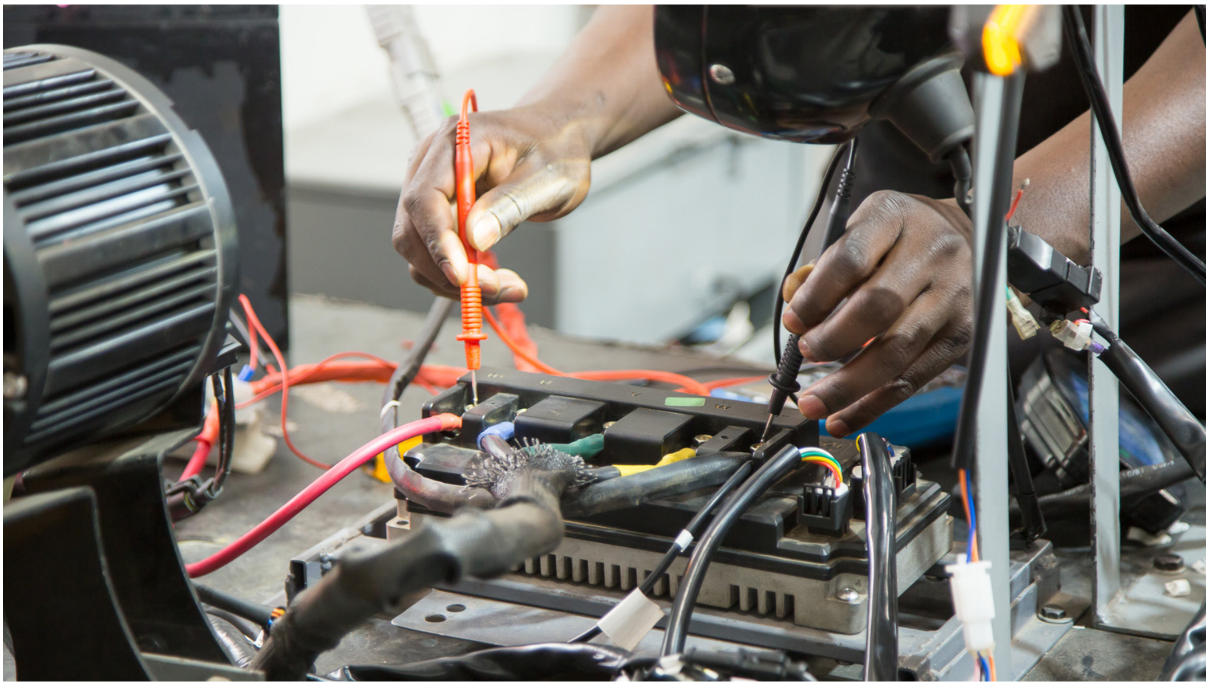
Policies and Regulations Supporting Deployment of EV Charging Infrastructure

Rwanda is instituting measures to decarbonize its transport sector. On 15th April 2021, the Cabinet approved a strategy to increase adoption of EVs in Rwanda (Ministry of Infrastructure, 2021). The strategy stipulates a raft of incentives for EVs and EV charging infrastructure aimed at getting users to opt for EVs as opposed to ICES. The incentives include the following:

- Electricity tariff for EV charging stations – EV charging stations will be billed at the industrial tariff level (US$ 0.091/kWh) which is significantly cheaper than the residential tariff.
- Import and Excise duty exemption for EVs, batteries and EV charging station equipment
- Zero-rated Value Added Tax for batteries and EV charging station equipment.
- Rent-free land for charging stations for land owned by the Government
- The building code and city planning rules will also include provisions for electric vehicle charging stations.

Status of EV Charging Standards in Rwanda

Rwanda has not mandated standards for publicly accessible charging stations. But discussions are underway to kickstart the process of developing standards for EV charging infrastructure.



BATTERY SWAPPING

Overview of battery swapping

> *"Battery swapping is a technology where a battery with a depleted state of charge is replaced with a battery that has a full state of charge."*

The basic structure of a battery swapping system has the power source, which could be from the grid or from a dedicated energy source for the battery swapping system, a battery housing structure, power cables for to connect the batteries to the power source, a human machine interface and a payment system. Figures 29 depict a battery swapping system structure

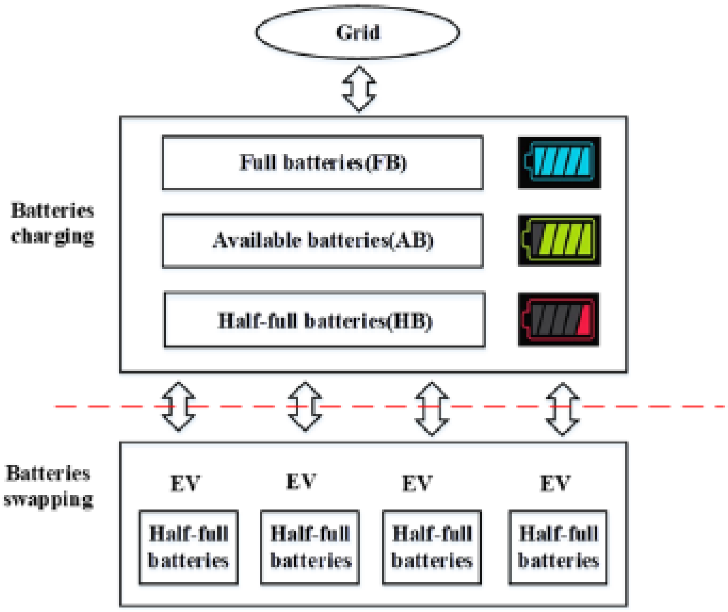


Figure 29 Battery Swapping Station Structure (Bo, et al., 2020)

Battery swapping systems can be categorized into two types – manual battery swapping systems and autonomous battery swapping systems. A manual battery-swapping system is a system where the batteries are placed and removed from the charging source manually - by hand. The Manual swapping stations are modular and occupy a less space compared to the other type of charging station. These systems are mainly used for two and three-wheelers vehicles as their batteries are smaller in size and weight. An autonomous battery-swapping system uses a robotic arm that is semi or fully automated. These systems are mainly used for four-wheeler and heavy vehicle applications whose energy storage systems are larger and heavier. Autonomous battery-swapping systems require more space are capital intensive.

Current Status of Battery Swapping Stations in Kenya

Electric 2 & 3 wheeler players

In Kenya the largest and fastest growing vehicle sector is the two-wheeler according to McKinsey's report on Manufacturing in Africa. The two wheelers are primarily used as taxis (boda-boda) and a typical boda-boda covers a distance of up to 90 km per day. Thus, it is feasible to invest in e-2Ws given the prevalent use of motorcycles in the country. Generally, e-2Ws have lower operational costs which can translate into improved social welfare of the boda-boda operators. In addition, the conversion from ICE to e-2Ws is a great way of reducing carbon emissions. Electric two wheelers can either be recharged by plugging in to an electrical supply or swapping the battery. Battery swapping is a promising option of charging e-2Ws and e-3Ws in Kenya. Table 23 shows a representation of e-2Ws and e-3Ws players in the country.

Company	***Description***
Ampersand	Ampersand is an EV company that builds affordable electric vehicles and charging systems motorcycle taxi drivers in East Africa. The company is based in Rwanda where they assemble electric motorcycles and operate battery swapping stations for their clients.
Arc Ride	ARC Ride is a 2&3 wheeler EV company that was established in East Africa in 2019 to spark an e-mobility revolution. The company is based in Kenya. Arc ride has invested in battery swapping stations to be used in the Kenyan market for their clients.
Ecobodaa	Ecobodaa is an EV company that assembles electric 2 wheelers in Kenya. The company has invested in battery swap stations as charging infrastructure for the electric bikes.

Fika	Fika mobility is a company that assembles 2 electric wheelers and provides smart battery solutions for electric vehicles in Kenya. The company also provides battery swapping solutions.
Kiri EV	Kiri EV assembles electric 2 wheelers and provides battery swap stations for charging. The company has already developed swap stations which are operational in Kenya.
Mazi	Mazi Mobility is a Kenyan Mobility as a Service (MaaS) company that is re-imaging mobility through the implementation of an electric vehicle ecosystem in Africa. The company assembles electric 2 & 3 wheelers and also offer battery swapping options for their clients.
Opibus	Opibus is a company that retrofits and assembles ICE four wheeler and 2 and 3 wheeler vehicles assembles electric 2 &3 wheelers. The company also does conversions of internal combustion vehicles and 2 & 3 wheelers to electric.
StimaBoda	Stima Boda is a company that offers electric 2 & 3 wheelers in Kenya and sub Saharan Africa. The company is in the process of rolling up its operations in Kenya.
Solar E-Cycles	Solar E-Cycles is a company that provides affordable solar-powered mobility and power for homes or small businesses. They assemble electric 2 and 3 wheeler cycles in Kenya. The company uses a an open-source, pay-as-you-go formula.
Bodawerk	Bodawerk is a company that assembles two and three wheelers EVs in Uganda. The company has expanded to Kenya and has operations around Lake Victoria region. The company operates battery swapping services for their clients. One of the battery swapping station is located in WeTu Hub in Homa Bay, Kenya.

Powward	Powward is a transport sustainability company that assembles e-bike in Kenya. The company also have solar-powered charging infrastructure for the e-bikes.

Table 23 2&3 wheeler EV Companies in Kenya

Battery Swap stations in Kenya

As end of March 2022, there were only four operational battery swapping stations in the country. A summary of existing battery swapping stations in the country given in Table 29. All the swap station specializes in swap systems for e-2Ws as they are affordable for the Kenyan market. The battery packs for these systems are also smaller and lighter, therefore easier to handle during swaps as the main battery swap technology that is implemented is the manual battery swap system. Two of the stations are located in Western Kenya whereas the other two are located within Nairobi County.

The battery packs swapping stations are relatively light (about 16.5kg for Kiri EV) which makes it easier to manually handle them. However, the battery packs are not standardized – they have a different form factor, connectors/plugs, battery nominal voltages and also use different communication protocols. This makes interoperability of the batteries a challenge. Figure 30 shows connector/plugs in use at WeTu battery swap station.

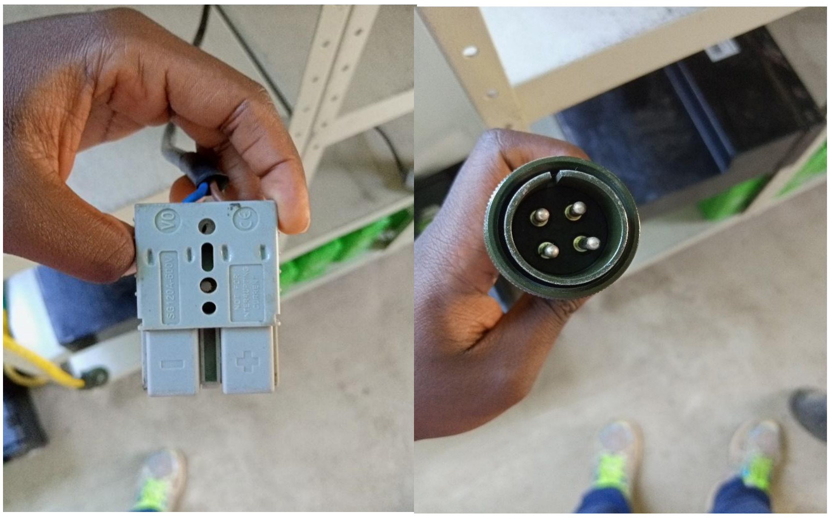


Figure 30 Battery charging ports

At all swap stations, the battery charger is plugged direct to the standard AC mains outlet. The battery chargers at the swapping stations are compatible with 50 Hz, 220-240VAC system. The battery charger at Kiri EV has a nominal output voltage of 72 V dc whereas the chargers at WeTu hub have nominal output voltages of 84 Vdc (current draw no more than 10A) and 48 Vdc (current draw no more than 20 A).

At the moment, Kenya does not have policies, standards or a taxation regime for battery swapping technology. However, this might soon change - as of writing of this report, The State Department of Transport had advertised for consultancy services in developing an E-mobility policy that is targeted to be ready before June 2022. Development of the policy will guide the E mobility sector and specifically supporting battery swapping technologies in the country

Battery Swapping Station	Location	Description of Battery Swapping Station	Photo
i. WeTu Hub	Homabay Town, Homabay	This battery swapping station has battery swapping systems for two companies – Opibus and Bodawerk. The battery swap station is a manual battery swap station. The batteries are removed from an e-bike and connected to a charging port. The charging ports for these two companies were noted to be different as shown in figure 30. The charging station is off-grid and is powered by a solar PV system.	
i. Ecoboda	Kibera	Ecobodaa has set up a battery swap station in Kibera. The station is a manual swap station.	
Powerhive	Kisii	Powerhive has developed a swap station in Kisii. The station holds 8 batteries at a time operating in manual mode. There are plans by powerhive to scale up the swap stations in the country.	

ii. Kiri EV	Kiambu Road, Nairobi	Kiri EV is at an advanced stage of implementing a battery swap station. They have developed a manual battery swap station that can take up to 8 battery units for their e-2Ws.	

Table 24 Current Status of EV Battery Swapping in Kenya

❱ International Best Practices of EV Battery Swapping Systems

Standardization

Battery Swapping International standardization

Standardization of battery swapping systems covers the general requirements for battery swapping systems, safety requirements and particular safety and interoperability requirements for battery swap systems operating with removable RESS/battery systems. This has been done by the International Electrotechnical Commission (IEC).

The standard developed by the IEC is the IEC 62840 series of standards. The series has three standards and also includes a publicly accessible specification (PAS).

Standard	*Title*	*Summary and Scope*
IEC 62840-1;2016	Electric vehicle battery swap system Part 1: General and Guidance	IEC TS 62840-1:2016 gives the general overview for battery swap systems, for the purposes of swapping batteries of EVs when the vehicle powertrain is turned off and when the battery swap system is connected to the supply network at standard supply voltages according to IEC 60038 with a rated voltage up to 1 000 V AC and up to 1 500 V DC. It is applicable for battery swap systems for EVs equipped with one or more swappable battery system.

IEC 62840-2:2016	Electric vehicle battery swap system Part 2: Safety Requirements	IEC 62840-2:2016 provides the safety requirements for a battery swap system, for the purposes of swapping swappable battery system of EVs. The battery swap system is intended to be connected to the supply network. The power supply is up to 1 000 V AC or up to 1 500 V d.c, in accordance with IEC 60038. This standard also applies to battery swap systems supplied from on-site storage systems.
IEC PAS 62840-3:2021	Electric vehicle battery swap system Part 3: Particular safety and interoperability requirements for battery swap systems operating with removable RESS/battery systems	IEC PAS 62840-3:2021 applies to battery swap systems for removable RESS of electric road vehicle when connected to the supply network, with a rated supply voltage up to 480 V AC or up to 400 V DC, for battery systems with a rated voltage up to 120 V DC. This document applies to battery swap systems for removable RESS for an EV, where the removable RESS for the EV is stored for the purpose of transfer power between the battery swap station and removable RESS for the EV.
GB/T 40032-2021	Safety requirements of battery swap for electric vehicles	This is a Chinese standard that specifies the specific safety requirements, test methods and inspection rules for battery swappable EVs. This Standard applies to pure electric vehicles that can be battery swapped.

Table 25 Battery Swapping Standards

INTERNATIONAL BEST PRACTICES FOR BATTERY SWAPPING

Rationale for policy intervention

Battery swapping allows separation of the cost of the battery from the vehicle cost lowering the cost of the EV with owners essentially paying a subscription for the battery. However, battery swapping stations are capital intensive and more importantly they are vehicle – battery – connector specific meaning they lack interoperability making their usage difficult to optimize. Optimizing batteries for swapping means standardization and it is often difficult to get automakers to agree though this may soon change at least for 2 wheelers. Another concern with battery swapping is the reliability of the leased battery packs – there are questions on the reliability and quality of EV batteries from battery swapping stations.

To address some of these issues, four major motorcycle manufacturers, Honda, KTM, Piaggio and Yamaha have agreed to form a swappable battery consortium (Hyatt, 2021). The consortium will focus on issues such battery life, recharging times, infrastructure and costs. The focus is swappable batteries for 2 wheelers – size of battery pack informed the choice. Battery pack for an electric car is typically large and expensive making swapping difficult and risky. On the other hand, a battery pack for a motorcycle is smaller than a hand luggage and lightweight (lithium-ion batteries) making it easier to swap. The consortium aims to:

01 Develop common technical specifications of swappable battery systems

02 Confirm common usage of the battery systems

03 Make and promote the consortium's common specifications as a standard within European and International standardization bodies

04 Expand the use of the consortium's common specification to global level

The following section reviews policy initiatives on battery swapping infrastructure in India, Thailand and Philippines. The objective is to highlight the range of fiscal and non-fiscal incentives that have been employed in these countries.

❱ Philippines

Battery Swapping Policies and Regulations

The key policy document in the Philippines for EV charging infrastructure is the proposed Senate Bill No. 1382 – Act. It provides the National Energy Policy and Regulatory Framework for the Use of Electric Vehicles and the Establishment of Electric Charging Stations. Battery swap stations are part of the EVCS.

Battery swap stations (BSS) are covered under EVCS policy guidelines issued by the Department of Energy in the Philippines. Under these guidelines a battery swap station is defined as an EVCS composed of systems which provide for battery mounting/ unmounting, battery transfer, battery storage, battery charging and other functions as defined by PNS IEC TS 62840-1. The BSS may include the following:

- Lane system – used to transfer the EV to a designated location in readiness for battery handling.
- Battery handling system – consist of swap equipment and transfer equipment
- Storage system – used to store the swappable battery system (SBS) safely.
- Charging system – used to charge the SBS safely.
- Supervisory and Control system – applicable to automated BSS

The scope EVCS policy guidelines cover all activities pertaining to the development, establishment, use, supply, distribution, and the operation of EVCS.

The following issues are covered:

- EVCS classifications compliant to the requirements of relevant Philippine Standards
- EVCS Dedicated Locations
- EVCS Energy Label and Marking Requirements
- Endorsement to the Board of Investments (Under the Department of Trade and Industry) to be provided of fiscal incentives under the Omnibus Investment Code. Under this code BSS businesses can receive an income tax holiday of between 3-6 years and capital equipment costs of up to USD 10,000.

Under The 2020 Investment Priority Plan, charging/refueling stations are listed as one of the preferred activities for investments in the Philippines. They can receive incentives from the Board of Investments.

Status of Battery Swapping Infrastructure Standards in the Philippines

In the Philippines, the majority of EVs on the road are two-wheelers and three-wheelers (e-2Ws, e-3Ws). These are equipped with detachable batteries that can be charged through plug-in or battery swapping. This makes e-2Ws and e-3Ws prime candidates for battery swapping. However, the first battery swapping station in the Philippines was for the electric jeepneys (jeepneys are Philippine equivalent of Kan matatus). The Philippine government plans to modernize jeepneys by adopting EV technology and implementing battery swapping is a sure way of making this viable.

Battery swaps are also done for e-2Ws (electric scooters and motorcycles) and e-3Ws (e-trikes). In Romblon Island for example, people ride electric motor-cycles powered by wind-charged swappable batteries. Figure 31 shows a battery swap station in Romblon Island. However, the battery packs have not been standardized which limit interoperability between battery packs from different vendors.

Figure 31 Battery swap station in Romblon Island

In Philippines the following standards pertaining to battery swapping technology are in place:

- PNS IEC/TS 62840-1:2016 - gives the general overview for battery swap systems, for the purposes of swapping batteries of electric road vehicles
- PNS IEC 62840-2:2016 - provides the safety requirements for a battery swap system.
- PNS ISO 12405-4:2021 – specifies test procedures for the basic characteristics of performance, reliability and electrical functionality for lithium-ion battery packs and systems

❱ India

Policies and Regulations Supporting Deployment of Battery Swapping Technology

Though battery swapping is applicable for electric 2 wheelers (e-2W), electric 3 wheelers (e-3W), electric 4 wheelers (e-4W) and electric buses, it is the e-2W and e-3W categories that are most suited and offer best promise for battery swapping technology in India. Traditionally, India is a market dominated by two-wheelers and three-wheelers with majority of them having detachable batteries that can be charged either through plug-in or battery-swapping.

The key policy instrument in India with regard to battery swapping is the FAME II policy document which extends financial support for both EVs and charging infrastructure. A notification issued by the Ministry of Roads Transport and Highways allows sale of e-2Ws and e-3Ws without batteries to reduce the high upfront cost of vehicles. Though, there is ambiguity as to whether battery-swapping can be made eligible for FAME II subsidy to reduce the cost of batteries.

Different states have also included battery swapping in their EV policies and some have ratified EV tariffs for battery swapping infrastructure (see Figure 32).

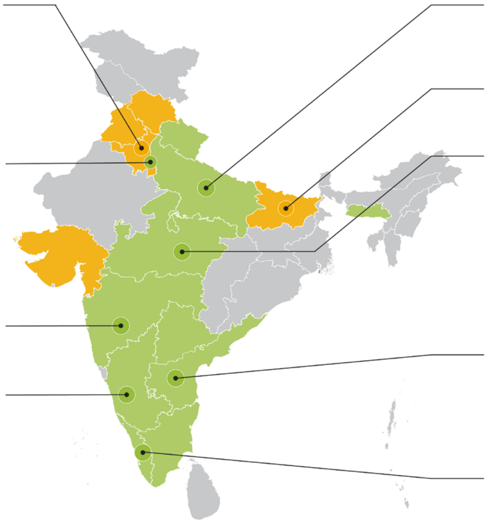
The Ministry of Power (MOP) Charging Infrastructure Guidelines and Standards give guidance on setting up battery swapping stations. In its capacity as a legislative authority, the MoP clarified that the operation of EV charging services (swapping stations included) did not require licensing under the Electricity Act 2003. The Central Electricity Authority (CEA) has notified amendments to existing regulations to facilitate grid connectivity for charging infrastructure.

These amendments recognize EV as an energy generation resource and introduces standards for charging stations connected or seeking connectivity to the electricity system.

Status of Battery Swapping Standards in India

The effective implementation of battery swapping requires a standard battery that can be used in all EVs. There is no uniform standard for batteries in EVs anywhere in the world or in India. In India, there have been calls to develop battery swapping standards for light electric vehicles and buses. The standardization will address battery form factor, connector, battery nominal voltages and communication protocol.

Selected Policy Initiatives for Battery-Swapping (BS) from State-level EV Policies



Haryana (2020)
- Land will be provided to set up BS stations
- Incentives for setting up BS stations in existing buildings (malls/ commercial buildings)
- 25% capital subsidy on fixed cost up to 10 lacs (excluding cost of battery inventory) for first 50 BS stations
- 100% SGST reimbursement on advanced batteries

Delhi (2020)
- 50% of purchase incentives to vehicle OEM & 50% to Energy Operator
- EOs will be invited to set-up swapping stations
- Land at bare minimum rental lease
- Capital subsidy on chargers installation cost to selected EOs
- Open Access & Power Banking facility for BS stations with RE integration
- 100% SGST reimbursement on advanced batteries

Maharashtra (2018)
Robotic arms will be established at Public Bus Stations for BS

Karnataka (2017)
25% capital subsidy on equipment/ machinery for BS stations up to:
- Rs 3 lacs per station for e-2Ws & e-3Ws for first 100 BS stations
- Rs 5 lacs per station for e-cars for first 50 BS stations
- Rs 10 lacs per station for e-buses for first 50 BS stations

Uttar Pradesh (2019)
25% capital subsidy on fixed cost for BS stations up to Rs 6 lacs (excluding land cost)

Bihar (2019)
Robotic arms will be established at Public Bus Stations for BS

Madhya Pradesh (2019)
- PCS must have standalone BS facility
- At identified locations, EOs will be invited through bidding to set up BS stations
- 25% capital subsidy on charging equipment/ machinery up to maximum subsidy amount
- Incentives for setting up BS stations in existing private buildings
- Rental holidays for EOs & V2G sale of power
- Open Access & Net Metering for BS stations with RE integration

Andhra Pradesh (2018)
- 25% capital subsidy on fixed cost up to 10 lacs (excluding cost of battery inventory) for first 50 BS stations
- 100% SGST reimbursement on advanced batteries
- V2G sale of power for BS stations

Kerala (2019)
- 25% capital subsidy on fixed cost up to 10 lacs for first 50 BS stations
- KSEB Ltd will establish first 150 BS stations for e-2Ws & e-3Ws

🟩 *States with Approved EV Policies*
🟧 *States with Draft EV Policies*

Source: WRI India authors

WRI INDIA
ROSS CENTER

Figure 32 Selected policy initiatives for battery-swapping at state level in India (Kumar, et al., 2021)

❯ Thailand

Policies and Regulations Supporting Deployment of Battery Swapping Technology

The automotive industry is an important sector in Thailand, accounting for around 10% of its GDP. Thailand is pushing to become a major EV production hub in the South East Asian (ASEAN) region and has developed an EV roadmap that aims to have EVs account for 30% of road vehicles production by 2030. The EV roadmap also covers battery manufacturing, charging infrastructure, power grid management, and the development of related safety standards and regulations. The vehicles covered by the EV roadmap include passenger cars, motorcycles, tricycles, buses, trucks and ferry boats. Motor cycles account for the majority of the vehicle stock in Thailand with over 21 million motorcycles registered and EV roadmap has set a target of electric motorcycle production to 675,000 units by 2030 (Thananusak, et al., 2020).

To achieve the goals of the EV roadmap, the National Energy Policy Board has set three operational phases (Thananusak, et al., 2020):

+ Phase 1 (2015–2017): Incentives, standards, electricity retail prices, and regulations of EVs were issued.

+ Phase 2 (2018–2020): The government would support investment in EV infrastructures.

+ Phase 3 (2021–2036): Expanding the EV usage and infrastructure across the country. A target of 80,000 charging stations by 2035 with individual charging stations being located no more than a 50-70 km radius from one another.

In February 2020, the Thai Prime Minister appointed the National Electric Vehicle Policy Committee. The main role of this committee is to drive the development of the EV industry in Thailand by ensuring EV targets and development plans are coherent with the 20-year National Strategy and approvals of the cabinet.

To promote e-2Ws, The National New Generation Vehicle Committee (Under Thailand's Ministry of Industry) has approved incentives for EV charging and battery swapping businesses.

The incentives are expected to result in deployment of at least 12000 EV chargers and 1,450 battery swapping stations. Summary of the incentives include (Bangkok, 2021):

a. EV batteries – pack assembly (corporate income tax exemption for 5 years). Module production (corporate income tax exemption for 8 years). Cell production (corporate income tax exemption for 8 years). Ninety percent (90%) reduction of import duties on raw/essential materials for 2 years.

b. EV charging station: Corporate Income Tax (CIT) Exemption for 5 years. Exemption of import duties on machinery

EV Charging Tariff

The Ministry of Energy has regulated EV charging rates. In March 2020, the approved the tariff of around US$ 0.079 /kWh, which made the operational costs of an EV cheaper compared to internal combustion engine vehicles.

Research and Development Activities

The National Science and Technology Development Agency (NSTDA) has formed a consortium with nine other institutions to develop a battery swapping platform for electric motorcycles. The consortium aims to (NSTDA, 2021):

- In collaboration with other stakeholders, define a standard battery swapping platform for motorcycles.
- Design and develop a standardized battery pack that will fit universally across motorbike types and brands as well as a standard charging station.
- Test the prototypes of the standardized battery pack
- Formulate recommendations on industrial standards, regulations and business models for battery swapping stations.

In 2020, the Electricity Generation Authority of Thailand (EGAT) developed 51 battery swapping e-motorcycles under the brand 'ENGY' as a pilot project in 19 sites across Thailand as illustrated by figure 33. The study was aimed at promoting use of public e-motorcycles and studied behavior of riders, electricity consumption of the e-motorcycles, satisfaction of riders/passengers, economics and environmental impact (Kamolnavin, 2021).

Figure 33 Engy e-motorcycle (Kamolnavin, 2021)

Status of Battery Swapping Standards in Thailand

A consortium led by NSTDA developed specifications for a standardized battery pack for e-2Ws which have been adopted as Thai National standards (TISI 3316-2564). The standard covers electric mopeds and electric motor cycles. It specifies nominal battery voltages and tolerances, battery dimensions, visual inspection criteria, marking and labelling requirements, battery pin-socket requirements and test methods to verify the requirements detailed in the standard. Thailand has also adopted IEC/TS 62840 series. This series of standards give requirements for battery swap stations for electric 4-wheelers.

CONCLUSION

Kenya is at the introductory stage of adoption of E-Mobility technologies, However there is increased investment for EVs & electric 2& 3 wheelers driven by a vibrant private sector in Kenya. Private sector companies mainly import and assemble EVs, convert internal combustion engines (ICE) to electric, and develop charging and battery swapping infrastructure.

> *"Policy, standards, programs, infrastructure and national plans are key in creating a conducive environment for e-mobility investment and adoption in the country."*

Policy and standards will guide the sector growth and avoid market chaos through regulation. Investors will also gain confidence in investing in the country when clear regulations are in place.

As Kenya has already developed a series of standards on E-mobility, further standardization of charging infrastructure & battery swapping is needed. In addition, a national policy on e-mobility is required for acceleration of the sector growth.

Kenya is at a pivotal point in determining the success of the sector as it transitions from the introductory stage to growth stage. Lessons can therefore be learnt and borrowed from countries such as USA, China, Norway and Netherlands which are at the growth stage. Lessons can also be learnt from Philippines, India, South Africa and Rwanda which are at different phases of the introductory stage.Policies, regulations, fiscal incentives and developed standards form key lesson areas to be learnt from these countries at both growth and introductory stages.

RECOMMENDATIONS

The development of EV charging and battery swapping infrastructure in Kenya presents both promising opportunities as well as challenges for Kenya's quest to transition to e-mobility. This section lists the recommendations that will help kick start EV charging and battery swapping infrastructure market in Kenya.

1. Policy

Range anxiety – the fear of not being able to reach one's destination – is one of the main concerns that drivers have when considering the purchase of an electric vehicle (EV). To ensure the swift adoption of EVs, policy makers therefore need to ensure that sufficient, reliable and easy-to-use charging infrastructure is available. To promote market driven roll out of charging infrastructure network in Kenya, it is important to increase confidence of potential investors by reducing investment stemming from lack of regulatory clarity. To achieve this, the following policy instruments should be developed and implemented:

a. **Develop a national guideline on charging infrastructure:** The guidelines shall cover licensing/permitting requirements for EV charging stations, details the minimum requirements for public charging infrastructure, provide guidance on location of public charging infrastructure and offer guidance on tariff/ metering for public charging station among others. As part of the minimum requirements, it is recommended to have a primary and secondary charger at all public charging stations. The primary charger will be a mandatory requirement whereas a secondary charger an optional installation for the Charge Point Operator (CPO). For starters, all public DC fast charging stations should have CHAdeMO and combined charging system 2 (CCS2). As for public AC charge points, they should have type 2 chargers with either type 2 to type 2, or type 1 to type 2 converters. These would be the primary charger's mandatory for public charging, with CPOs allowed to install any other secondary charger.

b. **Develop a national guideline on battery swapping for 2&3 wheelers:** In order to regulate the sector whilst promoting innovation, development of a national guideline on battery swapping is key. The guidelines shall cover development, establishment, use, supply, distribution and operation of battery swap stations (BSS). Additionally, it shall cover issues such as compliance of the BSS to relevant Kenyan standards. The guide will further classify installation locations as well as requirements on markings and energy label on the BSS.

c. **Revise the National Building code:** The building code should be revised to incorporate charging stations in buildings. Revision of the code should mandate that all commercial buildings and residential apartments to have provision of EV charging. Provision of this infrastructure in public residential areas will significantly boost EV uptake in Kenya.

d. **Revise the National Grid code:** Increase of EV charging will lead to an increase of demand on the Low Voltage (LV) distribution systems. This may result in thermal overloads, harmonics, phase unbalance and voltage deviations. Revision of the grid code will be essential in incorporating EV charging in Kenya. The code will provide regulation to EV charging through supply and sale of electricity to CPOs through retail metering at public charge points. It will also guide licensing of CPOs in retail sale of electricity.

e. **EV battery recycling policy:** With increase in penetration of EVs in the country, it is important to start planning on how to safely manage the disposal of EV batteries once they reach end of life. It will be beneficial to have a policy to repurpose EV batteries after the end of first life (< 80% state of health) to second life use in renewable energy applications such as solar PV battery energy storage.

f. **Conduct a study to assess the impact of integrating EVs into the electricity network:** A grid study will be key in mapping out probable EV charge points & simulating the effect of EV charging to the grid. This will be key in demand projections by the utility as well as informing future expansion plans.

2. Interoperability

For the transition to e-mobility to happen, it is essential to ensure interoperability of the EV charging stations. It is crucial to offer the same level of comfort to drivers that are used to drive ICEs and this can be achieve through seamless access of EV charging stations. Interoperability will ensure EV consumers are able to charge their vehicles at any charging station and will achieved through the following:

a. **Standardization** – In absence of mandated standards, it is feasible for every company to promote its own EV charger resulting in proliferation of different chargers that are incompatible. This will result in reduced accessibility of charging infrastructure which ultimately turn off people from adopting EVs. It is important to develop Kenya standards on charging infrastructure and battery swapping. Standardization of EV

charging infrastructure will address the following: system requirements, EV plugs/connectors, communication protocols, electromagnetic compatibility, supply equipment protection, EV charging cable and installation requirements. Standards on battery safety are also needed to ensure user safety.
These standards will cover test requirements for batteries, recommendations on transport of batteries and general safety requirements. In addition, batteries used in battery swap station should standardize the following aspects: dimensions, nominal voltages and tolerances, communication protocols, and charging ports (pin & socket)

b. **Payment -** to promote public charging infrastructure issues, interoperability of the payment options need to be addressed. Users of charge points are thus able to access different charging networks (e-roaming) without the need of having multiple payment cards through the interoperability of Radio Frequency Identification (RFID) cards for public station charging.

c. **Network -** Interoperability of network providers will enable charge point operators (CPO)s to switch between different network service providers without necessarily needing to change the providers. Open charge point protocol (OCPP) a standard used in Europe can be key in addressing network interoperability. The adoption of OCPP protects CPOs investments against obsolescence and further stimulates market competition.

3. Government incentives

An effective method of accelerating deploying EV charging infrastructure is by providing fiscal and non-fiscal incentives.

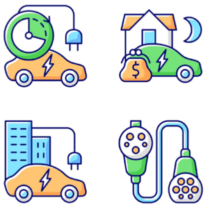
Fiscal incentives - such import tax and VAT exemption, and tax credits. Tax credits can be offered to charge station investors, with the intention of offsetting the cost incurred in setting up the charge stations. Moreover, the National or County Government can provide Government land at concessional rental rates to charging station operators to operate charge stations. This will make EV charging infrastructure and battery swapping business more lucrative and boost investments in the sector.

Non-fiscal incentives - There is also the need to address administrative barriers that make it difficult to set up a public charging infrastructure. This can be achieved by streamlining permitting and licensing process for installation of public charging infrastructure. Key Government players in regulation and licensing should be identified, and a working group formed to come up with a simple license procedure. This will accelerate investment in charging infrastructure by building investor confidence.

4. EV charging tariff

The government should design a special electricity tariff for public charging stations. Providing a special tariff to public charge point operators and battery swapping stations will increase revenue stream, boost investment. The tariff will aim at reducing the cost of electricity purchase by the CPOs which in turn results in lower charging costs for consumers. CPOs will be metered separately and offered concessional tariffs for public charging points.

5. Industry players to form a consortium



The two and three wheelers industry currently have a large local company presence. Development of a common unified industry voice will be key in growing the industry locally and regionally as well as stimulating healthy competition. At the international level, 2& 3-wheeler manufacturers, consortiums have been formed to standardize batteries. Similarly, the local consortium can kickstart discussions on aspects of EV batteries that can be standardized to ensure interoperability. At the moment, battery dimensions, nominal voltages and charging ports for electric 2 & 3 wheelers have not been standardized preventing interoperability of batteries from swap stations owned by different vendors. The local consortium will give players a platform to build consensus and develop common specifications for swappable battery systems to promote interoperability.

6. Use of Captive Renewable Energy Sources

In the development of charging stations, use of renewable energy sources is recommended as the power generation source, for example, solar photovoltaic systems with battery back-up systems or small-scale standalone wind power systems with battery back-up to ensure that there is an available, affordable, clean and reliable energy source for EV charging.

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ANNEX I

Related referenced IEC standards from charging standards

Other IEC standards referenced in EV charging standards and covering other aspects of electric mobility are as presented below;

STANDARD	***TITLE***
IEC 61140:2016	Protection against electric shock - Common aspects for installation and equipment
IEC 61009-1: 2013	Residual current operated circuit-breakers with integral overcurrent protection for household and similar uses (RCBOs)
IEC 61508:2010	Functional safety of electrical/electronic/programmable electronic safety-related systems
IEC 61540:1998	Electrical accessories - Portable residual current devices without integral overcurrent protection for household and similar use (PRCDs)
IEC 60664-1:2020	Insulation coordination for equipment within low-voltage supply systems - Part 1: Principles, requirements and tests

IEC 61557-8:2014	Electrical safety in low voltage distribution systems up to 1 000 V a.c. and 1 500 V d.c. - Equipment for testing, measuring or monitoring of protective measures - Part 8: Insulation monitoring devices for IT systems
IEC 60529: 2013	Consolidated version Degrees of protection provided by enclosures (IP Code)
IEC 60038:2009	IEC standard voltages
IEC 61000-6-1:2016	Electromagnetic compatibility (EMC) - Part 6-1: Generic standards - Immunity standard for residential, commercial and light-industrial environments
IEC 61000-4-4:2012	Electromagnetic compatibility (EMC) - Part 4-4: Testing and measurement techniques - Electrical fast transient/burst immunity test
IEC 61000-4-5: 2017	Electromagnetic compatibility (EMC) - Part 4-5: Testing and measurement techniques - Surge immunity test
IEC 61000-4-6:2013	Electromagnetic compatibility (EMC) - Part 4-6: Testing and measurement techniques - Immunity to conducted disturbances, induced by radio-frequency fields
IEC 61000-4-11:2020	Electromagnetic compatibility (EMC) - Part 4-11: Testing and measurement techniques - Voltage dips, short interruptions and voltage variations immunity tests for equipment with input current up to 16 A per phase
IEC 61000-6-1:2016	Electromagnetic compatibility (EMC) - Part 6-1: Generic standards - Immunity standard for residential, commercial and light-industrial environments

Table 26 Referenced IEC standards on EV charging

ANNEX II

In addition, the following ISO standards have been developed by ISO/TC 22/SC 37 and similarly adopted by Kenya.

STANDARD	***Title***
ISO 6469-1:2019	Electrically propelled road vehicles — Safety specifications — Part 1: Rechargeable energy storage system (RESS)
ISO 6469-2:2018	Electrically propelled road vehicles — Safety specifications — Part 2: Vehicle operational safety
ISO 6469-3:2020	Electrically propelled road vehicles — Safety specifications — Part 3: Electrical safety — Amendment 1: Withstand voltage test for electric power sources
ISO 6469-3:2021	Electrically propelled road vehicles — Safety specifications — Part 3: Electrical safety

ISO 6469-4:2015	Electrically propelled road vehicles — Safety specifications — Part 4: Post crash electrical safety
ISO/TR 8713:2019	Electrically propelled road vehicles — Vocabulary
ISO 8714:2002	Electric road vehicles — Reference energy consumption and range — Test procedures for passenger cars and light commercial vehicles
ISO 8715:2001	Electric road vehicles — Road operating characteristics
ISO 12405-4:2018	Electrically propelled road vehicles —Test specification for lithium-ion traction battery packs and systems — Part 4: Performance testing
ISO 18300:2016	Electrically propelled vehicles — Test specifications for lithium-ion battery systems combined with lead acid battery or capacitor
ISO 23274-1:2019	Hybrid-electric Road vehicles — Exhaust emissions and fuel consumption measurements — Part 1: Non-externally chargeable vehicles
ISO 23274-2:2021	Hybrid-electric Road vehicles — Exhaust emissions and fuel consumption measurements — Part 2: Externally chargeable vehicles

Table 27 ISO EV Standards 2

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