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solutions plus

Policy Advice Paper

Electric Vehicles Charging Infrastructure Kigali Demonstration Action

Imprint

Purpose
This deliverable aims to provide policy advice from the SOLUTIONS+ consortium partners to the Rwanda Ministry of Infrastructure on the deployment of an electric vehicle charging infrastructure for a variety of electric vehicles.

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The report draws from publications from SOLUTIONS+ partners, including the "STF Recommendations for public authorities for procuring, awarding concessions, licences and/or granting support for electric recharging infrastructure for passenger cars and vans", developed for the European Commission by TNO, POLIS and reviewed by FIER (Sustainable Transport Forum, 2021), "The impact of electric buses on urban life" (UITP, 2019) and "Large-scale bus electrification, the impact on business models" (UITP, 2021).

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Executive Summary

A reliable and user-friendly electric vehicle (EV) charging infrastructure is essential for the success of electric mobility systems in Kigali. To this end, public involvement will be key to address the classical hurdles faced when rolling out a charging infrastructure, including financial, technical, regulatory and awareness barriers.

To deploy a suitable EV charging infrastructure, it is important to take stock of the heterogeneous charging needs between light electric vehicles and larger electric vehicles. This distinction has significant impacts on power needs, charging technologies and speeds – from normal wall outlets to dedicated charging facilities, and associated costs. While several charging standards coexist, it is key to stress the need for interoperability, especially for larger electric vehicles. In addition, different use cases (private, shared, ride hail) also impact charging solutions and the choice between dedicated or publicly available charging points. The landscape of EV charging is evolving with ongoing innovations, including the development of battery swapping as an alternative to charging, or strengthened interactions between EVs and the electrical grid (e.g. smart charging).

Recharging electric vehicles other than buses may be undertaken at a wide range of private or public locations. Key principles in the roll-out of charging points include the prioritisation of regular over fast charging, and the recharge of vehicles when not in operation. Public authorities play an important role in the successful deployment of charging infrastructure by providing a long-term mobility vision and strategy, ensuring coherence between different agencies and cooperation with private stakeholders. The extent to which public authorities will be involved in the selection of appropriate locations for charging points will depend upon the choice of a centralized or a decentralized localisation method, as well as on the contractual model selected.

Finally, as charging infrastructure is developed, it is critical to ensure that electric mobility is integrated in a sustainable urban mobility paradigm, supporting a shift towards greater use of public transport, cycling and walking, while avoiding a lock-in of increased private motorisation. In Kigali, the allocation of financial resources and public space should support the use of high-occupancy and shared modes. Designing a consultative process that engages multiple stakeholders is essential.

Some key recommendations include:

- Electrification of the city bus fleet has high priority and will require the introduction of charging facilities at bus depots and terminals. The City of Kigali should identify or acquire land for publicly owned bus depots to facilitate the transition.
- Promoting innovative electric bikeshare solutions is essential as electric bicycles address Kigali's hilly terrains, potentially capture new user groups, and generally ease movement while keeping people active.
- The electrification of motorcycle-taxis addresses the issue of air pollution, as many Kigali residents use this mode. It should facilitate first- and last-mile connectivity to public transport.
- For private vehicles such as passenger cars, it is important for the government to establish open standards for public access charging points in order to facilitate interoperability.

Contents

1. Introduction

Today, several years after the initial roll-out in several markets across the globe, the electric vehicle (EV) technology has proven itself useful to reduce air pollution, especially in urban areas. The costs of acquisition and operation are falling, and the benefits have been validated.

In Kigali, Rwanda, electric mobility is on the rise, driven by several projects testing a variety of EVs and benefitting from a supportive regulatory environment. Small fleets of electric motorcycle taxis (Ampersand, Safi Ride, Rwanda Electric Mobility); electric cars for ride-hailing services (Volkswagen/Siemens); plug-in hybrid electric vehicles (Mitsubishi Motors Corporation/Victoria Motors Rwanda); and shared electric bicycles (Gura Ride) are either operational or at an advanced stage of prototyping or testing. The Rwanda Environment Management Authority (REMA) has installed an electric car charging station at its office in Kacyiru to demonstrate electric mobility, using a Mitsubishi Outlander plug-in hybrid electric vehicle. Simultaneously, the potential to introduce electric buses and reinforce last-mile connectivity via electric mobility is being assessed (GGGI, IFC/Government of Japan, World Bank, SOLUTIONSplus).

To support the uptake of e-mobility, Rwandan institutions have identified the need to prepare and adapt corresponding policy frameworks. Rwanda is a pioneer in the East Africa region, recognising the importance of e-mobility in its updated 2020 Nationally Determined Contribution (NDC), including a target of 9 percent reduction of GHG emissions in the energy sector via EVs by 2030. The NDC envisions a progressive adoption of electric buses, cars, and motorcycles from 2020 onwards, paired with the implementation of sustainable mobility systems. In addition, Sweco-ifeu (2019) provided information on the feasibility and prerequisites for the development of electric mobility in Rwanda.

MININFRA now intends to go further with a comprehensive master plan for electric mobility charging infrastructure, identifying strategic locations for charging stations countrywide for electric buses, light-duty vehicles, and cars. In the light of this evolution, the aim of this policy paper is to provide recommendations to MININFRA on regulatory conditions for EV charging infrastructure, ensuring that electric mobility is deployed in a coordinated, safe, and efficient way. This policy paper identifies main characteristics and principles that should guide the development of a charging infrastructure. It can support the work of ongoing feasibility studies for specific modes.

The scope of this report includes electric micromobility, two-wheelers, light-duty vehicles, and buses to match the interest of MININFRA and reflect the development of electric mobility in Kigali. The focus of this paper is on the city of Kigali. It covers passenger services, not freight although complementarity of charging infrastructure solutions for passenger and intra-city freight/logistics vehicles may be explored in a further step in order to improve the utilisation of the charging infrastructure.

The report is built around five chapters, outlining key characteristics and principles that should guide the roll-out of charging solutions in cities before addressing the case of the city of Kigali.

2. Background

2.1. The SOLUTIONSplus project

The SOLUTIONSplus project aims to enable transformational change towards sustainable urban mobility through innovative and integrated electric mobility solutions. It is funded under the European Union's Horizon 2020 research and innovation programme and is implemented from January 2020 to December 2023. The project encompasses city-level demonstrations to test different types of innovative and integrated e-mobility solutions, complemented by a comprehensive toolbox, capacity development, and replication activities. The project offers provide technical and financial input to partner cities from leading e-mobility industry and research actors.

In Kigali, the SOLUTIONSplus demonstration action supports electric mobility for last-mile connectivity. Kigali City is one of the beneficiaries of the grant agreement between the consortium and the European Innovation and Networks Executive Agency (INEA). Four main components are included in the demonstration action in Kigali:

- Electric shared bicycles,
- Electric motorcycles,
- Feasibility of electric buses, and
- Mobility as a service (MaaS) to support integration among transport modes.

During the first year of the project, significant progress has been made on local stakeholder involvement, user needs identification, and coordination between local and European counterparts. Upcoming activities in Kigali include:

- Training and e-learning activities, including an Africa regional training with a first module on EV charging infrastructure planned for September and October 2021. Further training activities will target Kigali and provide input on electric shared schemes, the deployment of electric mobility charging infrastructure within a Sustainable Urban Mobility Plan (SUMP) approach, and the management of EV batteries.
- Direct financial support to selected innovators (e-motos, e-bicycles) and further support on business viability via a start-up incubator.
- Support on urban planning, provision of non-motorised transport, street transformations, and car-free activities to increase the visibility of e-mobility.
- Support to improve gender-inclusive transport via women as EV drivers.
- Support to public institutions including technical input on standards, policies, procurement, regulation and analysis of opportunities to upscale e-mobility and address barriers including access to finance. This policy paper falls under this component.

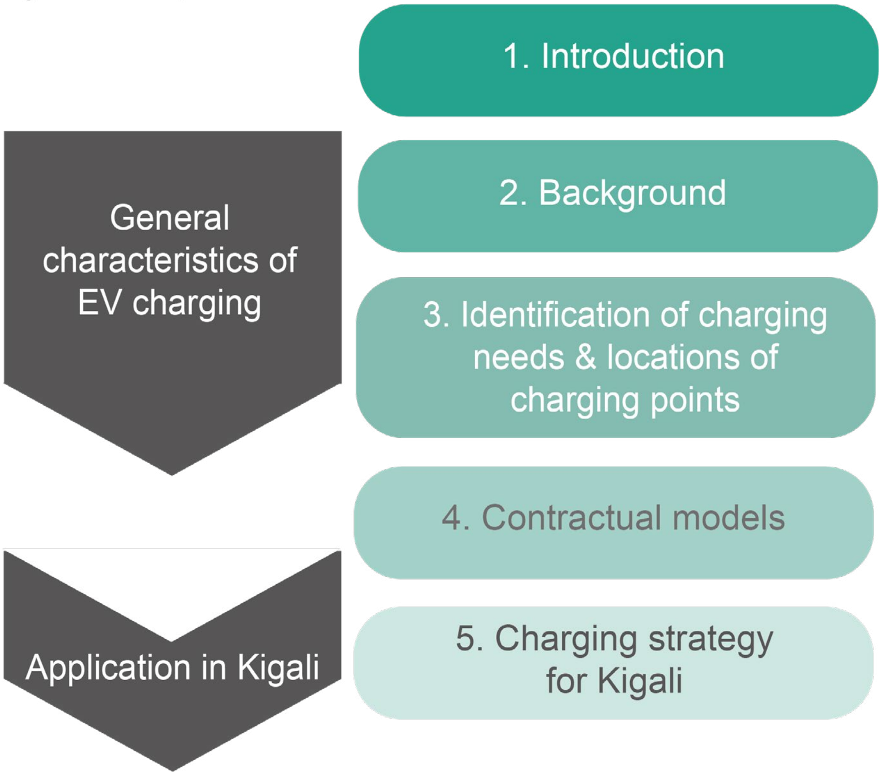
By the end of 2021, the SOLUTIONSplus project will provide the following concrete support:

- First module of the Africa regional training in September and October 2021 on EV charging infrastructure, addressing a wide array of dimensions including technical aspects, business models, financial and public procurement. Among others, this training will explain the practical steps to take to deploy charging infrastructure in a Sustainable Urban Mobility Plan (SUMP) approach. It will also include a training session on electric public transport (technology, charging options, financing models).

- Feedback on the IFC study on electric buses.

- Technical meetings on setting-up bike share systems that include electric bicycles (planning, financing, operations, charging) with input from various cities. The involvement of the City of Kigali will be key.

Figure 1. Report structure



2.2. E-mobility in Rwanda

2.2.1. State of activities on charging infrastructure in Rwanda

Policy support

On 14 April 2021, the Government of Rwanda approved a national strategy to support the adoption of e-mobility solutions, including fiscal as well as non-fiscal incentives. This strategy entails significant measures easing the establishment and operation of EV charging points, including reduced electricity tariffs; exemption of charging station equipment from VAT and import and excise duties; and rent-free land for charging stations on land owned by the government. Upcoming provisions are expected to cater for EV charging stations in the building code and city planning rules. In addition, a technical coordination committee is planned in order to ensure regular consultations among partners involved in electric mobility projects.

Standards

The 2019 Background and Feasibility report commissioned by KFC/FONERWA (Rwanda Green Fund) as part of the SMART project and funded by UNEP and KfW identified the need to review the regulatory framework and technical standards by 2021/22 to cover the supply, operation, and maintenance of EVs and charging infrastructure, as well as recycling of batteries and other recyclable materials from vehicles. The report identified the need to "standardise connections to charging points via for example CHadeMo, follow the EU regulation in this field, or IEC 62196".

The government is considering charging stations standards at national or regional level, as well as a master plan for charging stations, to ensure sufficient coverage of the charging needs. In 2021, the Rwanda Standards Board (RSB) started working on a technical standard on electric vehicle charging stations, based on the standards of the International Electrotechnical Commission (IEC): IEC 62196-1:2014, IEC 62196-2:2016, and IEC 62196-3:2014.

The Global Green Growth Institute in Kigali prepared a study on electric buses, including an evaluation of charging technologies and standards, assessing options for three bus lines and identifying options to locate four charging points, as well as financial and organisational options for bus charging infrastructure. Lastly, the International Finance Corporation (IFC) commissioned a study on electric buses, assessing charging technologies, business models, and financing options.

The absence of a master plan, guideline, or regulation related to the installation and operation of electrical charging stations for e-mobility was mentioned by several stakeholders during the SOLUTIONSplus User Needs Assessment in November-December 2020. Diverse actors, including university, manufacturer, and start-up representatives, indicated that a policy will be needed on how and where the new charging infrastructure will be provided. They felt that it could be a significant barrier and a possible safety risk if charging points are located at petrol stations. However, one company involved in two-wheeler activities also warned against prescriptive standards that could hamper ongoing R&D. The abovementioned national electric mobility is an important first step to ease the deployment of charging infrastructure and provide more visibility to stakeholders.

2.3. The importance of EV charging

To achieve successful sustainable mobility in the near future, sufficient, reliable, and user-friendly charging infrastructure are key factors to success. The major concerns of users who already own an electric vehicle (EV) or are considering switching to an EV include the availability and the speed of charging, as shown in a research conducted by McKinsey (2020) in four different markets worldwide. For the electric mobility business case to succeed, these concerns should be addressed: users should be convinced that charging their EV will never be a major hurdle but rather "as easy as filling a tank with gas".

To take these concerns away, the following objectives regarding (public) charging infrastructure should be considered:

- Ensure sufficient coverage of recharging infrastructure.
- Ensure seamless charging, with a consumer-centric focus.
- Ensure reliable and easily accessible payment method.

A steeper growth curve for EVs will depend on continuous technological development, further commercialisation and regulatory policies. Standards and interoperability underscore all of these trends, across vehicles, charging systems, and communication networks, and are a key driving force for electric vehicle adoption.

2.4. Typical barriers to the deployment of charging infrastructure

Barriers typically faced when deploying charging infrastructure need to be addressed. Key barriers to widespread adoption of EVs include high upfront cost, unfamiliarity with the technology, a lack of infrastructure to support the technology, inadequate charging infrastructure, insufficient driving range, and a lack of information. These barriers are classically grouped into four main categories: economic and financial barriers, technical barriers, policy and regulatory barriers, and lack of awareness.

- **Economic and financial barriers.** Though home charging stations are relatively inexpensive, public charging stations are expensive due to safety, stability, and faster-charging requirements. Publicly accessible charging stations are needed to address technical and user perception barriers related to range anxiety and charging convenience in terms of time taken to charge. Such stations can be expensive since a fast DC charger will need to be installed. Demand uncertainty is another important barrier leading to reluctance on the part of the private sector to set-up charging stations.

Table 1. Public and workplace charger hardware cost (for major U.S. metropolitan areas, based on Nicholas, 2019)			
Level	Type	Chargers per pedestal	Per-charger cost (USD)
Level 1	Non-networked 1.2-1.4 kW	One	813
Level 1	Non-networked 1.2-1.4 kW	Two	596
Level 2	Non-networked 3.3-6.6 kW	One	1,182
Level 2	Non-networked 3.3-6.6 kW	Two	938
Level 2	Networked 3.3-6.6 kW	One	3,127
Level 2	Networked 3.3-6.6 kW	Two	Two
DC fast	Networked 50 kW	One	28,401
DC fast	Networked 150 kW	One	75,000
DC fast	Networked 350 kW	One	140,000

- **Technical barriers.**
  - There are several charging and battery standards, with no consensus on a uniform standard. This can lead to the selection of a sub-optimal standard and technology lock-in.
  - For home charging, appropriate technical requirements may need to be established. The building code may need to be revised to include provisions for charging.
  - A lack of skilled personnel can hamper the wide deployment of EVs. Skill requirements for repair maintenance will differ compared to traditional ICE vehicles.
  - The use of fast chargers as well as scaling up of the public charging infrastructure may require grid upgrades and introduction of new technologies, such as smart grids and vehicle-to-grid (V2G), to optimally absorb renewable power and stabilise the grid.
  - New technologies such as battery swapping, which has become very popular in some countries such as India and China, particularly for two and three-wheelers, may require different infrastructure and policies. Similarly, a smart grid that could facilitate V2G technology adoption, may require technical changes in the charging infrastructure.

- **Policy and regulatory barriers.** A lack of regulation on the standards to be used for charging infrastructure can lead to the proliferation of charging equipment used in the country, leading to market fragmentation. The uncertainty on standards can therefore adversely impact the development of charging infrastructure as developers may not come forward to invest. The role of utilities and electricity distribution companies and the availability and price of electricity may require appropriate policies and regulations.

- **Information/awareness and other barriers.** Awareness has been identified as a major issue in various surveys, and it includes awareness about governmental policies and support. Greater institutional capacity is needed to design effective policies and take other actions to establish robust charging infrastructure.

2.5. Fundamentals of EV charging infrastructure

2.5.1. Different solutions for different vehicle types

It is important to note that within the "EV" terminology, there are two main different groups of vehicles that deserve different consideration in terms of infrastructure requirements:

• **Light electric vehicles (LEVs)** include scooters, bicycles, small motorcycles, and small three- and four-wheelers. These vehicles are typically powered by a low-voltage powertrain (typically up to 48 V), and their batteries—usually removable—can be charged by plugging them into the ordinary grid, similar to any household appliance. In principle, there is no need for dedicated charging infrastructure if the user has a socket to charge the vehicle overnight, as well as reliable power supply that does not rely primarily on a local diesel generator.

Yet, to incentivise the mass deployment of LEVs, safe, smartly distributed public charging points can be made available to support the deployment of an electrified shared or taxi LEV fleet, especially if the conditions above are not met. As charger types are limited and charging times are typically low, charging infrastructure for these vehicles is easy to deploy. LEVs are also ideal for centric urban areas in which available space is a constraint and where the users' turnover is high. These vehicles do not need to meet interoperability requirements.
The overall impact of LEVs on the power grid is generally low and limited to potential peak loads, should the grid be weak. Generally speaking, the impact will depend on various factors, including the overall installed capacity, vehicles electrified and charging times (electricity availability), load duration curve etc.

• **Larger electric vehicles** include high-power motorcycles, passenger cars, commercial vehicles, trucks, and buses. Heavier weight and larger range requirements lead to powerful motors that need to be fed by higher capacity batteries. Voltage is significantly increased, and safety requirements are a major technical concern for the vehicle, charging infrastructure, and communication protocols between the vehicle and chargers. Interoperability measures are important for this group.

Vehicle type	Charging system	Charging power	Suitable charging solution
Bicycles, scooters and light motorcycles	Direct grid and DC simple transformer	< 3kW	
High power motorcycles	Mode 3 and Mode 4	3 - 20kW	
Passenger utility vehicles	Mode 3 and Mode 4	3 - 100kW	
Passenger luxury vehicles	Mode 3 and Mode 4 HP	3 - 350kW	
Transport vehicles (vans)	Mode 3 and Mode 4	3 - 200kW	
Commercial vehicles (buses and trucks)	Mode 4 and high-power interfaces (e.g., pantographs)	50 - 600kW	

Table 2. Charging system typologies.

Source: IDIADA

2.5.2. AC vs. DC connectors

Electric vehicle types have varying power needs, which also determines the recharging speed, together with the specifications of the vehicle. Different technologies are being used with regards to different levels of power output; these are mainly divided into AC and DC recharging and are referred to as "modes". Most public-access AC recharging points provide between 3,7 and 43 kW, but the most common is 11 kW. AC recharging is usually referred to as "slow" recharging (up to 3,7 kW), "normal" (circa 11 kW), or "fast" (22 kW and higher). For power outputs above 43 kW, recharging point manufacturers provide DC recharging solutions, which are referred to as "high-power", or also "ultra-fast" recharging.
For these different "modes" of recharging, various standard connectors have been adopted, which differ slightly by continent. In Europe, the AC connector mandated by the EU is the Type-2 "Mennekes" connector, adopted for a variety of vehicles including passenger cars. Section 2.6 further elaborates on existing standards.

Choosing among different charging solutions (slow, fast, ultra-fast) not only has an impact on charging speed and the use of space, but also on costs of e-mobility systems and battery lifespans. All options must therefore be carefully assessed to identify solutions adapted to local operational, financial, and technical conditions, especially for buses.

Table 3. Charger types

	AC-recharging Wall outlet	AC-recharging Wall outlet IC-CPD	AC-recharging Wallbox	AC-public recharging-station	DC - recharging
Mode	1	2	3		4
Standard		IEC 62752/UL 2231	IEC 61851-1/-21/-22		IEC 61851-23
Power class	max. 1ph 16A (3.7kW) max. 3ph 16A (11kW) max. 3ph 32A (22kW)		max. 1ph 16A (3.7kW) max. 3ph 63A (43kW)		25kW - 400kW

	N. America	Japan	EU and the rest of markets	China	All Markets except EU
AC	J1772 (TYPE 1)	J1772 (TYPE 1)	Mennekes (TYPE 2)	GB/T	Tesla
DC	CCS1	CHAdeMO	CCS2	GB/T	

Source: European Alternative Fuels Observatory (EAFO)

2.5.3. Battery swapping

In addition to recharging, the alternative option of swapping exists. Swapping involves exchanging a depleted battery for a fully charged one, either with batteries owned by the user, or from commercial battery recharging stations. The swapping process requires only a few minutes and can be done manually or mechanically, depending on the battery size. Swappable batteries bring the advantage of eliminating the recharge time, which is a serious constraint and a typical hurdle for the uptake of electric mobility. Swapping schemes also enable smaller batteries. Multiple systems can co-exist as long as each one has a critical mass of clients. Swapping is less widespread worldwide because of challenges related to investment costs, the required number of batteries, and lack of standardisation (Eccarius & Lu, 2020; UNEP, 2020). Thus, the landscape of swapping and corresponding standards is less defined than charging. A further challenge lies in the interdependence of drivers and swapping service providers unless they fall under a single company.

Nonetheless, swapping is gaining traction in contexts characterised by intensive vehicle use: for instance, for two- and three-wheelers used for ride-hail services, including bikeshare systems. Business models where batteries are owned by energy operators and rented out to drivers or owners of vehicles, as is the case with LPG gas cylinders in many countries, are successful in India. Even if it induces a swapping fee, the separated ownership of the vehicle and the battery enabled by battery swapping mitigates the high upfront cost of EVs. Avoiding such higher upfront costs is key for the uptake of e-mobility.

In addition, for the swapping provider, battery swapping is also more than just selling electricity: drivers owning or renting electric vehicles are tied to charging with the provider, which ensures higher utilisation rates. Swapping schemes also offer great applications for rural electrification as well as the integration of mini grids. Conflicts between the integration of renewable energy sources—mostly solar energy in most of Sub-Saharan Africa—into the grid, and electric vehicle usage at daytime, when solar energy is produced, can be solved through the large number of batteries in a swapping system.

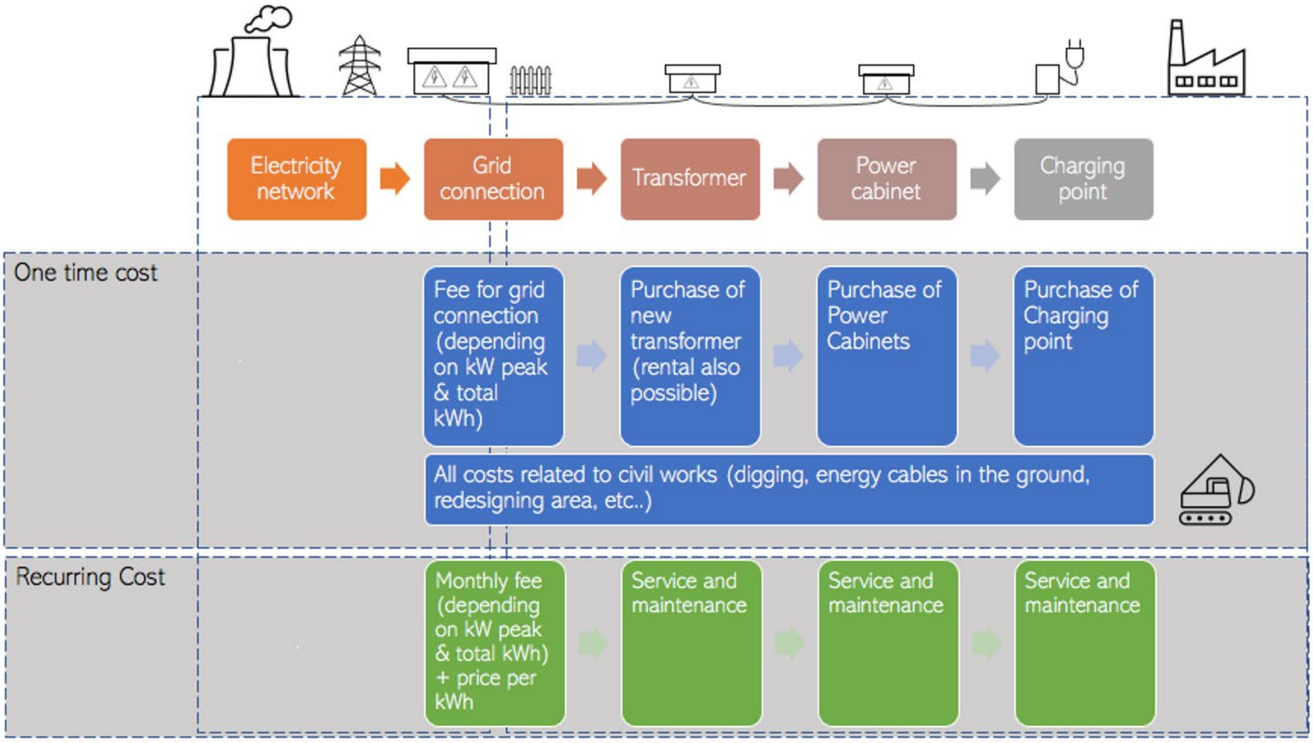
2.5.4. Installation costs

Installation costs are a function of charging powerr and the numbers of chargers per site. They differ for networked versus standalone solutions.

Table 4. Installation costs per DC fast charger by power level and chargers per site (costs across major U.S. metropolitan areas, Nicholas, 2019).

	50 kW				150 kW				350 kW			
	1 charger per site	2 chargers per site	3-5 charger per site	6-50 chargers per site	1 charger per site	2 chargers per site	3-5 chargers per site	6-20 chargers per site	1 charger per site	2 chargers per site	3-5 chargers per site	6-10 chargers per site
Labor	$19,200	$15,200	$11,200	$7,200	$20,160	$15,960	$11,760	$7,560	$27,840	$22,040	$16,240	$10,440
Materials	$26,000	$20,800	$15,600	$10,400	$27,300	$21,840	$16,380	$10,920	$37,700	$30,160	$22,620	$15,080
Permit	$200	$150	$100	$50	$210	$158	$105	$53	$290	$218	$145	$73
Taxes	$106	$85	$64	$42	$111	$89	$67	$45	$154	$123	$92	$62
Total	$45,506	$36,235	$26,964	$17,692	$47,781	$38,047	$28,312	$18,577	$65,984	$52,541	$39,097	$25,654

One-time costs as well as recurring costs have to be considered not only for purchasing charging equipment, but also for the connection to the electrical grid.



Source: FIER, 2021

Figure 2. Costs components of an EV charging infrastructure

2.6. Existing standards

Various standards (often mutually incompatible) are present in different markets. The main standardisation and protocols are:

- **CCS, prevalent in the European Union (EU) and the U.S.:** This standard is perhaps the most open protocol, composed of different control layers (basic charging, automatic connector, wireless charger, AC, bi-directional, etc.), causing great disparity among applications. At the same time, it also increases the potential range of services that can be offered through the charging infrastructure. It is therefore a complex but flexible baseline that can potentially reach higher performance when internal divergences within the standard are addressed.
- **CHAdeMO, prevalent in Japan:** Named as the acronym of "CHArge de MOve", this Japanese standard is a simpler, closed charging protocol, now compatible through specific adapters with EVs from some European and American OEMs.
- **GBT, prevalent in China:** China has developed another charging protocol that, even if using a pin layout similar to the IEC connector used in Germany, is incompatible with the other existing protocols.
- **ChaoJi, in China and Japan:** In June 2020, the China Electricity Council and the CHAdeMO association reported progress on a joint effort to develop a new standard, supposedly faster, safer, and compatible with all other main existing protocols in the market. It aims to become the international reference standard and replace existing standards by 2035.
- Ongoing work of the Bureau of Indian Standards on standards for LEVs, including parking bay charge points and battery swapping (AEEE, 2020).

As shown above, different countries are following two different approaches to make their standards progress. The EU is focused on adding new functionalities to the charging system, based on flexible protocols[1]. The drawback of this flexible development approach is the creation of serious interoperability issues in final applications. On the other side, China and Japan are joining forces to create a united protocol reference that can help them quickly increase global market share and replace any alternatives. However, the ChaoJi standard is more limited than the CCS protocol.

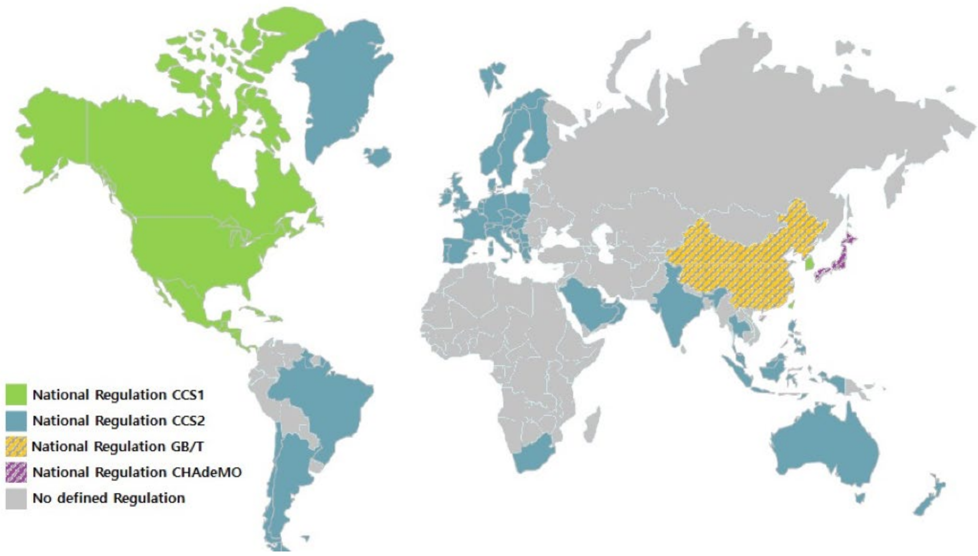


Figure 3. Various standards selected worldwide

1 Examples: vehicle to grid (V2G, that is EVs storing and discharging energy from renewable sources into the grid to smoothen demand), auto plug & charge payment, encrypted communications, wireless charging, dynamic load management, AC charging with digital communication, grid pricing forecast

2.7. Market actors

For an EV user to be able to charge at a public-access charging point, the two most important market stakeholders are the charge point operator (CPO) and the e-mobility service provider (eMSP). The CPO is responsible for the correct operation of the charge point, and in many cases is also the owner of the charge point. The eMSP offers eMobility services to end customers, such as recharging, search & find, routing, payment and other services.

Communication between the charge point and the charge point management system of the CPO is handled through an Open Charge Point Protocol (OCPP). If the EV driver uses a payment method provided by an electric mobility service provider (eMSP) through a smartphone app or an RFID card, the CPO then communicates with the eMSP by making use of the Open Charge Point Interface (OCPI) protocol. The standardisation of these communication protocols has resulted in a charging landscape that is interoperable among many different market roles and suppliers, preventing vendor lock-in for the EV driver and contributing to hassle-free national and international roaming, which is necessary for a good user experience. The figure below shows an overview of the most important roles and communication standards in Europe.

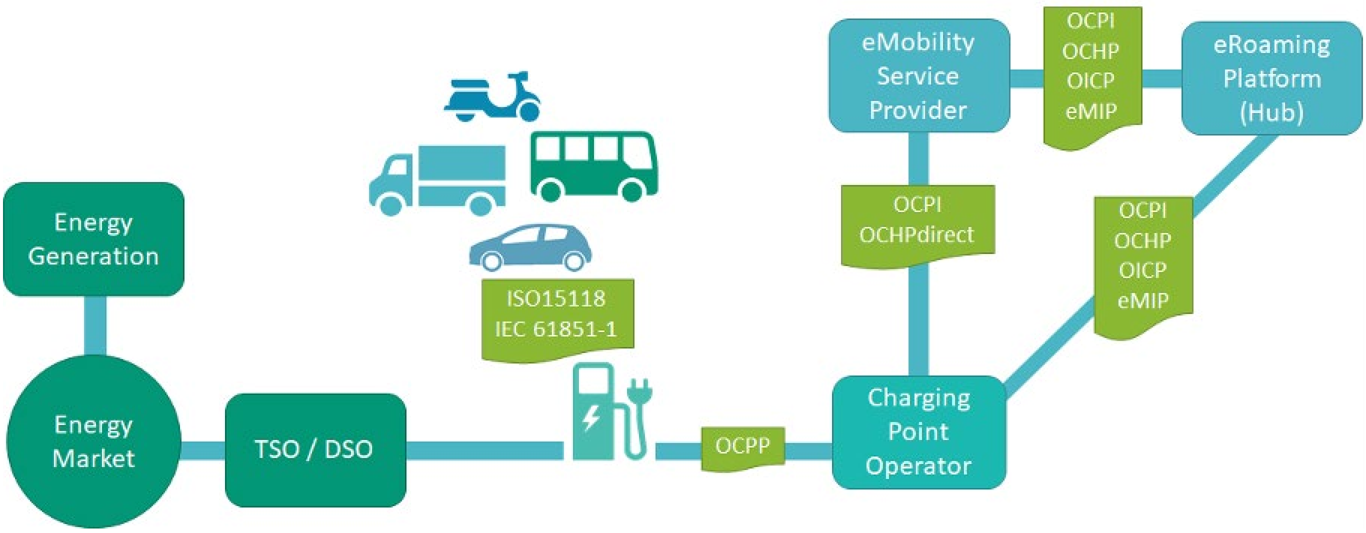


Figure 4. EV charging market protocols. (Source: FIER Automotive).

The glossary in Annex I provides a definition of the acronyms used here. Note: the case of e-bikes (electric pedal bicycles) differs as they tend to be recharged with adapters that are plugged into normal wall sockets (230V Schucko).

To facilitate the EV charging process, many different market players play different roles as depicted in the figure below. All parties involved in the chain have to work together and connect their systems. To do so, application integration is needed, and for that to succeed, the acceptance and implementation of standard protocols are of utmost importance. Standard protocols enable interoperability and can eliminate "translations" between different systems. The regulation of EV charging as a service should be clarified, and separate metering of EV charger considered. If, for instance, chargers are installed in a shopping mall, the power used for charging can be metered separately from the power supply for other functions at the mall.

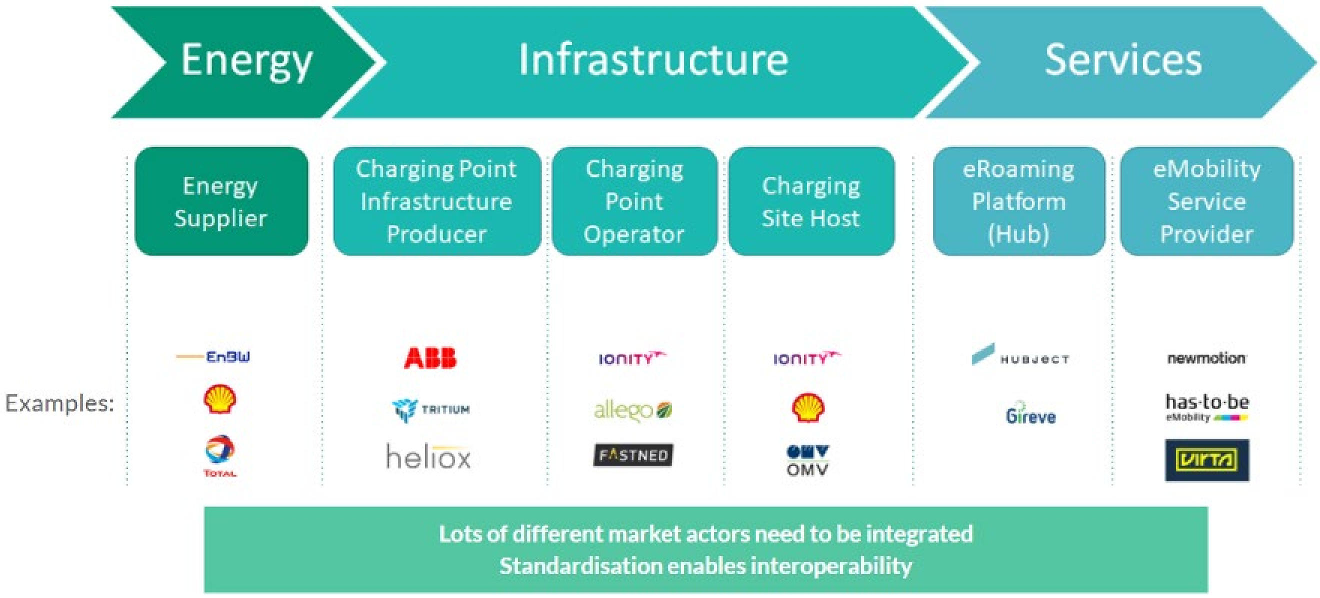


Figure 5. EV Charging Market: Many Stakeholders (Source: FIER Automotive).

2.8. The importance of open standards and interoperability

Despite the progress seen in EVs over the past years, especially with regard to the battery technology (thermal management systems monitoring and optimising the battery's performance, charge density, and aging), there is one aspect that is lagging behind in EV operation: charging interoperability. Charging interoperability refers to the ability of vehicles, chargers, networks, management systems and networks (Figure 2 above) to interact and manage data to ensure safety, functionality, and system reliability. Interoperability and compatibility can reduce the risk of premature obsolescence of assets and of failure to meet users' and operators' expectations on performance and cost. This is crucial today, at the verge of widespread proliferation of heavy-duty electric vehicles.

Assessing interoperability measures reveals the need for the industry to speed up development and homogenisation: various immature standards are being developed and implemented in parallel by separate committees. Some charging protocols use non-standardised connectors, and the major standards are competing for market share. New entrants are challenging incumbents by introducing new vehicle and infrastructure solutions in the market, sometimes disregarding reliability in favour of minimising time to market. Skipping the planning phase and letting suppliers define charging system parameters can result in fragmentation and sub-optimal charging infrastructure. This creates a risk that charging solutions will not be accessible to everyone and will become sunk assets.

Open standards and communication protocols, **especially for the category of larger EVs** (passenger cars, buses, commercial vehicles), can help for the following reasons:

- **Ensure safety:** hardware safety is important to avoid dangers for users. Charging solutions should follow proven, international standards. No equipment should be acquired without certification, and the equipment must be tested before being released to the public.
- **Avoid vendor lock-in and monopolies:** when a vehicle operator doesn't use standardised interfaces and protocols, users will have trouble to charge where they want, which can lead to vendor lock-in and limited utility of the equipment.
- **Protect digital security and access to data:** enforcing the use of open standards and protocols prevents market actors to "close off" the market with proprietary systems, which could hinder access to data for public authorities.
- **Competition and innovation:** standardised protocols enable competition. With a common standard to reference, any company can produce products and services that are compatible with other products and services running in the same field. This enables competition, which promotes innovation and lowers prices. The development of innovative technologies like smart charging and vehicle-to-grid charging is easier and faster when based on the same standards and protocols.

An example of an internationally accepted open communication protocol is the OCPP, which has become the standard for communication between the charge point and the electric vehicle.

2.9. Grid management

The electricity market will experience added demand due to vehicle electrification. Heavy-duty electric vehicles, especially buses, may affect the electric grid, especially in the absence of smart charging, energy storage, or other balancing technologies. The power sector also faces the challenge of developing a greener energy mix, while meeting demands of a stable energy supply and growing demand. Sustainable power sources such as solar and wind power are intermittent, thus influencing the stability of the energy supply and the grid balance.

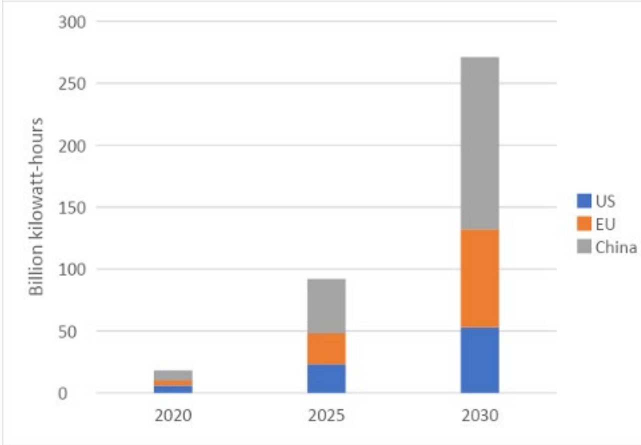


Figure 6. Charging energy demand for electric vehicles (McKinsey).

The use of high power chargers, combined with the growth of the electric fleets, will increase peak demand on grids. A grid that is unable to handle peak demand will slow down future growth of e-mobility. Therefore, load management (demand-side response) will be critical for realising peak shaving to prevent large investments in grid upgrades. Dynamic pricing to match renewable energy generation cycles can help in balancing of new energy sources and new energy mobility solutions. Furthermore, as battery prices reduce and as second life batteries become available, renewable energy projects need to include on site storage facilities so that the load and demand can be matched.

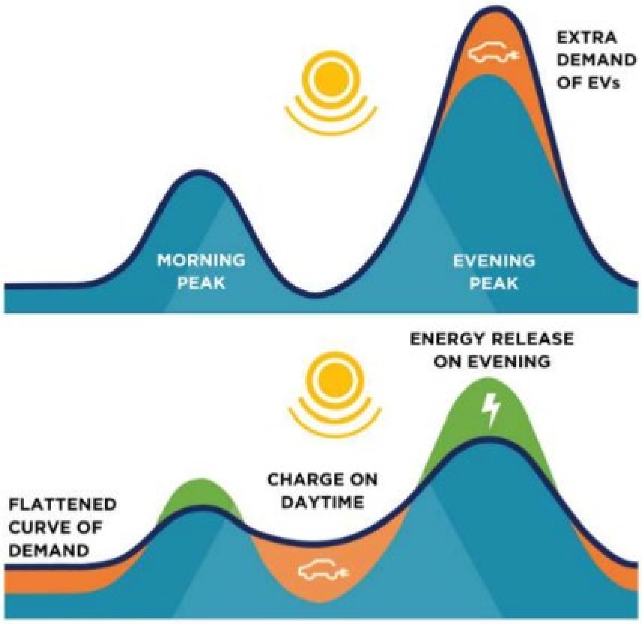


Figure 7. Electricity tariff structures and fleet charging schedules can help manage peak demand. (Source: SEEV4City).

The location of the power delivery and power demand is also crucial. The energy demand from high power chargers at a site can be so high that new medium-voltage connections with new transformers are needed. To make the best use of investments, it would be advisable to combine supply and demand as new grid connections are established.

2.9.1. Smart charging, bi-directional charging, and integration with the grid

Another important aspect of a functioning charging system is to enable and standardise “smart charging” (or V1G) and “bi-directional charging” (also known as vehicle-to-grid or V2G), the latter still at demonstration or pilot stage. The peak energy needed to charge many vehicles at the same time might be higher than what grids can supply, and the peak supply of renewable energy systems to the grid may not coincide with this peak demand. Grid investments to accommodate surges in peak supply and demand will lead to high additional societal cost. The total amount of power needed can be reduced by reducing the power and/or shifting charging times. A next step is V2G, which delivers energy from vehicle batteries back to the grid or even to other EVs and/or buildings, lowering congestion on local grids and therefore preventing large investments in grid upgrades.

Utilities and grid operators have started to reward vehicle operators for being able to control charging times and speed as well as for supplying energy back onto the grid, helping smooth and balance loads while creating incentives for fleets to operate in a grid-efficient manner. Access to charging infrastructure and availability of charging data are extremely important to enable utilities, authorities and/or service providers to control the charging and prevent congestion on the grid.

2.9.2. Bi-directional charging standards (V2G)

CHAdeMO offers built-in support for V2G and although this is implemented in the vehicles that are equipped with CHAdeMO (like the Nissan LEAF), most CHAdeMO chargers do not support V2G. There are some specially developed V2G-capable CHAdeMO chargers available in Europe, but this probably will not lead to a mass roll-out since CCS is the EU de-facto standard.

CCS v2.0 does not support V2G yet, but CharIn has announced that the CCS 3.0 standard will include support for the following features:

- Reverse power transfer to support V2G,
- Inductive charging,
- Wireless charging communication,
- Bus charging with “pantograph” current collector.

Since the most benefits from V2G are found in use cases where the vehicle is connected to the charger for a longer period of time, it seems to make most sense to make V2G available in cheaper AC charge points (slow) that can be rolled out in high numbers. ISO 15118 supports bi-directional charging for AC chargers; this has already been implemented and tested in the Netherlands by WeDriveSolar. Renault has developed a modified version of the Renault Zoé that allows for AC bi-directional charging.

2.10. Tackling barriers to the deployment of EV charging infrastructure

The barriers described in this chapter need to be addressed by targeted policies that will help create an enabling environment for the adoption and scale up of cost-effective charging technologies. Charging policies can have a significant impact on the cost of charging, facilitate building up charging infrastructure, and thereby enhance the adoption rate of EVs. Charging and parking policies are closely related in the case of EVs since a major part of charging can occur where vehicles are parked. Therefore, policies and regulations on optimal charging and parking are key for the deployment of electric vehicles on a large scale.

Table 5. Policies adressing the uptake barriers for EV charging infrastructure	
Economic and financial barriers	• Subsidies, incentives, and tax rebates on investment in charging infrastructure, import of related equipment, and operation of this charging infrastructure • More convenient i.e. better situated parking spaces made available to EVs; or reduced parking fees for EVs • Reduced electricity rates for charging • Low lease/rental price for establishing charging sites • Appropriate business models (subscription, pay per use, annuities etc.) • Mandates to well capitalised entities such as utilities or petroleum corporations to set up EV charging stations
Technical barriers	• Building codes requiring parking and charging facilities in existing and new construction • Technical requirements for home, workspace and public charging • Skill development programme for EVs maintenance
Policy and regulatory barriers	• Selection of appropriate technologies and standards for charging infrastructure, batteries etc. and their notification • Utility/electricity distribution companies (DISCOM) regulation • Building code regulations and charging facility regulations **(e.g., minimum proportion of car parking spaces allocated to electric vehicles; requirements for minimum bicycle parking and for e-bike charging equipment in commercial or office buildings)**; clarification of the legal framework applying to charging facilities (e.g. specific regulation, amendment of electricity regulation • Low Emission Zones, including EV public charging facilities • Integration or consideration of EV charging infrastructure in a Sustainable Urban Mobility Plan (SUMP), land use plans
	• Demonstration / pilots • Awareness campaigns • EV Champions for promotion • Institutional capacity building

These policies specifically target barriers related to EV charging infrastructure, which is the focus of this paper. Further policies can support the purchase or leasing of the vehicles: for instance, via policy strategies (national targets for EV penetration by a given date; shift of some vehicle types such as government vehicles to EVs from a certain date onwards, etc.) or fiscal measures easing the shift from ICE to EV for individuals (purchase subsidies, differential tax rates, or feebates based on level of carbon and pollutant emissions).

Ensuring a clear strategy, as well as coherence and alignment between different public authorities and parastatals is a crucial step to ensure a sound deployment approach:

- Public authorities should develop a **long-term mobility vision and strategy** with clear goals on future developments. Plans and strategies for the uptake of electromobility and the deployment of its recharging infrastructure should be part of this long-term mobility vision and should ideally include measurable targets to monitor progress and create a stable investment climate.
- **Coherence** between the long-term strategies for recharging infrastructure developed by different public authorities at different governance levels is essential. This is also the case between different policy domains (energy, mobility, housing, urban planning, industry, R&D, etc.) to reinforce and leverage impact.
- Examples of cooperation for the deployment of electric recharging infrastructure include different levels of administration and governance as well as **cooperation** between public and private actors (see below, an example from the Netherlands).

Many local governments are deploying electrification policies for passenger vehicles, public service vehicles (buses, waste collection, and cleaning), and urban freight. Some cities, including Amsterdam and Oslo, aim for fully electrified fleets by 2030 (ICCT, 2020). An important number of cities, including Rio, Vancouver, Santiago, Quito, Paris, or Cape Town, have pledged that major urban areas will be zero emission by the same date (ibid).

The Netherlands: cooperation between public and private stakeholders

In the Netherlands, the Dutch Ministry of Infrastructure and Water has drawn up a National Agenda Charging Infrastructure to ensure that a well-functioning infrastructure for electric transport can be rolled out. The National Agenda was drawn up in collaboration with public and private stakeholders, who jointly made agreements and defined the goals and actions on the deployment of charging infrastructure. The benefits of such a consultation have been reported, as it said to lead to improved coordination in the deployment of infrastructure, while ensuring broad multi-stakeholder buy-in.

Charging Policy in China

China is the leading country in the world with more than 3.38 million EVs in 2019 (IEA, 2020) and sales of more than 1.2 million in 2020. Salient features of China's charging policy include:

- In 2015, the central government set a target of providing charging infrastructure for 5 million EVs by 2020, including 10% of parking spaces for EVs in large public buildings, at least one public charging station for every 2,000 EVs, and at least 120,000 EV charging stations.
- Provincial and local governments have established financial incentives and requirements for residential and commercial buildings to have EV charging.
- Five national standards were issued in 2015 for electric vehicle charging interfaces and communications protocols.
- The 13th Five-Year Plan included RMB 90 million for charging infrastructure.
- The central government sets policies on retail electricity rates, including minimum and maximum prices for electric vehicle charging. The National Development and Reform Commission (NDRC) policy included EV charging rates for three classes of customers. Residential customers pay residential rates (lowest tariff), dedicated central EV charging and battery swap stations pay industrial customer rate, and government offices, public parking lots, and other businesses pay commercial rates (highest tariff). Many Chinese provinces and cities have time-of-use rates for EV charging. The cap on EV charging tariffs was removed in Beijing in 2018 to make EV charging a viable business.

Charging Policy in India

India has an ambitious programme to transition to EVs. The Ministry of Power established following measures (Potshangbam, 2019):

- Private charging at homes or offices will be permitted.
- There will be no licensing procedures to set up public charging stations.
- Stations should meet performance standards and protocols issued by the Ministry of Power and Central Electricity Authority.
- Minimum fast charger requirements specified for long-range and heavy-duty EVs. Charging stations for two and three-wheelers are given the flexibility to use any charger but need to meet specified technical and safety standards.
- Tariffs are determined by the electricity regulator. For domestic charging, the domestic tariff applies.

In addition, to promote faster adoption of electric vehicles, the Government of India has also allocated USD 135 million for subsidising charging stations. It is planning to set up at least one electric vehicle charging kiosk at around 69,000 petrol pumps (owned by public sector enterprises) across the country to induce people to go for electric mobility. It has also passed legislation allowing sale of EVs without the batteries to reduce their up-front costs and enable battery swapping.

3. Identification of charging needs and locations of charging points

This chapter covers light electric vehicles (LEVs), including electric two- and three-wheelers, and light duty vehicles (LDVs). Charging solutions and strategies for electric buses are specific and require a thorough assessment of the characteristics of the public transport system. Section 5.2.1 provides some initial principles on the deployment of electric bus charging infrastructure.

3.1. Choosing the adapted charging solutions

Setting up electric charging infrastructure requires analysis of city-specific characteristics, including travel patterns (mode split, distribution of origins and destinations, journey length); use and operations (e.g., typical driving ranges); housing stock; access to electricity; topography; and thermal variability. Those characteristics define the performance required for vehicles and the general energy and recharging requirements. The analysis should include identifying social objectives and corresponding technical requirements.

No "one-size-fits-all" charging solution: It is key to consider city characteristics

The following principles can guide the design of charging systems:

- **Prioritise regular charging instead of high-power, or opportunity charging** to smooth out the energy demand curve, maximise charging efficiency, and extend the lifetime of the EVs.
- **Charging, in as much as possible, should not be carried out during operation** but when the vehicles are not in use: parked at their destination. That entails the deployment of a dense network of mid-power chargers in large commercial areas, work centres, and residential districts as well as promoting the installation of private chargers at residential locations.
- **High-power charging should be deployed only to meet specific needs:** opportunity charging for private users during longer journeys, and partial recharging of commercial and public transport vehicles whose daily operation exceeds the battery range and emergencies. Ideally, high power chargers should be deployed at the intersections of the main arteries in the city outskirts, and in destinations in which users spend little time: small shops, restaurants in industrial areas, supermarkets, etc.

3.2. Forecasting charging demand

An analysis of the recharging needs (i.e. the number of needed charging points) is required to prevent short-term investments in suboptimal and redundant infrastructure, since charging infrastructure typically has a lifetime of at least seven years. **Public long-term strategies for recharging infrastructure** require a clear vision on how the local mobility and electricity demand situation should develop. Main factors to consider include:

- **Transport data:** number of daily commuters coming to a given area, amount of transit (long-distance) traffic, changes in traffic densities and traffic flows,
- **Present and forecasted transport electrification,** expected ownership or use of EVs, and resulting charging needs of specialised/captive fleets such as taxis, (urban) logistics, etc.,
- **Amount of semi-public recharging infrastructure as well as private one** (private parking space, stores, etc.),
- **Urban planning changes**, e.g., changes in the intensity of commercial activities and residential uses in particular city areas.
- **Forecasted modal shift,** e.g., a shift from the user of personal motor vehicles to walking, cycling, and public transport.
- **Changes in vehicle fleets,** e.g., number of e-vehicles and drivetrain types,
- **Technological developments of EVs**, e.g., battery size, recharging capabilities, etc.
- **Policy developments,** especially Urban Vehicle Access Regulations (UVARs) and Low Emissions Zones and,
- **Local energy** demand and hosting capacity of the local electricity grid.

3.3. Methods to determine the location of charging points

Charging may be undertaken at a wide range of private or public locations, such as homes, public transport stations, parking lots (workplace, residential buildings, retail centres, eateries, etc.), lampposts, kerb sides, fuel stations, bus depots, and electric utility facilities, among others.

Charging locations for private vehicles can be categorised into three classes:

- **Home charging:** refers to charging at users' residences, including in single homes or apartment complexes with parking spaces. Home charging is usually Level 1 charging and EVs are normally charged overnight.
- **Workplace charging and other private charging:** refers to charging at parking places a part of the workplace or near the workplace with parking reserved for the company employees. In this case, Level 1 charging is also used.
- **Public charging:** this includes parking on public streets, public garages, shopping centres / supermarkets, public charging stations similar to gas stations etc. Faster levels, such as AC fast or DC fast, are used in the case of public charging facilities, depending on the time the vehicle is expected to be at the charging point. A vehicle can be at a charging point for a few hours at

supermarkets and movie halls, or a few minutes at fast charging stations. Public charging is particularly useful for those without home charging capacity, depending on the vehicle type and living conditions (for instance, light-duty vehicles for an urban population living in apartment buildings), or in the absence of stable electricity in residential areas[1].

To the extent that city authorities are involved in planning the charging network, they should aim to balance ease of use and cost effectiveness, as described in the following table.

Table 6. Criteria for efficient charging infrastructure.	
1. Providing flexibility for electric vehicle users by:	a. defining the required number of recharging points, b. identifying appropriate locations, c. ensuring geographical dispersion, d. identifying appropriate power levels.
2. Reducing over-all deployment costs and nui-sance by:	a. making best use of existing infrastructures to limit installation costs e.g., shopping malls/schools etc. can be used during night for parking/ charging of a commercial fleet, b. limiting the use of (public) space, c. preventing nuisance during installation and maintenance works, d. maximising the occupancy rate of recharging infrastructure (effective EV parking policy).

1 In regions with good sunshine, charging can be combined with rooftop solar energy (e.g., Zembo in Uganda), but this decision should be balanced against a series of criteria, including availability, reliability, and cost of electricity via the grid and upfront investment costs from photovoltaic panels.

Selecting adequate locations for recharging infrastructure can be either made centrally by public authorities or (semi-)public undertakings (e.g., utilities, distribution system operator), or by market players or indirectly by prospective EV-users. This will depend on the methodology selected. In the European context, three main ways of selecting locations for recharging infrastructure have been identified, with a plethora of options to combine them:

1. **Central decision making:** modelling the charging demand;
2. **Utilising data** extracted from existing recharging points;
3. **Decentralised decision making:** responding to requests for a new recharging point from prospective EV owners.

Each method is detailed below, before showing examples from European cities combining these methods in different ways (box p.30).

In addition, the question of which entity is responsible to identify adequate locations for charging points (private and shared vehicles) is closely linked to the contractual model selected (see section 4.2). Finally, and as explained above, all of these should be **compared with the electricity grid** to ensure that existing capacity is used optimally and to avoid unnecessary upgrade costs. Hence, close involvement of the electricity distribution company is critical.

Focus on the 1st method: Central decision making – Modelling the demand

The main factors to consider when forecasting the charging demand have been presented above (section 3.2). Central planning of infrastructure may be useful in early stages of network development to establish a basic network, in order to convince the earliest-moving consumers to switch to electric vehicles (solving the “chicken-and-egg dilemma” of electric mobility), or if public authorities want to ensure a good geographical spread. When opting for this method, public authorities often delegate the decision to a specialised public undertaking or to the distribution system operator (DSO). Tables 7 and 8 provide further insights into aspects to consider in the modelling.

Parameters	Factors to consider
Location profile	Location, Topography, Demography, etc.
Type of transportation prevalent	Roadways, railways, airways etc.
Key statistics	Type of transport: 2 wheelers, 3 wheelers, 4 wheelers, Buses, Commercial vehicles, Personal vehicles Key attributes viz. • Spatial distribution of registered motor vehicles • Share of Different Modes of Transport in overall transportation sector (LCV, MCV etc.) • Average annual growth by category
Key areas	Ring roads, Commercial and industrial hubs, Expressways, Highways, Intra-city roads, Bus terminals
Forecasts for transportation sector	• Forecast for private and commercial vehicles • Forecast for freight transportation • Expected penetration of conventional vehicles and Electric vehicles in the future
Power infrastructure	• High level network overview with load growth forecasts • Overloaded / under-loaded areas • Optimal locations for solar power

Table 7. Key factors to consider in multi-criteria decision-making to select the location for EV charging infrastructure (Source: Deloitte analysis, cited in GIZ, 2021).

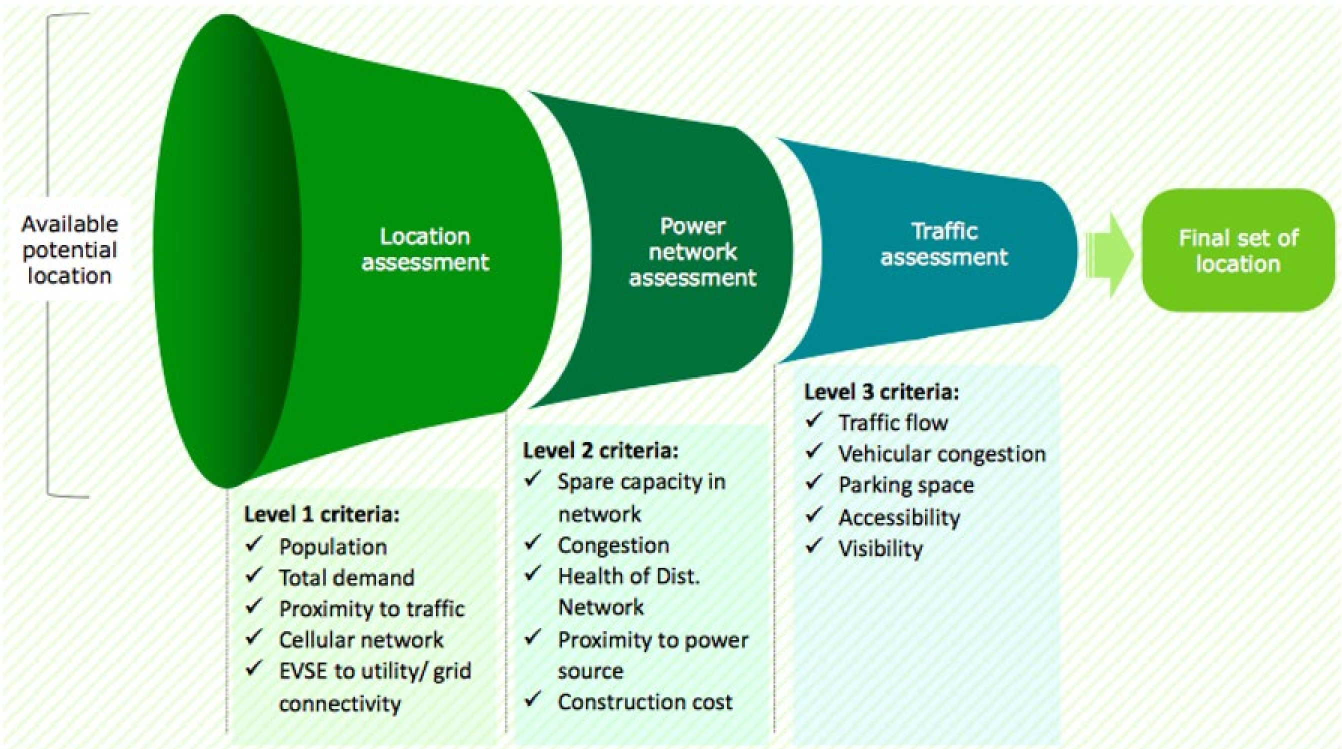


Table 8. Shortlisting criteria for selection of location of location for EV charging station (Source: Deloitte analysis, cited in GIZ, 2021).

Focus on the 2nd method: Using data from existing charging points

This method may be merged in some cases into the first one (modelling). In Europe, some cities, including Madrid, require data from concessionaires on various indicators such as the state of the network, recharging times, and consumption, in order to get a clear picture on electric mobility. Cooperating with universities is another way to collect and analyse data. For instance, in Amsterdam, the city and the Amsterdam University of Applied Sciences have collaborated to allow researchers and students to analyse the data collected via the more than 2,600 charging points (Gemeente Amsterdam, 2018). The city council is consulted on the research questions. Results support decisions on further deployment of charging infrastructure.

Focus on the 3rd method: Decentralised decision making – Demand-driven approach

Some cities allow EV users who don't have the possibility of charging their own vehicles at private premises, to apply for the installation of a recharging point in the vicinity of their home or work, assuming there are none yet. This decentralised "Amsterdam-model" or "demand-driven approach" has been applied in varying ways throughout the EU, often in combination with a centralised approach. This approach has proven beneficial in convincing consumers to switch to electric vehicles.

Very often, the demand-driven approach is combined with a "hierarchy of recharging", requiring that recharging of private vehicles takes place as much as possible on private premises, as shown in the figure below.

The Roll-out following the "Charging Ladder"

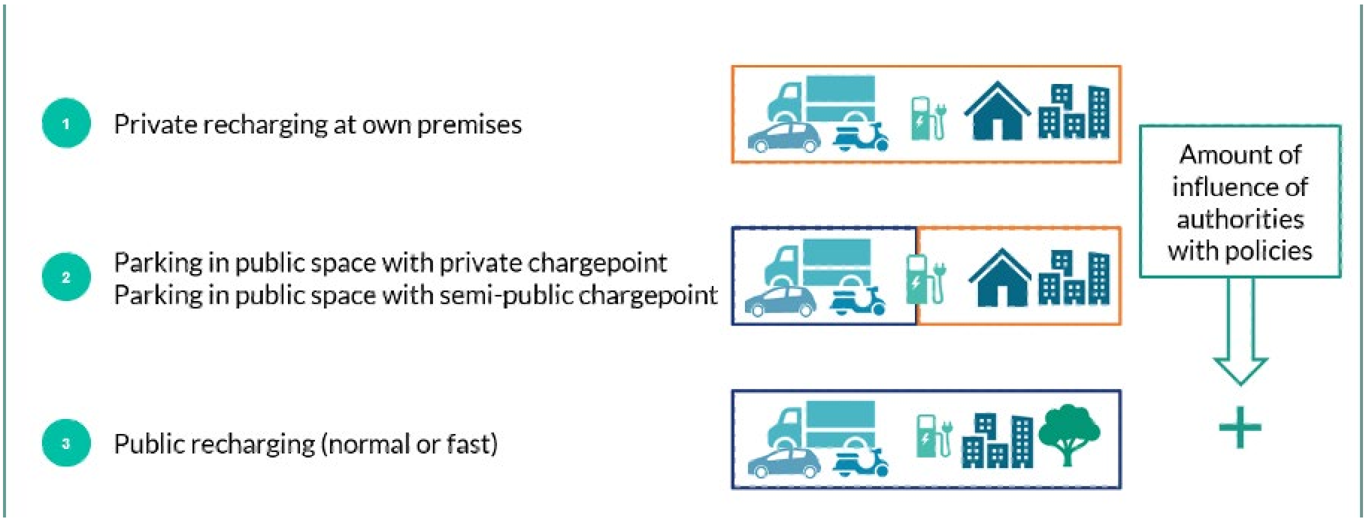


Figure 8. The Charging Ladder (Source: FIER Automotive).

Example: Antwerp's demand-driven approach

The policy vision of the Autonomous Antwerp city Parking Agency (AAPA) resembles the policies from Amsterdam and is based on two principles: the "hierarchy of recharging" and "recharging point follows EV".

Hierarchy of recharging. In AAPA's vision, residents and workers must recharge to a maximum degree on private property in accordance with the hierarchy of recharging.

Recharging point follows EV. "Recharging point follows EV" is a responsive strategy in which a recharging point is deployed in the vicinity of an EV-driver as soon as there is a certain guarantee that a resident (or company) will buy/lease an electric vehicle. Applications to the city of Antwerp can be done via an electronic form on the city of Antwerp website. Further conditions for the applicant include (future) possession or lease of an electric vehicle with a full electric range of 50 kilometres according to manufacturer's specifications and having their residence in the city of Antwerp or working for at least 18 hours per week in the territory of Antwerp.

Combining the three methods: various European examples

In **Madrid**, city authorities use data from the concessionaire to steer network deployment. In particular the concessionaire must "provide information concerning the parameters for the use of the recharging network, inter alia: state and maintenance of the network, recharging times, average consumption for each recharging session and user typology. Data must be transmitted in such a way that the collected information can be analysed to offer the city of Madrid a clear understanding of the development of electric mobility in its territory" (STF, 2021).

The city of **London** mainly takes the following elements into consideration when identifying new locations for the deployment of recharging infrastructure: locations of existing recharging infrastructure, current EV ownership, new licensing requirements for taxis and private hire vehicles and expected future uptake of EVs.

The city of **Dortmund** bases its deployment strategy on a forecast of EVs, grid analysis, socioeconomic data, and city planning data. The administration involves citizens in its decisions regarding locations and types of recharging points.

The city of **Stuttgart** bases its deployment strategy on the number of inhabitants and working places in each of the 152 city districts. The required number of recharging points in each city district is therefore determined at a macro level. It is subsequently left to market parties to decide where exactly in each city district they want to roll out the required amount of recharging infrastructure.

3.4. Combined charging infrastructure at strategic locations

In many cities, strategic locations for private vehicle charging infrastructure are also locations that are important for public transport and shared mobility. In many cases, the combination of dedicated charging infrastructure with an open charging infrastructure for public use, gives a better business case in strategically interesting locations. This resonates with the suggestion made in the Sweco-ifeu e-mobility feasibility study in 2019, that "charging points with combined solutions for motorcycles and cars could be an efficient solution". Such combined charging solutions may have:

- **Dedicated charging infrastructure for the operation of electric public transport buses or transport modes offered under a shared or taxi modality.** This infrastructure can be designed according to operators' specifications.
- **Additional public-access facilities for private vehicles** that should follow the standards for public-access charging stations set out by government authorities, and be interoperable.

Table 9 explains the principles to observe when planning combined charging points.

Table 9. Planning combined charging points.

1. Operations of own fleet comes first	A bus, or taxi/shared fleet operator may decide to set up a charging infrastructure for their electric fleet in a strategic location that can also be interesting for other users. The first check, when assessing whether it is possible to set up a combined charging point, is to ensure that the power supply is enough for optimisation of its own operations (bus, shared, taxi). Supply may be an issue with combined charging points, especially peak power use.
2. Separation of operations be-tween the two charging systems	If the abovementioned condition is fulfilled (enough power supply for other users), the bus or taxi operator sets up a dedicated charging infrastructure for its own fleet and may invest in additional open charging infrastructure for the public, located at the same site. Operations of both infrastructures should not be mixed, as it is important for fleet operators to have full certainty that the dedicated charging facilities will be available whenever they are required.
3. Implications for interoperability	The charging infrastructure part open to the public must comply with open standards and interoperability, but not necessarily for the dedicated part for its own fleet. This is also the case for the hardware part of it. The public-access charging points should comply with standards established by the government: e.g., CCS and or CHAdeMO.

4. Contractual models

Public authorities should adopt policy instruments and contractual models that support the development of a competitive market for recharging infrastructure and services. Combinations of instruments and contracts can be used for this purpose. A competitive market guarantees innovative and affordable infrastructure in the longer run.
In the context of emerging electric mobility services in East Africa, contractual models applied in other locations across the world can be useful within a learning process, as inspiration. Yet, it is essential to contextualise contractual models for the specific context of Rwanda, which will be discussed during the Africa training in September and October 2021.

4.1. Public transport

Electric buses have a higher upfront investment cost than diesel buses. Depending on the region, the purchase price of an electric bus can be two to three times higher than the price of a diesel one (IFC, 2020). However, electric buses have significantly lower energy and maintenance costs. The difference in the total cost of ownership (TCO) between ICE and electric buses will vary depending on the content. The extent of operational gains will depend on local characteristics such as fuel and electricity prices, distances driven per unit of energy consumed, types of bus, costs of finance, among others (IEA, 2020). In addition, e-buses also reach equal or even lower breakdown rates than ICE buses (ibid).

These particularities have led to the appearance of new business models and financial mechanisms that involve new stakeholders in the ownership of e-bus fleets for public transport. These models aim at making the uptake of electric buses more affordable, less risky, and scalable. Business models and contractual relationships must be designed in such a way that they reap the benefits of lower operational costs and facilitate the transition, for instance through leasing mechanisms (for vehicles or chargers).

Table 10. Key electric bus procurement models.	
1. Operator	This commonly applied procurement model is characterised by the purchase of the e-buses and the corresponding charging infrastructure by the public transport operator (PTO), which can be public or private. In this model, both the ownership and the operations of the vehicles remain in the hands of the PTO. This is usually made possible with public funding support to overcome the barrier of upfront capital costs, such as purchase subsidies provided at national or local level, targeting both vehicles and chargers. The purchase of electric buses could also be financed by debt, i.e., through concessional, market loans, or green bonds (GIZ 2019; WRI 2019c). This model can be applied in both net cost contracts (NCC) and gross cost contracts (GCC) (see glossary in Section 7 for more details on these contracts). In the race for public transport electrification, many cities are moving towards GCC with vehicle suppliers. Choosing the contract type depends on a series of parameters including previous bus operation mode, funding availability, costs and earning, technology, etc. GCCs, in which the government receives the fare revenue and pays the PTO based on a formula heavily weighted on a fee per kilometre of service provided, create incentives for a high-quality public transport service (ITDP, 2020). Examples: Medellín (Colombia), 69 e-buses purchased by the public PTO with municipal resources; Montevideo (Uruguay), 30 buses purchased by the private PTOs with a subsidy covering the difference between diesel and electric buses.
2. Public authority model	Public authorities may be responsible for the ownership of charging infrastructure (UITP, 2021). While this approach ensures that the infrastructure will not play a decisive role in future tenders, and allows competition between transport operators, it also means that the public authority will fund the construction of the infrastructure. There is also still limited return on experience on separating ownership and responsibility for operation and maintenance. Example: The Munich transport authority MVV issued a separate tender for the electric infrastructure and for the buses. The operators lease the infrastructure during their contracts. Similarly, in Finland, the public authority owns the depots and rents them out to different operators.
3. Leasing model with a third party	Leasing is a business model that is becoming more and more popular in fleet renewal processes, as the investment risk is shared among various parties. A third-party company, such as a utility company, battery manufacturer, or OEM, purchases the e-buses, the batteries, or the charging equipment and leases them to the PTO. The PTO then pays a fixed amount, which will depend on the terms defined in the leasing contract (GIZ 2019; WRI 2019c). Examples: In Santiago (Chile), the utility company leases the buses. In Bogotá (Colombia), a third party leases the buses, and the utility company provides the charging infrastructure.
4. Pay-as-you-save (PAYS)	PAYS is a business model developed by Clean Energy Works under which the PTO acquires the chassis of the buses and the utility company purchases the corresponding batteries and charging equipment. The investment costs are recovered over time through a fixed tariff charged on the electricity bill agreed beforehand in the terms of the contract service (GIZ, 2019). For example, Santiago, Chile, financed a fleet of 100 e-buses through as a PAYS arrangement (The Lab, 2018).

In addition, national funding support is key. For example, the government of India under the FAME-II scheme has allocated grant funding of USD 135 million over 3 years for meeting up to 100% of the project cost (depending on the proposal) for setting up charging stations including pantograph charging. It also includes the cost of one slow charger per e-bus and one fast charger for every 10 electric buses (Faster Adoption and Manufacturing of Electric Vehicles, 2019-2022).

4.2. Private and shared vehicles

Various contractual models exist in different cities. Table 11 presents diverse models identified in the European Commission full report and a handbook, developed with the help of some SOLUTIONSplus partners (p.18-22). This report applies to charging infrastructure for passenger cars and vans; we consider that these models can also apply to shared LDVs or even LEVs if provided in a shared or taxi modality and requiring publicly available charging stations.

The involvement of public authorities varies significantly, depending on the model selected. At one end of the spectrum, the license model requires the least effort from municipalities but gives them lower oversight over the infrastructure deployment. At the other end, the public contracting model ensures that the public authority keeps control of the infrastructure but bears responsibility for the project risks.

Table 11. Contractual models.	
License model	Public authorities authorise infrastructure deployment activities enabling parties that comply with these rules to be given the permission to install, manage, and operate charging points in public space. The licence may include requirements and constraints over what the private sector entity is allowed to do. Variations in the model exist: some European municipalities have decided to give a license to any party complying with the rules, while others have opted for licenses awarded to a limit number of applicants. The private entity retains control over the infrastructure and bears most of the project risks, from construction to operation. It finances the expenditures and collects the revenues from the consumer. In identified European examples, municipalities may limit the number of charging points, but have little influence over the location of charging points. This model has the following advantages: it requires minimal effort from municipalities and limited changes in local policy, leaving the private sector to facilitate, manage, and exploit the infrastructure. Yet, there are disadvantages as well, including the limited ability of the municipalities to influence the infrastructure deployment. For instance, charging points will be determined by the market, with no possibility for the municipality to require their installation in less favourable locations. This model also sometimes called the "independent model" and is common in the UK or the Netherlands.

Table 11. Contractual models.	
Concession model	The concession to install and operate a certain facility at given locations is given by the public authority to a private party ("concessionaire"), which bears the financial risks. The private sector finances the expenditure, possibly with subsidies from the public authority, and collects the revenues from consumers. The concession model enables the public authority to put more requirements on the locations and the modalities of the deployment of charging points, as compared to the license model (see above). For instance, it enables the public authority to ensure that these charging points will also be rolled-out in areas with lower demand.
Availability-based model	As in the concession model, the private entity finances the expenditure. However, in this model, the public authority collects the revenues from the consumer and therefore retains the revenue risk of the project. The private entity is paid by the public authority over the duration of the contract, as long as the infrastructure is available for the intended use. A variant of this model: the public authority pays an availability tariff for a period of five years and agrees to buy back the facility at a percent of the investment cost. At the end of five years, when the EV market has gained momentum and revenue streams are visible, it auctions the facility(ies) to the highest bidder, thereby covering the pay-out to the initial investor.
Joint-venture model	The control of the infrastructure is shared by the public and private sector. The project risks are shared between the public authority and the private sector based on their stake in the joint venture. The model is flexible regarding financing
Public contracting model	The public authority finances the expenditure (capital and maintenance) and collects the revenues from the consumer. It keeps control over the infrastructure and retains most of the project risk, from construction to exploitation. This model is associated with the possibility for the public authority to set strict conditions (for instance on the design, parking policy, etc.) and involves only one contract partner. However, it requires a higher public contribution and involvement, and may be linked to fewer room for innovation.

A progression in the business model for charging facilities is possible over time, as the municipality gathers experience on electric mobility, as shown below in the example of Berlin.

Selecting different models over time: the example of Berlin
The choice of a model may evolve alongside the increasing market maturity. Berlin is an example of a city that changed its policy from a grant awarding to a concession model. Figure 7 shows the perspective from Allego, the company providing charging stations in Berlin, on the evolution over time. According to Allego, the licence model is commonly used to deploy recharging infrastructure in an emerging market. When the market is taking off, authorities use concessions, licences and public procurement procedures. In more mature markets, concessions are predominantly used.

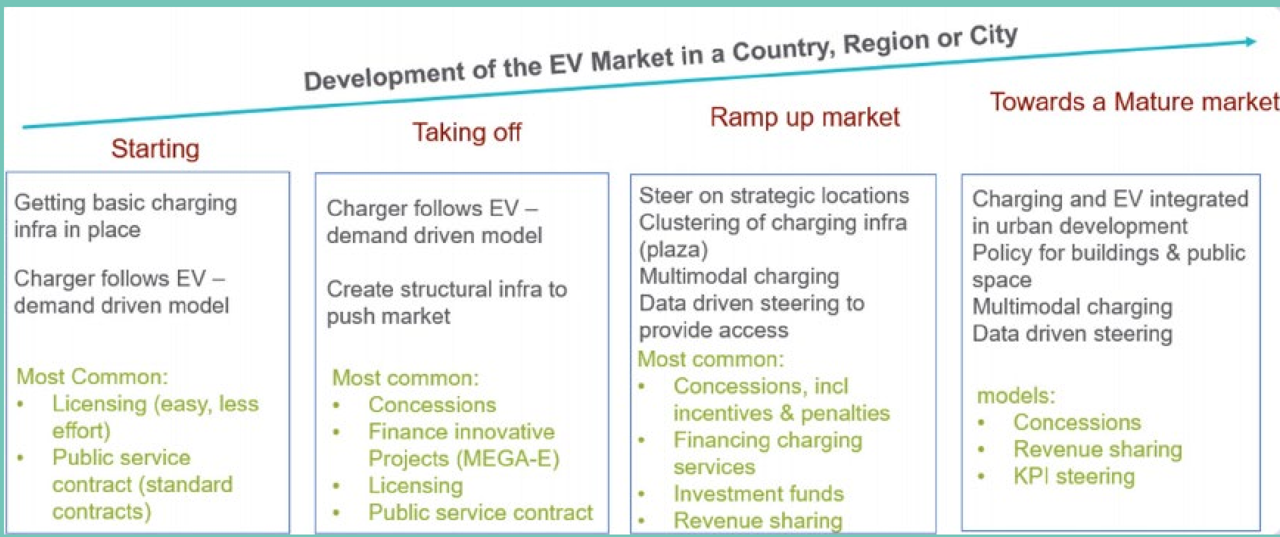


Figure 9. Experience of Allego on the evolution of policy instruments, depending on the market maturity (source: STF, 2021).

Beyond these models, national subsidies, awarded to the charging point developer and/or the municipalities, exist in several European countries, to ensure a minimum level of quality or coverage over a given area.

Utilities play a significant role in charging infrastructure business models in several countries, owning charging stations at their installations through PPP with Original Equipment Manufacturers (OEM). It is for instance the case of the State Grid Corporation of China and China Southern Power Grid (GIZ, 2021), or Convergence Energy Services Limited (CESL), a newly established subsidiary of the state-owned Energy Efficiency Services Limited company in India. Alternatively, utilities can own the charging infrastructure, operate them or through contracted third parties ("integrated model" in Canada, GIZ, 2021). Lastly, charging infrastructure may be identified by companies as an opportunity for secondary business, such as Tesla and its network of fast chargers on highways in the US, Europe, and Asia.

Further, the gradual proliferation of EVs and replacement of conventionally fuelled vehicles must prompt fossil fuel retailing companies to utilise their financial strength and existing infrastructure to gradually build up the e-charging business to make up for the loss of fossil fuel sales. The availability of land and other infrastructure at strategic locations throughout the city as well as on cross-country roads is an inherent advantage. For example, Hindustan Petroleum Corporation Ltd., a public sector enterprise (PSE), has tied up with another PSE, Convergence Energy Services Ltd., to set up EV charging points in cities across India.

5. Charging strategy for Kigali

5.1. Principles for EV deployment

Kigali residents rely heavily on sustainable transport, with high modal shares for public transport and non-motorised options (52% of trips done on foot or bike, 16% with public buses, 16% with motorcycle taxis, and 16% with cars per the 2020 Kigali Transport Master Plan). Unless measures are taken to incentive the use of sustainable modes, the use of private cars is expected to significantly grow in the coming years, leading to a significant increase in congestion levels. The number of motorcycles and cars in the country would almost double by 2030. The modal split of car and moto-taxis together is expected to reach 60 percent by 2050 without a bus rapid transit (BRT) system in place. Investments in higher quality facilities for walking, cycling, and public transport are urgently needed in order to achieve a more sustainable future. Following are key principles that should guide the charging strategy for electric vehicles in Kigali:

- **Align EV charging initiatives with sustainable urban mobility strategies**. E-mobility investments should support the shift towards greater use of public transport, cycling and walking, shared mobility options, while avoiding a lock-in of increased private motorisation and corresponding congestion.

- **Use public funds for electrification of high-occupancy modes.** Public funds should support the deployment of electrified public transport and shared modes, while the private sector can take the lead in rolling out charging solutions for low-occupancy vehicles (cars, taxis).

- **Prioritise sustainable and shared modes in the allocation of public space**. Public charging areas should prioritise micromobility (e.g., bikeshare and electric scooters), followed by vehicles used as taxis (e.g., moto-taxis or ride hail services), and finally private cars.

- **Pursue innovative e-mobility solutions.** Focus on innovative modalities such as electric bicycles. This offers the opportunity to further position Kigali as a continental and regional champion of sustainable urban mobility, leveraging the car-free days and CBD car-free zone.

- **Improve first and last-mile connectivity to public transport.** Deployment of e-mobility solutions and their charging locations should improve first- and last-mile connectivity, in line with the priorities identified in the 2020 Kigali Transport Master Plan. E-bikeshare stations should be deployed in the vicinity of bus terminals, BRT stations, and other major public transport nodes. In the case of moto-taxi, the deployment of charging infrastructure should encourage their use for last-mile connectivity rather than trunk trips that can be served through high-quality public transport.

- **Align e-vehicle incentives with GHG targets.** In the energy sector, the Nationally Determined Contribution updated in 2020 estimates a GHG emission potential of 9% from electric vehicles by 2030, achieved through electric buses, electric vehicles (cars) and electric motorcycles. Electrifying buses is key, in coherence with related strategies of bus promotion, public transport and mass transportation development, as well as replacement of minibuses by modern buses. The electric mobility feasibility study (Sweco & ifeu, 2019) forecasted possible reduction of GHG emissions based on an electrification scenario by 2030 reaching 30% electric motorcycles, 20% electric buses, 25% electric taxi and mini/microbuses, and 8% electric car (including jeeps). In addition, increasing the share of renewable energy sources in the electricity generation mix is paramount to reap mitigation benefits through electric mobility.

- **Ensure consistency with local plans and parking strategies.** It is crucial to ensure that the deployment of electric mobility in Kigali is consistent with the priorities set out in the 2020 Kigali Transport Master Plan. For instance, deploying charging infrastructure at parking places needs to be framed within the strategy of reducing the overall parking supply.

5.2. Charging strategies by vehicle type

This section outlines the key principles that should guide the deployment of a charging infrastructure. In the next subsections, the paper entails initial recommendations regarding the respective charging strategies, localisation criteria, interoperability recommendations, as well as the roles of government and the private sector that will differ by mode.

Some recommendations are included on the type of places where charging points could be located. However, it is central to recall that the degree of influence on the location of these points, depends on the contractual models adopted (Chapter 4.2). **In the light of dynamic private initiatives, Kigali authorities could explore a combination of the three methodologies presented in Section 3.3, namely central decision-making, use of data, and decentralised decision-making where both citizens and e-mobility companies could propose localisation points.** It is critical to design stakeholder participation to ensure adequation to needs and local ownership of the e-mobility transition.

5.2.1. Electric buses used in the public transport system

Electrifying public transport has to be done carefully, since introducing electric buses in a fleet does not simply mean replacing one type of bus for another. It rather requires rethinking the system on multiple level, including charging infrastructure, costs, maintenance, procurement, and training.

Table 12. Charging strategy for electric public transport buses.	
Degree of priority	**High priority.** Prioritising public transport electrification is consistent with the targets of the 2020 NDC, past and ongoing bus modernisation reforms, and Rwanda's focus on public transport development. Improving public transport is key to achieving sustainable urban mobility goals, increasing the attractiveness of public transport, and addressing growing private motorisation rates.
Charging mode and strategy	There is no one-size-fits-all regarding public transport electrification. The specific needs, characteristics, and solutions need to be assessed for each route. Various charging technologies exist, including low-power charging and high-power charging through conductive charging with physical connections (UITP, 2019). Furthermore, there are different charging strategies: overnight depot charging, opportunity charging, and a combination of depot charging and opportunity charging. A key principle is that the selection of the electric bus charging technology and strategy should be based on the route characteristics and the bus operations, not the opposite. The maximum distance that electric buses can be driven is a function of several elements including: topography, weather conditions, vehicle weight, number of passengers, drive cycle, and battery capacity. It is essential to analyse the following characteristics when preparing the transition to electric buses (UITP, 2019). It is also key to consider the changes in the bus fleet and schedule undertaken in 2020, as these changes have not always been factored in previous electrification studies (FONERWA/KfW, 2019; GGGI, 2021). The following factors should be considered in determining the appropriate charging technology: • Average and maximum mileage per day. Feasibility studies should select a variety of routes, as well as realistic mileages based on international examples and cities with in-depth experience with public transport electrification. • Service scheduling (frequency, stopping time, charging time in depot and/or at fast charging stations). • Topography. • Road conditions. • Position of the bus depots. • Availability of power supply for charging equipment, and simulations of impacts of various charging strategies on the grid. • Climate and humidity conditions.

Table 12. Charging strategy for electric public transport buses.	
Interoperability	The bus operator would have to set up its own dedicated infrastructure for overnight charging. However, for opportunity charging or top-up charging during operating hours, it will help if the charging systems are interoperable and can cater to buses independent of battery size, battery chemistry or manufacturer. Similar to automated teller machines ("ATMs"), each operator may start with its own infrastructure but over a period of time, it will be beneficial if the operators cooperate to achieve better utilisation of their buses as well as charging assets.
Localisation criteria	The location of the charging points for electric buses will depend on the charging strategies selected: overnight depot charging, opportunity charging, or a combination of depot charging and opportunity charging. Opportunity charging can be done at bus stops or at the start/end of the line, using inductive or conductive charging. Depot and opportunity charging have different impacts on the urban space. Existing depots in Kigali are owned by the private operators. Installing charging equipment in these depots would further establish the market position of the existing operators. The City of Kigali should establish publicly owned depots that can be provided to operators for the duration of operating contracts. Electric bus charging equipment can be installed in these publicly owned depots. This will make it easier to conduct competitive bidding for bus operations in the future.
Financial responsibility	The provision of high-quality bus services requires effective sharing of responsibility and risk between government and the private sector. The preferred business model is a service contract where operators are primarily compensated based on the number of kilometres operated, with incentives and penalties to incentivise compliance with service level standards. The private sector is responsible for buying, operating, and maintaining the buses. To ensure an equal playing field during the tendering process, government should establish publicly owned bus depots and terminals.

5.2.2. Electric bicycles

Promoting the electrification of two-wheelers is essential for multiple reasons. The innovative mobility option of electric bicycles offers the opportunity to address Kigali's hilly terrains, potentially capture new user groups, and generally eases movement while keeping people active.

Table 13. Charging strategy for electric bicycles.	
Use case	Bikeshare system
Degree of priority	**High priority.** The City of Kigali intends to promote bicycle usage to enhance active mobility through the introduction of a public bikeshare system. Bikeshare can serve short trips and improve last-mile access to public transport.
Charging mode	Some bikeshare systems charge the bicycles when docked at stations, while others utilise battery swapping systems. Swapping systems may avoid the need for electrical connections at each station but can introduce the need for human labour to swap the batteries and for additional vehicles distributing the batteries. Mobile charging lockers are a further option to swap batteries.

Table 13. Charging strategy for electric bicycles.	
Standards and interoperability	**Bikeshare schemes** do not need to meet interoperability requirements as the integrated charging and vehicle solution is supplied by the operator. In Kigali, the standards for normal wall outlets / plugs can be expected as a solution for electric bicycles; they include hardware interoperability and safety standards.
Localisation criteria	Deploying bicycle charging stations is proposed to enhance first and last-mile connectivity in connection to public transport (bus, BRT systems). In addition,these stations can also be deployed in streets and public spaces near "places of interests". They should be planned in parallel to the expansion of a network of cycle lanes. Public involvement is key; locations should be decided locally, based on demand and users' feedback. First and last-mile connectivity • Proximity to bus terminals and stops Points of interests • Car-free and pedestrian zones • Markets and business centres • Hospitals • University campuses • Government offices
Financial responsibility	Bikeshare systems are typically operated by the private sector with oversight from a government agency. The government defines key parameters of the system, including the coverage area, bicycle design features, payment media, and fare levels. The private sector procures, installs, operates, and maintains the hardware and software systems over a defined period of time. The government should adopt a robust contracting model that incorporates financial incentives for good service quality and data sharing protocols. Financial support from the public sector can ensure affordable pricing to users.
Use case	Personal e-bikes
Charging mode	Charging a personal e-bike can be done by using an external charger, connected to a regular wall socket. The connection between the battery and its charger is not standardised among e-bikes; it is brand dependent but not an issue, since the plug is standard (socket). Multiple models allow battery swap / removal, but the charging procedure does not change.
Localisation	Residential buildings, offices, commercial centres.
Financial responsibility	Provided by the private sector.

5.2.3. Electric motorcycles

Many Kigali residents use motorcycle-taxis, whose pollution levels need to be addressed. Moto taxis can provide first- and last-mile connectivity to facilitate the use of public transport and offer an alternative to ownership of private cars. Two-wheelers are more space efficient than cars: a single car parking space can be transformed into parking for five electric two-wheelers or more (UNEP, 2020). Setting up charging points for these vehicles is also cheaper than those for cars.

Table 14. Charging strategy for electric motorcycles.

Use case	Electric motorcycle taxis
Degree of priority	**High.** Motorcycle taxis currently provide for an important part of mobility needs of Kigali residents (16% of modal share). Electrifying the moto-taxi fleet will contribute to decarbonisation efforts, a conventional ICE motorcycle emitting 55.1 gCO_2/km, versus only 4.7 gCO_2/km (Sudmant et al., 2020). A full shift of the fleet would enable an annual reduction of 70 kilotons of CO_2 emissions by 2025, reducing total emissions from transport in Kigali by circa 10% (ibid).
Charging mode	In Kigali, most electric moto-taxi solutions currently utilise swapping schemes, with different battery technologies between service providers, and a still ongoing R&D. Battery swapping increases driver acceptance by drastically reducing charging time if recharged batteries are available.
Financial responsibility	Swapping stations to be provided by the private sector. Public authorities should only support the use of moto-taxis when services are complementary to the public transport system. Considering the cost-effectiveness of electric motorcycles, public support for this transition can focus on removing initial barriers.

Table 14. Charging strategy for electric motorcycles.	
Localisation criteria	At present, e-motorcycle providers are developing their own networks of swapping stations. The swapping facilities are sited in private premises procured by the providers. Some consult drivers on possible locations. In the perspective of linking motorcycle-taxi services and mass transit, incentivising the location of charging and swapping stations at the planned BRT and bus transit stations, public parking, and bus terminals, can support their role as feeder services. We recommend stakeholder consultations to ensure that the view of service providers and users are reflected
Standards and interoperability	Battery swap is not a standardised solution. Thus, it is brand dependent and interoperability between solutions is difficult. Any endeavours to standardise should be discussed with the sector, to make sure they do not impede current development in the market or create barriers to ongoing R&D. Interoperability of charging points: as presented in section 3.4 above, the preference for shared vehicles is to first have dedicated charging stations for a taxi fleet, that may be opened for public charging stations if there is enough power supply in this location. It is key for these shared vehicles to be used as much as possible and to have full certainty in the availability of dedicated charging whenever they need to be charged.
Use case	Personal electric motorcycles and scooters
Degree of priority	**Low.** The mode share for private motorcycles is minimal.
Charging mode	Charging modes include: •AC ch arge using mode 1, connecting the bike directly to a regular plug/socket. It is mostly used in small scooters. • AC charge using mode 2 charger connected to a regular wall socket. • Mode 3 connected to an EV charger can be used for the most powerful end of the motorcycle spectrum (powertrains over 48V). The charger should be compliant with IEC61851. Similar to personal electric bicycles, electricity requirements of motorcycles and scooters are relatively light, and these vehicles can be charged at normal wall outlets. We expect people to be able to charge at home or at work in a normal wall outlet.
Localisation	Residential areas or offices
Financial responsibility	Provided by the private sector.

5.2.4. Electric cars

Table 15. Charging strategy for electric cars.	
Use case	Car sharing
Degree of priority	**Medium.** Car sharing should be prioritised over the use of private cars, since the availability of shared cars can help users avoid private car ownership. Government can incentive the use of clean technologies in car sharing services. However, the overall use of cars should be managed through pricing mechanisms such as parking fees.
Charging mode	• Slow Charging / AC Charging using mode 2 connected to a wall socket (typically 3,7kW) or mode 3 connected to an installed EV charger (typically 7,4-22 kW) • Fast charging / DC Charging using CCS (typically 50-150kW) or CHAdeMO used by some Japanese OEM's (typically 50kW).

Table 15. Charging strategy for electric cars.	
Interoperability	The preference for shared vehicles is to first have dedicated charging points (CP) for a taxi fleet, that can be opened for public CP if there is enough power supply in this location.
Localisation criteria	Building control rules can encourage the provision of car-sharing services in commercial and residential premises, especially supermarkets, shopping malls, and hotels. The government can allocate some public parking spaces for e-vehicles in CBD areas. When deploying charging stations for shared cars, it is important to consider the need for adequate geographical distribution, which may be achieved through requirements for minimum distance between stations (e.g., 250 m identified in Csonka & Csiszár, 2017).
Financial responsibility	Provided by the private sector.
Use case	Ride hail services
Degree of priority	Higher than charging points for private cars, since cars used for ride-hailing address the issue of upfront investment and may disincentivize private motorisation, expected to grow in Kigali in the upcoming years. Government can incentivise the use of clean technologies in ride hail services. However, the overall use of cars should be managed through pricing mechanisms such as parking fees.
Charging mode	• Overnight slow Charging / AC Charging using mode 2 connected to a wall socket (typically 3,7kW) or mode 3 connected to an installed EV charger (typically 7,4-22 kW). • Fast charge/DC charging, if the EV range is too low to provide the service.
Interoperability	The preference for shared vehicles is to first have dedicated charging points (CP) for a taxi fleet, that can be opened for public CP if there is enough power supply in this location.
Localisation criteria	Charging can take place on private premises, with facility locations determined by private operators based on fleet and operational char-acteristics. Where appropriate, shared facilities with private (includ-ing logistics) and public users could be considered.
Financial responsibility	Provided by the private sector.

Table 15. Charging strategy for electric cars.	
Use case	Private cars
Degree of priority	**Low priority**, to avoid spurring a development of private motorisation
Charging mode	• Slow Charging / AC Charging using mode 2 connected to a wall socket (typically 3,7kW) or mode 3 connected to an installed EV charger (typically 7,4-22 kW) • Fast charging / DC Charging using CCS (typically 50-150kW) or CHAdeMO used by some Japanese OEM's (typically 50kW).
Interoperability	Interoperability and the use of open standards is key. It will help to remove the range anxiety amongst the new or would be EV owners if there were a greater number of charging stations. One quick way of ensuring that would be to have white label or interoperable charging stations which can charge EVs irrespective of the make/model of the vehicle.
Localisation criteria	Building control rules can encourage the provision of charging facilities in commercial and residential off-street parking areas. Some public parking spaces can be allocated to e-vehicles.
Financial responsibility	Provided by the private sector. Public authorities should avoid subsidising the use of private cars and instead invest in sustainable mobility modes.

6. Conclusion

It is important to frame the deployment of electric mobility within a sustainable urban mobility framework, as outlined in the 2020 Kigali Transport Master Plan. The charging strategy should prioritise public transport and active mobility (including e-bikes) while integrating taxi modes present in Kigali. The deployment of charging points can be decided by public authorities or by private parties, depending on the selection of a centralised or decentralised method, and contractual models appropriate for the mode in question. Charging facility deployment should be data-driven and should follow a consultative process that engages multiple stakeholders including transport operators, vehicle providers, utilities, and the public.

7. Glossary

EV - Battery Electric Vehicle	Also known as an all-electric vehicle, a BEV has all its power from its battery packs and thus has no internal combustion engine, fuel cell, or fuel tank.
CCS -Combined Charging System (Combo 2)	CCS (Combo 2) is the connector standard for DC recharging in the EU
CHAdeMO	"CHArge de MOve" Charging System / Trade name of a quick charging for battery electric vehicles delivering up to 62.5 kW of high-voltage direct current via a special electrical connector. It is proposed as a global industry standard by an association of the same name
Charging location	A location (public or private) where one or more recharging points are erected.
Public charging point or publicly accessible charging point	Meaning a recharging point which provides non-discriminatory access to users. Non-discriminatory access may include different terms of authentication, use and payment
CPO – Charge Point Operator	Entity responsible for the management, operation and maintenance of one or more recharging points. The role of a CPO can include both the administrative operation (e.g. access, roaming, billing to EMSP etc.) and technical maintenance of recharging points
Connector	A connector is the physical interface between the recharging point and the electric vehicle through which the electric energy is ex-changed
DSO – Distribution System Operator	The organisation that designs, operates and maintains the public distribution grid through which electricity is supplied to recharging points. The recharging points are connected to the DSO grid through a delivery point
eMSP - Electromobility Service Provider	An entity offering eMobility services to end customers (services offered may include recharging, search & find, routing and other services)
eRoaming platform	A central organization connecting multiple electromobility market players. They are responsible for contractual clearing and enabling electromobility services between the connected actors and end consumers
EV	Meaning a motor vehicle equipped with a powertrain containing at least one non-peripheral electric machine as energy converter with an electric rechargeable energy storage system, which can be recharged externally. When used as opposed to LEV (light electric vehicles, see below), it corresponds to more powerful four-wheelers.
EVSE	Electric Vehicle Supply Equipment
Grid Operator - GOP	The term Grid Operator refers to a Transmission System Operator, a Distribution System Operator or a local grid operator (e.g. CEMS)

GCC - Gross Cost Contracts	Under a gross cost contract, the bus operating company receives a service fee that is heavily weighted according to the number of kilometres operated. Fares are typically collected by an independent entity and deposited in a trust fund. Payments are made from the trust fund according to a predefined formula incorporating incentives for meeting quality of service standards. The formula may include a small fee per passenger in order to incentivise good service and stopping at the designated bus stops. A gross cost contract may necessitate the provision of subsidies if the service fee is greater than the revenue collected from passenger fares. Payment to the operator = Kilometres operated x Fee per km + Passengers x Fee per passenger + Bonuses – Penalties
ICE – Internal Combus-tion Engine	An engine which generates motive power by the burning of petrol, oil, or other fuel with air inside the engine, the hot gases produced being used to drive a piston or do other work as they expand.
Interoperability	The ability of two or more networks, systems, devices, applications, or components to interwork, to exchange and use information in order to perform required functions (safety, compatibility of equipment and protocols, functionality, system reliability, system availability)
kWh – Kilowatt hour	Measure Unit of energy equal to 1,000 watt-hours, or 3.6 mega-joules. The kilowatt-hour is commonly used as a billing unit for en-ergy delivered to consumers by electric utilities
LEV	Light Electric Vehicles
LDV	Light Duty Vehicles (not to confuse with LEVs), including passenger cars and light commercial vehicles such as pick-ups and delivery vans
MaaS - Mobility as a Service	The integration of various forms of transport services into a single mobility service accessible on demand
NCC - Net Cost Con-tracts	Under a net cost contract, the bus operating company receives customer fare revenue directly. The operator typically has a monopoly over a specific set of routes or zones and takes on the revenue risk. Net cost contracts typically give the government less control over the quality and quantity of service; make it harder to redesign routes when necessary; and tend to result in a less reliable, unsafe service, with less service off-peak and on lower volume routes. Operator profit = Passengers x Fare per passenger – Licence fee – Operating costs
Networked / non networked	Networked / non-networked refers to the charger's ability to establish communication with the electricity utility company and are part of an EVSE network. Networked chargers are more complex and expensive due to the communication unit, while non-networked chargers as stand-alone units are simpler and don't have a communication unit.
OCPI – Open Charge Point Interface, and OICP – Open Interchange Protocol	Roaming - Authorise recharging session, reservation, billing, roaming, provision of CPO information
Roaming - Authorise recharging session, reservation, billing, roaming, provision of CPO information	Roaming - Authorise recharging session, reservation, billing, roaming, provision of CPO information

OEM	Original Equipment Manufacturers, in this context referring to au-tomotive manufacturers
Renewable energy sources	Energy from renewable non-fossil sources, namely wind, solar (solar thermal and solar photovoltaic) and geothermal energy, ambient energy, tide, wave and other ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas, and biogas.
RFID - Radio Frequency Identification	Automatic identification technology which uses radio-frequency electromagnetic fields to identify objects carrying tags (usually RFID cards) when they come close to a reader
SUMPs	A Sustainable Urban Mobility Plan (SUMP) is a strategic plan de-signed to satisfy the mobility needs of people and businesses in cit-ies and their surroundings for a better quality of life. It builds on existing planning practices and takes due consideration of integra-tion, participation, and evaluation principle
Smart charging	Smart (re)charging (or controlled recharging) is a term used for techniques that manage the energy supply to recharge electric ap-pliances and vehicles in such a way that the peaks in network load are reduced and possibly the best use is made of available sustaina-bly generated electricity. This can be done in different ways and with different degrees of complexity. In a simple form, this means that the recharging session of certain coupled vehicles is temporari-ly postponed, interrupted or the power level altered, for instance driven by electricity market price signals
Swapping	Exchanging a depleted battery for a fully charged one, either with batteries owned by the user, or from commercial battery recharg-ing stations, and requiring only a few minutes
TSO - Transmission System Operator	A TSO is responsible for a stable power system operation (including the organisation of physical balance) through a transmission grid in a geographical area (his control area). The System Operator will also determine and be responsible for cross border capacity and exchanges. If necessary, he may reduce allocated capacity to ensure operational stability. Transmission as mentioned above means "the transport of electricity on the extra high or high voltage network with a view to its delivery to final customers or to distributors. Operation of transmission includes, as well the tasks of system operation concerning its management of energy flows, reliability of the system and availability of all necessary system services" (definition taken from the ENTSO-E RGCE Operation handbook Glossary)
Swapping	Exchanging a depleted battery for a fully charged one, either with batteries owned by the user, or from commercial battery recharg-ing stations, and requiring only a few minutes
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Type-2 AC - Type 2 AC Connector Charging System	The IEC 62196 Type 2 connector (also known as Mennekes) is used for recharging electric cars, the connector is circular in shape, with a flattened top edge and capable of recharging battery electric ve-hicles at 3–70 kilowatts.
V1G	Smart charging (see above)
V2G	Vehicle-to-grid-technology enables electric vehicles to function as demand response parties in the electricity system, by feeding elec-tricity stored in the EV battery back into the grid

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