Transport Electrification

Regulatory Guidelines for the Development of Charging Infrastructure

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Executive Summary

The following document aims to provide a guideline regarding the development of an electric mobility charging infrastructure ecosystem and the necessary actions to be taken by policy makers to promote its deployment. Governments and Public Authorities play a key role in the deployment of charging infrastructure for electric vehicles, through the development of mechanisms and tools to enable and facilitate stakeholders' involvement.

An adequate deployment of the charging infrastructure network is required in order to ensure that electric mobility targets and goals are achieved. On this end, this document focuses on the key issues to be addressed and considered within the regulatory decision-making process related with:

(i) **Enabling** the deployment of charging infrastructure to cover electric mobility users' needs by the definition of **the charging stakeholder ecosystem**.

(ii) **Ensuring** the charging **infrastructure network interoperability** through regulations and guidelines to adopt international standards' minimum requirements.

(iii) **Assessing technical and safety electrical requirements,** through the definition of **standards guidelines** on the installation and operation of charging infrastructure.

(iv) **Pricing regulation mechanisms** to address fair pricing of charging services, when and where are pricing regulations required.

(v) Complementary measures and regulations to **enhance readiness** for an increasing share of electric mobility adoption.

It must be highlighted that Regulators and Public Authorities should aim to **enhance regulations and policies as enabling and non-restrictive tools** to promote electric mobility adoption and charging infrastructure deployment. In addition, the Governments' vision and mission are key drivers within early stages of electric vehicle charging infrastructure and electric mobility adoption in order to enable gradual and phased strategies and maximize the deployment of charging points.

In addition, within this document, different measures and actions regarding the previous issues have been developed, considering that these require an evaluation of the level of electric mobility penetration, in order to ensure the success on the definition and implementation of the desired measures. The **development and evolution of electric mobility penetration will drive to an increasing complexity on the development of the necessary measures** to ensure an adequate and interoperable charging infrastructure deployment, **whilst in early stages** of electric mobility penetration, **simple measures and actions by policymakers can make a significant impact** on charging accessibility and deployment.

On this end, the document focuses on **the definition of a Charging Infrastructure General Framework (Section 2), which includes the regulatory decision roadmap for regulators and policymakers**, considering different actions attending to the following:

(i) the different types and use of charging infrastructure, where regulators and policymakers' actions are addressed considering the deployment of private charging infrastructure, publicly available charging infrastructure and public long-distance available charging infrastructure, and

(ii) the level of electric mobility penetration, as actions and regulations will vary attending to the stage of electric mobility adoption within the region. Higher levels of electric mobility penetration will require regulators and policymakers to increase their action.

Furthermore, throughout Sections 4 to 5 of the document, additional details and business cases have been provided regarding:

i) Charging infrastructure standards, including further details on charging modes for electric vehicles, charging components and common international standards adopted worldwide. Within this section, **technical charging communication standards, as well as, safety, communication and complementary standards**, amongst others, have been considered.

ii) **Business models** around charging infrastructure deployment, which provides details on the charging infrastructure frameworks commonly adopted, based on the definition of the stakeholder ecosystem ruling.

iii) Complementary considerations on regulatory needs and priorities, considering the key actions to be considered by regulators and policymakers when taking steps towards enabling the deployment of a charging infrastructure network.

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1- The need to develop a regulatory framework to increase electric mobility adoption

Climate change, together with air quality, is emerging as major global concern with serious social and environmental impacts on the World's population. Mitigating actions are being developed internationally with respect to policy development focused on de-carbonization targets and global emissions objectives.

Governments worldwide are focusing on the reduction of the impact on climate change in order to avoid the point of no return that could cause sea levels to increase by 200 feet and a 4ºC to 5ºC increase in global average temperatures that would result in the apparition of natural hazards (Loria, 2018).

Amongst other solutions, electric mobility arises as a technology to contribute on the mitigation of greenhouse gas emissions and its impact on climate change. Electric mobility enables the integration of both the transportation and the electricity systems in order to achieve exponential benefits at a national and local level. Amongst these benefits, the following must be highlighted:

- Full electric vehicles do not contribute with dust emissions. Hence, they contribute to a reduction in urban pollution from mobile sources, and therefore to an improvement of air quality, along with life quality for the population.
- Electric mobility enables a reduction of fossil fuel dependence and supports carbon neutrality goals. An increase in the reduction of fossil fuel dependence levels is achieved when combined with an energy mix strategy moving towards an increasing share of renewable resources and low emission energy generation technologies.
- In addition, electric mobility offers the opportunity to increase the integration of renewable energy resources within the generation mix. The development of solutions and strategies to promote electric mobility as a distributed storage option within the electricity value chain, contributes to mitigate variability of renewable energy resources and increase reliance on renewable technologies.
- Electric vehicles are more energy efficient than conventional vehicles, as the thermal yield for the former is 90% while the thermal yield for the latter is close to 25%. As such, the average amount of energy saved from transportation in electric vehicles when compared to conventional vehicles approximates to 40% (SCAME, 2020).
- Empowerment of users considering increasing options to interact with the electricity system, provides an opportunity for the user to better understand their bill and identify possible cost reduction solutions.
- The need to address increasing demand of electricity supply represents an opportunity to increase the security of supply and quality of supply by considering demand aggregation and charging patterns.

  Hence, the electricity system can integrate the use of local networks with energy storage in electric vehicles, reducing the congestion of the grid and the generation mix.
- Electric vehicles have a huge potential for consumers to integrate self-consumption solutions.

- Electric mobility also contributes to the national economy, as it will stimulate the development of new businesses and activities.

  Along with the creation of products and services, there will be job creation, resulting in greater employment rates.

- Maintenance of electric vehicles is cheaper than conventional vehicles as they have less components, and thus a lesser probability of malfunctioning.

However, electric mobility represents a new technology, which is in the path of further development and evolution. In addition, early deployment requires the need for assessment and awareness of the requirements to successfully deploy electric mobility at a national or local level. Furthermore, two key drivers must be enhanced:

- The cost of an electric vehicle is still higher than the price of a fossil-fueled vehicle.
- The required infrastructure to enable the deployment and use of electric mobility. Electric vehicles require the development of charging infrastructure to operate.

While the former key driver is addressed considering technological improvements, such as batteries capacity increase and technology cost reduction, the latter poses a number of questions regarding the needs and requirements to enable its deployment. Key questions and issues to be considered under the design and development of a charging infrastructure system rely on the requirements to determine the design and capacity of available charging infrastructure and time of charging planning in order to satisfy the deployed electric mobility needs for users.

This paper focuses on the different issues related with the deployment of charging infrastructure, more precisely on the different standards and technical and regulatory solutions that currently exist and the best practices on strategies developed regarding the charging infrastructure roll-out.

HOW MANY EVSE MUST BE DEVELOPED?

According to the Global EV Outlook 2019 (IEA), ratios of publicly accessible chargers per electric car (EV) across the world are:

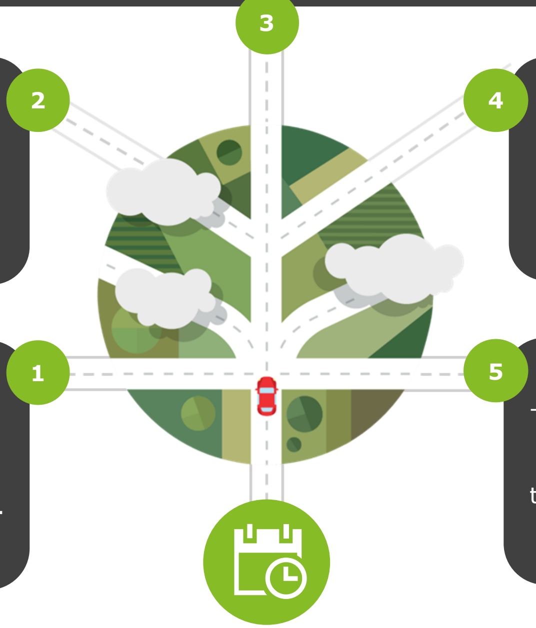
- Worldwide: 0.11 chargers per EV
- European Union Alternative Fuels Infrastructure Directive: 0.1 chargers per EV
- United States: 0.2 chargers per EV
- Netherlands: 0.25 chargers per EV
- Denmark: 0.125 chargers per EV

WHAT ARE THE DIFFERENT TYPES OF EVSE AND ITS STANDARDS?

Depending on the manufacturer of the EV considered, plugs vary. Automakers employ different charging infrastructure standards. **This document covers the different classification and standards and how they are defined**.

WHO MUST DEVELOP EVSE?

There has been a number of sustainable **business plans for planning, financing, operating and maintaining charging infrastructure** developed worldwide and will be **covered in this document**.



WHERE TO INSTALL EVSE?

As with fuel pumps, EVSE are better placed in highways and points of interest (such as shopping malls, tourism attractions, etc.). In order to optimize movement from users, it is suggested to establish an analysis with available mobility data from both privately owned vehicles.

For more development make reference to the energy saving trust[1].

WHAT IS THE TIME HORIZON?

There is a global urgency for slowing down climate change by reducing greenhouse gas emissions. Electric mobility responds for the urge of reducing emissions from the transport and energy sectors, as combined, they represent 66% of global emissions[2]. As such, **the path for electric mobility must be developed as soon as possible**.

Development of Electric Vehicle Supply Equipment (EVSE)

[1] Energy saving trust. (August, 2019). Positioning chargepoints and adapting parking policies for electric vehicles. Retrieved from energy saving trust Website: https://energysavingtrust.org.uk/sites/default/files/Local%20Authority%20Guidance%20-%20Positioning%20chargepoints.pdf

[2] IEA. (2017). Data and statistics. Retrieved from IEA Website: https://www.iea.org/data-and-statistics?country=WORLD&fuel=CO2%20emissions&indicator=CO2%20emissions%20by%20sector

Figure 1: Key areas to address on the deployment of Electric Vehicle Supply Equipment (EVSE).

2- Charging Infrastructure Overview

The adoption of electric mobility requires the deployment of a charging infrastructure network that ensures the satisfaction of the users' charging needs.

On this end, different types of charging infrastructure arise, depending on the type of use intended from the users:

- **Private charging**, considering privately owned chargers not accessible by the public ("at home charging"). Usually placed in private garages of private users.
- **Public charging**, especially in urban areas, which includes on-street charging ("public-public charging") or charging at commercial locations ("public-private charging).
- **Long-distance fast charging,** based on charging needs for long-distance travels, ensuring range anxiety needs are covered. Commonly this type of charging takes place along highways and corridors.

The different types of charging profiles and uses sets focus on:

a) The different types of charging infrastructure and how to optimize deployment according to users' charging profiles.

   Ensuring that the charging levels are aligned with the users' transit needs.

b) The different stakeholder value chain ecosystem arising from the deployment of charging infrastructure.

2.1- Types of electric mobility charging

In order to satisfy users' needs, different types of charging equipment have been developed, considering the power needs and charging speed. Therefore, electric vehicle charging equipment is commonly classified according to different charging levels, which are described below. In addition, for further details on the types of charging and international standards see Section 4.

Classification in use	Level (SAE J1772)	Modes (IEC 61851-1)	Current	Power	Location within the city
N/A	Level 1	Mode 1 and Mode 2	AC	≤3.7 kW	Private homes and workplaces
Slow chargers	Level 2	Mode 3	AC	>3.7 kW and ≤22 kW	Private homes, workplaces, public charging
Fast chargers	Level 3	Mode 4	AC Triphase	>22 kW and ≤43.5 kW	Public charging and highways corridors
			DC	Currently <200 kW	

Figure 2: Types of Electric Vehicle Supply Equipment charging

- **Level 1 Charging**

Level 1 charging is commonly used for private home charging and does not require specific Electric Vehicle Supply Equipment. The basic Level 1 charging simply connects to a standard outlet, as the charging level is enough for overnight charging.

This type of charging and the full recharge of an electric vehicle battery varies between 8 to 12 hours and 1 to 2 days, depending on the capacity of the battery.

- **Level 2 Charging**

The level 2 charging requires the existence of electric vehicle supply equipment that serves as an intermediation component between the vehicle and the power outlets.

Level 2 charging is commonly used for private charging when searching for an increase on flexibility use of charging and faster recharge of the vehicle, as well as, for publicly available charging networks where users park the vehicle for a period at a time and charging ranges between 4 to 8 hours.

- **DC Fast Charging**

DC fast charging enables a rapid charging of the electric vehicle battery, up to approximately 80% of the battery in 30 minutes. This Type of charging is commonly used within in corridors or fueling stations as to address long-distance charging for users.

Fast charging stations commonly require utility network upgrades and dedicated circuits, as of the need of higher electrical current supply.

2.2- Charging Infrastructure Stakeholder Value Chain

The charging infrastructure value chain can be defined within three main general blocks of activity:

1. Power supply

The electricity generation and distribution activity include the supply and delivery of the required power to satisfy the users charging needs.

The power supply activity also needs to consider the need for investments to upgrade the grid capacity to support an increasing demand of electricity from electric mobility charging needs, as well as, the need to enhance the transmission and distribution network in order to fully exploit electric mobility charging benefits from charging technology development.

2. Charging Infrastructure Provider

The charge point provider activity area considers all aspects related to the hardware of the charging infrastructure: manufacture, installation and maintenance of the charging infrastructure components and parts.

In addition, the software requirements to provide users management solutions, is considered under this activity. On this end, the charging software component can be considered jointly with the related hardware aspects, or, on the other hand, as a standalone activity.

Software includes both back-office services (billing and payment methods), and data collection and information management (metering).

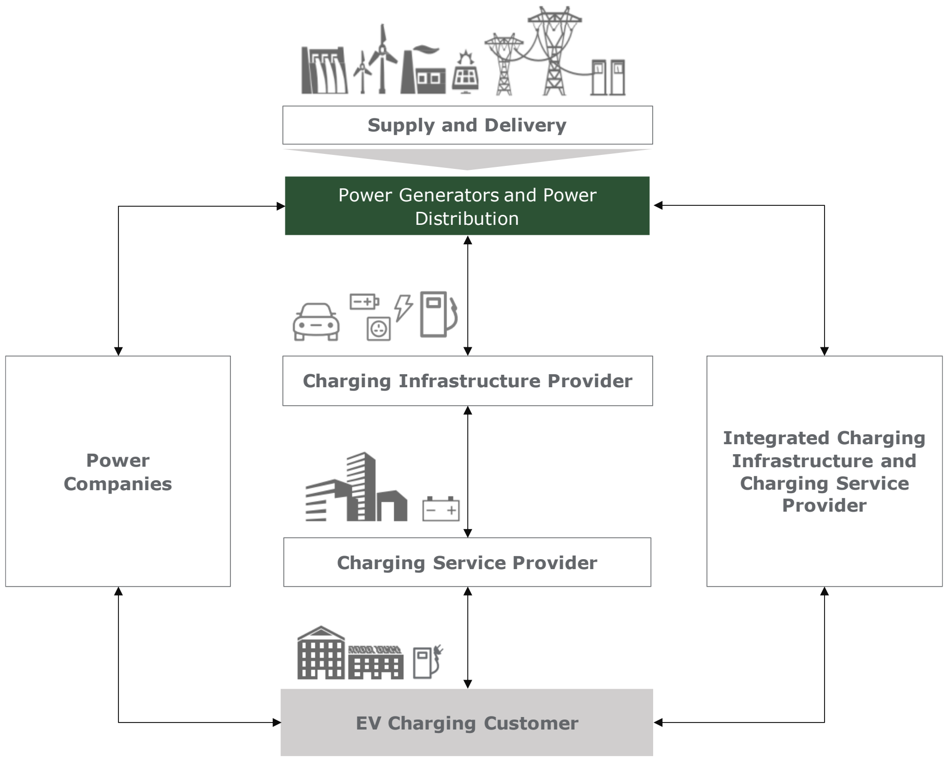


Figure 3: Key players in the EV charging Supply Chain

3. Charge Point Service Providers

The charging infrastructure operators rely on the offering of the charging services to end users. Under this activity, charging infrastructure hosts include the provision of charging services at a contractual level.

The key aspects to consider under the service provision activity rely on giving access to charging, sale of the service to the customer, etc.

It must be highlighted that the stakeholder composition along the different activities of the charging infrastructure value chain will determine the needs to develop the required regulations and related policies.

The stakeholder structuring can result on a segmented electric mobility charging market, considering multiple actors under each of the activities of the supply chain, or an integrated supply chain, where the actors can develop simultaneously several activities. As an example, the case where the Utility company, while acting as the power supplier, also serves as a charge point hardware and service provider.

Considering the previous, the involvement and structuring of the stakeholders within the value chain results on the appearance of different business models, and therefore the regulatory needs to achieve a well-functioning activity.

In addition, depending on the regulations, as well as, the stakeholders, consideration must be set regarding the charging infrastructure, as well as, the cost recovery mechanisms.

Further details on the charging infrastructure value chain and business models are hereby described in Section 5.

3- Charging Infrastructure Guidelines for regulators and policymakers

3.1- General Framework Guidelines

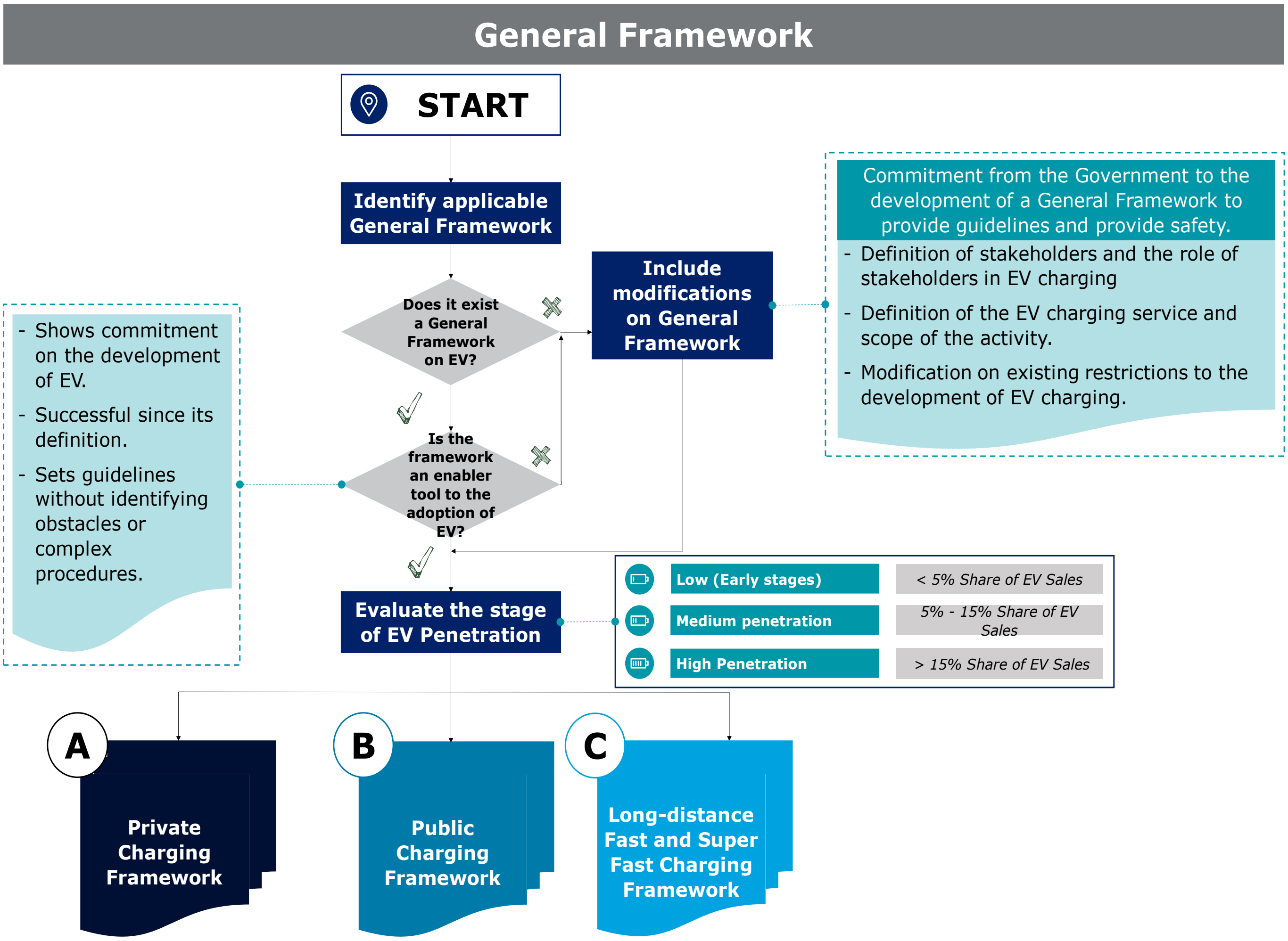


Figure 4: General Framework Decision Flowchart

The action and intervention of policymakers, regarding the development of a charging infrastructure framework will vary according to:

i) the type of charging infrastructure, and
ii) the stage of development and adoption of electric mobility.

Within this section, the key frameworks and decisions to be made by policymakers are detailed considering:

i) Private charging infrastructure deployment;

ii) Public charging infrastructure within high density areas;

iii) Long distance public infrastructure deployment.

Policymakers will also need to address the decision-making process according to the degree of electric mobility penetration. **Therefore, the measures and policies to**

be developed by policymakers will require to be flexible and be adapted along with the market development conditions. Within the specific frameworks detailed in the following sections of this document, the different steps and measures have been classified considering the EV penetration levels and charging infrastructure market development, considering that measures adopted within early stages of electric mobility ecosystem development will require to be modified when increasing shares of electric vehicles or further development of the ecosystem is achieved.

Nevertheless, the first step for policymakers relies on the definition of an approach regarding a general framework for electric vehicle charging infrastructure.

Under this approach, the following areas need to be addressed:

1. **<u>Identification of the applicable framework:</u>**

    - Is there an existing framework that includes the electric vehicle charging infrastructure activity?
    - Is the framework an enabling tool for stakeholders to deploy charging infrastructure?
    - Does the general framework applicable require modifications?
    - Under which activity and industry frameworks is there a need to include electric vehicle charging infrastructure activity guidelines?

    The key actions required by policymakers need to address the development of an enabling and non-restrictive general framework, aimed to promote the charging infrastructure deployment.

2. **<u>Evaluation of the level of electric vehicle penetration</u>**

    The level of electric vehicle penetration is critical in order to ensure the adoption of adequate measures.

    Measures, and required policies will vary depending on the different stages of electric vehicle penetration:

    a) Early stages of electric vehicle adoption will require policymakers to develop more simple measures aimed to promote charging infrastructure deployment.

    b) Further increase on the electric vehicle penetration will require the development of more complex measures and policies, in order to ensure an adequate charging infrastructure deployment.

    However, these measures will need to focus on addressing that users' needs are covered.

3. **<u>Government's commitment to boost electric mobility and facilitate the charging infrastructure network deployment</u>**

    Considering the decisions to be developed within in the early stages of electric vehicle adoption and charging infrastructure deployment, the first step for Governments and Public Authorities relies on the reflection of commitment to promote electric mobility within the population. In order to boost electric mobility, it is common that population and specifically electric mobility users, won't take the lead unless there is a public positioning towards the direction Governments are willing to take.

Therefore, within early stages of adoption, below are shown the first steps to a public approach commitment:

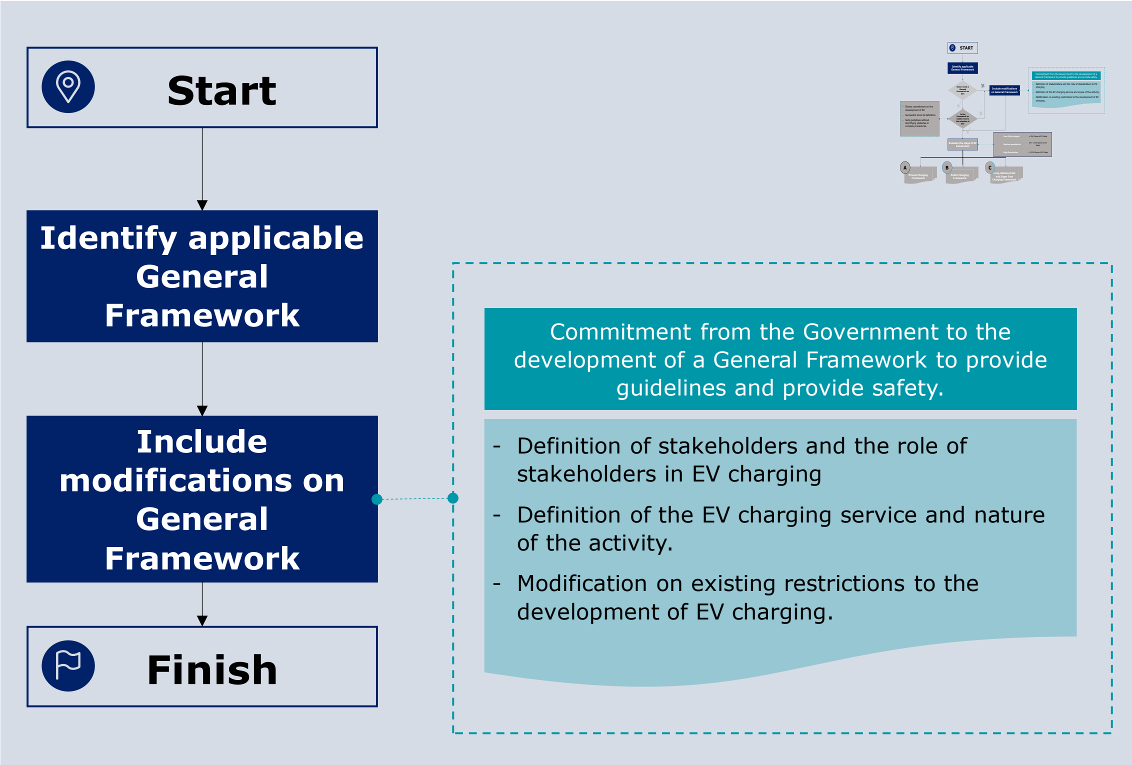


Figure 5: General Framework Early Stage of EV Penetration Decision Flowchart

a) Identification of the applicable General Framework

The first consideration must be set on the decision as to which, within my current regulatory framework, addressing the following issues: Which code should include the Government's first appointment, showing involvement and positioning to enable the activity has a place? Should it be the Energy Framework, the Transportation Framework or the National Planning Policy?

Common practices can take different approaches which will impact significantly on the early stages of electric mobility adoption:

(i) the reinforcement from the Government's commitment with the development of an electric mobility strategy, where the definition of targets and goals are established. Under this strategy, focus on the path that wants to be followed as well as the initial steps and competent authorities are defined.

(ii) inclusion of the Governments national electric mobility vision within the national or sectorial plans.

(iii) the development of a public statement as to what is the Governments' vision for the country or region in the matter.

This type of actions reflects the Governments intentions and its vision to enable and facilitate electric mobility adoption and the need to bet on the development of the ecosystem, with special focus on guaranteeing the charging infrastructure needs.

b) Include modifications to the General Framework

Including modifications, does not necessarily require the development of specific detailed regulations that set the path. The modifications to be considered within early stages of electric mobility penetration are focused on setting the initial considerations and guides as to the consideration of the charging infrastructure activity and services. The aim of these actions by Governments and Regulators is to (i) show real steps taken to achieve their vision, and (ii) enable and incentivize users to electric mobility adoption.

Within common practices, the modifications over the existing frameworks usually include:

1. **Establish targets and high-level vision or action lines to the development of policies** to promote electric mobility charging infrastructure deployment within the national or local plans.
2. **The definition of recharging infrastructure services within the Electricity Framework**.
3. The **definition of the different stakeholders within the value chain and charging infrastructure ecosystem**: ownerships of the charging infrastructure, service operators and service providers, users…

Considering the previous, simple modifications on the general framework gives the signal of moving forward towards a vision of transition to a cleaner transportation system and enables and facilitates the users to its adoption.

An example of the development of a general framework on electric vehicle charging infrastructure is United Kingdom, under the development of a Plug-In Vehicle Strategy (See Box 1).

Box 1. United Kingdom Strategy for Plug-In Vehicle

The Office for Low Emissions published a Plug-In vehicle infrastructure strategy to offer the vision regarding the infrastructure, as well as the measures or actions addressed in order to eliminate restrictions or barriers to stakeholders willing to participate on the deployment of the charging infrastructure.

Under this document, the main key points that are emphasized rely on the exposure of the vision towards the promotion of a favourable deployment for a charging infrastructure, and the actions taken by the Government as enabler tools.

"*Making the Connection. The Plug-In Vehicle Infrastructure Strategy*

This Strategy

1.6 In addition to making plug-in vehicles more affordable and stimulating technological innovation, having the right infrastructure in place to support plug-in vehicle owners is the other critical component in maintaining the UK's favourable market position. By providing a clarity of approach and removing barriers for those wishing to invest in, provide or benefit from such infrastructure, this Strategy aims to stimulate and accommodate the growth in the plug-in vehicle market that we expect to see up to 2020.

The role of Government is not to mandate a charge point on every corner, nor to set aspirational targets for charge point numbers for some distant future date – this is such a fast moving technological field that any such prediction produced now will be wrong. Rather, infrastructure should be targeted where it will be most used, to allow people to make the journeys they want and to foster a commercial market in plug-in vehicle infrastructure provision.

Our vision for recharging

1.8 For plug-in vehicles to appeal to, and be a viable solution for, consumers, recharging needs to be convenient and safe. Plug-in vehicles allow a different approach from refuelling a car, as it is no longer just a case of vehicles having to go to infrastructure – infrastructure can be located where vehicles are parked for the longest periods, which many consumers may find more convenient.

1.9 We want to see the majority of recharging taking place at home,4 at night, after the evening peak in electricity demand. This is not only most convenient for drivers but maximises the environmental and economic benefits of plug-in vehicles by using cheaper, lower carbon night-time electricity generation. Off-peak recharging will also enable best use of available electricity network capacity.

1.10 After home recharging, we want to see workplaces providing recharging opportunities, both for fleet vehicles and employees for whom recharging at home is not practical or sufficient.

1.11 Although charge points in public places and destination recharging will be the most visible type of recharging, we want this to be targeted at key destinations, where consumers need them, such as supermarkets, retail centres and car parks, supplemented by a focused amount of on-street infrastructure. This infrastructure will generally be used for top-up recharging or to extend journeys, although there is likely to be a role for public infrastructure in supporting those plug-in vehicle owners who do not have access to off-street parking.

1.12 Above all we want recharging to be simple for consumers, with trouble-free, safe, recharging at home or work, supported by public infrastructure that is easy to access, backed up by effective information on where it is located. (…)"

Below is described a general overview of the decision-making process and guidelines for regulators considering different existing models and the stakeholder sponsorship on the charging infrastructure deployment. It must be highlighted that specific decisions and guidelines are transversal as they focus on ensuring the users' service availability and interoperability. However specific consideration within the decision-making process is focused on stakeholders in order to enable and promote involvement, specially within initial stages of charging infrastructure roll-out.

<table>
<tr><th rowspan="2">Stakeholder Sponsorship</th><th colspan="3">General Framework</th><th colspan="3">Technical Requirements</th><th colspan="3">Tariff regulations</th><th colspan="3">Complementary Regulations</th></tr>
<tr><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th></tr>
<tr><td>Public - Private Stakeholders</td><td>• Deployment Planning Strategy
• Subsidizing programme</td><td>• Public Private Partnerships</td><td>• Bidding and concesión mechanisms</td><td rowspan="3">• No need for specific technical regulations
• Modify existing technical instructions network access and connection
• Interoperability Guidelines (Technical, Economic and safety standard guidelines)</td><td rowspan="3">• Specific technical instructions network access and connection for EVSE
• Economic interoperability standards for public network</td><td rowspan="3">• Technical guidelines to Network Grid Communication and Smart charging Communication</td><td rowspan="3">• No changes in tariffs
• Tariff promotion to enhance charging at home
• Public charging Pay as a service regulated tariff</td><td rowspan="3">• Time of Use Tariffs</td><td rowspan="3">• Dynamic Pricing</td><td colspan="3" rowspan="3">• Construction Codes for Residential and Non-Residential Buildings
• Requirements for Public Institutions publicly availablle charging infrastrucure deployment
• Regulation to enable public lightning as Access to charging intrastructure deployment
• Requirements for Public Institutions publicly availablle charging infrastrucure deployment
• Regulation to enable public lightning as Access to charging intrastructure deployment
• Requirements for Public Institutions publicly availablle charging infrastrucure deployment
• Regulation to enable public lightning as Access to charging intrastructure deployment
• Construction Codes on the maintanance and development of road infrastructure.</td></tr>
<tr><td>Public Stakeholders</td><td colspan="3">• Deployment Planning Strategy
• Deployment financing schemes development
• Operation Bidding procedure
• Operation guidelines</td></tr>
<tr><td>Utilities Stakeholders</td><td>• Pilot programmes for initial Roll Out
• Cost recovery mechanisms</td><td colspan="2">• Last Resort Regulation</td></tr>
</table>

Low level of electric mobility penetration

Medium level of electric mobility penetration

High level of electric mobility penetration

Figure 6: General Overview of the Stakeholder Decision-making process

3.2- Private use charging infrastructure framework.

Private charging infrastructure would include privately owned chargers not accessible by the public. Usually placed in private garages of private users. Regarding the deployment of private charging infrastructure, three key areas of decision arise for policymakers:

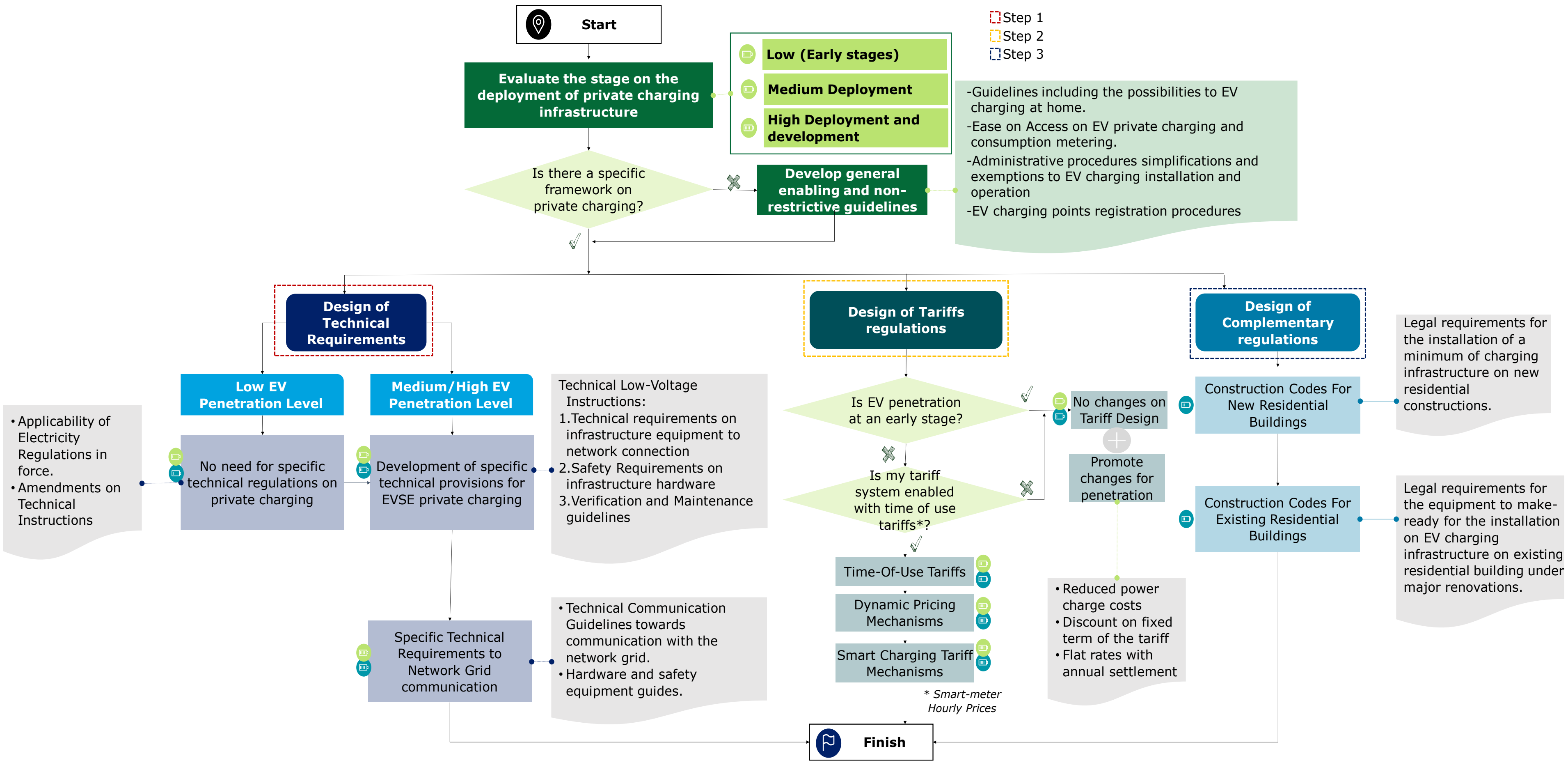


Figure 7: Private Charging Decision Flowchart

a) Development and implementation of technical requirements

Technical instructions are aimed to establish the requirements to be applied during the process of installation of the charging infrastructure, and to comply with network grid connection requirements.

Common practices relate to the publication of the corresponding regulation where the appliance of technical requirements of the EV supply equipment is referenced to the current electrical provisions, as in the case of Portugal (Box 2 – Portugal Case Study).

Box 2. Portugal Case Study – Technical requirements definition

Since 2014, Portugal has been developing regulatory actions to promote and develop electric mobility across the country. As a result, in 2016, Portugal provided with an ordinance that establishes the technical requirements to connect charging infrastructure to the electric grid. Moreover, Portugal also adapted its Technical requirement for low voltage power installations code: "*Ordinance 220/2016 (Portuaria 220/2016)*

(…) ***Article 3. Technical requirements for charging infrastructure***

1 – Electric vehicle charging infrastructure must comply with the RTIEBT, namely with section 722 related with electric infrastructure for electric vehicle charging, according with Ordinance n.º 252/2015, of August 19th, that proceeds to the amendment of Ordinance n.º 949-A/2006, of September 11th".

Therefore, the development and specification definition regarding the technical requirements for charging infrastructure are covered within the technical instructions, *Technical requirements for low-voltage power installations (Regras Técnicas das Instalações Elétricas de Baixa Tensão) [requirements only related to electric vehicles, according to Ordinance n.º 252/2015].* Further detail on this technical requirement can be found in Appendix 2 of this document.

However, it must be highlighted that within early stages of electric vehicle deployment, simple measures to enable users to at home charging are commonly used. These types of measures enable to use the residential electrical facilities for electric vehicle charging.

On this end, the technical instructions and guidelines for private charging infrastructure commonly include the following:

i. The definition of to what extent of private charging infrastructure the technical instruction is applicable.

ii. Detail different technical aspects required to design the installation related to hardware specifications, applicable to both the development of new infrastructure, as well as, modifications to existing charging infrastructure.

iii. Safety requirements, including safety measures required related to direct and indirect contacts, safety measures related to external effects, safety measures to prevent overloading.

b) Tariff and charging pricing mechanisms

Tariff mechanisms based on the level of EV adoption aim to provide flexibility and send price signals to EV users, whilst minimizing impact on the network grid investments to cover an increasing demand.

i) Low levels of EV penetration commonly have low impact on the network grid. Therefore, no significant investments to reinforce the integration of EVs power demand should be required.

ii) An increasing demand from higher shares of EV penetration will require the grid reinforcement to ensure security of supply. On this end, tariff mechanisms can achieve that this impact is minimized and benefit end costumers. Time-of-use tariffs are used in order to incentivize consumers to charge on off-peak timeframes.

iii) High power demand from an increasing EV adoption, combined with technology development provides an opportunity to develop smart charging tariffs:

   a. Technology implementation such as smart metering, smart charging and automated control load management can increase the benefits of EV integration.

   b. Dynamic tariffs to support renewable resources integration, considering vehicle to grid opportunities.

On this end, current tariffs, within early stages of deployment, both for energy and network charges, can be maintained for EV private charging services.

c) Complementary policies or mandates to promote the deployment of charging infrastructure in new and existing buildings

Aligned with the definition with an electric mobility strategy, the definition of additional regulations appears in order to promote electric mobility adoption goals.

Under this consideration, and within the private charging infrastructure Governments can develop additional regulations regarding the building codes requirements, focused on new buildings, as well as, non-residential existing buildings.

The aim of this regulation sets the requirements for the installation of charging infrastructure.

Commonly, a specific regulation to boost charging infrastructure deployment considers: (i) new residential and non-residential buildings and (ii) existing non-residential buildings is developed.

The definition of the regulation should consider:

i) The definition of the scope of application of the regulation, considering which buildings are under the scope;

ii) The definition of the different type of buildings;

iii) The definition of the requirements of installation of the charging infrastructure considering the type of building;

iv) Reference to technical and safety specific requirements related to the charging infrastructure;

This should include the related specific technical and safety standards guidelines for each type of building.

v) Exemptions for the applicability of the regulation. It should be incorporated within the regulation, under which circumstances the building requirements would not be applicable.

<u>The development of an enabling environment to promote private charging infrastructure on early stages of EV penetration.</u>

i. Development of a general enabling and non-restrictive guideline

The development of a general guideline must aim to reflect Government's commitment towards electric mobility adoption. On this end, the general framework should focus on:

1. Provide a signal to private users of the awareness of the Governments to facilitate private charging services;
2. Reflect the possibility of private users to access charging of their electric vehicles, by providing a guideline that includes the definition of charging at home;
3. Enable mechanisms to promote the charging at home by the possibility of simplified electricity access procedures.

Commonly, the key concepts to be included under the general framework rely on:

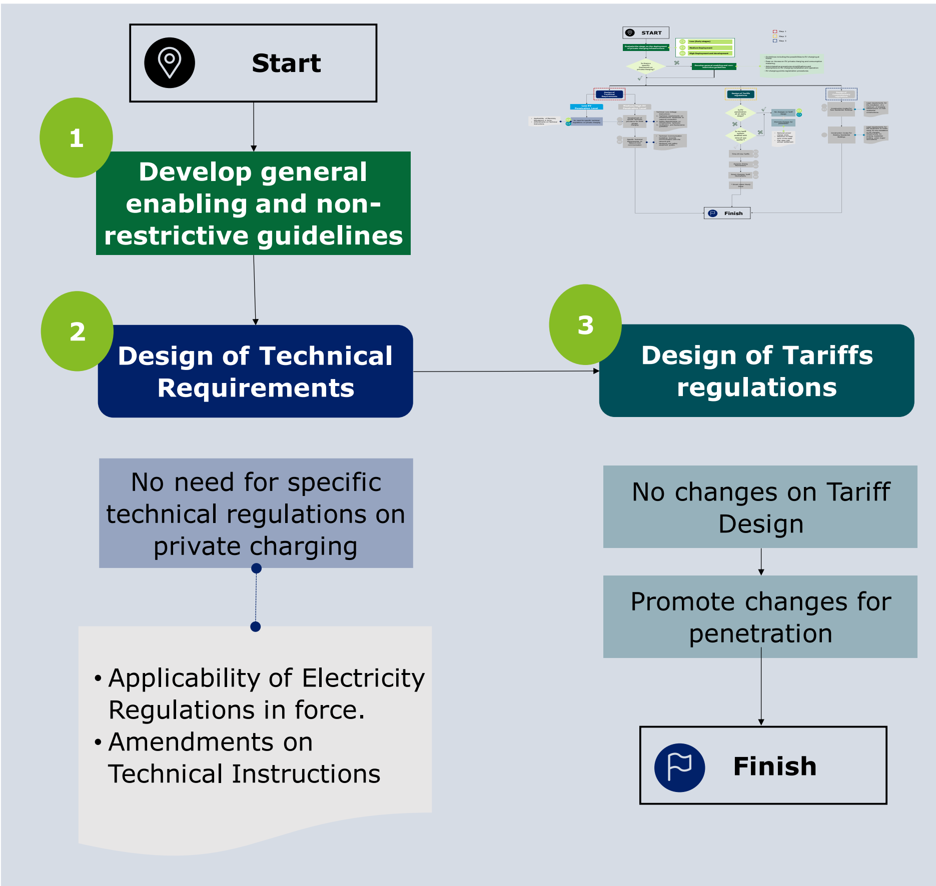


Figure 8: Private Charging Framework Early Stage of EV Penetration Decision Flowchart

1. Definition of **private charging services and the types of private charging** based on the capacity required;
2. **Guidelines published by the Regulators to inform** of the different types of charging at home;
3. Guidelines to whether there is to be considered the **installation of specific hardware charging infrastructure**. Definition of the circumstances under which there is no need for the development of charging infrastructure (for example limited charging capacity);
4. **Metering and billing guidelines** to facilitate the metering and billing procedures under the electricity domestic consumption, including applicable tariffs.

ii. Design of technical requirements

Under low levels of electric vehicle penetration, electricity demand from charging services is not significant in order to affect security of supply. In addition, common practices, within early stages of electric vehicle penetration, in order to promote private charging for the users tend to enable the use of existing electrical infrastructure for EV charging at home. Under this scenario, technical requirements regarding the connection to the electricity grid will fall under the user's access conditions to electricity supply.

However, in order to enable this possibility, there is the need to review the existing electrical technical provisions, in order to enable that private charging is considered within the current access procedures if required.

Common practices, rely on:

(i). enabling private charging through the existing housing electrical infrastructure (no requirements or obligations to install a charging point for the EV charging at home);

(ii) the applicability of current low voltage technical provisions in the cases of the installation of specialized charging infrastructure.

In addition, the revision of current technical provisions or electrical regulations to comply with the technical instructions are set to ensure that charging infrastructure services are included under the nature. On this end, amendments on these existing provisions in order to include charging infrastructure as an activity and its installation subject to the requirements included on that provision.

iii. Tariff Designs

Tariff mechanisms based on the level of EV adoption aim to provide flexibility and send price signals to EV users, whilst minimizing impact on the network grid investments to cover an increasing demand. Low levels of EV penetration commonly have a low impact on the network grid. Therefore, no significant investments to reinforce the integration of EVs power demand is required at first. On this end, current tariff structure can be maintained in early stages to EV private charging services.

In addition, in order to promote the adoption and use of private charging for users within the tariffs different options arise:

- Separate tariffs to differentiate domestic consumption from electric vehicle charging consumption. On this end, both tariffs are currently in force. The Selection of a low voltage tariff that would be suitable for EV charging while domestic tariffs would remain the same;
- Offering rebates or discounts on fixed charges;
- Flat rates which will liquidate on an annual basis.

In order to adopt differentiation for EV charging consumption tariffs, options arise towards incentivizing private charging through policies that enable private users to differentiate consumption of EV charging. These pricing mechanisms aim to provide users with the option to install charging infrastructure and not affect the domestic tariffs applicable to day to day consumption by the increase on the electricity consumption due to the electric vehicle charging consumption.

As an example of measures to an enabling private charging environment, it can be highlighted the Mexico Case (See Box 3).

Box 3. Mexico Case Study – Residential EV Charging Metering Support

The Electricity Federal Commission of Mexico ("CFE") provided the support towards the installation of an additional electricity meter, which is separate from the domestic metering system. This measure aims to provide consumers with the technical hardware metering system to electric vehicle charging electricity consumption, in order for users to not be affected in electricity billing. On this end, this measure avoids the users to transfer to higher capacity tariffs, and therefore an excessive cost for the users.

In addition, the CFE provides support on the electricity supply for the electric vehicle recharging services in private homes applicable, under which the consumption of the electric vehicle charging, based on the installation of a low charging infrastructure up to 1MW, the applicable tariff is set to apply within a Tariff 2, commonly used in low voltage.

In order to ensure awareness of the users regarding the previous measures, the CFE published a guideline regarding "Guideline for the contracting of recharging services for electric vehicles for residential clients".

"Guideline for the contracting of recharging services for electric vehicles for residential clients.

1. Objective

To publicize the steps to follow to obtain the electric power supply service for recharging electric vehicles in houses - rooms.

2. Scope

Applicable to the contracting of electricity supply services in low voltage for recharging electric vehicles. This procedure applies to chargers in the slow charge mode up to 10 kW, for CFE customers.

3. Procedure

3.1. Having an electrical installation exclusively for recharging the vehicle, independent to the service of residential use. The installation must comply with the applicable subsections established in the Official Mexican Standard NOM-001-SEDE Current electrical installations (Utilization), available at the electronic address (…)

3.2. Have the preparation where the metering device will be installed. This must comply with the provisions of the CFE specifications, depending on the load, current wires and type of network, which can be consulted via the Internet at the following email address (…).
3.3. Request the CFE to contract a new service in rate 02, for general use in low voltage. (…)
3.4. When the service is installed in the common services and general connection in horizontal condominiums or residential buildings with more than three levels it must have the verification report of electrical installations issued by the Verification Units accredited by the Secretary of Energy (…)
4. Notes
4.1. In the case of new residential services, where energy is also required for recharging electric vehicles, it will apply the corresponding according to what is established in the Regulation of the Law of the Public Electrical Energy Service in the area of contributions.
4.2. The installation of chargers that allow the return of energy from the electric car battery to the grid.
4.3. The CFE recommends that the chargers comply with the provisions of the standard IEC / CISPR25 and in the quick guide IEC-107. In addition, the CFE recommends that the Total Harmonic Distortion of allowable Current will be up to 5%.
(…)
6. Cost of the procedure
The completion of the procedure has no cost for the user".

3.3- Publicly available charging infrastructure framework.

Public charging infrastructure consider slow and normal chargers that provide a service to consumers and, therefore, are publicly available. (public-public and public-private):

a) Public-Public Charging infrastructure, considered as the charging points available to all users, commonly refers to the charging infrastructure deployed along public spaces;

b) Public-Private: refers to charging infrastructure available to the public and located on private spaces, such as, commercial areas, parking spaces…

Regarding the deployment of publicly available charging infrastructure, the key areas of decision that arise for policymakers are:

STEP 1: Enable and define a general framework

The definition of the general framework needs to be addressed as an enabling and non-restrictive tool for policymakers.

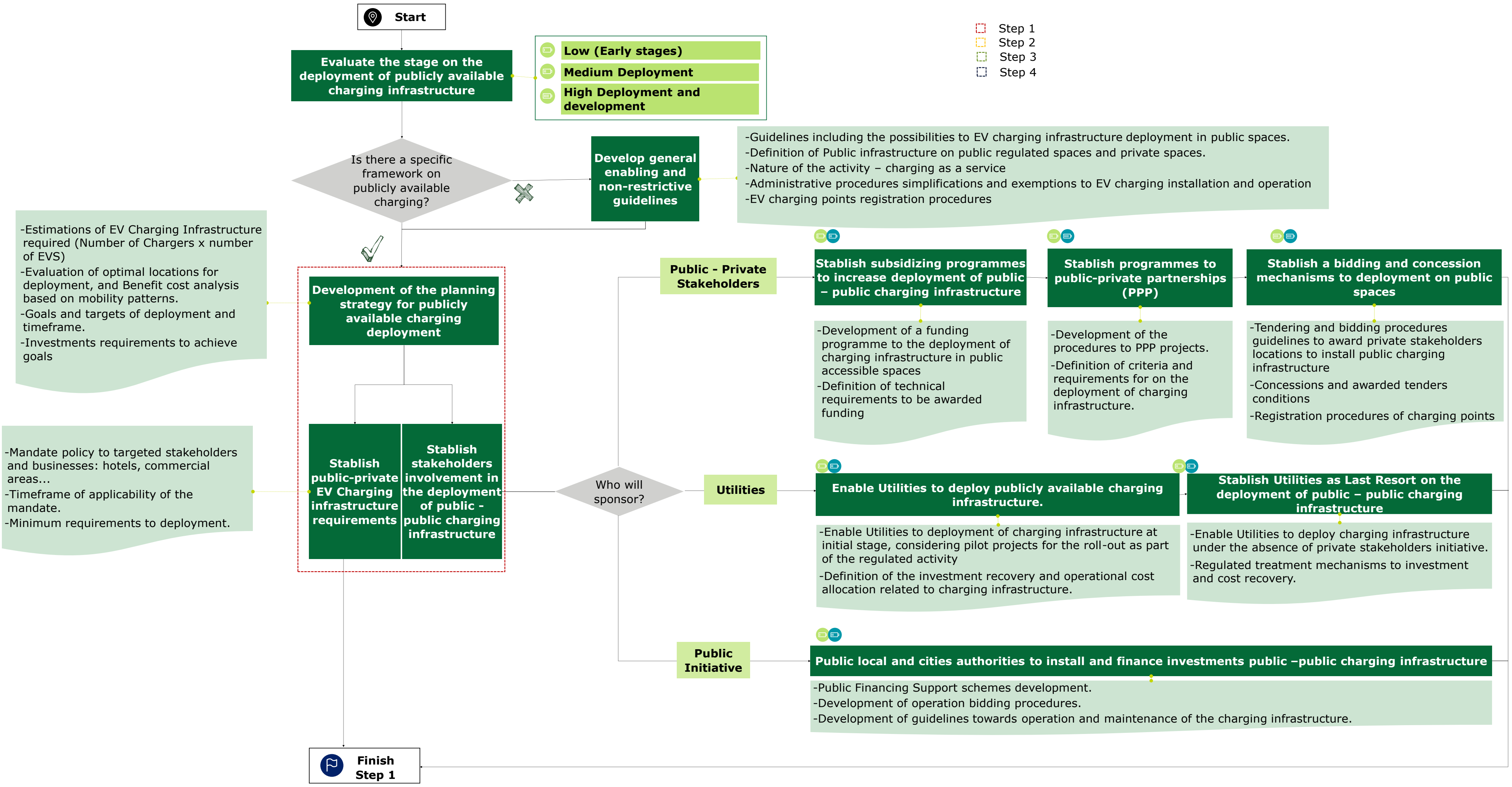


Figure 9: Public Charging Framework Decision Flowchart (Step 1)

The aim on the definition of publicly available charging for users relies on ensuring the users need are covered, by the definition of an adequate environment to achieve stakeholder's involvement on the publicly available charging infrastructure.

On this end the first consideration for policymakers should focus on:

(i) The definition of the nature of the public charging activity;
(ii) The definition of public spaces subject to charging infrastructure deployment;
(iii) The definition of public procedures applicable to charging infrastructure services and activities.

An example on the definition of a General Framework is the case of Spain, that establishes the charging services considerations, including the definition of the general principles and stakeholders under the scope of the Energy Lay as shown below:

<u>**Box 4. Spain Study Case. General Framework on electric recharging services.**</u>

"Law 24/2013. Modified Article 48. Energy recharge services.

1. The main function of the energy recharging service will be the delivery of energy for free or onerous costs through vehicle charging services and storage batteries under conditions that allow charging efficiently and at minimum cost to the user and for the electrical system.

2. The energy recharging services may be provided by any consumer and must meet the requirements established by the Government by regulation. The provision of recharging services in one or more locations may be carried out directly or through a third party, in an aggregated manner by one holder or by several holders through interoperability agreements.

3. Vehicle charging facilities must be registered in a list of charging points managed by the Autonomous Communities and by the Autonomous Cities of Ceuta and Melilla corresponding to the location of the points, which will be accessible to citizens by electronic means. The information included in the aforementioned lists must be communicated by the Autonomous Communities and the Autonomous Cities of Ceuta and Melilla to the Ministry for Ecological Transition, for an adequate monitoring.

4. By order of the Minister for Ecological Transition, the information that must be submitted by the owners of the charging points and under what conditions will be determined. The terms and conditions for the submission of information, as well as the facilities required to send it, will be set based on the load capacity of the facilities, or location at points of special relevance due to vehicle traffic or expressways. of the road network".

In order to ensure the adequate definition and application of the general frameworks, as well as, the additional measures to be adopted to promote charging infrastructure deployment, a public planning strategy appears as a key driver. In addition, the definition of a vision and a target reflects the commitment and the support from local authorities, as well as, engaging stakeholder within the process. This planning strategy, commonly comprises:

i) Estimates and targets on the charging infrastructure aimed to be deployed on public spaces;

ii) Location planning regarding the optimal charging infrastructure network;
iii) Investment requirements to achieve the targets.

In order to successfully achieve the established strategy, the need to set the path to accomplish the goals and targets arise as a critical issue. Therefore, **it is necessary for policymakers to act on the definition of an environment for stakeholders' engagement.**

On this end, two different approaches should be considered**:**

a) Public-Private charging infrastructure deployment requirements

Initial steps can be taken by policymakers towards private stakeholders to deploy publicly available charging infrastructure.

Mandate policies arise as an option in order to initiate publicly available charging infrastructure for users. This type of policies can vary depending on the electric vehicle stage of penetration:

i) Mandate for specific business to enable a minimum electric vehicle charging infrastructure. Criteria is commonly based on the business annual turnover or public transit;

ii) Enabling businesses to deploy charging infrastructure through different commercial strategies, such as offering charging services for free.

b) Public-Public charging infrastructure deployment requirements

Regarding the deployment of charging infrastructure deployment on public spaces, different options arise related to which stakeholder should sponsor the public charging infrastructure deployment.

The different options require the previous definition of who are enabled to provide charging services, commonly stablished within the general framework.

i. Public-Private Stakeholders

This approach aims to engage private stakeholders to deploy charging infrastructure. On this end, policies, regulations and incentivizing programs are required to promote engagement:

- Within early stages, common practices rely on the definition of **subsidizing programmes,** which will require the following measures to be developed:
  - Development of a subsidies program to enable private stakeholders an initial return for the development of the charging activity and the charging infrastructure deployment.
  - Definition of procedures to award subsidies to stakeholders (technical requirements, subsidies conditions…).
- With increasing electric mobility penetration, public policies transition in order to boost private stakeholders' willingness to deploy public charging infrastructure. Common practices rely on:
  - The definition of Public-Private Partnership Projects aimed to promote innovation;

- Definition of bidding and public spaces concession procedures when increasing competition from private stakeholders.

ii. Utilities

This approach relies on enabling utility companies to deploy the charging infrastructure:

- In early stages of deployment, it is common to enable utilities to an initial roll-out of public charging infrastructure under the regulated regime.

  This approach will require to define the investment recovery and cost allocation mechanisms, in order to ensure fairness for customers on the definition of charging tariffs.

  Different practices can be considered within the definition of how investment and operation costs from the charging infrastructure deployment will be translated to the customers or users through electricity tariffs:

  (i) Specific tariffs to electric vehicle charging, and therefore investment and operation costs will be recovered through EV users.

  (ii) Investment recovery through electricity tariffs applicable to all utility customers.

  (iii) Combination of the previous practices.

- Additional practices arise, as electric mobility penetration increase, such as the definition of utilities as last resort stakeholders.

  Last resort regulations aim to enable deployment of charging infrastructure by the utilities, where the private initiative is not attracted to invest on its deployment.

  These measures focus on ensuring that the electric vehicle users' charging needs are covered. However, it must be highlighted that for utilities to act as last resort providers, requires the development of a multi stakeholder electric vehicle charging ecosystem and an open to competition activity. Therefore, these measures will require policymakers and regulators to develop regulations and policies to enable private stakeholders to deploy and operate publicly available charging infrastructure.

  As an example of this type of regulation, Spain published a Royal Decree to enable Utilities as Last Resort stakeholders when considering the deployment of publicly available charging infrastructure (See Box 5 below).

<u>Box 5. Spain Study Case - Utilities Regulation as Last Resource on Charging Infrastructure Deployment</u>

The Royal Decree 647/2011 regulated the activity of a charging supplier in Spain until 2018. This Royal Decree established that utilities could not provide the service of charging infrastructure operator under any condition.

However, in order to promote the deployment of publicly available charging infrastructure, the Royal Decree-Law 15/2018 was published, by which he released this condition. Since then, utilities can deploy charging infrastructure when the private sector has not effectively deployed charging infrastructure. This Royal Decree incorporates modifications under the Electricity Sector Law, in order facilitate the deployment of charging infrastructure.

The modifications to the electricity Law were stablished by the following:

"***Law 24/2013. Article 38. Distribution Regulation***.

(…) 10. Without prejudice to the provisions of article 6.1.g, distribution companies may be the last resort holders of infrastructures for recharging electric vehicles, provided that after a concurrent procedure it is resolved that there is no interest in private initiative, in the terms and conditions established by regulation by the Government. The Government may regulate procedures for the transmission of these facilities by the distribution companies to other owners, when the conditions of economic interest are met, the former receiving adequate compensation".

iii. <u>Public Initiative</u>

Local authorities to take the lead on the deployment of charging infrastructure. On this end, public models commonly arise at initial stages, in order to ensure enough charging infrastructure for users.

This sponsorship model focus on the funding of the investment and ownership of the charging infrastructure, whilst enabling operation to third parties.

An example on how policies incentivizes the public initiative towards establishing the requirement to provide the investment needs to promote electric vehicle charging infrastructure is the case of Costa Rica, shown below (Box 6).

<u>Box 6. Costa Rica Study Case – Public Investment Required to deploy EV charging Infrastructure.</u>

In the case of Costa Rica, the Law 9518, related to the incentive and promotion of the electric vehicle, aims to regulate the regulatory framework towards promoting electric vehicle adoption in the country, and reinforce public policy to incentivize its use within the public sector, as well as, the general population. This law sets the guide to regulate the Public Administration organization. Specifically, regarding the charging infrastructure, Article 19 stablishes the need for the public bodies to invest on the deployment of charging infrastructure, as follows:

"*ARTICLE 19-Investment in infrastructure. The Public Administration, public companies and municipalities will make the necessary investment for those infrastructure works aimed at strengthening and promoting electric transport, such as recharging centers, exclusive lanes, preferential parking for electric vehicles, rail networks and others*".

STEP 2: Enabling an interoperable charging infrastructure network

Publicly available charging infrastructure requires ensuring interoperability. Public authorities can set guidelines and measures to ensure that charging infrastructure is available and can be accessed by all users.

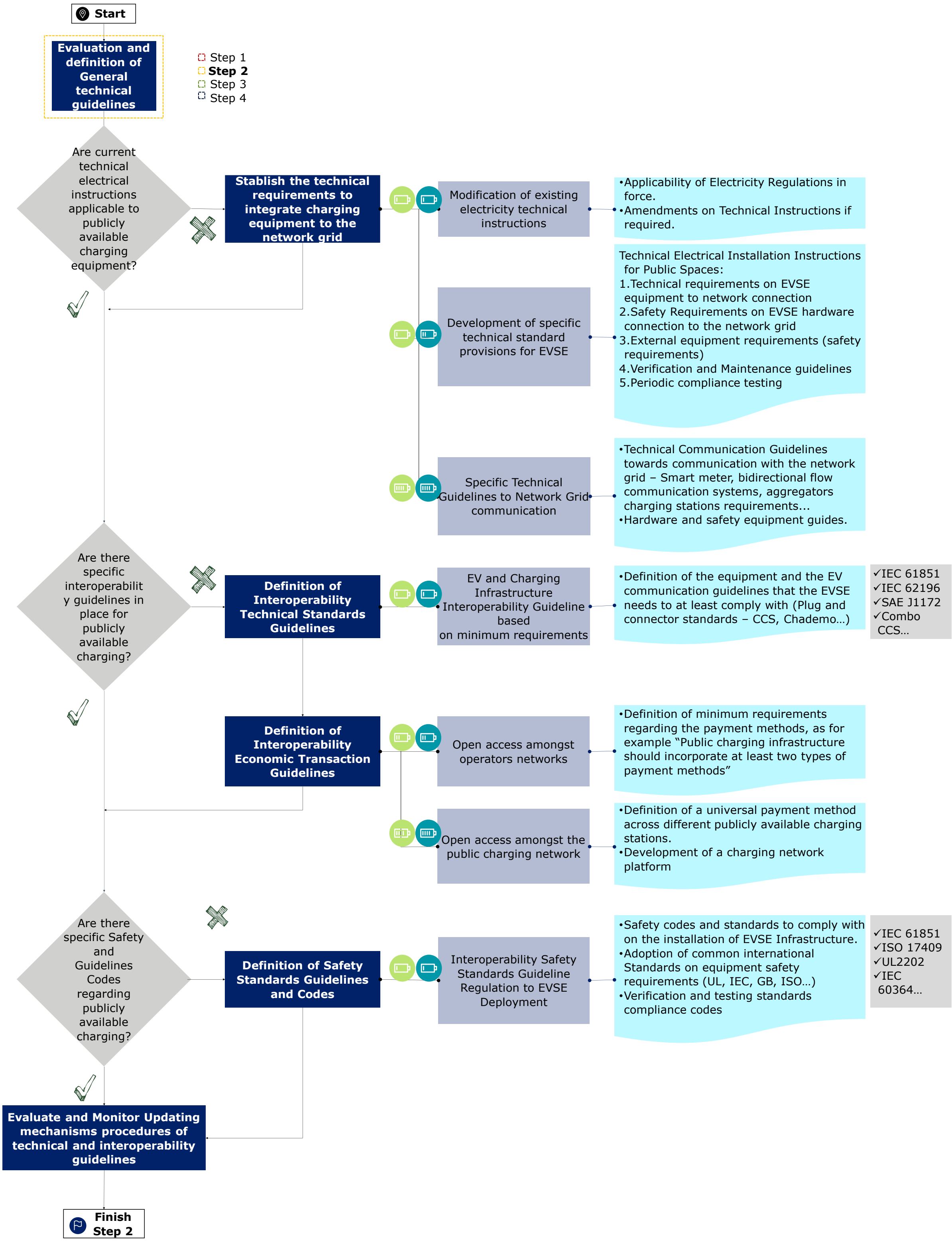


Figure 10: Public Charging Framework Decision Flowchart (Step 2)

Interoperability must be addressed under different areas:

- **Technical specifications and requirements.**

  Technical requirements should be addressed considering:

  a) Connection to the network grid

  Network connection will increase its complexity when considering an increase on electric mobility penetration, as well as, technology development.

  In early stages, simple measures can be adopted, considering the existing access and connection requirements, such as, amendments to current requirements in order to be applicable to charging infrastructure deployment.

  Further development of electric mobility technology, and increasing electric mobility penetration, will require policy makers to:

  - Develop specific technical network access instructions and requirements, including:
    - Planning access procedures;
    - Technical requirements definition;
    - Testing and verification procedures.
  - Develop technical Communication Guidelines towards communication with the network grid, in order to exploit full benefits of further development of electric mobility technology;

  It is common, within early stages to promote pilot programs based on specific technical requirements to ensure an adequate functioning of the charging infrastructure and the network grid communication.

  b) Technical charging infrastructure hardware equipment

  The definition of common technical standards towards the deployment of charging infrastructure.

  Local authorities should consider the definition of minimum requirements on the hardware specifications to ensure interoperability for users.

  Common practices show the adoption of international standards on the deployment of charging infrastructure.

  The implementation of this measures by local authorities will vary depending on the stakeholder ecosystem (standards guidelines regulation, technical requirements on the bidding process…). However, the **common component relies on setting a minimum requirement on hardware specifications so as deployed charging infrastructure must comply within public spaces**.

  However, commonly the technical requirements should include:

  a) The definition of the charging infrastructure equipment and technical specifications:

     i. Transformer equipment and related safety appliance;

ii. Lines and cables equipment;

iii. Civil Works required;

iv. Electrical works ensuring safety;

v. Vehicle access conditions;

vi. Chargers specifications: regulations should include:

a. Requirements regarding the number of charges for the charging station;

b. Type of chargers with which the charging stations are required to be equipped.

Different type of charges should be considered, as well as the possibility to combine different types within a same charging station.

c) Safety requirements

Safety requirements arise as a key concern for users when accessing publicly available charging infrastructure.

The definition of safety standards and guidelines by local authorities aim to ensure operational risk mitigation.

In addition, there is the need to develop verification and compliance procedures and requirements policies.

The development of a guideline for the installation and the operation of the charging infrastructure is commonly addressed through the adoption of international standards - UL, IEC, GB, ISO…

- **Financial transaction interoperability.**

Economic transaction interoperability guidelines are required in order to ensure that users have access to the charging infrastructure network.

The definition of the guidelines will vary depending of the electric vehicle penetration level.

Within early stages of electric mobility adoption, guidelines can focus on the definition of the payment methods requirements guidelines, such as the definition of the minimum payment methods available for users at the charging infrastructure (Open access amongst operators' networks).

On this end, action from local authorities will require to define a guideline with minimum payment specifications, such as, to be equipped at least with credit card or app network payment methods.

Increasing development of electric mobility will require to define guidelines that ensure users to access any charging station within the electric vehicle charging network (Open access amongst the public charging network).

The previous will require the definition of a universal payment method across different publicly available charging stations.

An example on how to address the definition of guidelines for publicly available charging infrastructure regarding payment and transaction service interoperability is the case of California shown below. (Box 7):

Box 7. California Study Case – Regulation to "Electric Vehicle Supply Equipment Standard".

In the case of California, the California Air Resources Board ("CARB") proposed the development of a new regulation based on minimum requirements regarding the standards of access of publicly available electric vehicle charging. The aim of this regulatory proposal relied on facilitating users on the access to public charging service.

The California Air Resources Board, aims to stablish with this regulation the following requirements, amongst others, to ensure open access to users to charge their electric vehicle: (i) accessibility to the Electric Vehicle Service Providers network, ensuring that both members and non-members have access to charging infrastructure, and (ii) payment methods minimum requirements to be enabled.

The final regulation order establishes:

"*Adopt new sections 2360, 2360.1, 2360.2, 2360.3, 2360.4 and 2360.5 in new Chapter 8.3 of Division 3, Title 13, California Code of Regulations, to read as follows:*

(…) This chapter applies to all Electric Vehicle Service Providers (EVSPs) operating one or more publicly available Level 2 or Direct Current Fast Charger (DCFC) Electric Vehicle Supply Equipment (EVSE) installed in California. If an EVSP also operates EVSE that are not publicly available, the requirements of this chapter apply only to that EVSP's publicly available Level 2 or DCFC EVSE installed in California.

(…)

2360.2. Payment Method Requirements for Electric Vehicle Supply Equipment.

(a) Applicability. The requirements of this section apply to publicly available EVSE installed in California that require payment.

(b) The EVSP shall ensure that each EVSE subject to this section that it operates complies with the requirements of this section.

(c) Compliance deadlines.

> *(1) DCFC EVSE compliance deadline. A DCFC EVSE installed on or after January 1, 2022, shall comply with the requirements of this section. A DCFC EVSE installed prior to January 1, 2022, shall comply with the requirements of this section when the EVSE is replaced but in no case later than July 1, 2033.*
>
> *(2) Level 2 EVSE compliance deadline. A Level 2 EVSE installed on or after July 1, 2023, shall comply with the requirements of this section. A Level 2 EVSE installed prior to July 1, 2023, shall comply with the requirements of this section when the EVSE is replaced but in no case later than July 1, 2033.*

(d) All EVSE subject to this section shall have a credit card reader device physically located on either the EVSE unit or a kiosk used to service that EVSE. The credit card reader device shall comply with all of the following requirements:

(1) The credit card reader device shall accept, at a minimum, the Euro MasterCard Visa (EMV) chip and, at a minimum, one of the following credit card types: Visa, MasterCard, or American Express.

(2) The credit card reader device shall be non-locking and shall always permit customers to remove their credit card without damage to the card, including during a fault situation or power failure.

(3) The credit card reader device shall comply with PCI – DSS Level 1.

(e) All EVSE subject to this section shall have a mobile payment device physically located on the EVSE or kiosk used to service that EVSE.

(f) The EVSP shall provide and display a toll-free number on each EVSE or kiosk used to service that EVSE that provides the user with the option to initiate a charging session and submit payment at any time that the EVSE is operational and publicly available.

STEP 3: Pricing policies and regulations

Pricing policies mechanisms focus on obtaining the balance between incentivizing competition amongst stakeholders whilst guaranteeing a fair charging service pricing for users.

On this end, the following steps and questions within the framework decision process, require to be addressed by policymakers and regulators:

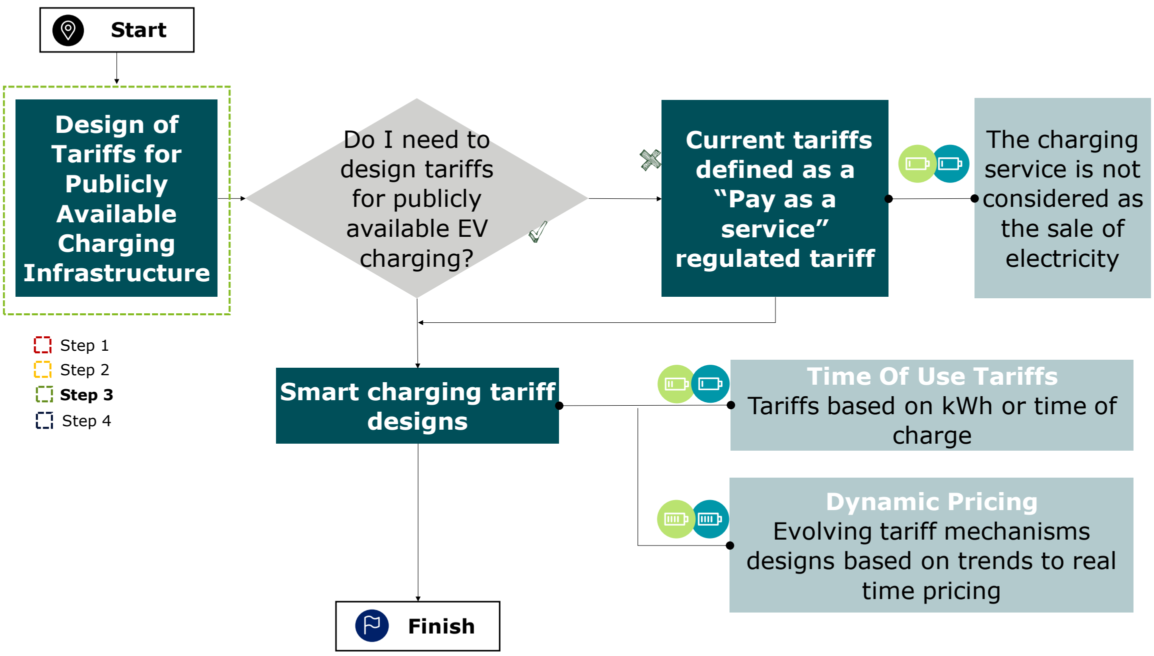


Figure 11: Public Charging Framework Decision Flowchart (Step 3)

On this end, the first decision in the decision-making process needs to address whether the charging service falls under a regulated market scheme or if it is to be considered as free – market activity.

Pricing policies and regulations, as well as the definition of regulated tariffs, need to be addressed considering both the level of electric mobility penetrations, as well as, the network system communication development:

- Early stages of electric mobility adoption commonly do not require a high digitalized network grid. The definition within the initial roll-out of regulated tariffs rely on considering charging as a service instead as the sale of electricity.

  Under this approach, policymakers and governments common practices set the service pricing principles based on a price-cap methodology, where policy addresses a limit over a specific rate to which service providers can offer charging service, as for example, a percentage over the applicable electricity tariff or a maximum charging service rate. However, the adequate approach needs to ensure information transparency for the users', as well as, fair price competitiveness amongst stakeholders and equative cost recovery conditions.

- Increasing electric mobility penetration and the consequent increase on the electricity demand to cover charging needs, will drive to consider the development of smart charging tariffs and innovation solutions to fully exploit electric mobility benefits. Different options appear under this approach:

  - Consideration of Time of Use Tariffs, which enable charging services to be metered considering a variable charging tariff approach.

  - Dynamic Pricing, considering evolving tariff mechanism designs based on real time pricing.

STEP 4: Ensuring long-term readiness through complementary measures

Additional measures and actions can be taken by policymakers and local authorities, aimed to ensure readiness to successfully cover users' needs.

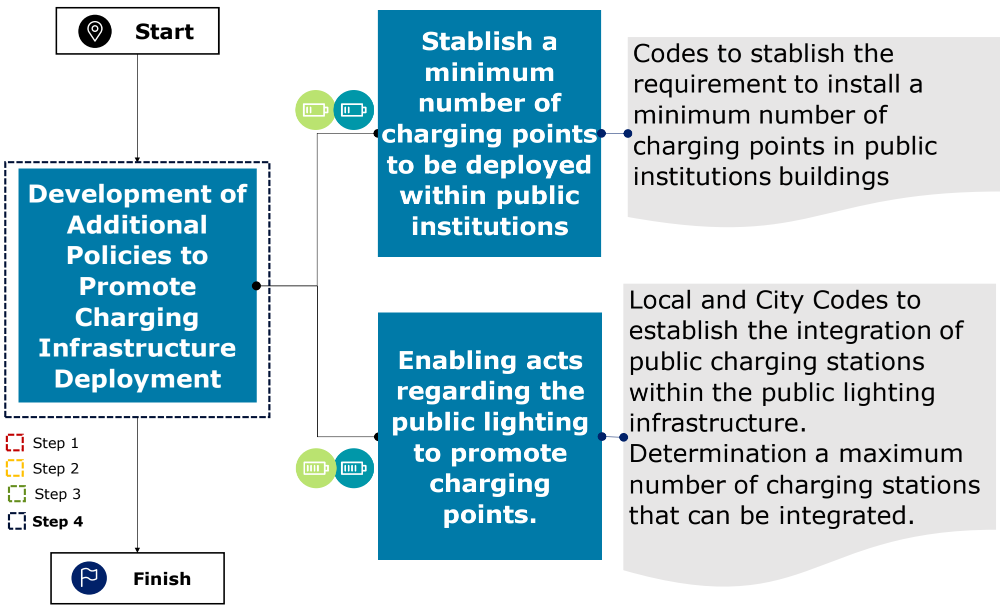


Figure 12: Public Charging Framework Decision Flowchart (Step 4)

Common practices address:

i) Establish a minimum number of charging points to be deployed within public institutions.

   The definition of a mandate towards public institutions to gradually deploy available charging infrastructure under their premises.

   This commonly sets a minimum of charging points to be deployed.

ii) Enabling acts regarding the public lighting to promote charging points.

   The aim is to exploit synergies amongst public lightning by enabling charging through the electrical equipment of public lightning during the day whilst not require to be functioning.

   On this end, installation and deployment investments are significantly lower. However, local authorities require to establish the guidelines to enable the deployment of charging infrastructure through public lightning.

First steps to incentivize the deployment of a publicly available network of charging infrastructure

Figure 13 shows the first steps for policy makers and local authorities to promote and enable publicly available charging infrastructure.

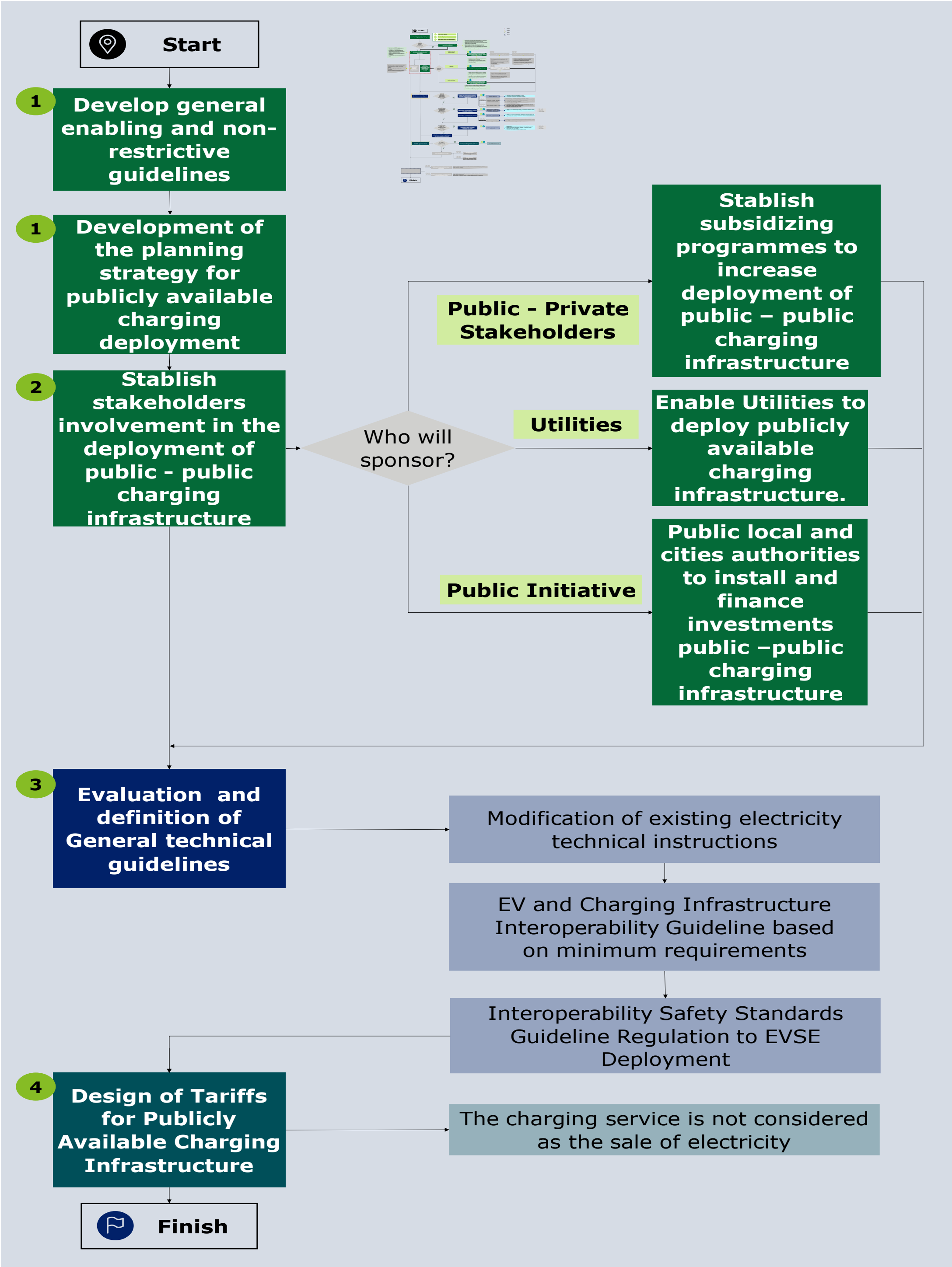


Figure 13: Early Stages Public Charging Framework Decision Flowchart

This process is focused on the key pillars to enable and incentivize initial roll out of publicly available charging infrastructure, as well as, taking steps to set the basis for long-term developments on the electric mobility charging infrastructure ecosystem.

The key areas of decision within the early stage of electric mobility adoption rely on:

a) **Enabling a general framework to cover the definition and the nature of public charging**.

Consideration must be set on the definition of the stakeholder ecosystem, in order to set a non-restrictive framework for different stakeholders willing to engage on the deployment of charging infrastructure.

b) **Development of a planning strategy** to reflect public engagement and roadmap to the deployment of an accessible charging network.

Planning strategies require to analyze, assess and include:

- Customer trends and driving patterns;
- Identify the optimal locations for charging deployment;
- Set goals in order to ensure the deployment of an adequate network.

c) **Definition of the stakeholders mapping ecosystem and related policies to address engagement:**

i. Establish subsidizing programs for private stakeholders to deploy public charging infrastructure, which will require to address the following issues:

- Definition of criteria to apply for public funds;
- Definition of the application procedures;
- Specific conditions on the granting of funds.

ii. Enabling utility companies to deploy charging infrastructure by:

- Definition of a framework for initial roll-out of the charging infrastructure, considering pilot programs;
- Definition of Utilities as Last Resort, to ensure availability of charging infrastructure for users in areas where the private initiative is not interested in its deployment.

These measures aim to provide charging infrastructure due to the absence of private stakeholders' deployment.

However, these actions should not restrict private stakeholders to be enabled to deploy charging infrastructure, but instead enable coexistence.

iii. Face deployment through public local initiatives, by financing the investments on the deployment of charging infrastructure and establishing bidding process for the operation.

d) **Evaluation and development of measures to ensure minimum interoperability through:**

i. Amendments to electricity technical instructions to ensure the applicability to charging infrastructure of network grid connection requirements.

ii. Definition of technical and safety standards guidelines based on minimum requirements.

e) **Definition of applicable regulated tariff mechanisms**, considering charging service independent of the sale of electricity. Definition of a service regulated tariff.

As an example of the previous measures, in the case of India the Government released policies and a standards guideline regarding Public Charging Infrastructure which includes the definition of the nature of the activity and a general framework for deployment, technical equipment requirements and compliance with standards, as well as, references to applicable tariffs for charging services (Box 8).

Box 8. India Study Case - Setting up Guidelines and Standards Regulation

One of the main obstacles regarding the electric vehicle adoption relies on the lack of publicly available charging infrastructure to reduce range anxiety from users. In the case of India, in order to overcome this barrier, the Government released policies and guidelines regarding Public Charging Infrastructure. The published guidelines aim to promote the deployment of public charging infrastructure and enhance the country's readiness towards the future considering an increasing electric vehicle penetration.

Under this, the Indian Government published the Revised Guidelines aimed to simplify the procedures to towards the installation of charging infrastructure ("Charging Infrastructure for Electric Vehicles (EV) -Revised Guidelines & Standards-reg.", October 2019) Under these guidelines, the concepts included, amongst others, refer to (i) different types of charging infrastructure, differentiating amongst private and public charging stations, (ii) the nature of the activity related to the different types of charging infrastructure, considering the **public charging infrastructure as a delicensed activity**, (iii) **technical equipment requirements for public charging** infrastructure, including charger standards, (iv) **compliance with technical and safety standards**, and (v) **utility tariff and service charges** guidelines for public charging.

In Light of the above, it has been decided as follows:

1. Private charging at residences / offices shall be permitted. Distribution Companies (DISCOMs) may facilitate the same.

2. Setting up of Public Charging Stations (PCS) shall be a de-licensed activity and any individual/entity is free to set up public charging stations provided that, such stations meet the technical, safety as well as performance standards and protocols laid down below as well as any further norms/ standards/ specifications laid down by Ministry of Power and Central Electricity Authority (CEA) from time to time.

2.1 Any person seeking to set up a Public Charging Station may apply for connectivity and he shall be provided connectivity on priority by the Distribution Company licensee to supply power in the area.

2.2. Any Charging Station/ Chain of Charging Stations may also obtain electricity from any generation company through open access.

2.3 For these guidelines, Electric Vehicle Supply Equipment (EVSE) shall mean an element in EV infrastructure that supplies electric energy for recharging the electric vehicles.

3. Public Charging Infrastructure (PCI)- Requirements:

3.1 Every Public Charging Station (PCS) will have the following infrastructure: (i). An exclusive transformer with all related substation equipment including safety appliance, if required. (ii). 33/11 KV line/cables with associated equipment including line termination etc, if required. (iii). Appropriate civil works (iv) Appropriate cabling & electrical works ensuring safety (v). Adequate space for Charging and entry/exit of vehicles (vi) Public Charging Station shall have, any one or more chargers or any combination of chargers from the table given below in one or more electric kiosk/boards:

Type	S. No.	Charger Connectors	Rated Output Voltage(V)	No. of No. of Connector guns (CG)	Charging vehicle type (W=wheeler)
Fast	1	Combined Charging System (CCS) (min 50 kW)	200-750or higher	1 CG	4W
	2	CHArge de MOve (CHAdeMO) (min 50 kW)	200-500 or higher	1 CG	4W
	3	Type-2 AC (min 22 kW)	380- 415	1 CG	4W, 3W, 2W
Slow/Moderate	4	Bharat DC-001 (15 kW)	48	1 CG	4W, 3W, 2W
	5	Bharat DC-001 (15 kW)	72 or higher	1 CG	4W
	6	Bharat AC-001 (10 kW)	230	3 CG of 3.3 kW each	4W, 3W, 2W
*In addition, any other fast/slow/moderate charger as per approved DST/BIS standards whenever notified. Note :Type -2 AC (min 22 kW) is capable of charging e-2W/3W with the provision of an adapter					

vii. Charging Station for e-two/three wheelers shall be free to install any charger other than those specified above subject to compliance of technical & safety standards as laid down by CEA.
viii. Tie up with at least one online Network Service Providers (NSPs) to enable advance remote/online booking of charging slots by EV owners. Such online information to EV owners should also include information regarding location, types and numbers of chargers installed/available, service charges for EV charging…ix. Share charging station data with the appropriate DISCOM and adhere to protocols as prescribed by CEA for this purpose. CEA, Central Nodal Agency (CNA) and State nodal agency (SNA) shall have access to this database.

Electric Vehicle Supply Equipment (EVSE) shall be type tested by an agency/lab accredited by National Accreditation Board for Testing and Calibration Laboratories (NABL) from time to time.

3.3. The above minimum infrastructure requirements do not apply to Private Charging Points meant for self-use of individual EV owners (non-commercial basis).

3.4. Captive charging infrastructure for 100% internal use for a company's own/leased fleet for its own use will not be required to install chargers as per para 3.1 and to have NSP tie ups.

3.5. Charging Station may also be installed by Housing societies, Malls, Office Complexes, Restaurants, Hotels, etc. with a provision to allow charging of visitor's vehicles which are permitted to come in its premises.

4. Public charging Infrastructure (PCI) for long range EVs and/or heavy duty EVs:

4.1 Fast Charging Stations (FCS) i.e. Public charging stations for long range EVs and/ or heavy duty EVs (like trucks, buses etc) will have the following:
At least two chargers of minimum 100 kW (200- 750 V or higher) each of different specification (CCS /CHAdeMO or any fast charger as approved by DST/BIS for above capacity) with single connector gun each. (…)
4.2 Such Fast Charging Stations (FCS) which are meant only for 100% in

house/captive utilization, for example buses of a company, would be free to decide the charging specifications as per requirement for its in- house company EVs.

5. Location of Public Charging Stations:

5.1 In case of Public Charging Stations, the following requirements are laid down with regard to density/distance between two charging points:

i. At least one Charging Station shall be available in a grid of 3 Km X 3Km. Further, one Charging Station shall be set up at every 25 Km on both sides of highways/roads.

ii. For long range EVs and/or heavy duty EVs like buses/trucks etc., there shall be at least one Fast Charging Station with Charging Infrastructure Specifications as per para 4.1 above at every 100 Kms, one on each side of the highways/road located preferably within/alongside the stations laid in para 3 above. Within cities, such charging facilities for heavy duty EVs may be located within Transport Nagars, bus depots.

5.2 Additional PCS/FCS can be installed even if there exists a PCS/FCS in the required grid or distance.

5.3 The above density/distance requirements shall be used by the concerned state/UT Governments/their Agencies for the purposes of land use planning for public charging stations as well as for priority in installation of distribution network including transformers/feeders etc. This shall be done in all cases including where no central/state subsidy is provided.

5.4 The appropriate Governments (Central/Statf/UTs) may also give priority to existing retail outlets (ROs) of Oil Marketing Companies (OMCs) for installation of Public EV Charging Stations (in compliance with safety norms) to meet the requirements as laid above. Further, within such ROs, Company Owned and Company Operated (COCO) ROs may be given higher preference.

6. Database of Public EV Charging Stations:

Central Electricity Authority (CEA) shall create and maintain a national online database of all the Public Charging Stations through DISCOMs. Appropriate protocols shall be notified by DISCOMs for this purpose which shall be mandatorily complied by the PCS. This database shall have access as finalized by CEA and Ministry of Power.

7. Tariff for supply of electricity to EV Public Charging Stations:

7.1 The tariff for supply of electricity to EV Public Charging Station shall be determined by the appropriate commission in accordance with the Tariff Policy issued under section 3 of Electricity Act 2003 as amended from time to time.

7.2 The tariff applicable for domestic consumption shall be applicable for domestic charging.

7.3 The separate metering arrangement shall be made for PCS so that consumption may be recorded and billed as per applicable tariff for EV charging stations.

8. Service charges at PCS:

8.1 Charging of EVs is a service as already clarified by Ministry of Power vide letter No. 23/08/2018-R&R dated 13.04.2018.

8.2 In such cases where the PCS/FCS has been installed with Government Incentives (financial or otherwise), State Nodal Agency/State Government/Appropriate Commission shall fix the ceiling of Service Charges to be charged by such PCS/FCS".

3.4- Long Distance Fast Charging Infrastructure Framework.

Long-distance charging infrastructure refer to fast charging stations that are usually placed alongside corridors.

The deployment of charging infrastructure to cover long distance travels is critical in order to ensure a full transition to electric mobility, as well as, addressing range anxiety issues for users, which increases when considering long distances transits.

Different options and possibilities arise for policymakers in order to ensure the deployment of a long-distance charging infrastructure network, considering the following steps.

STEP 1. Definition of a General Framework, Planning Strategy for deployment and Stakeholder ecosystem.

The definition of a general framework that defines the nature of long-distance fast charging stations will define further measures that can be adopted by policymakers. Figure 14 shows the decision framework flowchart.

On this end, the framework should focus on eliminating barriers to charging infrastructure deployment by:

- Enabling the engagement of different stakeholders on the deployment of the charging infrastructure;
- Simplifying procedures to install charging infrastructure along public corridors and highways;
- Defining electric charging infrastructure registration procedures;
- Enabling current infrastructure to engage on the deployment of charging infrastructure. Hence, not to be considered as a new activity.

In addition, it is necessary to analyze the road network and transit patterns in order to optimize investments and ensure the deployment of a charging network that addresses users' mobility needs. Commonly, the public planning strategy includes:

- Analysis of transit and mobility patterns throughout the road number;
- Estimations of required electric mobility charging infrastructure by distance range;
- Evaluation and prioritization of optimal locations for the deployment of charging infrastructure;
- Definition of targets and goals to be achieved within a specific timeframe;
- Estimates of investments required to achieve deployment targets.

Furthermore, policymakers should address the stakeholder ecosystem definition, as the measures to be adopted will vary considering the stakeholders involved in the deployment process.

i. <u>Public-Private Stakeholders</u>

Measures and regulations to engage private stakeholders vary depending on the electric mobility penetration level and the charging demand from users:

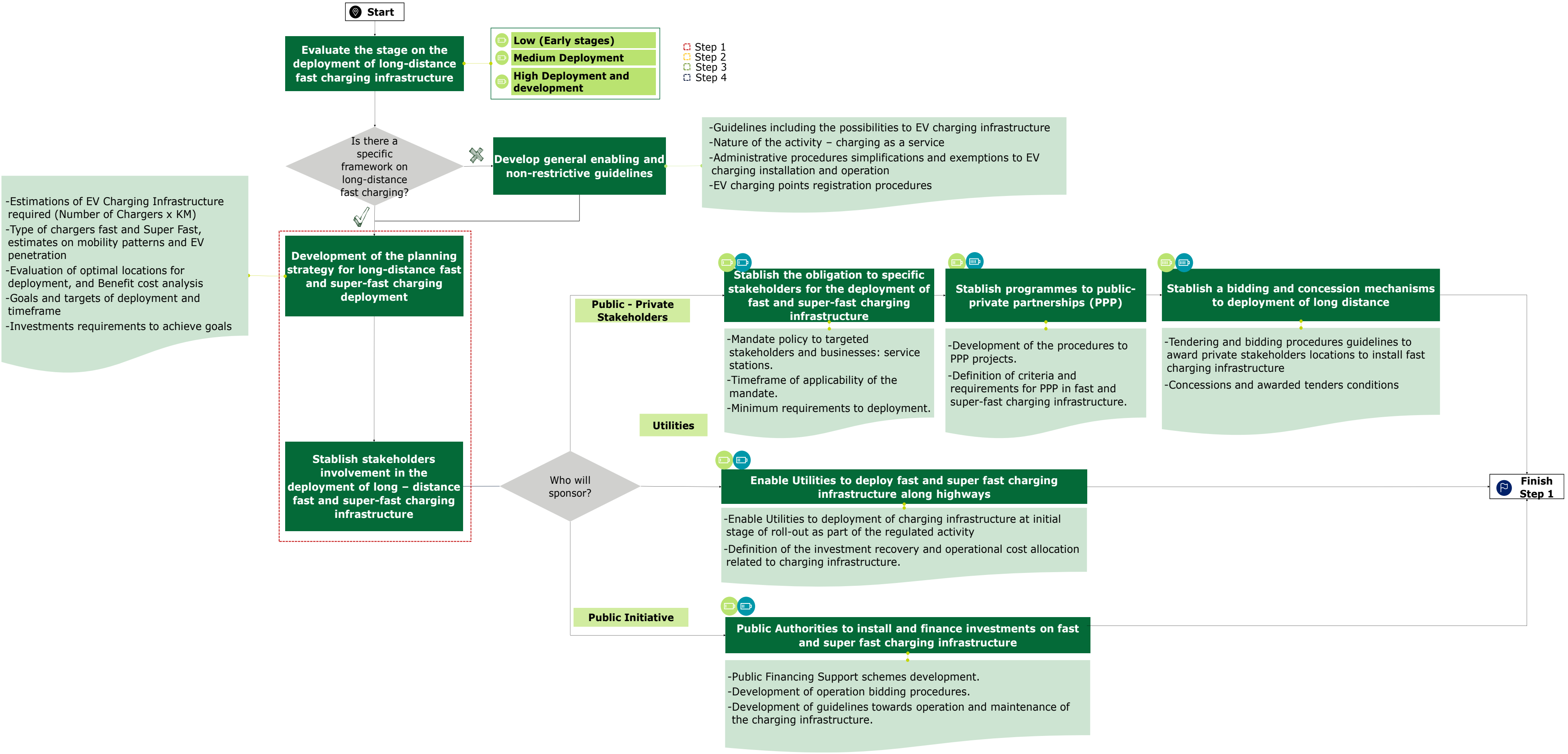


Figure 14: Long-distance Charging Framework Decision Flowchart

- Early stages of electric mobility where there is low demand, is commonly characterized by the absence of investment in the deployment of fast charging infrastructure.

  In order to address the issue, consideration must be focused on the development of mandate policies to establish the obligation to install charging infrastructure to specific stakeholders, such as service stations along corridors and highways.

  These policies should include:

  - Stakeholders subject to comply with regulation. The definition of the stakeholders' requirements can be based on drivers such as annual turnover, transit indices, facility capacity…
  - Definition of charging infrastructure installation requirements for each stakeholder.

  These policies will require to define the timeframe of application, if considered to be a temporary policy.

  An example of this type of policies is the case of Spain, as shown below (Box 9).

Box 9. Spain Case Study – Development of a fast charging infrastructure network through the existing service station network

On the case study of Spain, the road transportation sector represents, approximately 25% of the country's greenhouse gas emissions. One of the main barriers towards the adoption of electric vehicles relates to the lack of an amplified available fast charging infrastructure network.

The country counts with an extensive network of vehicle petrol service stations, accounting for 11,400 over the national landscape.

Aimed to guarantee the existence of an adequate charging infrastructure, a bill is being processed to introduce the obligation to install electric vehicle charging infrastructure on existing service stations based on the annual sales of gasoline and diesel. On this end, the obligation is intended for those service stations that exceed 5 million liters of gasoline and diesel in annual sales. These service stations add up to 10% of the national network. The resulting installed charging infrastructure must have a capacity of at least 50kW. The obligation is set on the stations which presumably have a higher economic and financial capacity to face the required investments.

In the case of the concessions on the national road network, the obligations previously indicated will be satisfied by the licensees of the same. The obligation regime framework will be applied on the same conditions as for the owners of the fuels service facilities. In addition, the bill proposal includes a Government mandate to develop and deploy a publicly available information platform related to the charging points.

The competent Government body ("Ministerio para la Transición Ecológica y el Reto Demográfico") will dictate the necessary provisions to regulate this obligation, including, amongst others, the exceptions and technical restrictions for its compliance, the list of fuel service stations obliged to comply with this law, as well as, the content and the information requirement procedures of the infrastructures by the charging service providers.

The proposed regulatory development in Spain is as indicated below:

"***Article. Installation of electric recharging points.***

1.The Government will make public available information on electric charging points for vehicles through the National Access Point for real-time traffic information managed by the autonomous Central Traffic Headquarters. For this, previously, the providers of the electric recharge service must submit electronically to the Ministry for the Ecological Transition and the Demographic Challenge updated information on the location, characteristics, and availability of said facilities, as well as the sale price at electricity or recharging service.

2. The owners of the fuel supply facilities for vehicles whose aggregate annual sales volume of gasoline and diesel A in 2019 is greater than or equal to 10 million liters shall install, for each of these facilities, at least one infrastructure electric recharging power equal to or greater than 50 kW in direct current, which must provide service within 21months from the entry into force of this Act.

3. The owners of the fuel supply facilities to vehicles whose aggregate annual sales volume of gasoline and diesel A in 2019 is greater than or equal to 5 million liters and less than 10 million liters, will install, for each of these facilities, at least an infrastructure for electric recharging with a power equal to or greater than 50 kW in direct current, which must provide service within 27 months from the entry into force of this Law.

4. In the event that in a region or island there is no installation of fuel supply to vehicles whose aggregate annual volume of sales of gasoline and diesel A in 2019 is greater than or equal to 5 million liters, the holders of the facilities that, ordered from highest to lowest volume of aggregate annual sales of gasoline and diesel, jointly or individually reach at least 10% of total annual sales in the aforementioned geographical areas in 2019 will install, for each of these facilities, at least an infrastructure for electric recharging with a power equal to or greater than 50 kW in direct current, which must provide service within 27 months from the entry into force of this Law.

5. Beginning in 2021, owners of new facilities for supplying fuel and fuels to vehicles or undertaking a reform of their facility that requires a review of the administrative title, regardless of the aggregate annual volume of gasoline and diesel sales of the facility, They will install at least one electric recharge infrastructure with a power equal to or greater than 50 kW in direct current, which must be serviced from the start-up of the installation.

6. Throughout the Royal Decree it will establish the list of fuel supply facilities required by the sections and technical impossibilities for compliance.

> *7. By order of the Minister for the Ecological Transition and the Demographic Challenge, the regulation of the content and media regarding the requirements of the information of the recharging points to the Ministry for the Ecological Transition and the Demographic Challenge will be established by the providers of the recharging service.*
>
> *(…)9. In the case of concessions in state highway networks, the obligations referred to in sections 2, 3, 4, 5 and 6 will correspond to the concessionaires of the same. The obligation regime will be the same as that established for the owners of fuel supply installations for vehicles, as indicated in the aforementioned sections of this article.*

- With the development of electric mobility, and an increasing demand of long-distance charging, will require public measures to evolve in order to promote an increasing deployment of fast-charging infrastructure to satisfy users':
    - Definition of Public-Private Partnerships Programs. These programs will require policymakers to determine the selection criteria and the partnership conditions within the deployment, as to stakeholders' roles and obligations;
    - Definition of bidding and concession mechanisms to award private stakeholders the public permits required to install charging infrastructure on the public road network.

ii. Utilities: enable utility companies to the initial roll-out of the road network fast charging infrastructure.

This framework needs to ensure that the deployment of charging infrastructure is not limited exclusively to utilities but allow for private stakeholders to participate on the deployment. On this end, different options arise:

- Designate Utilities for an initial roll-out, considering under their current activity;
- Enable partnerships amongst utilities and private stakeholders.

Under this approach, policymaker will be required to develop the policy in which utilities are designated or enabled to deploy the charging infrastructure, including the cost recovery conditions.

As an example of policies where Utilities (Power Companies) are designated as the responsible stakeholders regarding the roll-out of charging infrastructure along the national road network would be the case of Costa Rica, as shown below (Box 10).

<u>Box 10. Costa Rica Case Study - Fast-Charging Infrastructure deployment</u>

In 2019, the Costa Rican Ministry of environment and energy (*"Ministerio de Ambiente y Energía"* or MINAE) developed the National Plan for electric mobility 2018-2030, to promotes the use of electric vehicles amongst the nation as strategic objectives.

Power companies are obliged to develop charging infrastructure along the national system, even though they can form partnerships with public or/and private companies. Charging stations should be developed every 80 kilometers for national roads and every 120 kilometers for cantonal roads. Through a number of workshops between distribution operators, the regulatory body, the minister and societal representation, it was established that charging stations should at least include CHAdeMO and CCS Combo 1 connectors, both being fast charging solutions.

Moreover, in order to increase easiness of use from consumers, it was established that the operational and payment management will be centralized in a unique platform.

"<u>*Executive Decree number 41642-MINAE*</u> *(Decreto Ejecutivo número 41642-MINAE)*

Article 6- Electric charging infrastructure of the network

Electricity distribution companies, as providers of public distribution and marketing services, will have the responsibility of building and operating the charging infrastructure in the geographical location established by MINAE.

Charging infrastructure will be the only ones authorized to sell or market electricity and should only use dispensers for fast charging of electricity. The set of electric fast charging stations will form a network that will allow the supply of electricity to electric cars, throughout the national territory.

The network of fast charging stations that are regulated in this article, will form part of the assets of the distributors as elements of the distribution network and are affected to the public service of electricity supply in the distribution and retailing stage.

Article 7- Continuity of the operation of the charging stations

The charging stations in the network must be publicly accessible, guaranteeing continuity of service for users. Charging stations must have lighting for users who use the service during the night period.

In the event of operating and security situations that prevent the distributor from providing the service, it must notify ARESEP and take the necessary actions to guarantee the continuity of the service.

Article 8- Alliances with fuel sales service stations

Distributors will be able to install the charging infrastructure in fuel sales stations or related services through an alliance, association, joint venture or other type of business structure and, where it exists, they will be able to take advantage of the available infrastructure. This installation must comply with all the safety conditions and environmental aspects that are stated in the regulation that governs for the service stations for the sale of fuel and the provisions of article 10 of this regulation.

Article 9- Alliances with owners of other establishments
Distributors will be able to install charging stations in alliance with public, private or both actors, and when it exists, they will be able to take advantage of the available infrastructure, for which they will be able to establish rental figures, agreements and others, as permitted by their legal framework, verifying the compliance with the provisions of article 10 of this Decree.
Article 10.- Charging stations in fuel service stations or related services
Distributors may install charging stations in fuel service stations or related services, as long as they have the approval of the DGTCC, in order to not affect the fuel supply service.
Article 11.- Retailing of electrical energy in charging stations
The distributors that have the concession of distribution and retail of electricity are the only ones that will be able to commercialize or sell electricity in the charging stations.
The operation, operation and maintenance of the charging stations included in these regulations are the responsibility of the distributors.
Article 12- Affiliation for the use of charging stations
Distributors must ensure that there is a single mechanism for affiliation to the computer platform so that users can use the network of charging stations. Similarly, they must agree on the method of invoicing and the means of payment.
Article 13- Adjustments in the network of charging infrastructure
The MINAE will adjust the distances, the location and the number of recharging centers that distributors must build and maintain in operation at each geographic site in the country. The criteria for the expansion or relocation of the network of electric recharge centers will be the following: a) Frequency of use. b) Increase in the use of electric cars. c) Topographical aspects. d) Sites of tourist interest, development or places of commercial interest. Distributors, should they consider it necessary, may submit to MINAE proposals for adjustments to the network of charging stations with their respective technical support for their assessment and authorization of modifications to the network. The MINAE, if deemed appropriate, will authorize said adjustments

iii. Public Initiative

Authorities to take the lead on the deployment of charging infrastructure. On this end, public initiative commonly focuses on the subsidizing of the investment and ownership of the charging infrastructure, whilst enabling operation to third parties.

STEP 2: Enabling an interoperable charging infrastructure network.

Technical requirements and guidelines are critical in order to ensure an interoperable network, as well as, to address an adequate functioning considering safety conditions.

Policymakers should address, within the definition of policies and regulations towards promoting interoperability and safety, the following key areas:

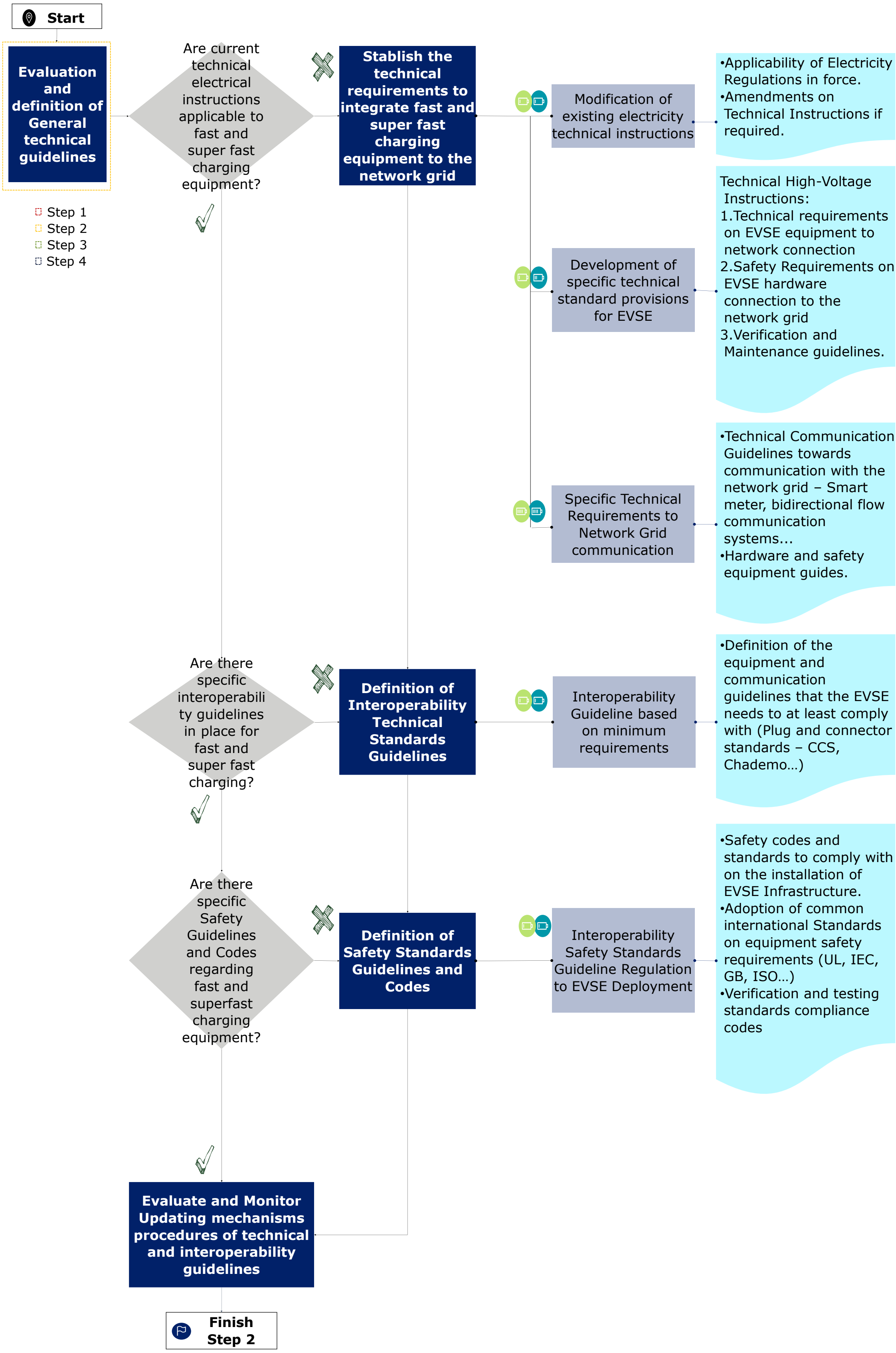


Figure 15: Long Distance Fast Charging Framework Decision Flowchart (Step 2)

It must be highlighted that technical and safety guidelines can be addressed jointly considering the different types of charging infrastructure to be deployed developing a unique instruction or separately considering the technical specific needs to be addressed in each type of charging infrastructure, as for example the development of an instruction for low voltage supply to the charging infrastructure and an instruction for high voltage electricity supply.

When considering a unique instruction, the development of the following steps will be realized all in one with the corresponding steps detailed previously regarding the private and publicly available charging infrastructure deployment.

- **Technical specifications and requirements to integrate fast charging to the network grid:**

  The purpose of this policies relies on the definition of normalized and technical safety electrical equipment and network connections.

  Technical instructions are aimed to establish the requirements to be applied during the process of installation of the charging infrastructure, and to comply with network grid connection requirements.

  On this end, the technical instructions and guidelines should include the following:

  - Nature and scope of applicability, including if considered any exemptions, such as facilities based on capacity requirements.
  - Technical specification guidelines related to hardware equipment and related connection to the network grid.
  - Charging infrastructure technical maintenance guidelines to equipment connected to the network grid.
  - Safety requirements to be developed or applicable to connection and access point to the network grid.

  It must be highlighted that it is common, within early stages of deployment that existing electricity technical instructions and provisions are applicable to the installation of the charging infrastructure. Therefore, actions by policymakers in order to include fast charging under the scope of electricity technical instructions is considered.

- **Technical Standards Guidelines on EVSE equipment.**

  Technical minimum standards are required regarding the hardware of the charging infrastructure, in order to ensure interoperability. On this end, common practices define guidelines where the adoption of international standards are recommended.

  In addition, options related to the development of a standards regulation are to be considered. This regulation should focus on minimum requirements of compliance by stakeholders.

  Commonly these regulations establish that charging infrastructure should be equipped at least with a specific number and type of vehicle connection hardware (plug and connector standards).

- **Safety Standards Guidelines**

  The definition and implementation by the authorities regarding Safety Instructions are aimed to establish the guidelines to a safe installation and operation of the charging infrastructure.

  In addition, these guidelines require the consideration of Safety standards, which should be included.

  On this end, the decision-making process, towards the development of the safety guidelines will consist on the following:

  A) Definition of the nature of the instruction or provision.

  Different provisions can be developed based on the type of charging, required voltage or a unique instruction.

  However, in this section it must be highlighted whether there are special considerations or charging infrastructure types which are not subject to comply with the instruction.

  B) Definition of General safety requirements.

  General safety requirements should include the definition of:

  i. The requirement of design and installation verification procedures;

  ii. The requirement of testing and inspection validation procedures;

  iii. General requirements regarding the technical equipment, such as, indications related to the adaptors, electrical charge under disconnection of the infrastructure, etc...

  C) Definition of Protection System Requirements.

  The protection system requirements will need to address the minimum technical specifications to comply with the instruction.

  D) Definition of Testing System.

  The testing systems needs to include the indicators and the tolerated levels required to ensure compliance with the instruction.

  E) Definition of additional requirements

  Additional requirements should be included regarding:

  - Periodic maintenance and safety assessment of the charging infrastructure;

    This should include the stakeholder responsible to perform the assessment;

  - Safety provisions defined in compliance amongst specific international safety standards;

  - Requirements related to compliance of the charging infrastructure under international safety standards.

STEP 3: Pricing policies and regulations

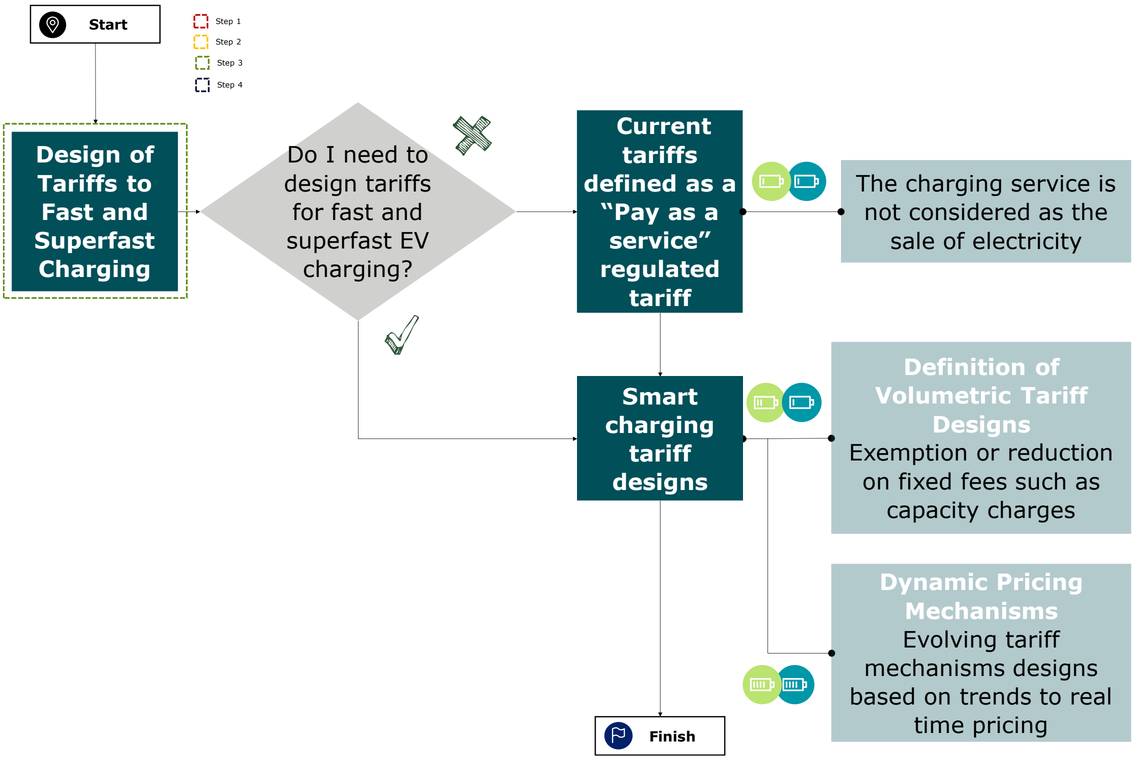


Figure 16: Long Distance Fast Charging Framework Decision Flowchart (Step 3)

Tariff design mechanisms considering fast charging infrastructure is critical due to power and capacity requirements, as costs of electricity supply are commonly higher the tariff design and the services charges fees regulations needs to be addressed over the different stages of electric mobility evolution.

Regulations require to address services charges through the definition of requirements on the design of users' service rates, or if rates are market driven.

On this end, within early stages of electric mobility adoption tariff design can rely on the definition of a regulated rate for users', not considering charging service as the sale of electricity. Common practices establish a regulated rate based on a methodology where charges cannot exceed an established limit.

However, consideration must be set on investment recovery for stakeholders through charging tariffs, specially within early stages in order to promote deployment from stakeholders, such as the definition of volumetric or variable:

- Exemptions on capacity charges for a transitory period for charging services.
- Application of variable fees based on consumption. Therefore, the design of a specific tariff should be considered.

Furthermore, increasing demand of fast charging services, aligned with technology and network innovation or communication and metering reinforcement, will drive tariffs eventually towards dynamic pricing mechanisms, where policy makers will be required to act.

The Costa Rica case reflects the approach and regulatory development for fast charging infrastructure pricing determination. (Box 11). In addition, further detail on the calculation methodology has been included in the Appendix 2 of the document.

Box 11. Costa Rica Case Study - Fast-Charging Infrastructure pricing

Following the previous regulation, the quartermaster of energy of the public services authority established the rules for the tariffs of the charging stations deployed. In the RE-0056-IE-2019, the quartermaster of energy establishes that it has no data regarding tariff calculation and sets a number of premises on the calculation of tariffs.

As such, a transitory tariff is calculated, while data is generated, under a number of premises, as follows:

"CALCULATION PROCEDURE FOR FAST CHARGING CENTERS RATE

The National Electric System (SEN) faces a deep transformation process, influenced by the impact of disruptive technologies, as is the case of the distributed generation, energy storage, smart grids electric mobility, internet of things among others.

In this context, it is necessary to have a flexible regulatory framework capable of adapting in a timely manner to the changes induced by this process of technological innovation, which is consistent with the public policy developed around the implementation of the sustainable development goals of the 2030 Agenda and the National Decarbonization Plan 2018-2050 dictated by the Executive Branch, instrument related to the National Development Plan and Public Investments (2018-2022) and the Strategic Plan for Costa Rica 2050.

In this regard, in compliance with the provisions established in Law 9518 of Incentives and Promotion for Electric Transportation and the Executive Decree 41642-MINAE, Regulations for the construction and operation of the electric charging centers for electric cars by the electric power distribution companies, the Regulatory Authority of the Public Services (ARESEP), in the exercise of its powers, presents the procedure for calculating and fixing the transitional fee for the first time applicable to the sale of electrical energy in fast charging centers.

Since the definition of this rate is intended to promote the use of electric vehicles, a single transitory rate is proposed for the entire country, providing a price signal lower than the cost of fuel and higher than the cost of burden at home, with the purpose of gradually influencing electric vehicle users' consumption habits, seeking the highest use of renewable energy and electrical infrastructure outside the hours of greatest demand. The previous, foreseeing that the network of fast recharging, given the increasing level of autonomy of electric vehicles, has been conceived as a security mechanism for users in order to facilitate access to electricity to deal with situations of emergency across the country.

In this regard, the Tariff Methodology corresponding to the electric power distribution service, according to resolution RJD-139-2015 does not establish a mechanism to define the rates that make up the rate structure of the distribution system provided by electricity companies.

Therefore, said calculation and application is carried out based on technical criteria and in accordance with the provisions of Law 7593 and its modifications.

STEP 4: Additional policies and regulations to enhance readiness for increasing electric mobility penetration

Policymakers can take action to enhance readiness and anticipate high levels of electric mobility needs.

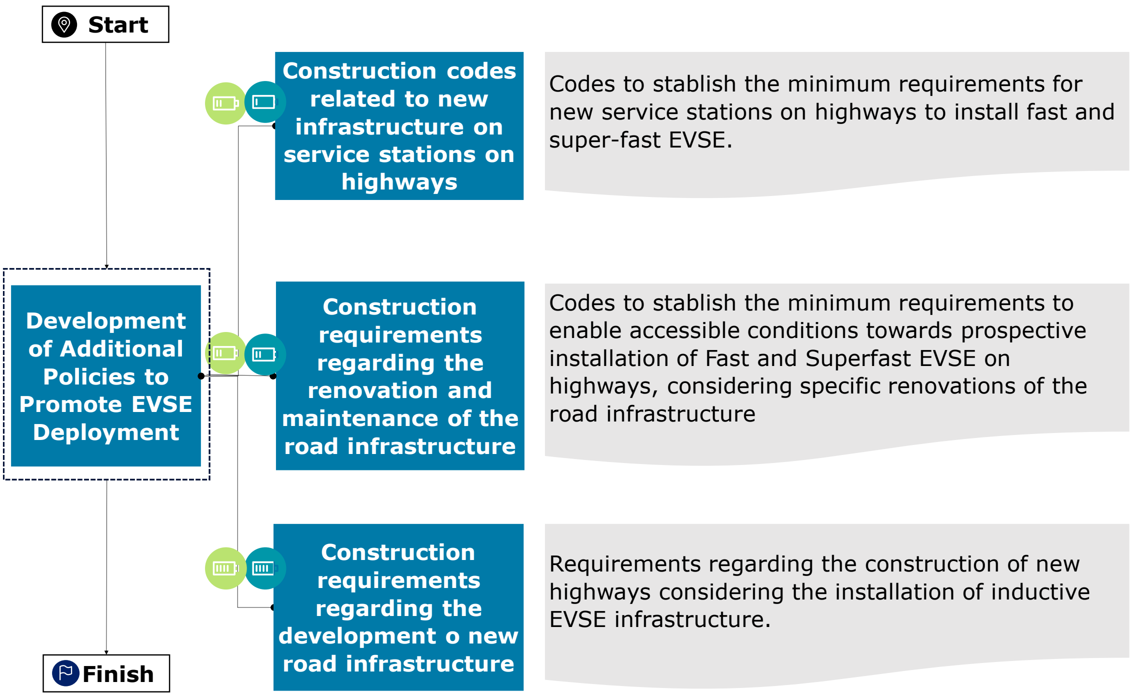


Figure 17: Long Distance Fast Charging Framework Decision Flowchart (Step 4)

The development and implementation of measures and regulations to enable medium and long-term needs for development aims to develop and action plan that will reduce the investments required.

This type of action is commonly defined within complementary activities, in order to take advantage and prepare for an increasing demand of charging infrastructure.

The following policies must be highlighted:

a) Construction and building codes related to new service station facilities on highways and road corridors.

   The establishment of requirements regarding the installation of a minimum number of charging points within the construction of new service station facilities.

   The requirements should consider:

   (1) Building regulations modifications if applicable, in order to include charging infrastructure requirements.

   (2) Definition of the number of charging points required to be installed. Differentiation amongst service stations should be considered. Therefore, specific and measurable criteria to define the minimum requirements must be established. For example, road transit indexes, ratio based on the number of pumps of the service station.

   (3) Construction control compliance procedures and monitoring.

b) Construction codes regarding new road infrastructure, as well as, renovation and maintenance of the road infrastructure.

   The purpose of these policies relies on taking advantage of intended construction projects to be realized, in order to, install in advance the required electrical equipment for future deployment of fast charging infrastructure to minimize investment costs.

These codes would establish the minimum requirements of electrical equipment to be installed alongside the road network.

On this end, these codes should include:

(1) Definition of what is considered as renovations and maintenance projects subject to comply with the codes. As an example, definition of major renovation works based on the surface area which will be modified.

(2) Definition of new road infrastructure subject to comply with the code, such as, road construction over a specific distance range.

(3) Definition of the technical requirements to be installed regarding the electrical equipment.

The previous is to be considered specially when considering the deployment of inductive charging infrastructure in the long-term.

Development of a fast charging infrastructure on an early stage of deployment through existing service station network.

Considering previous steps, in the following figure it is shown the decision flowchart for an early adopter focusing on the measures, policies and regulations necessary to be developed by policy makers in order to promote the deployment of charging infrastructure alongside road corridors.

It must be highlighted that within early stages, policy needs to aim to enable, facilitate and encourage stakeholders to engage on the further deployment of the fast charging infrastructure network.

On this end, the key steps to be taken on the decision-making process by regulators and public bodies within an initial stage of electric mobility adoption to ensure an initial roll-out of the required charging infrastructure rely on the following:

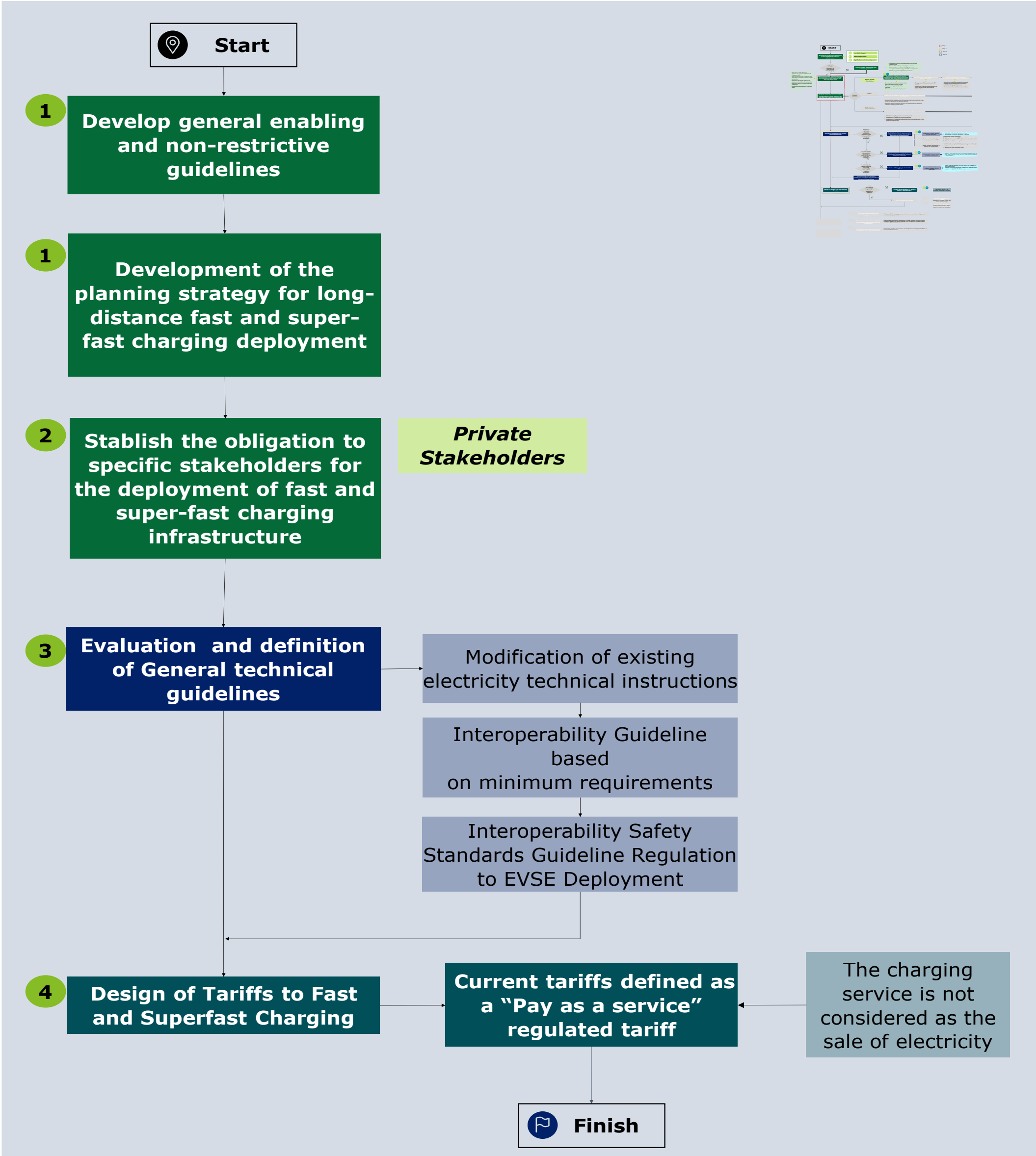


Figure 18: Early Stages Long Distance Fast Charging Framework Decision Flowchart

i. Definition of a general framework that defines the fast charging activity nature and stakeholder ecosystem possibilities. It is crucial that this framework considers the possibility of coexistence amongst stakeholders;

ii. Development of a planning strategy and definition of targets and goals to be achieved on the deployment of fast charging infrastructure on the national or regional road network;

iii. Development of a mandate policy to target specific stakeholders to an initial roll-out of the charging infrastructure. This mandate policy will require to be aligned with the planning strategy;

iv. Definition of technical and safety standards guidelines as minimum requirements;

v. Definition of the applicable tariff for fast charging services based on a service regulated tariff.

4- Electric vehicle standards roadmap

Electric mobility will radically change the way population understands mobility.

For instance, the refueling process for conventional vehicles is well established and is perceived as a simple action for users. However, charging an electric vehicle brings a number of difficulties as it increases time spent on the "refueling", there is less charging infrastructure and it can be expensive if not planned adequately, both at a national and local level.

As a result, in order to maintain operational benefits from electric vehicles, the deployment of the required charging infrastructure needs to cover the following issues:

- The charging infrastructure needs to be provided with sufficient power capacity for an adequate operation (especially when considering simultaneous charging).
- The regulatory framework for the operation of charging infrastructure may be insufficient in many countries, as the technology is still developing. This may raise financial viability questions regarding the development of a business case for its deployment.
- There is more than a single standard for vehicle charging. Moreover, a standard includes different plugs and concepts that can be overwhelming when first addressing electric mobility.

  Moreover, the deployment of standardized charging infrastructure needs to consider the current industry situation, and future trends, due to the technological disruptive process aimed to globally achieve generally accepted standards.
- Even though costs have decreased in the recent years, the installation of publicly available charging points is still expensive and cost recovery appears as a recurrent issue.

Therefore, this section covers the possible threats and difficulties inherent to the deployment of charging infrastructure, including the development of the key differences between the different standards.

In addition, the standards included within this section, reflect the current situation and the most commonly adopted standards worldwide. Nevertheless, the development and adoption of technical standards needs to consider dynamic evolution due to the technological disruptive process inherent to electric mobility. Technical standards of charging infrastructure will evolve along with the electric mobility technology development, not only in relation to electric vehicles technology, but also regarding the technology required for the integration with related industries, such as, the energy sector.

4.1- Charging modes for electric vehicles

Different solutions arise when considering the charging infrastructure required for the deployment of electric vehicles. Most common solution adopted is the plug-in charging. Nevertheless, other charging options have been developed, such as inductive charging, battery swapping and pantographs.

4.1.1- Plug-in charging

Plug-in charging is the most conventional charging method for an electric vehicle and consists on the connection of the electric vehicle to the electric grid through EVSE (Electric Vehicle Supply Equipment) or wiring. It is also known as conductive charging.

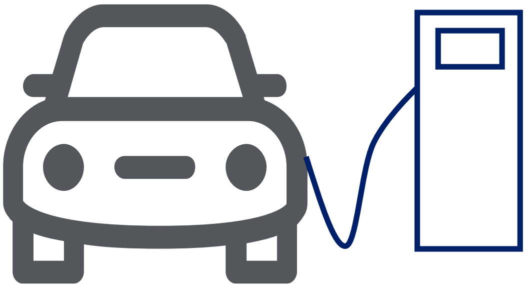


Figure 19: Schematic representation of plug-in charging.

Charging time will depend on the power injected in the electric vehicle.

Automakers have developed different plugs for conductive charging. In addition, international organizations have developed different standards that allow to charge a vehicle within safety conditions. Classification of plug-in charging usually distinguishes between Alternating Current charging and Direct Current charging and two classifications prevail amongst others:

- U.S. Terminology or SAE J1771: Levels 1, 2 and 3. For technical specifications refer to Figure 30.
- E.U. Terminology or IEC 61851-1: Mode 1, 2, 3 and 4. For technical specifications refer to Figure 30.

Efficiency of plug-in charging varies from 96% for slow charging to 94% for fast charging.

The main challenges of plug-in charging include the high charging time for slow charging (Alternating Current) and high costs for fast charging (Direct Current).

4.1.2- Inductive charging

Inductive charging represents a charging method where there is no physical connection. As such, inductive charging equipment can be above the ground or buried, allowing for energy transfer through concrete, asphalt, ice… This technology is also found on other applications such as mobile phone charging.

Efficiency of inductive charging arise to 91%.

Benefits of this technology include ease of use and reduced maintenance costs as it avoids careless handling of plug-in wires by intensive usage of people.

On the other side, it arises as an expensive technology compared to plug-in charging and needs additional hardware in order to enable bi-directional flows of electricity.

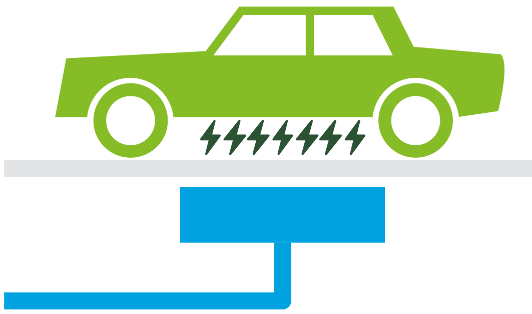


Figure 20: Schematic representation of inductive charging.

4.1.3- Battery swapping

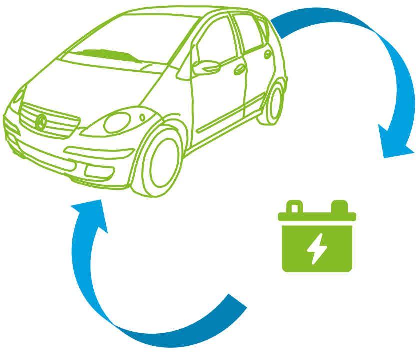


Figure 21: Schematic representation of battery swapping.

This charging method is based on the substitution of a used battery of an electric vehicle with a fully charged one.

As such, it represents a fast charging method, taking only from 2 to 5 minutes considering the entire charging method process.

However, it requires the ecosystem to have extra batteries which can be inefficient. As such, it is usually considered as a cost intensive system.

4.1.4- Pantographs

Nowadays, pantographs are very common for electric trains. Nevertheless, the technology is also applicable for electric vehicles, especially electric buses.

As a result, a number of business cases of deployed electric bus fleets are partially based on pantographs in order to enable charging at bus stops and reduce the range anxiety related to the reliability of electric public services.

As established in Figure 22, this charging method, allows to collect power from an overhead collector.

This technology allows buses to keep operating and mitigate battery consumption while on-road.

Electric bus fleets usually combine this charging method with plug-in charging, as developed in Section 5.1.4.

The key benefits and drawbacks regarding the different charging solutions described are detailed in Figure 24.

In addition, even though there are many solutions, this paper will focus in plug-in charging as it arises as the most commonly adopted charging solution.

Figure 22: Schematic representation of pantograph charging.

4.2- Main components of plug-in charging of an electric vehicle

Power income for electric vehicle charging is based on Direct Current, even though the national grid provides Alternating Current power.

Consequently, in order to provide the possibility to charge directly with the grid, electric vehicles usually have an on-board charger that converts power from Alternating Current to Direct Current to charge the battery, as shown in Figure 23:

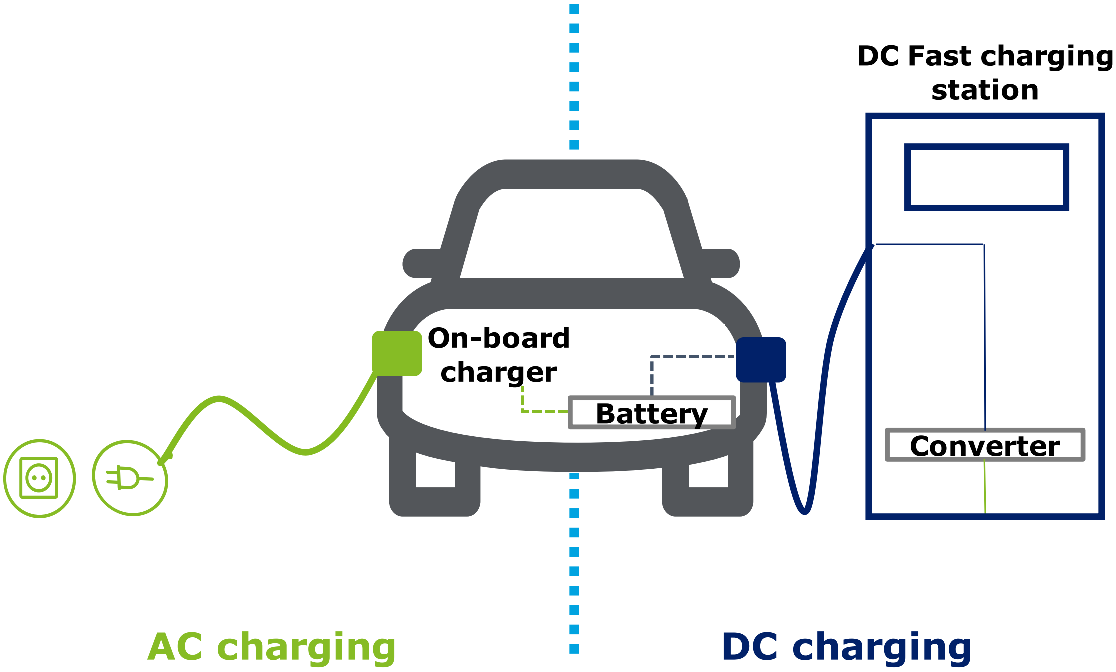


Figure 23: Schematic representation of electric vehicle charging through Alternating Current or Direct Current.

Alternating Current represents a slower option than Direct Current charging, due to physical limitations within the electric vehicle, considering that the on-board charger will limit the charging power maximum supply.

Electric vehicles charged with Alternating Current are usually connected to the national grid through two types of infrastructure:

Charging mode	Benefits	Drawbacks
Plug-in charging	**Slow charging (AC):** • High efficiency in charging, • Ease of installation, • Low installation costs, • Allows vehicle-to-everything solutions.	**Slow charging (AC):** • Up to 8 hours charging, • The electric grid may need to be adapted.
	Fast charging (DC): • High efficiency in charging, • Up to 20 minutes charging, • Allows vehicle-to-everything solutions.	**Fast charging (DC):** • Expensive, • Business models may not be profitable, • Adequation of the electric grid.
Inductive charging	• Ease of use. • Low maintenance costs as users are unable to deteriorate the infrastructure.	• Very expensive. • Existing standards limit the technology. • For vehicle-to-everything solutions, additional hardware is needed. • Adequation of the electric grid.
Battery swapping	• Ease of use. • The whole process operation takes between 2 to 5 minutes.	• Cost-intensive as it requires to have many batteries. • Management of batteries can be harsh, as state of charging needs to be carefully supervised. • It does not allow for vehicle-to-everything solutions by itself.
Pantographs	• Ease of use. • Allows electric vehicles to extend their range of autonomy. • Can be compatible with other charging solutions.	• Only feasible for electric buses. • Increases visual contamination. • It is not an efficient technology to fully charge vehicles. • Some solutions may difficult vehicle-to-everything management.

Figure 24: Main benefits and drawbacks of explained charging methods.

- Power outlets for slow charging (2-3 kW at maximum). This infrastructure is commonly deployed at private residential and workplaces locations and considering Alternating Current charging units have relatively low costs.

  It is important to highlight that there is a quasi-compatibility for the use of AC charging unit.

- Smart charging devices (up to 22 kW) allow to feed larger power inputs to the on-board charger, while allowing for remote control and activation, timetable programming (with future vehicle-to-grid solutions) and additional interoperability functions.

Direct Current, on the other side, needs conversion outside of the vehicle and is directly injected to the battery. As such, the conversion takes place in the charging points. As there are no physical limitations within the charging point space, it can feed larger power directly to the battery, thus providing with reduced time when charging an electric vehicle.

Contrary to Alternating Charging, Direct Charging offers no possibility for interoperation as charging units have different communication protocols and safety concepts.

As a result, all electric vehicles have an Alternating Charging input charger and most of them have a Direct Charging input charger as well.

4.3- Electric Vehicle Supply Equipment

Internationally speaking, the term Electric Vehicle Supply Equipment ("EVSE") is employed when referring to the "*off-board device that connects vehicle to the grid*" (Energy Research Institute, 2016).

The different components that are part of what is traditionally addressed by EVSE is detailed in Figure 25.

It is important to note that some of these components may be inexistent in some conductive charging solutions. As an example, the control device can be avoided in slow and uncontrolled charging.

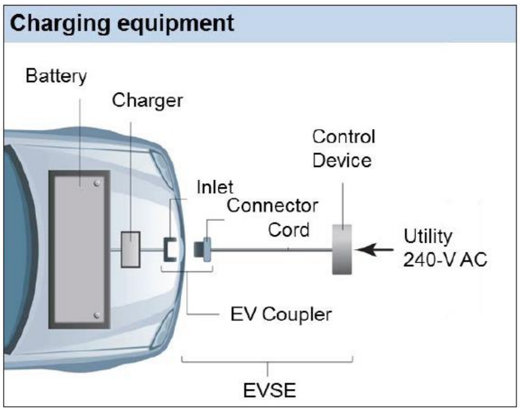


Figure 25: Schematic diagram of charging equipment, detailing the different components in the charging process (Energy Research Institute, 2016).

4.4- Plug and connector standards

In pursuance of electric vehicle deployment, automakers (Original Equipment Manufacturers – "OEM") have developed a number of different charging standards regarding their charging systems, resulting in a variety of plugs that are used worldwide. The detail of existing plugs worldwide, the technical requirements and their most common uses are described in Figure 30.

In addition, different stakeholders of the electric vehicle industry have developed technical communication standards regarding the communication between charging infrastructure and the electric vehicle in order to optimize the energy and data flow, amongst other technical aspects.

Amongst the organizations developing global charging standards, the following are included:

- Society of Automotive Engineers (SAE),
- International Electro technical Commission (IEC),
- Institute of Electrical and Electronics Engineers (IEEC),
- International Organization for Standardization (ISO),
- GuoBiao (GB).

Each of them have designed different norms regarding charging systems and electric vehicle appliance standards.

The definition of standards to ensure safety operation and boost solutions with the electric grid will allow to set base for charging infrastructure deployment.

4.4.1- SAE J1772

SAE J1772 covers the general physical, electrical, functional and performance requirements to facilitate conductive charging of EV/PHEV vehicles. The connector includes five pins:

- 3 pins for charging,
- A control pilot pin,
- Movement control pin, to avoid vehicle movement while charging.

This standard includes operational safety requirements, communication requirements, as well as, information regarding the plugs for both alternating current and direct current.

The SAE J1772 standard defines four charging levels in its October 2017 revision: 2 AC and 2 DC.

Alternating current – Level 1

It is the slowest charging speed, providing power with a 120 V AC plug and it does not need additional charging equipment installation for its operation.

All electric vehicles are equipped with an on-board Level 1 charger which can be plugged into an ordinary power outlet.

Level 1, depending on the vehicle and battery type, can add between 2 and 5 miles of range per hour of charging time.

Alternating current – Level 2

Alternating Current Level 2 provides charging through a 240 V (in residential buildings) and 208 V (in commercial locations) electrical service.

Although this charging option can operate up to 80 A and 19.2 kW, most residential level 2 equipment operates at a lower power: 30 A delivering 7.2 kW.

It requires the installation of additional charging equipment.

This level can add between 10 and 20 miles of range per hour of charging time, depending on the type of vehicle, battery and circuit capacity.

Direct Current Fast Charging (DCFC) - Level 3

Direct Current Fast Charging is able to provide charging through 208/480 V.

However, it needs further highly specialized equipment and may even need to adapt the electricity grid. As such, when installing this type of charging infrastructure, it is essential to develop a study that includes the power capacity of the electricity grid.

It can add between 60 and 80 miles to an electric vehicle in 20 minutes.

As this level enables fast charging, they are mostly suitable to be installed in heavy traffic corridors and charging stations in highways.

4.4.2- IEC 61851

The IEC 61851 standard covers the characteristics and operating conditions of charging infrastructure, connection between electric vehicles and the charging infrastructure, the requirements for electrical safety and digital communication regarding the charging infrastructure control mechanisms, both under AC and DC solutions.

More specifically, the standard IEC 61851-1 defines four modes of charging, considering the type of receiver, the level of voltage and the existence of a number of features: a protection device, dialogue between charging infrastructure and the electric vehicles, ground lines and control lines.

Mode 1 – Slow charging

Figure 26: Schematic diagram of Mode 1 under IEC 61851.

Under IEC 61851, mode 1 means charging at a regular 230 V socket (AC) without special safety systems.

Since this charging method lacks communication and therefore safety, the charging capacity is limited to a maximum of 3.7 kW (one-phase, 10 A).

Mode 2 – Normal charging

Mode 2 includes the charging from regular main sockets, but a special cable, In-Cable Control Box (ICCB), is required in order to control the power level and protect the user and the vehicle -mostly at a regular 230 V sockets or a charging station at home.

Figure 27: Schematic diagram of Mode 2 under IEC 61851.

Although the maximum charging capacity is 3.7 kW (1-phase, 10 A), a charging maximum capacity of 7.4 kW may also be deployed (1-phase, 32 A) either 22 kW (3-phase, 32 A).

Mode 3 – Semi-fast charging

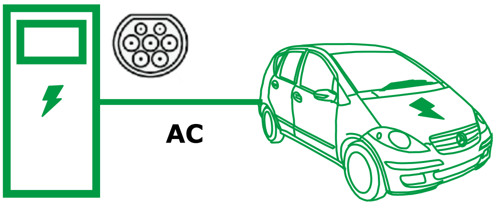


Figure 28: Schematic diagram of Mode 3 under IEC 61851.

Unlike, Mode 1 and 2, Mode 3 needs a specific charging equipment, guaranteeing a safe usage and enabling communication between the vehicle and the charging equipment.

It delivers in most cases 11 kW, 22 kW or even 43 kW (fast charging).

Mode 4 – Fast-charging

Contrarily to Mode 1, 2 and 3 where the AC/DC conversion takes place inside the vehicle, Mode 4 makes use of an AC/DC converter in the charging equipment, delivering directly DC power to the vehicle.

It is commonly used for fast charging power level starting at 50 kW.

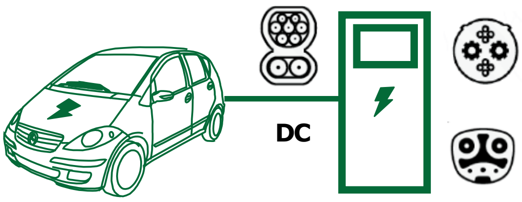


Figure 29: Schematic diagram of Mode 4 under IEC 61851.

4.4.3- Additional standards for charging plugs

CHAdeMO

The CHAdeMO standard is a widely extended DC charging standard formalized by Japanese manufacturers and Japanese power companies. In early 2010, it was the first and only DC charging option until the appearance of CCS (Combined Charging Systems) in 2012–2013.

This standard develops a charging protocol currently enabling Electric Vehicles charging with power from 6kW to 400kW with 900kW in preparation.

GuoBiao

The GB/T 20234 represents the Chinese charging standard. It supports both level 2 and level 3 AC, and may even support three-phase AC, and supports 250-volt and 400-volt DC.

The AC standard specifies the general requirements, functions definition, type structures, parameters and dimension of AC charging coupler for conductive charging of electric vehicles, of which the rated voltage shall not exceed 440 V (AC) and the rated current 63 A (AC).

The DC standard specifies the general requirements, functions definition, type structures, parameters and dimension of DC charging coupler for conductive charging of electric vehicles, of which the rated voltage and rated current are less than or equal to 750 V (DC) and 250 A (DC), respectively.

Tesla

Although Tesla is not a standard itself, it is compelling to mention when talking about electric vehicle charging infrastructure, as Tesla cars have a particular charging system, different to all standards mentioned before.

Tesla vehicles are compatible with other connector types but charge faster with Tesla connectors.

Tesla connectors accept all voltage inputs, so there’s no need of having a specific connector for DC fast charge, as the other standards require.

Only Tesla vehicles can use their DC Fast Chargers (Superchargers). Tesla installs and maintains DCFC stations that can only be used by Tesla’s users: even with an adapter cable, it would not be possible to charge a non-tesla EV at a Tesla Supercharger station.

4.5- Other standards related with electric vehicles

Additionally, other standards have been developed for the standardization of communication protocols, charging topologies, accessory compatibility and safety issues.

The most relevant standards are listed hereafter:

- Communication protocols:
    - SAE – J2847/x,
    - SAE J-2931/x,
    - IEC 61850-x,
    - IEC 61851-24,
    - ISO/IEC 15118,
    - IEEE 80211P.

  This group of standards include interoperability requirements for electric vehicles with DC charging stations, including the design of communication flows and its safety. Some of them develop as well electric vehicle and grid requirements for the development of vehicle-to-grid solutions.

  Digital communication between vehicles, EVSE, the utility or service provider, interfaces with customers and much more are also included within these standards.

- Charging topology:
    - IEC 61439-7,
    - IEC 61851-1,
    - IEC 61851-21,
    - IEC 61851-22,
    - IEC 61851-23,
    - IEC 61980,
    - SAE J2836/x,
    - IEEE 1901/.2,
    - IEEE P1547/.1/.2/.3,
    - IEEE P2030/.1/.2/.3.

  These standards define plugs for electric vehicle conductive charging, switchgear and control-gear assemblies for the installation of charging points.

  Some of these standards include as well interconnection standards and test for interconnection operation and certification.

- Accessory compatibility:
    - IEC 62196-1,
    - IEC 62196-2,
    - IEC 62196-3,
    - SAE-J1771.

  These standards define the architecture of conductive charging systems for electric vehicles, including operational functional and dimensional requirements for the vehicle inlet and its mating connector.

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

Figure 30: Classification of the main types of chargers

- Safety issues:
  - IEC 60529
  - IEC 60364-7-722,
  - ISO 6469-3,
  - ISO 17409,
  - SAE J1766,
  - SAE J2344,
  - SAE J2380,
  - SAE J2464,
  - SAE J2578,
  - SAE J2929.

  These standards define the safety procedures for operating electric components in different locations and tests for electric vehicle batteries and its safety.

When regulating and defining the concepts around electric mobility, policy makers need to address the standards required to be developed and norms, in order to be prepared for a technical definition of the different procedures around charging infrastructure, including their equipment.

In addition, the development of guidelines regarding end-to-end users' experience are critical, including guidelines related to the management and standardization of economic flows, as well as, the development of technical solutions to enable the provision of information for users.

The development of an accessible service experience contributes to an increasing engagement from users towards the adoption of electric mobility. On this end the standardization of the payment services within the charging infrastructure system in the region plays a critical role, especially considering the existence of multi-service provider environment.

The definition of the management of the economic flows and payment processes will impact on:

(i) Accessibility of the users to the charging services. The definition of a standardized economic flow and payment service within the charging infrastructure system contributes to simplifying the service experience for users.

(ii) The definition of the communication systems to be implemented.

Standardization of payment systems and interfaces, as well as the management procedures of the economic flows from charging services, is also required to ensure the development of information security guidelines, such as, cybersecurity and privacy guidelines.

It must be highlighted that different approaches can be considered in the development of standardized payment processes depending on the stakeholder structure of the charging infrastructure system:

(i) Single-stakeholder approach the requirements for standardization are required to ensure the service deployment throughout the system is interoperable. Multimodal payment systems need to be developed to achieve a higher user experience.

(ii) Multi-stakeholder approach: a more complex environment where the need for standardization is higher to overcome the perceived obstacles for charging from users. Not only standardization is required on payment processes and multimodal payment options, but also amongst options provided by the different service providers ("cross-operator accessible").

On this end, guidelines to define and manage payment services, should consider a multimodal payment system approach. Common practices within the different payment methods for users include:

(i) Contracts and User arrangements with charging service providers to enable pay as you go services. This type of payment services would include different payment modes, both pre-paid mechanisms based on fixed rates, or arrangements based on used services.

    This type of payment services will require the development of payment and invoicing guidelines, when considering a multi-operator environment, in order to avoid the complexity for users due to the existence of different charging operators, as well as, to define the options for users to use the charging infrastructure from a different service provider.

(ii) Payment through the charging infrastructure. The development of common platforms throughout the charging infrastructure system, independent of the service provider will reduce complexity on access for users. However, there is the need to develop guidelines and requirements regarding the payment mechanisms within the charging infrastructure service and use for users.

On this end, when developing the required charging infrastructure system, guidelines are required to adequately achieve cooperation between charging infrastructure operators and charging service providers in order to reduce the market system complexity.

The development of common payment platforms amongst the different service providers and charging operators, will enhance access for users and promote interoperability.

Consideration must be set when including involvement of Utilities' within the provision of charging services, as to the development of payment and invoicing of services through additional options, such as the electricity bill.

It must be highlighted, when considering private charging infrastructure deployment, additional procedures and guidelines are required for the development of payment and invoicing mechanisms to incorporate an integrated service considering smart charging solutions.

In addition to the development of guidelines to define an interoperable user experience, the creation of publicly available information databases for users contributes to enhancing users' access to the charging infrastructure system. Commonly, public and private stakeholders' involvement is required in the development of an interoperable charging information system.

On this end, it is required to set the guidelines of the charging infrastructure requirements towards ensuring data collection for users, as well as, the information procedures to report and update information amongst stakeholders.

5- Existing business models around charging infrastructure for electric vehicles

5.1- Charging infrastructure value chain and main agents

5.1.1- Main concepts

When developing a public policy regarding the rollout of charging infrastructure at a national level, it is very relevant to consider and understand the different locations for the deployment of charging infrastructure. In addition, the roles that private companies or public organizations have in the deployment of charging infrastructure is key in order to address the development of the regulatory needs to ensure the well-functioning of the electric vehicle charging system.

On this end, Governments decisions in order to define the path towards the deployment and development of the national charging infrastructure system is critical.

Different options arise for Governments and Regulators when taking the first steps in the development of the necessary framework for the charging infrastructure system. Commonly, these frameworks set the basis on the rules for stakeholders and their involvement throughout the process.

The most common charging infrastructure frameworks developed by the public authorities include:

i) Mandatory approach: Governments and Public Authorities establish the charging infrastructure approach based on mandates which set the requirements for stakeholders to develop charging infrastructure within their activities.

   Commonly, mandate policies are developed regarding the obligation to install charging infrastructure within conventional activities, such as, petrol stations or parking spaces.

ii) Private initiative approaches: private stakeholders take the lead within the deployment and operation of the charging infrastructure system. In addition, under this approach, the stakeholder structure is a key driver in the development of guidelines and policies in order to address relations amongst stakeholders in the value chain.

iii) Approach regarding the involvement of the Utilities Companies. Different solutions arise in the definition of the scope of the utilities role in the charging infrastructure system:

   a. Frameworks developed in order to define the Utilities activity as independent providers of charging infrastructure services.

   b. Frameworks developed to define the scope of the activity as Last Resource Providers. Utilities are enabled to develop and deploy charging infrastructure where no action from stakeholders is being taken, in order to ensure that users' needs are satisfied.

These different approaches can be combined by public authorities in order to promote the deployment of charging infrastructure within the different stages of development of charging infrastructure, as well as, the evolution on the shares of electric mobility penetration.

On this end, the adoption of an approach towards the development of the charging infrastructure needs to take into consideration:

i) Electric mobility penetration and demand needs for publicly available charging infrastructure.
ii) Stage of the charging infrastructure ecosystem development.

In addition, **it must be highlighted that the adoption of an approach should not be considered as static or permanent, but this should evolve as the electric mobility ecosystem develops**. Different approaches commonly co-exist within the different stages.

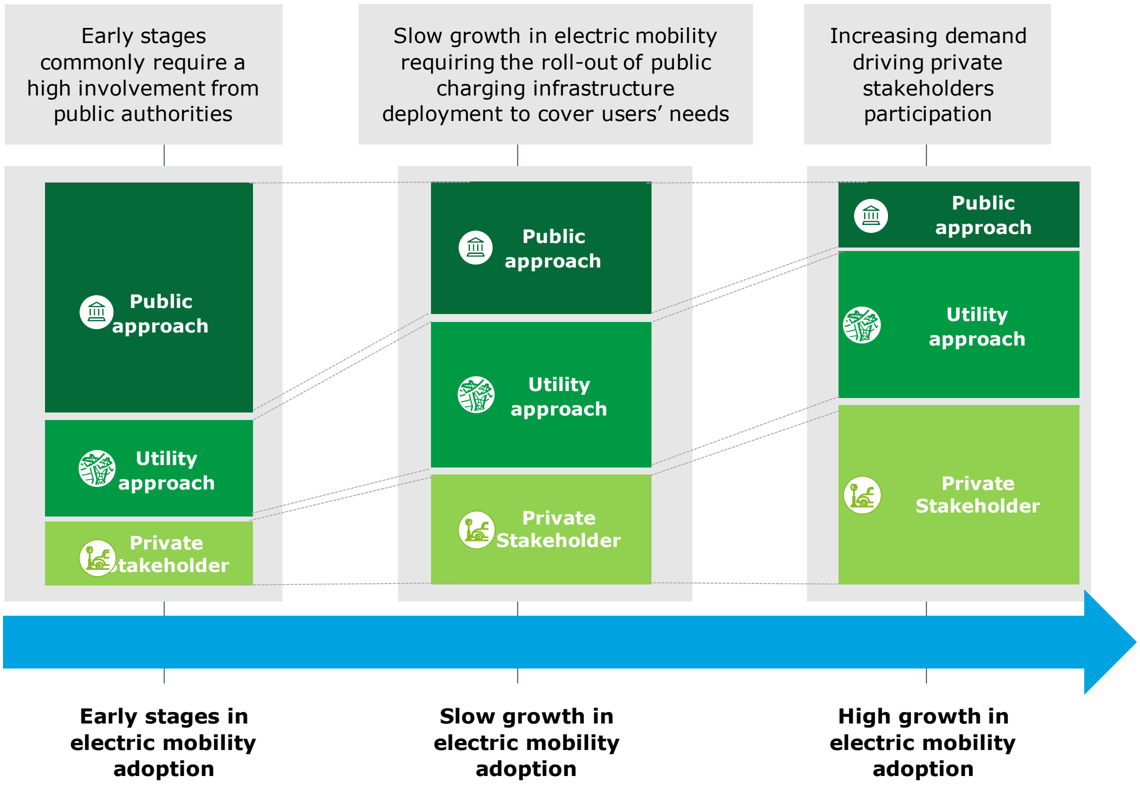


Figure 31: Illustrative example of approach coexistence.

Early stages of electric mobility adoption commonly require the adoption of mandatory approaches regarding the initial roll out of publicly available infrastructure. It is common to stablish mandates or policies which are aimed to ensure an initial roll out, combined with:

i) The need on early stages of public initiatives and support to promote charging infrastructure roll out.

   Considerations on this stage to an approach that includes public-private partnerships to promote initial roll-out.

ii) Initial roll out of charging infrastructure by public authorities.

iii) Mandates to stablish a requirement to install charging infrastructure to specific stakeholders.

iv) Mandates regarding the designations of the stakeholders in charge of the initial roll-out plan of publicly available charging infrastructure.

Within the initial stages, designation of both stakeholders in related industries, as well as, utilities are considered. This type of approaches aims to ensure the deployment of the charging infrastructure under a scenario where the private initiative is still reluctant to enter the business.

<table>
<tr><th>Type</th><th>Location</th><th>Vehicles affected</th><th>Less aggressive target</th><th colspan="2">Most aggressive target</th></tr>
<tr><td>Private</td><td>Private garage</td><td>Electric vehicles with private garages</td><td colspan="3">90% of purchasers</td></tr>
<tr><td>Curbside</td><td>Urban streets
Public car parks</td><td>Electric vehicles without private garages</td><td>1 connection per 100 vehicles</td><td rowspan="2">1 connector per 10 vehicles</td><td>1 connection per 2-3 vehicles</td></tr>
<tr><td>Charging station</td><td>Commercial areas
Urban charging stations
Roads</td><td>All electric vehicles</td><td>1 connection per 500 vehicles</td><td>Maximum number of profitable rapid stations</td></tr>
<tr><td>Fleets</td><td>Carsharing fleets
Public transport</td><td>Bus fleets and other electric vehicle fleets</td><td>• 1 connector per 10 fleet-based vehicles
• 2 connectors per electric urban bus route</td><td colspan="2">1 connector per 3 electric buses or electric vehicle fleet</td></tr>
</table>

Figure 32: National targets worldwide.

Considering **a stage of increase on the electric mobility penetration shares, the charging infrastructure ecosystem tends to evolve, considering an increase on the interest for the private stakeholder participation**.

Under this scenario mandatory approaches are also considered in order to ensure the deployment of the required charging infrastructure to fulfil users' needs:

(i) Mandates or policies regarding the designation of stablished stakeholders to cover the deployment of charging infrastructure where no private participation is involved.

Utilities can be considered as last resource stakeholders on this stage.

(ii) Mandates and policies regarding the requirements of new activities, as building codes and the need to include the charging infrastructure on new construction developments.

In addition, the utility model approach under an increasing adoption of electric mobility can be combined, considering the coexistence with initial stages of private stakeholders' participation.

It is common that the utilities participation dilutes, but not disappears, as the private participation on the deployment of charging infrastructure increases.

A combined framework is commonly developed within national policies. In addition, the charging infrastructure framework will define the different business models that may arise within the value chain of the charging infrastructure and therefore include additional regulatory needs to ensure the well-functioning of the activity.

Within this section, best practices have been included in order to illustrate the different business models around the charging infrastructure system deployment.

In addition to the development of the general framework, Governments and Public Authorities commonly include within their national strategies, specific targets for the development and deployment of charging infrastructure, to promote and support electric mobility penetration.

It must be highlighted that these targets are commonly set aligned with the electric vehicle share penetration throughout a planned time horizon. Therefore, strategies regarding charging infrastructure deployment are commonly phased out considering the different types of use of charging infrastructure, private and public, developing specific policies and required additional measures.

These policies and measures are aimed to:

(i) Set the rules and guidelines for the different stakeholder's activity performance.
(ii) Set public actions to promote and incentivize the deployment of charging infrastructure.

On this end, the strategy of implementation, the development of regulatory needs and the charging infrastructure deployment targets will vary considering the following categories:

1. **Privately accessible chargers**

- Private: charging infrastructure developed by private users for their own use. These charging points are usually developed within private residential locations and tend to be slow chargers (up to 22 kW). Charging for everyday needs should take between 6 to 8 hours.

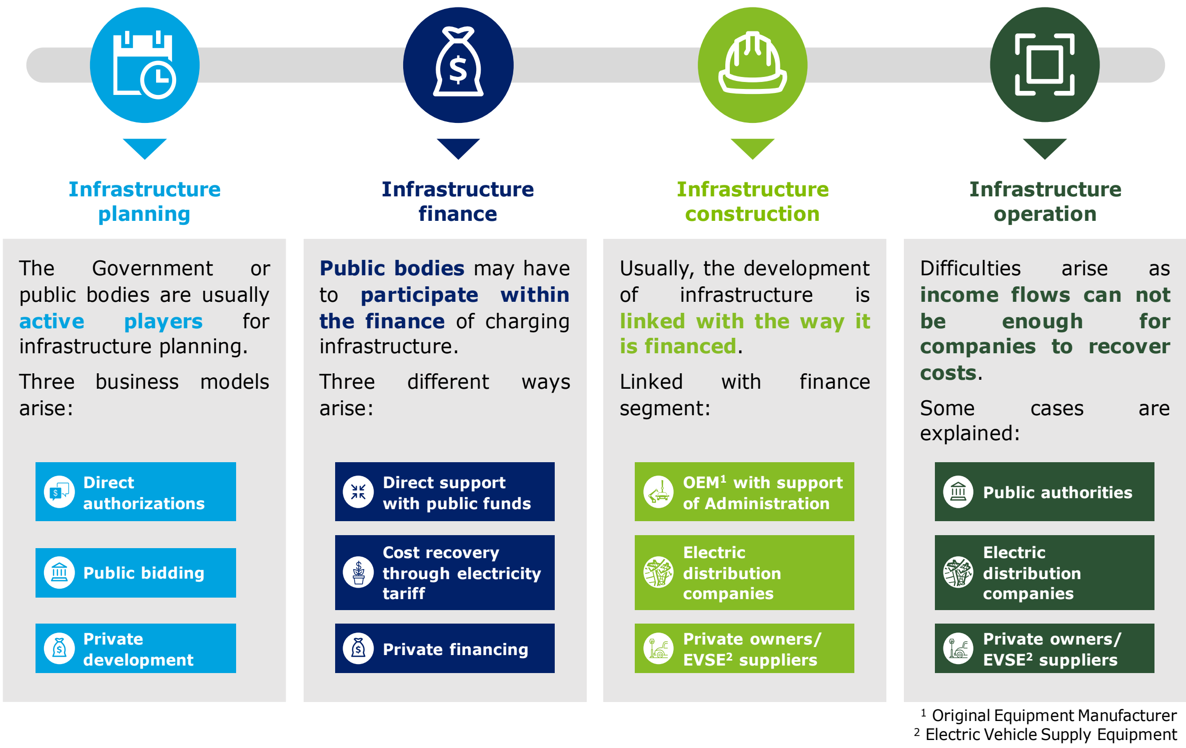


Figure 33: Visual representation of different options for each step of the value chain of public charging points.

2. **Publicly available chargers**

- Curbside: charging points developed in the curbside include the development in urban streets or centers and public locations. They usually have two connectors, normal and semi-rapid, combining AC and DC charging. Charging times can be reduced up to 3 to 4 hours.

  Curbside charging infrastructure allows electric vehicle users to charge their car for their daily journeys and for those cars parked in the streets (and therefore users that may not own a private charging point). However, it is crucial to make these charging points available for users as curbside charging points are a first step for the initial mass deployment of electric mobility.

- Charging stations: this include charging points developed in commercial areas, such as plazas or shopping areas, urban charging stations and charging points developed in road. Stations usually have four connectors, allowing for two vehicles to charge at the same time. They usually combine AC and DC charging, including semi-fast charging (3 to 4 hours) and fast-charging (20 minutes for 80% battery charging) solutions.

- Fleets: electric fleets usually include buses, taxis, shared-services fleets and first-response fleets. Different charging technologies can be employed for charging. Furthermore, electric bus fleets can combine conductive charging with pantographs.

When considering public goals throughout different countries, targets for the development of each category are considered. As such, Figure 32 reflects a less aggressive scenario and a most aggressive scenario considering existing national targets and which have been established in countries that have developed electric mobility charging infrastructure such as Europe, China and the United States.

Targets are set considering the expected electric mobility penetration shares to be achieved, as well as, the required the deployment of the charging infrastructure to fulfil the users' needs. Under his targets, measures and policies are required to be developed, and differentiated amongst the different types of charging infrastructure.

Deployment of private charging infrastructure, which will be dependent on the user's decision, will require of policies and regulations to ensure interoperability with energy network, as well as, regulations to stablish the requirements for the construction and operation, including safety procedures.

However, even though considering an extensive deployment of private charging infrastructure, the need to develop a publicly available charging system is a must which shall consider the requirements in extent of the countries' range and the users mobility patterns, to ensure the deployment of an adequate charging system.

Moreover, solutions arise when combining policies regarding curbside and charging stations deployment, as both are publicly available charging points, for the use of private fleets and are essential to ensure mass deployment of electric vehicles.

This initial deployment of publicly available infrastructure must be synchronized with electric mobility penetration. On this end, specific prioritization is required to be stablished in order to ensure an aligned charging infrastructure deployment. Prioritization is commonly addressed considering the following:

- First, deployment in urban areas is targeted, including urban and suburban environments (i.e. large cities, high-density population areas, highly visited areas, etc.) as a high share of the population commutes daily within these areas.

- Highways represent a deployment priority to install charging infrastructure as they connect urban areas. For initial deployment 50 to 100 km distance between charging points has been considered a reasonable ratio.

5.1.2- Private charging points

Even though private charging points will have large numbers, its implementation will not determine the success of electric mobility penetration within a country, as only 1 to 3 electric vehicles will benefit from it. As such, a good measure to increase the development of private charging infrastructure relies on measures to subsidize its acquisition and implementation.

In the United States, average costs for private users' are around $510-$540 per electric vehicle sold and around 38% of electric vehicle owners will need to upgrade their in-home electric grid, increasing the average cost to $1,400 (Nicholas, 2019).

5.1.3- Public charging points

Value chain for public charging posts

Publicly available charging infrastructure reduces one of the negative effects considered by the users, for electric mobility adoption: "range anxiety" as it allows users to charge their vehicles similar to conventional vehicles fueling needs. As their implementation is necessary for any economy seeking to develop electric mobility, business models for publicly available charging points need arise, and therefore the need to develop regulatory guidelines to ensure the correct operation and activity performance.

Public charging infrastructure development models need to address the main stages for charging availability regarding electric mobility penetration, including: (i) planning, (ii) investment and financing, (iii) installation and ownership and (iv) management and operation.

The definition of the involvement of the different stakeholders within the infrastructure deployment main stages needs to be developed to allow charging station availability.

Stages can be addressed differently or even combined, depending on the needs of each nation or region:

1. Infrastructure planning

The Government usually takes the lead on planning the deployment of charging infrastructure by one of the two following ways:

- Direct authorizations: assigning another agent for the deployment.
- Public bidding: establishing public tenders for the construction, conditioning of the area and connecting to the electric grid. Public bidding can include the operation of the charging points. Drivers for the selection of the best offering, can be based on cost, projected tariff for sale or other considered drivers.
- Public deployment: the Government or public authorities can participate in the deployment of charging infrastructure.

In any case, in order to select the different locations for the deployment of charging points, traffic analysis must be conveyed. Points of interest, such as tourism attractions, shopping centers and commercial areas tend to be optimal locations, but on-street planning is also a necessity.

Moreover, the regulatory framework can also allow for private companies to deploy charging infrastructure. Planning deployment for these companies should be market driven.

2. Infrastructure finance

Three main options arise regarding the financing mechanisms aimed to support the deployment of charging infrastructure:

- Direct support from the Government or public authorities with public funds.
- Allowing cost recovery through the electricity retail tariff. This mechanism requires the development of a new tariff segment for electric vehicle public charging towards allocating adequately costs to the users', as otherwise the subsidy would not be correctly allocated (as an example, a low-income family could pay through their household tariff a part of the charging infrastructure grid without owning an electric vehicle).
- Private financing.

3. Infrastructure construction and installation

Usually, the development of infrastructure is linked with the way it is financed, reducing the possibilities for stakeholders to start with the construction of charging infrastructure:

- Original Equipment Manufacturers (OEM) with support of the Administration or the Government;
- Power companies;
- Private owners or EVSE suppliers.

4. Infrastructure operation

Difficulties arise as income flows may not be enough for companies to recover costs for the deployment of charging infrastructure.

Different business strategies arise within the infrastructure operation:

- Power companies can recover operation costs through the design and development of a specific tariff. Within the design of this tariff, costs must be transparent and address the cost allocation.
- Some private agents that have developed charging infrastructure, such as shopping malls or public parking may offer the service for free, as they can recover the cost by providing their normal services.
- EVSE suppliers can establish fees per use or monthly plans for unlimited use of their infrastructure. A combination of both solutions is also possible, reducing the consumption term with a monthly package. The prices for EVSE suppliers are usually market-driven but also requires the definition of requirements by a regulatory commission.
- Established prices (or free-of-charge) by the public authority in charge.

5. Business models

As a result, Figure 34 establishes three main business models that details different development possibilities regarding the deployment of a charging infrastructure system, considering the different phases of the value chain, as described previously.

Resulting business models

1. Public model

Usually when business cases of publicly available charging infrastructure are not profitable, the Public Administration takes the lead (generally at a local level).

International best practices regarding the development of public business models include the Netherlands (with the municipal councils of Amsterdam as star cases), Norway (mainly Oslo) and France (especially in the main cities).

In most of the cases, even though public authorities take the lead, specific phases in the deployment of charging infrastructure are outsourced to private companies attending to the expertise and knowledge.

2. Utility model

Giving the responsibility to a public utility to plan, finance and deploy EVSE has a number of benefits:

- Initial deployment of EVSE is guaranteed;
- Cost control through investment plans;
- Tariff can be set in advance in order to achieve competitive costs;
- Existence of control mechanisms for on-time and cost accordance with plan.

However, for an optimal performance a number of considerations should be included in the energy regulatory framework:

- There should be a specific tariff for electric vehicle charging as an increase in the general consumption tariff represents a bad allocation of costs (a cost increase directly allocated to the general consumption tariff will make low income population that does not own an electric vehicle pay for the charging infrastructure). This tariff could be established both on a per use tariff or with a fix charge.

- Unbundling the activity related to the development and operation of the charging infrastructure is considered in order to establish a better cost control for the energy price and the premium for charging infrastructure deployment and operation.

Operation, on the other side, might be outsourced to a third-party company or company of the same group.

International best practices include the state of California and Ireland.

3. Integrated charging provider

Under this business model private developers lead the deployment of charging infrastructure. Agents that take the lead usually include charging infrastructure suppliers, vehicle manufacturers or companies in the tertiary sector (hotels, shops, etc.).

These agents or companies commonly develop the infrastructure if they perceive they can achieve a certain benefit or as an additional service (value added service in their business model).

Incentives or aids for the development usually allow to foster the deployment under this case as private companies can access to financing support mechanisms and therefore are incentivized to increase the development of charging infrastructure.

The main challenge of this business case is usually cost recovery through future revenue flows.

Under cost recovery challenges, the business models will vary and evolve considering the electric mobility development within the country, as well as within the different policy scenarios.

On this end, the utility model provides advantages regarding cost recovery of the charging infrastructure investments and operation costs regarding public available charging infrastructure through tariff design and cost allocation mechanisms. This approach is considered as an option to overcome the challenges for initial roll out of public charging infrastructure, specially where private stakeholders participation does not extend to initiatives and investments that are not financially viable through charging fees, such as in the deployment of charging infrastructure for long distance ranges.

This alternative offers a solution for nations that are willing to develop this infrastructure but are unable to do under public budget. It offers a solution for a quick development charged indirectly to users. Nevertheless, this business model needs to have a number of rules set in advance, such as the tariff allocation, form and cost.

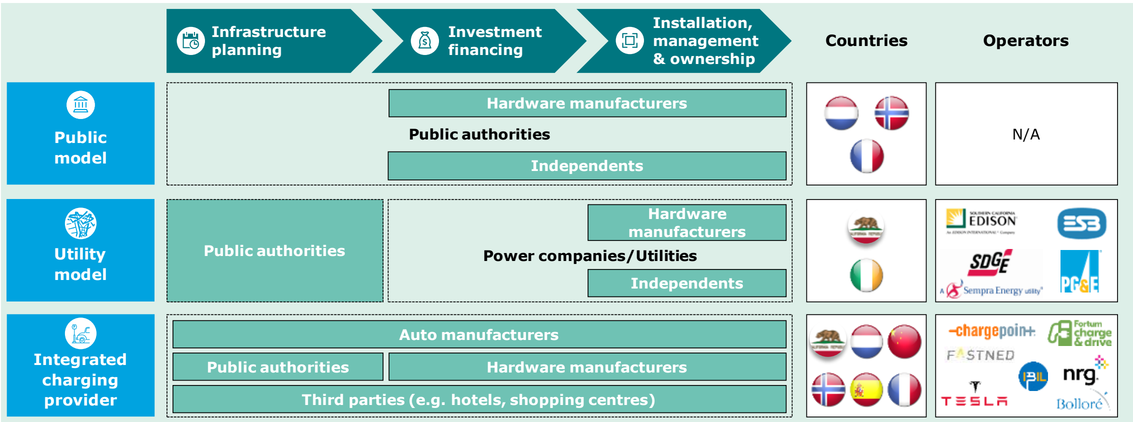


Figure 34: Business models for electric vehicles.

5.1.4- Charging models for fleets

When operating an electric vehicle fleet, business models tend to focus around two main categories.

Electric car fleets

Fleets of electric cars are usually privately owned. As an example, taxi fleets or car-sharing fleets are best examples under this category.

This type of fleets can have large parking spots with several charging points available to charge the vehicles mostly overnight, also called "depot charging".

However, it is important to consider charging management. An unmanaged charging of the fleet charging infrastructure will increase the consumption peak, and thus the electricity bill. This procedure would most likely increase the unitary cost of operation. Therefore, companies running electric fleets should develop procedures to manage the load of their electric vehicles.

Managed charging infrastructure deployment needs smart charging devices that are more expensive to acquire than normal connection to the power outlet.

Thus, even though operational savings can be reduced by an uncontrolled charging, controlled charging will allow to increase these savings and possibly generate an additional revenue stream from vehicle-to-grid solutions.

In order to increase fleet-owners awareness, communication programs, including conferences and promoting public events, in order to make stakeholders aware of the benefits of controlled charging, are required.

Electric bus fleets

Electric buses

Even though, the market maturity level of electric buses is not as high as the maturity level for electric cars, some business models are already successful.

Charging solutions for electric buses

Overall, there are two main solutions for electric bus fleet charging:

- <u>Charging along the route or "opportunity charging"</u>: under this solution, electric buses are charged occasionally, along their transit route. When charging along the route, two solutions can be used: pantographs or induction charging, both described in section 2 of the present document.

  As such, pantographs and/or induction charging points must be planned and developed along the route as it is the only way buses will be able to benefit from charging.

  These charging mode comes with a number of drawbacks, as there is increased visual and noise pollution, difficulty to be deployed within urban centers, loss of flexibility within bus routes, complexity of connecting to the grid in every point, complex management of the charging points and operating benefits, such as vehicle-to-grid are highly reduced.

- <u>Charging in hubs or parking lots or "depot charging"</u>: electric buses are grouped in charging hubs at depots or parking facilities. As such, the company is able to easily manage their state of charge. Moreover, this solution allows for controlled charging, highly reducing operation costs.

  Under this solution, slow, semi-fast or fast chargers can be employed. However, slow and semi-fast solutions result optimal in order to allow for vehicle-to-grid solutions.

  This solution still has some major drawbacks as well. For instance, battery sizes are still insufficient, batteries in actual models are very heavy, reducing top speed of buses and batteries lose capacity over time (around 20% of their capacity in 5 years). Last, hubs must be located where the electric grid can bring enough power to the charging hub which might increase complexity in the deployment of this solution, as well as, considering the need for buses to travel to the recharging point, which could be temporarily out of service.

As a result, some business model includes both solutions, providing full charging at night by "depot charging" and on route charging by "opportunity charging", mainly pantographs due to the lower required costs when compared to induction charging.

5.2- Benchmark: Public model

5.2.1- Public model 1: Norway

Norway stands out as an international reference regarding the adoption of a public business model. As such, Norway is currently accountable for 12,365 charging points of which 11,041 are publicly available (The Embassy of the Kingdom of the Netherlands in Norway, 2019).

Access to public grants are similar for normal and fast charging, with some differences:

- Regarding normal charging, different areas along the road network appear where operators compete for public funding. All these stations are owned and/or operated by charging operators.
- On the other hand, in reference to fast charging deployment, ENOVA, a publicly owned company, has supported the deployment of around 230 fast chargers.

Additionally, two main companies own the majority of the stations: Fortum Charge & Drive and Grønn Kontakt. Recent trends show that FC operators are installing stations without public support.

ENOVA is a government-owned company that contributes to the reduction of greenhouse gas emissions, development of environmentally friendly energy production and consumption, development of climate technology and enhancement of security of supply.

Regarding a recent case, ENOVA sought to develop charging infrastructure in the so called Finnmark (the north of Finland). Due to extremely cold temperatures, the Finnmark represents an area where population spends the highest share of their salaries on fossil fuels (Nielsen, 2020). As such, ENOVA announced a competition where they found 100% of the approved investment costs for the deployment of charging infrastructure in 11 sites. Each location must include the following technical specifications (Enova, 2020):

- Two DC combo charging contacts (CCS) with a minimum 150 kW power,
- Two DC CHAdeMO charging contacts with a minimum 50 kW power,
- Two AC charging chargers with a minimum 22 kW power.

In order to allocate this competition, ENOVA establishes that the grant will be allocated to the most price competitive company that covers the minimal technical requirements established. Moreover, only companies registered in Norway are able to access to the grant.

Once the company has deployed the charging infrastructure, it has the right to operate it.

Fortum Charge & Drive and Grønn Kontakt provides customer a specific payment mode where the user pays per minute and not by kWh consumed: 2.50 NOK/minute (0.26 USD/minute). The per minute charge is independent of kWh consumed by the vehicle and provide an incentive for an efficient use of the public charging infrastructure, leaving free the charging infrastructure as charging in the street is expensive compared to home-charging (around 1 NOK/minute or 0.11 USD/minute).

Moreover, Norway has established different policies based on tax and fiscal incentives, to both EV and charging infrastructure Main incentives for the development of charging infrastructure are:

Normal charging infrastructure incentives:

- In 2009-2010, ENOVA developed a support scheme for public charging infrastructure that funded 100% of the installation costs of household charging infrastructure. The maximum support amounted to 30 thousand NOK (around 3,000 USD) and total subsidies arised to 50 million NOK (around 5 million USD) for 1,800 new household sockets (schuko-points) (National Transport Plan).

  However, as Schuko-points have less than 3.7 kW of power, they have been proved as not ideally suited for the long term and type 2 connectors were developed.

- In 2016, the Norwegian Ministry of Transport developed a regulation to require the development of charging infrastructure in new building and parking lots. As such, 6% of places need to be allocated for electric vehicles.

- The City of Oslo has a budget allocated for EVSE deployment that allocates to housing associations. In 2017 the budget amounted up to 10 million NOK (around 1 million USD) and 20 million NOK in 2018 (around 2 million NOK).

Fast charging infrastructure incentives:

- From 2010 to 2014, Norway established support to fund 100% of installation costs of fast charging infrastructure (not operational costs though) subject to payment solutions for users before the operation of the charging infrastructure (National Transport Plan).

There is public funding to deploy fast charging stations every 50 kilometers on public roads (National Transport Plan).

5.2.2- Public model 2: The Netherlands

The Netherlands have a total number of 32,000 public stations (Nederland Elektrisch, 2020).

In 2009, a number of cities in the Netherlands teamed up in order to bring a "snowball" effect in the deployment of charging infrastructure.

After that, the Government of the Netherlands developed an action plan called *Elektrisch Rijden in de Versnelling 2011-2015* ('Electric Mobility steps up a gear'), establishing a number of incentives on the rollout of charging infrastructure.

Regarding this deployment, the Netherlands have mainly relied on ElaadNL and EVnetNL for the deployment of more than 3,000 pubic charging stations.

ElaadNL (a partnership company that consists on the united grid operators managing the Dutch grid of electricity and gas) leads the coordination regarding the connection of the public charging stations to the grid. In 2014, ElaadNL gave the responsibility for the management and operation of charging infrastructure to EVnetNL, also a partnership company under the same conditions, in cooperation with the main municipalities.

Charging infrastructure development is assigned through tenders developed by ElaadNL, serving as connection between electric mobility and the power system.

Tenders are based on (i) safety and reliability of the solution, (ii) the use of open standards (for future cross-border interoperability) and (iii) innovation and use of smart charging solutions.

The Government of the Netherlands extended grants for the funding of charging infrastructure. Extended grants were reduced from 900 € in 2016 to 600 € in 2017 and to 300 € in 2018.

Moreover, a number of regional incentives arise for each municipality in the Netherlands, as a complement of national policies. As such, the national government gas committed 7.2 million EUR to EVSE deployment as part of the Green Deal on Publicly Accessible Charging Infrastructure.

Operational costs are recovered through sales with a considered margin inside the tariff. In the long-term, tariffs are expected to be market driven.

Although electric mobility is starting to be de-regularized, the most important assessments realized rely on are:

- Maturity model of public charging of electric vehicles (2018).
- Publicly Accessible Electric Charging Infrastructure Green Deal (2015).
- Policy rules drew by the Association of Netherlands Municipalities (VNG) (2013).

The Maturity Model of charging infrastructure is especially relevant when considering initial deployment of charging infrastructure, in order to set goals and aggressive targets.

Last, the Netherlands provide an incentive for companies to develop charging infrastructure, as companies are allowed to deduce corporate and income taxes from charging infrastructure. Companies can apply to the Environmental Investment Deduction Alliance (*Milieu Investeringsaftrek* or MIA).

5.3- Benchmark: Utility model

5.3.1- Utility model case 1: California

Until December 2014, utilities operating in California could not operate electric vehicle charging infrastructure.

However, after a number of discussions, Decision 14-12-079 (California Public Utilites Commission, 2014) establishes that a case-specific approach for each utility is applicable in California.

CPUC regulatory activities are related to four categories (CPUC, 2018):

i) Electricity rates and costs of fueling,
ii) Infrastructure deployment and incentives,
iii) Vehicle to grid integration policy and pilots,
iv) Evaluation and coordination.

As such, six electric Investor-Owned Utilities (IOU) have developed pilot programs on the deployment of charging infrastructure across the Californian state. This deployment represents the support of the private sector for the transition to zero-emission vehicles established by the California Public Utilities Commission (CPUC).

As a result of this regulatory update, IOUs have assigned a budget for charging infrastructure deployment and CPUC has approved different tariffs for each utility.

The CPUC Decision 16-01-045 has approved that the San Diego Gas & Electric (SDGE) company installs 3,500 charging stations with a 45 million USD budget. This budget is addressed for multifamily and workplace charging stations, establishing Time-of-Use (TOU) tariffs for users under their operation. Moreover, they offer vehicle to grid integration rate, considering if the consumer is a driver or a host.

The CPUC Decision 16-01-023 approves Southern California Edison (SCE) for the deployment of 1,500 charging stations with a 22 million USD budget. This budget is addressed for multifamily, workplace and public charging stations. The ownership of charging infrastructure is for the site host and SCE establishes a TOU rate to the site host.

The CPUC Decision 16-12-065 approves Pacific Gas & Electric (PG&E) for the deployment of 7,500 charging stations with a 130 million USD budget. The operation of the infrastructure is for the site host and ownership of PG&E is only allowed in multifamily or disadvantaged communities with a 35% participation. PG&E will charge TOU tariffs to the driver or the host of charging infrastructure.

Even though the described proposals arise to 13,000 charging points and close to 230 million USD, the initial proposal by the different utilities amounted to 60,000 charging points and a budget of 1,100 million USD.

It is to be highlighted that mentioned tariffs or rates are exclusive for electric vehicle users.

5.3.2- Utility model case 2: Ireland

In 2010, ESB Networks developed a subsidiary company for the deployment of charging infrastructure. As such, ESB ecars started as a three-year pilot project that aimed to develop 1,500 charging points in Ireland.

From the initial 470 million EUR provided in 2011, 50% were obtained through a loan from the European Union long-term lending institution and the other 50% was provided by ESB Networks (European Commission, 2011).

As such, ESB is responsible for the planning, deployment and operation of the charging infrastructure in Ireland and recovers the costs through the electricity tariff.

By 2017, ESB ecars was operating and maintaining 1,200 publicly available charging points all over the Irish island (The EV network, 2017).

At first, the service in Ireland consisted on a monthly fee of 16.99 EUR that included unlimited use of all standard (AC charging) public charge points and fast public chargers. After April 2016 charging in fast public chargers increased to a 0.30 EUR fee per minute of usage (ESB ecars, 2015).

However, with the increased demand of electric vehicles, ESB announced on October 2019, together with a further 20 million EUR investment, a different pricing scheme (ESB ecars, 2019).

As a result, ESB ecars introduced two different price plans for fast charging:

- Pay as you go, charging 0.33 EUR per kWh,
- A 5.00 EUR monthly membership that allows for a reduced fee of 0.29 per kWh.

The AC charging infrastructure network pricing is supposed to be introduced in 2020 as a result of the different upgrades that are currently under development.

Moreover, ESB ecars introduces an overstay fee consisting in 5.00 EUR for charging session that are longer to 45 minutes in order to introduce an incentive for users to empty the charging point (ESB ecars, 2020).

The tariff in Ireland is based on a per kWh consumed as ESB conducted different studies that concluded that the Irish population prefers a per kWh charge rather than other charges.

Even though ESB ecars have been operating in EV charging, the Commission for Energy Regulation (CRU) published in October 2017 the Decision Paper CRU17283 where the CRU explains why the electric system will not be funding anymore the development of EV charging infrastructure.

In this paper, they established the treatment for tariffs of the project operated by ESBN cars through its subsidiary ESB ecars. Moreover, they develop that the assets should either be sold or maintained by ESBN on a commercial basis. CRU also concludes that "any further funding required would have to come from other sources such as, for example, subsidies or from fees recovered from the users of EVs".

5.4- Benchmark: Integrated charging provider

5.4.1- Integrated charging provider model 1: China

The Chinese case represents the coexistence of different business models. As such, the Chinese Government has set policies for charging infrastructure development within the following documents:

- Guidance on accelerating the promotion and application of new energy vehicles. Under this guidance, the Government established a tax stimulus for consumers. Moreover, grid utilities were required to support the adoption of electric vehicles.
- Guidance on Accelerating the Construction of Electric Vehicle Charging Infrastructure. This guidance establishes that new residential constructions must include equipped EV charging for 10% of parking spaces and at least one public charging station for 2,000 electric vehicles.

  This guidance included as well mechanisms to develop public-private partnerships for the development of charging infrastructure in shopping malls, grocery stores, etc.

  Last, grid utilities were allowed to include the investment of charging infrastructure within their rate base.
- Guidelines for Developing Electric Vehicle Charging Infrastructure (2015-2020) establishes different degrees of EV infrastructure promotion depending on the region of China. This includes the case of Shenzhen, one of the cities were most actions were taken. This case study is further developed in section 5.5.1.
- The National Energy Administration released a notice in January 2016 communicating five new national standards for the interface of charging infrastructure.
- The Five-Year Plan for New Energy Vehicle Infrastructure Incentive Policies released in January 2016. This Plan included 90 million RMB (around 12.5 million USD) in funding for the deployment of charging infrastructure. It established as well a number of rules for the deployed posts.

- The Notice on Accelerating Residential EV Charging Infrastructure Construction developed standards and procedures for residential charging. It also established some areas for its development.

Despite the strong initial uptake developed by the Government and strong financial aids provided, most charging infrastructure posts are privately-owned.

According to Xinhua, the official state-run press of the People's Republic of China, charging infrastructure surpassed a million points, of which 412,000 were owned by the state or state-owned companies and 590,000 privately-owned (Xinhua, 2019).

Although the Government is committed to ensure a minimum number of charging stations, most of the charging station are owned by third-parties' companies (together they account for 58.9% of all stations).

These charging station bill a price that reflects: (i) fixed charges (to cover capital and operational expenditures) and (ii) the price of electricity. These prices are regulated by provincial governments.

As an example, regarding the use of electric vehicle charging in Shanghai, users pay 0.26 USD/kWh (0.19 charging service fee and 0.07 electricity fee) for public charging. The Government of Shanghai was committed to provide a subsidy of 0.03 USD/kWh for public charging service suppliers before 2020 (Qiao, 2019).

By 2019, China continued on the path to expanding its electric vehicle-oriented policies through the New Energy Vehicle (NEVs) Mandate policy. This policy sets NEV credit targets: 10% of conventional passenger vehicles market in 2019 and 12% in 2020. This mandate is inspired in California's ZEV mandate.

Part of this plan is to sell 4.6 million of EV by 2020 along with the prohibition of Internal Combustion Engine vehicles over the following years.

Last, there are also some subsidies at a regional level in China. As matter of example, many provinces and local governments support the development of EV charging infrastructure with financial incentives.

5.4.2- Integrated charging provider model 2: Barbados

Barbados has become a regional leader on both electric vehicles and the deployment of charging infrastructure.

Megapower is an electric vehicle importer that also develops charging infrastructure around the island.

Megapower is allowed to deploy the charging infrastructure as third parties are allowed to deploy charging infrastructure. The Barbadian regulation considers the provided service as an access service rather than electricity sales.

Moreover, Megapower is aligning its interests with the Barbadian utility: Barbados Light & Power Co. Ltd in order to deploy more charging infrastructure around the island (Viscidi, Lisa et al., 2020).

5.4.3- Integrated charging provider model 3: Spain

The Royal Decree 647/2011 regulated the activity of a charging supplier in Spain until 2018.

This Royal Decree established that utilities could not provide the service of charging infrastructure operator under any condition.

On the 5th of October, Spain released the Royal Decree-Law 15/2018 by which he released this condition. Since then, utilities can deploy charging infrastructure when the private sector has not effectively deployed charging infrastructure in an area in order to foster the development of charging infrastructure and reach the established objectives (more than 1.000 charging points in urban areas).

Regarding financing of charging infrastructure, the Government of Spain, through the FEDER (European Regional Development Fund) has developed a subsidy for the deployment of charging infrastructure. As such, the Government of Spain, through the public body IDAE will provide with 20 million EUR for applicants. Applicants can be private companies, local entities or public bodies and must develop a technical solution of more than 7 kW of power (IDAE, 2017). As such, different types are defined:

- Normal charging: between 7 kW and 15 kW,
- Semi-fast charging: between 15 kW and 40 kW,
- Fast charging: Between 40 kW and 100 kW,
- Ultra-fast charging: Above 100 kW.

For private users that have deployed their own charging infrastructure, a special electricity tariff has been established, providing with TOU differentiation to customers. However, customers are free to choose any other electric rate available in the market.

Considering publicly available charging infrastructure, the business model varies. Slow or normal charging (mainly AC charging) can be found at no cost with quite ease, as many points of interest offer the service as a complement of their usual business, in order to attract more customers or by green consciousness in order to "clean" the city. A number of parking spaces provide the service as well for "free" as a compliment of their paid tariff (Fernandez, 2020).

However, when it comes to DC charging the model changes as operators establish a tariff per kWh consumed. This tariff is publicly available for consumers.

Last, as of mid-February 2020, the Minister of Spain has recently announced that they are expecting soon a new decree that fosters the deployment of fast-charging solutions in highways.

5.5- Benchmark: Bus fleet implementation

5.5.1- Bus fleet implementation model: Shenzhen

In 2009, the Government of China selected Shenzhen, along with 12 other Chinese cities, in order to develop a pilot program for the implementation of new-energy vehicles.

By the end of 2017, the city of Shenzhen had developed a full electric bus fleet with 16,359 electric buses. Evolution of electric buses since 2012 is established in Figure 35:

Figure 35: Electric bus adoption in Shenzhen, China from 2012 to 2017 (Lu Lu, 2018)

Early 2019, the high-tech hub of Shenzhen announced that 99% of the total taxi fleet had gone electric (more than 21,000 of the 21,689 fleet), turning Shenzhen in the second city worldwide, after Taiyuan (China), to achieve the full electrification of their taxis fleet.

Overall, Shenzhen is the first city at a global level to reach the full electrification of both its bus and taxis fleets.

In order to attain these aggressive objectives, the electrification model sets base in four main pillars (Lu Lu, 2018):

1. **Establish national and local subsidies**

As upfront costs of electric buses are still high, bus operators in Shenzhen have heavily relied on subsidies from the Government of China and the City of Shenzhen.

As an example, before 2016, subsidies for a 12-meter e-bus in Shenzhen amounted to 150,000 USD. This number represents more than half of the vehicle's price.

Even though this number is especially high, lower subsidies work as well when developing public policies.

Moreover, some studies establish that in terms of the lifecycle cost of an electric bus, or total cost of ownership, electric buses are competitive towards conventional vehicles. As such, for the Shenzhen case in 2016, the total cost of ownership of an electric bus, for an eight-year time period, raised to 375,457 USD while the total cost of ownership for a diesel bus raised to 342,855 USD (Shenzhen Urban Transport

Planning & Design Institute, 2017). These numbers include procurement, energy and maintenance costs.

Moreover, according to the IEA Global electric vehicle Outlook 2019, electric buses that travel around 40,000 to 50,000 kilometers per year are competitive for battery prices of 260 USD/kWh in regions where diesel attracts high taxes (IEA, 2019).

2. **Vehicle leasing in order to reduce acquisition costs**

Instead of directly purchasing electric vehicles, some bus operators in Shenzhen got subsidized prices by leasing the vehicles from automakers. As such, the price of an electric bus decreased up to a range of 90,000-120,000 USD.

This fact allowed bus operators to a further acquisition of electric buses while reducing their debt financing needs, allowing for more simple and sustainable business cases.

However, it is important to note that Shenzhen represents a key figure for automakers as it is the home for the headquarters of BYD, the highest electric vehicle sales company from 2015 to 2018 (BYD, 2019).

3. **Optimize bus charging and operation**

A key factor for the electrification of any public fleet relies on its operational needs and costs.

As such, the operational model of electric buses in Shenzhen arises as a successful model as they adopted a type of electric buses that could operate almost for a day without charging as they had 250 kilometers (155 miles) autonomy. The battery is fulfilled within a five-hour charge, mostly at night but is complemented with charging infrastructure along the route and recharging at terminals at off-peak travel times. The ratio of charging outlets to the number of buses arises to 1:3 (Lu Lu, 2018).

Moreover, another fact allows for financial operability of this charging infrastructure, as any electric vehicle driver can profit from the charging service in charging infrastructure along bus routes.

4. **Establish direct negotiations with automakers**

Last, Shenzhen managed that automakers provided lifetime warranty for vehicles and batteries as they are better positioned to manage financial risks than bus operators due to their continuous innovation on batteries.

This allowed to further cut operational costs for Shenzhen bus operators.

Even though this pillar is not viable for every city that seeks to switch their bus fleet from conventional to electric, the idea to establish direct negotiations with OEM arises as a great opportunity for a mass rollout.

5.5.2- Bus fleet implementation model: King County, Washington, U.S.A.

King County Metro Area (KCMA) is based in the Seattle area and has committed to a zero-emission fleet by 2040 and to acquire only zero-emission vehicle from 2020 onwards.

It all started in February 2016 with a grant concession from the Federal Transit Administration of 4.70 million USD for the purchase of three electric buses (Proterra 40-foot Catalyst full battery buses). Immediately, a number of performance tests were conveyed to analyze bus possibilities within their routes. As the performance was extremely good, KCMA acquired eight additional buses.

Since then, tests have been executed on electric buses to analyze their reliability under different environmental conditions: different terrain ranges and cold temperatures in order to test different bus deployment options.

As such, KMCA has had a continuous communication with automakers, especially Proterra as well as with the local electric utility: Seattle City Light and Puget Sound Energy for the deployment of charging infrastructure by sharing deployment costs.

KMCA had by October 2019 185 zero-emission buses in service: 174 trolley buses and 11 Proterra battery buses and expect to include 120 new buses by 2021.

Regarding operational benefits, KMCA has conveyed a number of analysis between its electric bus fleet and the conventional fleet (U.S. PIRG, 2019):

- Diesel buses can travel up to 5.3 MPGe and electric buses up to 15.9 MPGe.
- Cost per mile arises to 0.57 USD/mile for electric buses versus 0.30 USD/mile for diesel buses. However, this is mainly due to high demand charges for the company.
  Moreover, demand charges vary from 0.30 USD/kW off-peak to 8 USD/kW. This, combined with the fact that, when having only few buses, the demand charge distribution is high for every mile. Nevertheless, when expanding the fleet the demand charge remain the same, reducing the per-unit costs.
  As such, in the long run it is expected that these energy costs will decrease over time.
  Last, KMCA is developing pilot programs on vehicle-to-grid management.
- KMCA has also quantified environmental and health benefits from electric buses. Results for a 40-foot diesel-hybrid bus amounted up to 121,000 USD and 19,000 USD for a 40-foot electric bus that uses renewable energy as main energy source.

Last, KMCA is having support from the county as it is supporting on the consecution of environmental goals established in the Strategic Action Plan.

5.6- Charging infrastructure operation: service selling strategies

Besides planning, finance and deployment strategies, companies that operate charging infrastructure need to decide on the selling/pricing strategies. These strategies will impact on cost recovery. The main analyzed strategies for charging infrastructure are detailed hereafter:

1. **Loss leader**

Under this pricing strategy, the cost of charging is totally absorbed by the operator. As such, the consumer is offered free charging services. This can be established for different purposes:

- Increase of customer base: for a company operating a grid of charging infrastructure, offering a reduced cost will surely add more customers to their existing customer base.
- Value-as-a-service: for companies which their main business value relies on another service(s), a reduced or no cost for using the recharging service can add value to their main service, allowing for price increases for their main service.

This strategy results very popular within electric vehicle drivers and can help on increasing brand loyalty, footfall, dwell times and expenditure on average baskets. This type of strategies are usually developed by retail parks, shopping malls or supermarkets (curbside and charging stations from Figure 32 classification).

2. **Cost recovery pricing**

This pricing strategy is based on the premise of cost recovery principles. However, these strategies can vary depending on the level of cost recovery intended to achieve, considering a total or partial cost recovery strategy.

Commonly, the charge fee applied under these strategies is focused on the total recovery of operational costs by translating to the users the cost of each unit sold (kWh and/or minute for charging infrastructure).

In addition, a margin can be used to increase the charging fee for users in order to achieve cost recovery of the investments regarding the infrastructure deployment.

This type of strategies are aimed to attract electric mobility charging users and is based on users whose customers need to use the charging infrastructure services.

These strategies within the public charging infrastructure networks enables a more competitive network environment, where the users are able to choose amongst different charging service options.

3. **Contribution margin-based pricing**

This pricing strategy, also known as cost-plus strategy or profit-making strategy, allows for cost recovery and adds a margin for benefit making.

Under this strategy, companies perceive an additional revenue stream from charging infrastructure deployment and operation. It is usually considered in urban locations (charging stations from Figure 32 classification) where there is an urge for deployment, allowing companies to charge a premium. This selling strategy is usually undertaken by companies that seek profit from charging infrastructure development and operation.

These types of strategies are aimed at locations or areas with low availability of charging infrastructure for the users.

In addition, these strategies can also be designed based on an intended specific users' profiles to attract.

Concerns regarding users' perceptions arise if there are additional charging providers offering lower fees for the charging service. Commonly to mitigate these, additional strategies in order to increase the perception of added value for the users are required.

From the consumer-side, as consumers feel the necessity to use the charging infrastructure, they will use the service. However, as there is a premium on the service, they have the economic incentive to minimize its use, increasing availability of the charging post for other users.

6- General regulatory needs and proposals for an increasing deployment of charging infrastructure

6.1- What do consumers seek?

A number of studies define that electric vehicle drivers have strong preferences when it comes to public charging.

As such, according to a ZapMap survey from over 1,600 users in the United Kingdom, the most frequently valued features of charging infrastructure are: charge point reliability, ease-of-use and competitive pricing on per kWh basis. Additionally, for rapid chargers, contactless payment is also a valued feature (Lilly, 2018).

On the other side, main obstacles include poor reliability, unit communication issues and higher-than-average costs.

Moreover, there is a number of factors to improve electric vehicle users' experience:

- The existence of enough charging points to cover or exceed the demand.
- Provide a customer service to solve any technical issue with the service.
- Provide with complimentary services for the time users are charging their vehicle.
- Users must be able to easily identify charging infrastructure, by signposting them. The registration of the charging points in mapping platforms also increase the ease of location.
- The existence of third-party membership schemes are usually perceived as hurdles that prevent a one-time charging.
- Mobile payment solutions are usually better perceived than RFID card payments.
- Some international businesses do not start charging as soon as the plug is connected to the car, allowing the user for some time before claiming the payment. If the payment is not claimed in some minutes, the charging service stops.

6.2- Guidelines and Regulatory proposals

In order to boost the development of electric mobility and the deployment of charging infrastructure, a number of general measures are usually considered. Within this context, Governments must establish objectives for electric mobility penetration, reduction of greenhouse gas emissions and fuel dependency, as well as considering the definition of goals regarding the roll out of publicly available charging infrastructure.

In order to promote and monitor the deployment of a charging infrastructure system, specific regulatory policies and guidelines need to be developed. This policies need to address: (i) an adequate performance of the activity related to the charging infrastructure, considering the different phases of the value chain, (ii) amendments of existing policies to guarantee integration with related industries and sectors, (iii) policies to promote deployment of charging infrastructure, and (iv) ensure interoperability of the charging infrastructure system through the definition of technical guidelines and requirements.

1. Regulatory priorities

Charging infrastructure activity guidelines and regulatory framework development.

The key priority in the development of a charging infrastructure system relies on the definition of the scope of the activity and the regulatory developments necessary.

Commonly, the activity related to charging infrastructure services is considered as a de-regulated activity, which will require the definition of a specific regulatory framework.

In addition, specific guidelines and policies should be addressed throughout the different phases of the value chain of the charging infrastructure system, especially considering the publicly available charging infrastructure deployment.

On this end, it must be considered the following:

i. The design of a general framework to regulate the activity related to charging infrastructure services.

   The design of the general regulatory framework should define at least the following aspects:

   a) Definition and scope of the activity related to the charging infrastructure system.

   b) Entities and individuals subject to the regulation applicable to the charging infrastructure activity.

   c) Requirements for entities and individuals to develop the charging infrastructure activity.

   d) Obligations, responsibilities and rights of the entities and individuals developing the activity.

   e) Definition of the different stakeholders and their roles within the regulatory framework.

      Supervisory and regulatory entities should be designated, as well as, the public authorities responsible for the monitoring of the activity performance.

ii. Updates on existing policies, such as the national energy policies, transport policies or urban planning policies.

   The update of existing policies is required in order to ensure the integration of the charging infrastructure activity with other related industries and sectors. In addition, specific updates on existing regulations are considered to promote and incentivize the charging infrastructure deployment.

   Commonly the required policies updates focus on:

   a) Energy policy update to consider:

      - New tariff structures towards consumption from electric mobility, both on private and public charging infrastructure consumption.
      - Access and connection to the network grid procedures and requirements regarding the charging infrastructure integration to the power grid.
      - Mechanisms and requirements for load management communications within the charging infrastructure system and the power system.

- Requirements and policy development to regulate the bidirectional flows between the charging infrastructure system and the network grid and include smart charging solutions.
- Mechanisms for the roll-out of charging infrastructure on areas demand-driven, considering the utilities where there is no market interest.

b) Transport policies updates regarding the deployment of public charging infrastructure for public services requirements in order to ensure quality service levels.

   In addition, transport policies should consider the development of guidelines regarding the uses for the public service charging infrastructure, as well as, charging planning requirements and guidelines aligned with the energy system network management.

c) Urban planning policies updates can include the development of mandates to incentivize the charging infrastructure deployment:

   - Mandates to oblige the construction of charging infrastructures on new buildings.
   - Policies to promote the deployment of public charging infrastructure under specific locations, as well as, the definition of the requirements to accessible public locations for charging infrastructure installation.

   In addition, the definition of policies to determine the administrative procedures and permits required for the deployment of charging infrastructure is required to be developed. Commonly updates on policies focus on the planning timetable procedures design update, and construction permit requirements.

d) Tax Policy Framework update in order to define the charging infrastructure activity taxation and fiscal regime.

iii. Development of policies and guidelines addressing specific measures based on public incentives for charging infrastructure deployment:

   - Specific policies considering the charging infrastructure planning procedures considering the mechanisms adopted by public authorities to promote public available charging infrastructure.

     Under this scope policies to determine the procedures and the requirements through: (i) direct authorizations for public charging infrastructure deployment, and (ii) public bidding process.

   - Specific policies considering the charging infrastructure financing mechanisms through public funds to support public charging infrastructure deployment.

     This policy will require to develop guidelines to access financing, verification and compliance procedures to grant funding.

     In addition, common guidelines include additional requirements on the deployment and operation of public charging infrastructure deployed under the public authorities financing schemes.

Electricity Retail Tariffs Mechanisms for Electric Mobility Charging.

Moreover, it is imperative for electric vehicle users to have signals for recharging their vehicles in order to increase and develop energy efficiency and load management measures. As such, in the short-term, regulation might need to be adapted.

Time-of-Use (TOU) tariffs are a key enabler to increase operational costs gap between electric vehicles and conventional vehicles. TOU tariffs are a key enabler to shift the demand to off-peak generation periods.

Progressively, more complex load management solutions should arise. As such, dynamic pricing solutions for electric vehicle charging must be developed, enabling value stacking through vehicle-to-grid, vehicle-to-home and similar solutions in the national market. Therefore, this evolution should be considered within the regulatory changes in order to allow the market to naturally transition in case the private initiatives allow it.

Nevertheless, the implementation of these solutions must not forget that retail electricity tariffs must reflect the generation mix in order to give price signals to users. As such, when there is abundance of renewable energy, retail tariffs should decrease for almost all electric vehicles to charge and allow for a further price reduction.

As a result, the electric system will be able to benefit from this management, enhancing ancillary services, reducing grid congestion, flattening the energy demand curve, etc.

A potential issue regarding tariff allocation and development comes within this context as high tariffs can discourage users to connect their electric vehicle and allowing operation from the electricity system.

However, consideration on the development of adequate tariffs regarding charging infrastructure use needs to be considered differentiating amongst private charging infrastructure and public available charging infrastructure, considering the level of uptake on electric vehicles.

On this end, the design and implementation throughout the policy making process needs to consider both the definition of a tariff structure regarding the electricity consumption applicable to both private and public infrastructure, as well as, the guidelines and regulations to address the cost of services provided through the public available charging infrastructure.

Policies and guidelines are commonly designed regarding:

a) **Specific retail tariffs for electricity consumption arising from the private users**.

b) **Specific policies and guidelines for public charging pricing regarding the rates structure requirements and efficient competitiveness**.

   Guidelines under this scope should be designed considering the different business models, in order to set a fair structure for users.

On this end, it must be highlighted that when considering the retail tariffs mechanisms and policies to be adopted, this should pursue the following objectives:

a) **Sufficiency**: cost allocation mechanisms must aim to be designed based on cost recovery.

b) **Efficiency**: tariffs should be designed to reflect the costs each users' group generates to the system, avoiding subsidizing and encouraging efficiency.

c) **Transparency**: the tariff setting mechanisms should be defined throughout an open and public process, enabling stakeholder involvement. In addition, the definition of the calculation methodology requires to explicit and transparent.

d) **Objectivity**: the defined mechanisms to establish an adequate tariff must consider objective variables and criteria, not subject to arbitrariness.

e) **Non-discriminatory**: the mechanisms and methodologies to determine tariffs must reflect no differences amongst players of the same characteristics.

Furthermore, there are some key aspects to take into consideration, which are regularly followed by regulators according to international best practices:

i. **Fairness**: consider a fair distribution amongst players, as not all of them contribute equally to the peak demand of the services.

ii. **Simplicity**: based on the ease of application.

iii. **Stability**: remain stable over time, to enable an efficient communication to users of price signals.

iv. **Additivity**: mechanisms should be additive.

v. **Purpose**: consider social and business activities aspects and not hinder competitiveness and efficient business.

In addition, special consideration must be set on the definition of tariff mechanisms to fast long-distance charging infrastructure.

Under this type of charging infrastructure, the design of tariffs considering fixed component fees represent an issue regarding the financial viability of the same.

Fast charging stations commonly rely on higher capacity, which translate on higher supply tariffs to be recovered. Tariff setting mechanisms based on demand represent an optimal solution to address this issue and incentivize private involvement on the development of this type of charging infrastructure.

In addition, regarding the public available charging infrastructure pricing services, it must be highlighted that the development and design of policies is commonly limited to the participation of the public authorities in the deployment of the charging infrastructure system.

Common public guidelines are developed when the charging infrastructure deployment is subsidized throughout public funds, or benefits from other incentives from the Government.

On this end, policy mechanisms commonly focus on the establishment of a limit on the public service rates.

On the other hand, it must be considered within the deployment of charging infrastructure through the utility investment, the regulatory need to recover the costs of infrastructure investments, whilst maintaining the principles of utilities' activity to obtain a fair return. However, these regulatory requirements need to be cautious as it may drive to a significant increase on electricity costs and therefore customer electricity rates. Therefore, the approach to be considered on the definition of investment and cost recovery for utilities will need to address whether to be applied to all customers, exclusively to EV charging customers or a combination of the previous.

Cost allocation mechanisms and revenue requirements related to the deployment of charging infrastructure, within the utility's activity, will need to consider:

(i) Investments on the installation of charging infrastructure. Cost allocation for these investments should be considered under a business model where utilities play a role on the deployment of charging infrastructure.

(ii) Investments on the reinforcement of the grid network to ensure supply from the increasing demand, as well as, the grid connection.

(iii) Investments on the network digitalization to integrate charging solutions and load management solutions.

Considered mechanisms to define cost allocation and revenue requirements to recover utilities investments can be based on a Regulatory Asset Base mechanism ("RAB").

This type of mechanism consists on the definition of a cost recovery methodology where the utilities' revenue requirements are calculated during the useful life cycle of the investments, considering investment recovery, depreciation costs and a rate of return.

Moreover, the definition of the regulatory mechanisms related to utilities cost recovery requirements, needs to consider the application to all electricity customers, or through specific customer segments.

Furthermore, the application to all electricity customer should be considered whilst achieving fairness in the defined rates, establishing the benefits customers will obtain from the investments realized by the utility and its impact on the overall electricity supply.

2. Technology standardization priorities

For the proper development and future integration of distributed storage solutions such as electric vehicle integration in the electricity system, it is important to consider interoperability of the different technologies and that users are secured.

As such, it is imperative that different technologies coexist and that specific committees ensure their interoperability. Moreover, users must be covered from possible cybernetic attacks, including physical and financial cybersecurity.

When it comes to the design of the integration of electric mobility within the electric system, the solution will vary depending the generation mix (actual or future) of the system. As such, systems that rely on solar power generation, will need that the solution incentivizes users to be connected to the grid during midday and in the evening to provide the energy back to the system. For a wind power-based system, necessities vary as unplanned charging may be effective as a consequence, different technological improvements must be considered depending on the energy mix.

As highlighted previously, the existing different technologies require to be standardized through policies and public guidelines in order to ensure interoperability of the charging infrastructure system deployment.

On this end, **Governments and Public Authorities are required to define and determine the technical requirements and general guidelines for the deployment of the electric mobility charging infrastructure**. Under this need, special focus and consideration must be set on the related activities as well as the requirements of amendments on existing policies, both energy and transport policies.

The definition of the requirements through public authorities aims to support the development of a homogenous and interoperable charging system throughout specific areas, regions and locations.

The development of this guidelines will require to define and determine the technical requirements necessary for the deployment of the publicly available charging infrastructure.

The definition of this requirements should consider:

1. Charging standards required in each charging infrastructure.

   The selection of the charging standards to be adopted on the deployment of the charging infrastructure should consider: (i) the charging methods to be deployed, (ii) communication protocols to be adopted, and (iii) technical components specifications, such as, plugs and connectors, necessary.

2. Application of different standards based on the different types of charging infrastructure.

   Consideration on the definition of standards adoption requirements can vary depending on the types of charging infrastructure through the differentiation of the needs amongst slow, semi-fast and fast charging infrastructure.

3. Charging infrastructure Standards application should also consider requirements based on the (i) location of the infrastructure, as well as, (ii) the types of fleets aimed for the use, and (iii) the type of use proposed for the infrastructure.

4. The definition of procedures to verify and test compliance regarding the technical, communication and safety standards.

5. Additional specifications should be included regarding advanced components and features considered in the deployment of the charging infrastructure, including innovation developments integrated in the facility, additional measures and components requirements to be included in the deployment of the charging infrastructure.

6. Grid access and connection requirements based on the technical specifications of the charging infrastructure.

   In addition, procedures regarding the process to connect to the network grid should be developed, as well as, considered within the development of the regulatory framework applicable to the activity to deploy the charging infrastructure system.

Plug- In International Standards	Safety and Qualification International Standards	Communication International Standards
IEC 62196	IEC TC 69/64	IEC 61850
IEC 61851	IEC 61851	IEC 61851
GB/T20234	GB/T 20234	ISO 15118
GB/T 18487	GB/T 18487	SAE J1772
SAE J1172	ISO 17409,	SAE J2847
CHAdeMO	UL2202/ UL 2231	SAE J2931
Yazaki	IEC 60364	IEEE 80211P
Combo CCS		GB/T 27930

Figure 36: Common International Standards Adopted.

Consideration on this aspect should include addressing the need to update existing technical requirements for network grid access, in order to include specific technical requirements to ensure a reliable, secure and safe supply, as well as, guaranteeing the network sustainability.

7. Requirements regarding the charging infrastructure data collection needs and communications applications.

   Guidelines regarding the minimum requirements of data collection a facility should register considering the (i) type of information and (ii) the purpose of the information including users' needs for information, as well as, monitoring consumption and communication with the network grid.

Public authorities' guidelines and regulations or decisions provides the path to ensure interoperability.

This will require a decision-making process aimed to achieve a Standards regulation, which will need to include:

a) The definition of the charging infrastructure equipment and technical specifications:

   i. Transformer equipment and related safety appliance;

   ii. Lines and cables equipment;

   iii. Civil Works required;

   iv. Electrical works ensuring safety;

   v. Vehicle access conditions;

   vi. Chargers specifications: regulations should include:

      a. Requirements regarding the number of charges for the charging station;

      b. Type of chargers with which the charging stations are required to be equipped.

      Different type of charges should be considered, as well as the possibility to combine different types within a same charging station.

Under theses specifications, differentiation should be detailed regarding Publicly available charging infrastructure fast charging stations and slow or moderate charging stations.

Additional considerations regarding the possibility of deployment of charging stations with different technical standards should be included within the technical charging guidelines.

On this end, the guidelines should include the required process to approve the installation of different technical standard public charging infrastructure.

It can be highlighted as additional options the case of California, where within the California Codes of Regulation, there is the requirement for electric vehicles to be equipped with a conductive charger inlet that meets the specifications in the SAE J1772 Standard.

In addition, China, developing National Standards has stablished the standards as Mandatory, equivalents to a law, or Voluntary adoption. On this end, the GB 50966 standard regarding the "Code for design of electric vehicle charging station" is considered to be mandatory, whereas additional electric vehicles charging standards (GB/T) remain voluntary.

b) The definition of the safety standards application and protocols in public charging infrastructure

   On this end, inclusion of additional standards regarding the verification and testing of compliance with standards is needed within public charging infrastructure. As an example, could be the adoption of UL standards.

   In addition, specific safety instructions and requirements are also included or amplified within the technical electrical codes of each country.

   In the case of Spain, regulatory technical and safety instructions have been developed and published through the Technical Instruction ITC-BT 52 including the definition of a technical and safety requirements for the charging infrastructure.

Within the process of the definition of the technical and safety requirements to the deployment of the public charging infrastructure, public authorities can act through tenders, where the minimum requirements are set. An example would be the case of The Netherlands, where The Government has worked through partnerships focused on the consultation with private and local governments to policy. In addition, local municipalities consider and apply within the tenders the need to incorporate smart charging requirements, open protocols and security and safety requirements.

Also, the Norwegian Government launched a program to provide the funds to establish a minimum of two multi-standard stations every 50km.

Considering the previous, Governments participation amongst the deployment of public charging infrastructure vary through the different business models, however policies or actions to ensure the success can be incorporated whilst promoting deployment.

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Appendix 2: Case Studies Details

<u>Portugal Case Study – Technical requirements definition</u>

<u>Technical requirements for low-voltage power installations</u> (Regras Técnicas das Instalações Elétricas de Baixa Tensão) [requirements only related to electric vehicles, according to Ordinance n.º 252/2015]

[E] 722.1 APPLICATION FIELD

The set of rules indicated in this part of the technical rules apply to:
Circuits intended for electric vehicles (EV) loading;
Protection to ensure safety in case of power return to the distribution network, public or private, from the electric vehicle;
These rules do not apply to induction charging.
Charging modes 3 and 4 of electric vehicles defined under the standard EN 61851 require power supply and exclusive charging equipment that include communication and control circuits (see standard EN 61851).
The charging modes 1 and 2 of the electric vehicles defined EN 61851 can use sockets powered by the electrical installation.

[E] 722.2 NORMATIVE REFERENCES

Under this section of the Technical Rules, in whole or in part, the following documents are indispensable for the application.
When the reference to a given document is followed by a specific date, only the document with that date must be applied.
When the reference to a given document is not followed by a date, the latest edition of that date shall apply, including any additions in the document.
EN 60309 (series) - Plugs, socket -outlets and couplers for industrial purposes (IEC 60309, series).
HD 60364 (series) - Low -voltage electrical installations (IEC 60364, series).
<u>(…)</u>

[E] 722.4 PROTECTION TO ENSURE SAFETY

[E] 722.41 Protection against electric shock

[E] 722.410.3.5

The protection against direct contact, the measures "protection through obstacles" and "Protection by placing out of reach" shall not be applied.

[E] 722.410.3.6

The protection against indirect contact, the measure "protection for equipotential union not connected to protective earth" shall not be applied.

[E] 722.413.1.2

If an ungrounded source is used with simple separation, the measure "protection by electrical separation" can be applied, as long as the source feeds a single EV.

[E] 722.413.3.101

When the protection measure "protection by electrical separation" is used, the circuit must be powered by means of a fixed separation transformer that meets the standard EN 61558 -2 -4.

[E] 722.5 SELECTION AND EQUIPMENT INSTALLATION

[E] 722.51 Common rules

[E] 722.512 Conditions of service and external influences

[E] 722.512.2 External influences

[E] 722.512.2.101 Presence of water (AD)

When the EV connection point is installed outdoors, the equipment must have a code IP not less than IPX4, to protect from the water falling (AD4).

[E] 722.512.2.102 Presence of foreign solid bodies (AE)

When the EV is installed outdoors, the equipment must have a code IP not less than IP4X, to ensure protection against very small objects penetration (NA3).

[E] 722.512.2.103 Impacts (AG)

Equipment installed in public areas and in parking lots must be protected from mechanical actions (code AG2 - severity average impacts). This protection must be carried out by one or more of the following means:
Selection of position or location to avoid damage resulting from predictable impacts;
Placement of general or local mechanical protections;
Installation of equipment with an IK code (protection against external mechanical impacts) not less to IK07 (see standard EN 62262).

[E] 722.53. Apparatus (Protection, control and sectioning)

[E] 722.531 Protection devices against contacts indirect by automatic feed cut

[E] 722.531.2.101 Differential devices (DR)

Each EV connection point must be individually protected through a DR with a current -residential differential stipulated IΔn not exceeding 30 mA that interrupts all active drivers, including the neutral.

The DR must be at least type A. three-phase loads, if the load characteristic is not known, protection measures against currents defects likely to have continuous components (DC), using, for example, a type B DR.

[E] 722.533 Overcurrent protection devices

[E] 722.533.101 The supply circuits of the EV charging points must be equipped with devices protection against overcurrent.

[E] 722.536 Control and disconnecting devices

[E] 722.536.4 Emergency cut-off devices

[E] 722.536.4.101 Installations with emergency cut-out devices requirements, must be able to cut off the current from the respective installation and cut off all active conductors, including neutral conductor.

[E] 722.54 Protecting earth and protective conductors

[E] 722.543 Protective conductors

[E] 722.543.101 Control signals circulating protective conductor (PE) must not pass to the fix electrical installation, according to the rules in section 7.5.2 of standard EN 611404. These signals, and related devices, do not prevent the correct functioning

of devices installed to ensure cutting protection measures automatic feeding, such as DR.

[E] 722.55 Other equipment

[E] 722.55.101 Sockets and connectors

[E] 722.55.101.1 The EV connection points must be provided with at least one socket or connector that meets an appropriate standard such as, for example, EN 60309 -1 or EN 62196 -1, when the interchangeability, and with EN 60309 -2 or IEC 62196 -2, otherwise. The power sockets stipulated may also be used not exceeding 16 A, which satisfy NP 1260.

[E] 722.55.101.2 Sockets must be installed as close as possible to the EV to be fed. Sockets must be installed within fix frames or enclosures as moving sockets are not allowed. Equipment boxes for embedded or outgoing assembly comply with this rule.

[E] 722.55.101.3 Each outlet or connector must feed a single EV.

[E] 722.55.101.4 For load modes 3 and 4 there must be an electrical or mechanical system that prevents the insertion or removing the plug, unless the EV plug or connector have been disconnected from the power supply.

[E] 722.55.101.5 The bottom edge of the sockets must be placed at a distance from the finished floor between 0.5 m and 1.5 m.

[E] 722.55.101.6 Precautions to be taken for the supply of energy to fix feeding facilities by EV. In charging modes 3 and 4, measures must be taken to prevent the VE from feeding the fixed installation in an unintended way.

In charging modes 1 and 2, the EV cannot power the fixed installation in an untended way".

<u>Costa Rica Case Study – Fast Charging Infrastructure pricing</u>

ARESEP - RE-0056-IE-2019

"CALCULATION PROCEDURE FOR FAST CHARGING CENTERS RATE

The National Electric System (SEN) faces a deep transformation process, influenced by the impact of disruptive technologies, as is the case of the distributed generation, energy storage, smart grids electric mobility, internet of things among others.

In this context, it is necessary to have a flexible regulatory framework capable of adapting in a timely manner to the changes induced by this process of technological innovation, which is consistent with the public policy developed around the implementation of the sustainable development goals of the 2030 Agenda and the National Decarbonization Plan 2018-2050 dictated by the Executive Branch, instrument related to the National Development Plan and Public Investments (2018-2022) and the Strategic Plan for Costa Rica 2050.

In this regard, in compliance with the provisions established in Law 9518 of Incentives and Promotion for Electric Transportation and the Executive Decree 41642-MINAE, Regulations for the construction and operation of the electric charging centers for electric cars by the electric power distribution companies, the Regulatory Authority of the Public Services (ARESEP), in the exercise of its powers, presents the *procedure for calculating and fixing the transitional fee for the first time applicable to the sale of electrical energy in fast charging centers.*

Since the definition of this rate is intended to promote the use of electric vehicles, a single transitory rate is proposed for the entire country, providing a price signal lower than the cost of fuel and higher than the cost of burden at home, with the purpose of gradually influencing electric vehicle users' consumption habits, seeking the highest use of renewable energy and electrical infrastructure outside the hours of greatest demand. The previous, foreseeing that the network of fast recharging, given the increasing level of autonomy of electric vehicles, has been conceived as a security mechanism for users in order to facilitate access to electricity to deal with situations of emergency across the country.

In this regard, the Tariff Methodology corresponding to the electric power distribution service, according to resolution RJD-139-2015 does not establish a mechanism to define the rates that make up the rate structure of the distribution system provided by electricity companies.

Therefore, said calculation and application is carried out based on technical criteria and in accordance with the provisions of Law 7593 and its modifications.

1. Considerations

The fast recharge centers that will be installed in the country require medium voltage infrastructure, given the demand for required power in a short period of time.

(…)

The Electric Transportation Incentives and Promotion Law No. 9518, in its article 32, establishes that Aresep must define the fast charging center fee in accordance with the functions established in Article 5 of its Law No. 7593.

2. Premises

*i. A constant power of **50 kW** available in fast charging stations is considered.*

ii. Medium voltage tariffs are used as a starting point for calculating the tariff in fast charging infrastructure, due to the required infrastructure.

*iii. The **load factor** will be used, taking the capacity of the electric vehicle battery to determine said factor.*

*iv. A **utilization factor of 288 minutes per day** is considered, which corresponds to 4.8 hours a day, which represents a utilization factor of 20%, which will be taken as a starting point to adjust the rate towards a price signal adjusted to the objective. of public policy, which provides a price signal lower than the cost of fuel and higher than the cost of loading in the home.*

The use of the fast charging infrastructure is expected to be eventual and not intensive. This utilization factor means a recharging service for approximately 10 vehicles per day.

(…)

6. Time period considered

The hourly periods considered in the calculation are those defined by the Energy Administration in the current tariff specifications for each regulated electricity company, as described below.

***On-peak period**: Between 10:01 a.m. and 12:30 p.m. and between 5:31 p.m. and 8:00 p.m.*

***Off-peak period**: Between 6:01 and 10:00 and between 12:31 and 17:30 hours.*

***Night period**: Between 20:01 and 6:00 the next day.*

7. Estimated energy demand

The energy demand per power is determined considering a constant power of 50 kW, an adjusted load factor of 20%, considering a month of 30 days and 5 hours for the peak period, 9 hours for the valley period and 10 hours for the night period:

(…)

8. Estimated amount of energy and power

The calculation of the amount of energy and power is made, according to the rates in force for each electricity company:

$$T_{PE} = \frac{Imp_{power} + Imp_{energy}}{D_{kWh}}$$

T_{PE}*: flat rate per company*
Imp_{power}*: power term in colons*
Imp_{energy}*: energy term in colons*
D_{kWh}*: demand in kWh*

(…)

9. Calculation of the rate in fast recharge centers (colons / kWh)

First, a flat rate per company is calculated following the following formula:

$$T_{PE} = \frac{Imp_{power} + Imp_{energy}}{D_{kWh}}$$

T_{PE}*: flat rate per company*
Imp_{power}*: power term in colons*
Imp_{energy}*: energy term in colons*
D_{kWh}*: demand in kWh*

(…)

Then, a weight is determined that uses the weight of the number of fast charging stations that each company of the distribution companies must install according to Executive Decree 41642-MINAE:

(…)

*Finally, the applicable rate is obtained in fast charging stations based on energy (kWh), for this, the weighted average of the flat rates per company calculated is performed, as detailed in Annex 1 of this report, obtaining a Weighted T-VE Flat Rate of **182.71 colons / kWh**".*

***On-peak period**: Between 10:01 a.m. and 12:30 p.m. and between 5:31 p.m. and 8:00 p.m.*

***Off-peak period**: Between 6:01 and 10:00 and between 12:31 and 17:30 hours.*

***Night period**: Between 20:01 and 6:00 the next day.*

7. Estimated energy demand

The energy demand per power is determined considering a constant power of 50 kW, an adjusted load factor of 20%, considering a month of 30 days and 5 hours for the peak period, 9 hours for the valley period and 10 hours for the night period:

(…)

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The calculation of the amount of energy and power is made, according to the rates in force for each electricity company:

$$T_{PE} = \frac{Imp_{power} + Imp_{energy}}{D_{kWh}}$$

T_{PE}*: flat rate per company*
Imp_{power}*: power term in colons*
Imp_{energy}*: energy term in colons*
D_{kWh}*: demand in kWh*

(…)

9. Calculation of the rate in fast recharge centers (colons / kWh)

First, a flat rate per company is calculated following the following formula:

$$T_{PE} = \frac{Imp_{power} + Imp_{energy}}{D_{kWh}}$$

T_{PE}*: flat rate per company*
Imp_{power}*: power term in colons*
Imp_{energy}*: energy term in colons*
D_{kWh}*: demand in kWh*

(…)

Then, a weight is determined that uses the weight of the number of fast charging stations that each company of the distribution companies must install according to Executive Decree 41642-MINAE:

(…)

Finally, the applicable rate is obtained in fast charging stations based on energy (kWh), for this, the weighted average of the flat rates per company calculated is performed, as detailed in Annex 1 of this report, obtaining a Weighted T-VE Flat Rate of ***182.71 colons / kWh***”.