Decarbonizing the Transport Sector in the Arab Region

Guidelines for Charging Stations

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Acronyms

AC	Alternating Current
CCS	Combined Charging System
CP	Control Pilot
DC	Direct Current
EgyptERA	Egyptian Electric Utility and Consumer Protection Regulatory Authority
EMC	Electromagnetic Compatibility
EVCS	Electric Vehicle Charging Station
EVs	Electric Vehicles
EVSE	Electric Vehicles Supply Equipment
ICEs	Internal Combustion Engines
IEC	International Electrotechnical Commission
kA	Kiloampere
kV	Kilovolt
kVA	Kilovolt Ampere
kW	Kilowatt
LAS	League of Arab States
mA	Milliampere
MVA	Megavolt-ampere
NDCs	Nationally Determined Contributions
OCPP	Open Charge Point Protocol
PLC	Programmable Logic Controller

Executive Summary

Rapid urbanization requires proportional development of sustainable transportation systems with the expansion of infrastructure that is dependent on accessible green energy. Motorized urban transport accounts for a large share of energy consumption in the Middle East, and it is hence the main contributor to the CO_2 emissions from that sector. Therefore, any policy aimed at mitigating the effects of climate change must list sustainable transport among its priorities.

There has been an increasing interest in the utilization of EVs as an alternative to conventional motor transportation technologies. Hence, comprehensive guidelines need to be developed to enable the effective use of EVs without negatively impacting the urban transport system.

The main objective of these guidelines is to help regulators and network operators to define the requirements necessary for the safe connection and operation of Electric vehicles Supply Equipment (EVSE) either for individuals or for the public and commercial. The guidelines include general requirements and specifications for grid-connection, communication, safety, licensing and permits with a focus on the unidirectional charging technology.

The approach adopted to develop this document is to provide the LAS member countries with a global guidelines and standards suitable and tailored for the regional context. It is worth mentioning that each LAS member state could adopt these guidelines.

These guidelines split into five main parts:

- The first part summarizes the background information necessary for regulators, policy makers, and end-users to understand the basic terminologies and charging protocols available globally for EVs. This part ends up with conclusions about the GHG emissions associated with the transport sector within the LAS member states, as well as the data gaps related to the development of sustainable transport markets.
- The guidelines for individual and public charging stations are presented in the second and third parts of this document. These guidelines are from the perspectives of the electricity grid, and

include the requirements for communications, safe operation, wiring, grid-connections, and permits and licensing.

- The fourth part entails the general requirements for chargers from a transportation, zoning, and accessibility perspectives.
- Last part is for successful business models that would result in promoting the E-Mobility markets. This part includes global success towards EVs charging policies, utility rates, financial incentives, etc.

Introduction

Understanding of the assignment

Background and rationale

The transport sector is one of the biggest contributors to the global inventory of greenhouse gases amongst all the different economic activities. For that reason, countries are planning to cut transport emissions to achieve its declared commitments towards climate mitigation. Most of the Arab Countries have issued their updated NDCs with proposed actions related to a low-carbon transport sector, these actions include the market uptake of E-Mobility.

The importance shift to E-mobility using clean energy sources as well as establishing the necessary infrastructure became crucial and require a clear reflection on the regional strategies and political support considering the fact that the markets of the League of Arab States (LAS) Member Countries still not matured.

Investments from both the public and the private sectors are crucial to support the gradual transition from Internal Combustion Engines (ICEs) to E-vehicles. However, there are other factors such as regulatory framework and financial support needed to upscale the market towards this green mobility transition.

There is a noticed growth rate of the number of licensed e-vehicles in many countries. Infrastructure still not ready and requires a lot of development work, though. These guidelines form the basic requirements for connecting Electric Vehicles (EVs) charging stations with the electricity grid in the Arab Countries.

Objective and scope

The main objective of these guidelines is to help regulators and network operators to define the requirements necessary for the safe connection and operation of Electric vehicles Supply Equipment (EVSE) either for individuals or for the public and commercial. The guidelines include general requirements and specifications for grid-connection, communication, safety, licensing and permits with a focus on the unidirectional charging technology.

Approach and methodology

These guidelines have been developed through a review process of the adopted requirements in different jurisdictions in Europe, North America, Africa, and Asia. Even though these requirements are generic and not specific to certain jurisdictions, they can be further tuned for the local context of the Arab Countries.

Skeleton of the Guidelines

The guidelines split into four parts, the first part focuses on the E-Mobility's market enabling tools (scope is limited to national policies and regulations) in the LAS Member Countries as well as basic background information about the available charging technologies. The second and third parts present the technical guidelines for connecting EVSE to the grid, global practices for business models and financing schemes are presented in the fourth part.

1. Setting the Scene

1.1. Background Information

An Electric Vehicle Charging Station (EVCS), interchangeably known as a charge point or electric vehicle supply equipment (EVSE), could have different categories depending on the charging system and charging requirements of each country, or either being an Alternating Current (AC) or a Direct Current (DC) charging station.

There are three dominant charging systems worldwide; Type 1, Type 2, and GB/T[1]. The main difference between these systems is that Type 1 and Type 2 use Programmable Logic Controller (PLC) for communication, while the GB/T uses a Controller Area Network (CAN Bus) protocol instead.

An EVCS is designed to fulfil the following criteria: (i) safe charging process, (ii) efficient operation, and (iii) reliability. EVCS are either using an Alternative Current (AC) or Direct Current (DC). AC charging stations supply the E-vehicle with single or three phase AC. The AC flows to the vehicle’s on-board charger that converts AC to DC before it enters the battery. In this mode, the on-board charger is responsible for controlling the charging process and monitoring the charging speed. Due to weight and volume restrictions, on-board chargers are compact and designed for small charging capacities <23 kW; therefore, AC charging stations are usually characterized by its low charging speed.

To the contrary of AC stations, DC ones convert grid electricity from AC to DC and directly supply the battery (off-board charger). In this type, charging stations are responsible for the whole charging process. Hence, DC chargers are characterized by its high-charging speed and capacity (up to 350 kW).

Table 1 Differences between on-board and off-board chargers

On-board	Off-board
▪ Low charging speed ▪ long charging time ▪ Small size ▪ Light weight ▪ Low cost ▪ Low impact on the grid	▪ High charging speed/ ▪ Short charging time ▪ Big size and ▪ Heavy weight ▪ High cost ▪ High impact on the grid

[1] GB stands for “Guo Biao” in simplified Chinese, or the National Standards; while the T refers to “tuijian” in Chinese language, which means recommended. Hence, GB/T is the Recommended Chinese Standard.

On-board	Off-board
▪ Minor effects on battery health ▪ Inside the vehicle and controls the whole charging process	▪ Major effects on battery health ▪ Inside the charging station and controls the whole charging process

The charging cable (i.e., the connector) with its inlet and outlet sockets shall be compatible with both the E-vehicle and the charging station. Connectors are classified according to the current (AC or DC), charging mode, and charging system. Figure 1 shows the different classifications of connectors based on current and charging system.

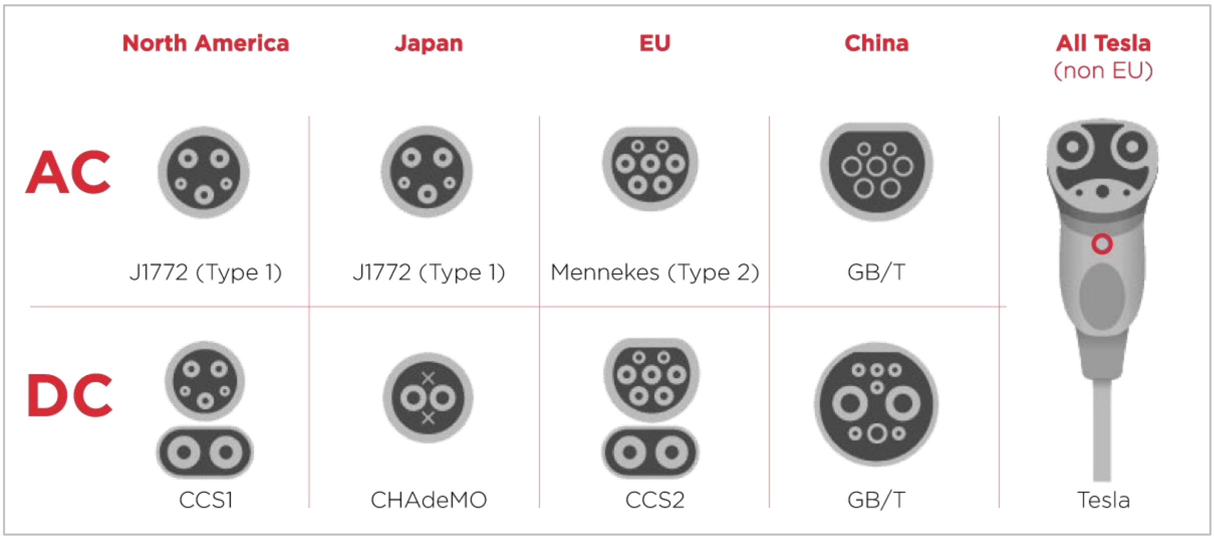

Figure 1 Different charging connectors[2]

Table 2 summarizes the different charging systems.

Table 2 Different charging systems

System	Description
Type 1 (SAE J1772)	• A north American standard for charging. it works with an AC source at 120 V. The connector has five pins which are L1: AC line, N: AC neutral, PE: earthing, PP: proximity pilot[3], and CP: control pilot[4]. • The Combined Charging System CCS 1 builds on this standard by adding two extra pins for DC fast charging up to 350 kW. The connector uses green PHY Power Line Communication (PLC) in communication.
CHAdeMO	• CHAdeMO is an IEC/EN standard: IEC 61851-23 and 61851-24 (covering communication between the charger and the EV). CHAdeMO uses CAN BUS for Signaling.

[2] PBC | PV BESS EV Charging Station Systems - Battery Storage | AGreatE.
[3] This is responsible for communication and control before the charging process starts, which prevent the vehicle movement while connected to the EVSC.
[4] This responsible for the communication and control over the course of the charging process, which provide the charging level between the car and the EVSC and other charging parameters.

System	Description
Type 2 (IEC 62196-2)	• A European standard for charging. it works with an AC source at 230 V single or 400 V three-phase. The connector has seven pins which are L1, L2, L3: AC lines, N: AC neutral, PE: earthing, PP: proximity pilot, and CP: control pilot. The Combined Charging System CCS 2 builds on this standard by adding two extra pins for DC fast charging up to 350 kW. The connector uses the identical signaling protocol used in Type 1. Tesla introduced a type 2 charging connector for their vehicles in Europe.
GB/T	• A Chinese standard for charging. It works with an AC source at 250 V single or 440 V three-phase. The connector has seven pins which are L1, L2, L3: AC lines, N: AC neutral, PE: earthing, PP: proximity pilot, and CP: control pilot. The connector is physically compatible with a Type 2 connector but with different configurations and signaling. • The DC charger uses a different and larger connector. There are four pins for signaling; two for charging confirmation similar function as PP in Type 2 and two for communication by CAN BUS.

Real photos of connector plugs are shown in Figure 2.

Figure 2 Charging connectors, SAE J1772 (upper left), CHAdeMO (upper right), type 2 (lower left), GB/T (lower right)

There are four charging modes as presented in Table 3.

Table 3 Different charging modes

Charging mode	Description
Mode #1 - slow charge	• Works with AC through traditional home socket. • No communication between the car and the charger.
Mode #1 - slow charge w/ communication	• Works with AC through traditional home socket. • There is communication and protection between the charger and the E-vehicle through cable control and protective device (IC-CPD).
Mode #3 - faster charge	• Works with AC charging stations. • Communication and protection through the off-board charger.
Mode #4 - fast charge	• Works with DC charging stations. Charging stations are more voluminous compared to other modes. • Communication and protection through the off-board charger.

Figure 3 shows the different charging modes.

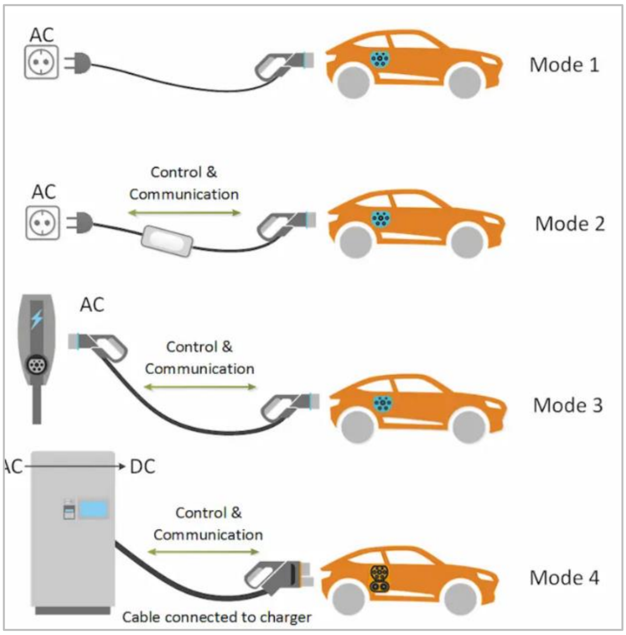

Figure 3 Different charging modes of E-vehicle

The IEC 61851-1 Committee of “Electric vehicle conductive charging system” has then defined the abovementioned four charging mode[5]. It also defines the socket types such as Type 1 and Type 2. At the end of year 2014, CHAdeMO became a published international standard[6].

There are some adaptors available in the market to convert from Type 2 to GB/T, but they are neither authorized nor tested according to standards. It

[5] EV charging stations and modes: International standards – study.

[6] CHAdeMO - Wikipedia.

is not recommended to use such adaptors, especially with the DC fast chargers as it may lead to destroying the charging system and the E-vehicle[7].

1.2. GHG Emissions Inventory

Over the past two decades, transport sector in the Arab region has significantly progressed with the licensed passenger vehicles represented nearly 60% of total road fleets, while the remainder is for trucks, buses, motorcycles, etc. Subsidized fuel prices and low utilization rates of mass transit and public transport had also contributed to the significant reliance on passenger cars. Hence, traffic congestion became growing problem in our countries that resulted in high pollution levels[8].

In most Arab States, there are factors that could embark the green energy transition within the transport sector, these factors are:

- Aging of vehicles' fleet - vehicles in most countries in the region, except for the Gulf Cooperation Council (GCC), tends to be old, with high fuel consumption and low efficiency.
- Modes of traffic management - traffic management doesn't facilitate smooth flow, and the limited public awareness of appropriate traffic management procedures leads to limited control of public behavior, and hence more traffic congestion and generated emissions.
- Low market uptake of mass-transit and car-pooling: The most used mode of transport in Arab countries is private cars that aggravates congestion and high-pollution levels.
- Lack standards and regulations: Environmental standards and regulations relating to the transport sector are either non-existent or not enforced.

Based on the latest IEA data[9], it was recorded that the total emissions from all economic activities within the LAS member countries had reached 1,596 MT CO2eq, out of that number, the transport sector is responsible for 448 MT CO2, (i.e., 28% of total LAS countries emissions).

Figure 4 below shows the transport emissions as well as its national share for 2020.

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[7] Feedback from private sector and owners of E-vehicles in Egypt.
[8] Transport for sustainable development in the Arab Region: Measures, progress achieved, challenges and policy framework. ESCWA, 2009.
[9] https://www.iea.org/countries.

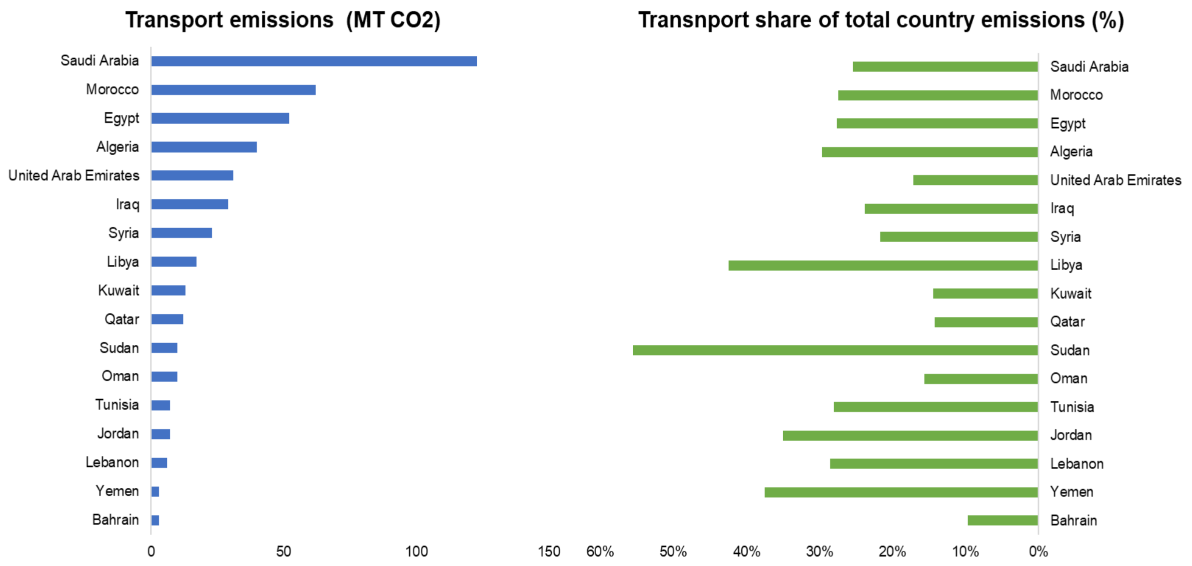


Figure 4: Transport emission for member state countries in year 2020

Saudi Arabia, Morocco, Egypt, and Algeria have the lion shares of transport emissions that was amounted at 277 MT CO2 in 2020.

Relative transport emissions shares within the LAS member countries are shown in Figure 5.

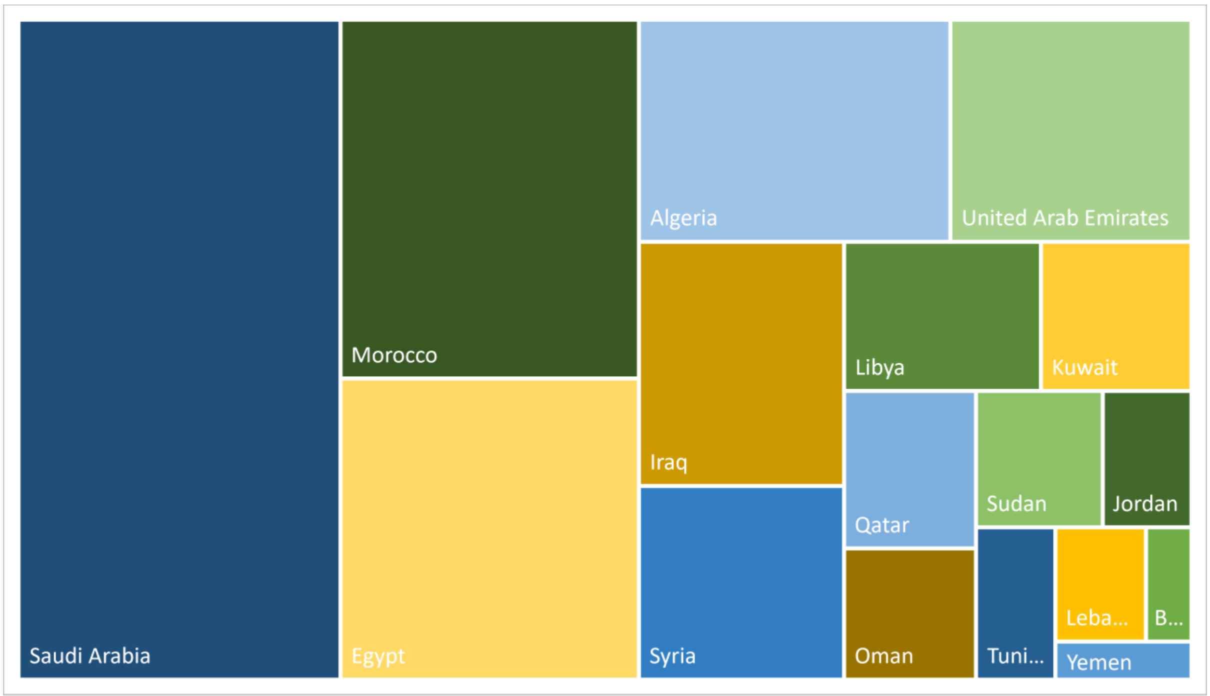


Figure 5 Share of member states countries from the emission of transport sector, 2020

There are five countries that don't have credible data sources, which are Palestine, Comoros, Djibouti, Mauritania, and Somalia. The data available for Comoros and Somalia is old (2010), the transport sector represents more than 50% their total emissions, though.

1.3. Data Gaps

Data is crucial for transportation planning and for understanding the behavior and preferences of the users in each country. The basic data needed to upscale E-Mobility in the market shall include the following:

- Traffic Data
    - Transportation networks.
    - Traffic studies.
    - Traffic flows.
    - Travelled times, travelled distances and vehicle compositions.
- Existing and future masterplans
    - Electric vehicle data:
    - National strategies.
    - Existing EV charging stations.
- Regulatory framework.
- Market enablers.

The conclusion of the data collection process is that there are data gaps. Data availability was found to be limited to:

- No. of licensed vehicles.
- Road network data.
- Few statistical data for ridership.

The above collected data has been analyzed from a transportation point of view. Therefore, the approach adopted to develop this document is to provide the LAS member countries with a global guidelines and standards suitable and tailored for the regional context.

It is worth mentioning that each LAS member state could adopt these guidelines.

2. Guideline for Individual Charging Stations

The individual charging stations are those stations that run for the personal use not for the commercial one. They are typically with small capacities compared to commercial chargers. These chargers shall follow the following requirements in their installation, connection, and operation. It should be noted that these requirements complement those in the building and network codes.

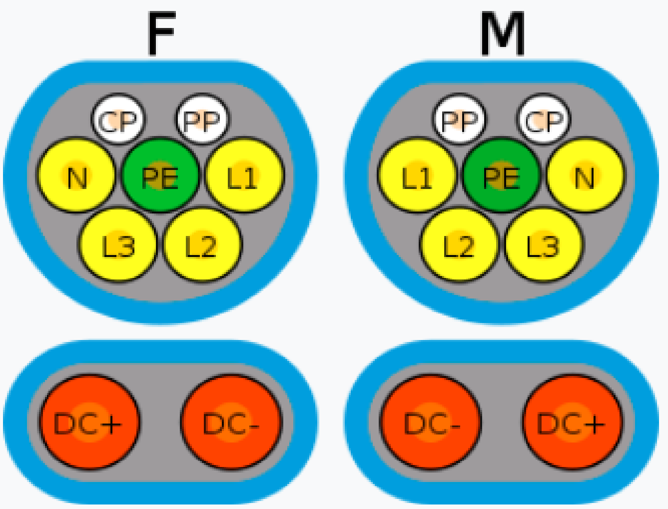
2.1. General Guidelines

2.1.1. Communication Requirements

The IEC 61851 -1:2017 “electric vehicles conductive charging system – Part 1: General requirements” defines the EV charger types: communication and safety requirements and classifies the charging modes into 4 modes as summarized in Table 3 and Table 4.

All the charging modes except Mode 1 has the following two capabilities:

- A ground fault indication capability thus offers safety against electric shock.
- Besides an “EV-EVSE” handshake that communicates the ability of the vehicle on-board charger to handle the charging capacity and thus provides safety in terms of power drawn capability.



Pinouts for Type 2 female (charging station outlet/vehicle connector) and male (vehicle inlet/outlet side plug) electric vehicle charging plugs

PP	Proximity pilot	pre-insertion signalling
CP	Control pilot	post-insertion signalling
PE	Protective earth	full-current protective earthing system—6-millimetre (0.24 in) diameter
N	Neutral	single-/three-phase AC / DC-mid
L1	Line 1	single-/three-phase AC / DC-mid
L2	Line 2	three-phase AC / DC-mid
L3	Line 3	three-phase AC / DC-mid

Figure 6 Type 2 female station outlet / vehicle connector (left) – male vehicle inlet / outlet side plug (right)

The charging process of an electric vehicle requires sufficient communications between the vehicle and the EVSE to communicate the ability of the vehicle on-board charger to receive certain capacity in addition to indicating the ground fault incase present. Therefore, Mode 2 will be sufficient for individual charging points as per the IEC 61851.

Figure 4 shows the charging modes according to the IEC 61851-1 standard.

2.1.2. Safety Requirements

In terms of resistance of enclosure against the intrusion of dust and liquids, the EVSE shall be designed for outdoor use with ingress protection rating of IP54 according to the IEC 60529. Furthermore, it shall have an impact protection resistance level of an IK 10 against mechanical impact according to the IEC 62262.

In terms of location, the electric vehicle charging point should be kept away from areas with potentially explosive material.

2.1.3. Equipment and Wiring Requirement

The EVSE shall follow the requirements of the IEC 62196 "Plugs, socket-outlets, vehicle connectors and vehicle inlets – Conductive charging of electric vehicles" namely with the operating charging range as follows:

- 690 V AC 50 Hz to 60 Hz, at a rated current not exceeding 250 A.
- 1500 V DC at a rated current not exceeding 800 A.

The IEC 62196 including its series further defines the requirements, tests, for vehicle connectors and inlets for conductive charging of electric vehicles. These connectors, sockets and plugs shall include additional contacts that provides the needed communications for electric vehicle charging procedures.

As part of the series, the IEC 62196-2 describes three types (Type 1, 2, and 3) with different designs for its male and female connection, configurations along with its current rating.

For example, type 2, which is widely used in Europe, consists of a plug and an outlet that enables mode 2 and 3 communications as per the IEC 61851 mentioned earlier.

As shown in figure 2, it consists of a round housing with a flat side for orientation with a maximum of seven contacts for four AC conductors, a protective conductor and two signal pins. Two additional DC contacts shall be added into the Combined Charging System (CCS) as will be described later.

The charging points shall be sized to be at least 125% of the maximum demand.

2.2. Grid Connection Requirements

It shall be ensured that the operating voltage remains within allowed limits as per the distribution system requirements. In this regard, it is the responsibly of the distribution company to assess the suitability of the grid capacity at the connection point and propose needed extensions if needed.

For example, the Saudi Electricity Company requires a certain voltage range of +- 5% that shall be maintained all-over the distribution network when connecting a charging point.

In turn the charging point shall continue to operate as long as the voltage remains within the allowed limits. These allowed limits vary from certain judication to another. For example, the Saudi Electricity Company allows for continuous operation in a range +-10% of the nominal voltage.

Furthermore, the charging point shall continue in operation as long as the grid frequency remains within allowed limits. These allowed limits vary from certain judication to another. For example, the Saudi Electricity Company requires the following performance in different frequency bands as in Table 4.

Table 4 Operational Frequency Range and the required response - Saudi Electricity Distribution Code

Operation requirements	Below nominal frequency (Hz)	Above nominal frequency (Hz)
Continuous	58.8 – 60	60 - 60.5
For a period of 30 minutes	57.5 – 58.7	60.6 – 61.5
For a period of 30 seconds	57 – 57.4	61.6 – 62.5

No reverse power shall be fed into the grid.

The charging station shall comply with the allowed power factor limits as per local requirements. In Egypt, it’s required to maintain an average power factor of not less than 0.9 lag, whereas customers are incentivized to have higher power factor.

In term of power quality parameters, the phase voltage unbalance shall be kept within limits. The charging point shall also keep the harmonic injection level in the allowed limits. These allowed can be defined by the relevant standard such as:

- IEC 61000-3-2 Electromagnetic compatibility (EMC) – Part 3-2: Limits – Limits for harmonic current emissions (equipment input current ≤ 16 A per phase).
- IEC 61000-3-12 for equipment above 16 A.
- It can also be defined by national regulation and codes. For example, the Saudi Electricity Company sets a max value for the total harmonic distortion at 5% for voltage levels up to 1 KV and individual level as presented in Table 5.

Table 5 Total harmonic distortion level expressed in % of voltage at the fundamental frequency – Saudi Electricity Distribution Code

Nominal Voltage	Total Harmonic Distortion (%)
230 – 400 V	5
127 – 220 V	5
11 kV & 13.8 kV	4
33 – 69 kV	3

The protection equipment shall provide protection against short circuit currents at the point of connection. A short circuit level at different loads can be considered a system design reference such as the one Provided the Saudi Electricity Distribution Code in Table 6.

Table 6 Short Circuit Ratings - Saudi Electricity Distribution Code

Connection Voltage	Load (kVA)	Short circuit level (RMS Symmetrical (kA))
220 / 127 V	≤152	21
	≥152	45
380 /20 V	≤500	20
	≥500	30
400/230 V	≤500	20
	≥500	30
13.8 kV	All	21
33kV	All	25
69kV	All	31.5

It shall further ensure protection against earth leakage current, over-current protection and over temperature protection functions. The charging point shall have proper earthing following the earthing requirements in the jurisdictions in addition to lightning protection. It should be mentioned that protection against earth leakage current with a residual current device shall be of an operating current rating not above 30 mA.

2.3. Permits and Licensing

Not all countries license individual charging stations. Indeed, it's advisable at this early adoption stage that administrative processes shall be kept to the minimum. Therefore, the distribution utility can only be notified in case the charger capacity above 11 kW and advise the customer on the operating scenarios given the local network parameters. In this case, it shall ensure the compliance with all the above requirements.

3. Guideline for Public Charging Stations

Public charging stations are those charging points that are commercially operated to serve the public as opposite to those charging points that run to serve individuals. Typically, they are characterized by their higher charging capacities besides their presence in charging stations as several points. Therefore, public charging stations would typically have a total charging capacity of at least 50 kW.

It should be noted that these requirements complement those in the building and network codes.

3.1. General Guidelines

3.1.1. Communication Requirement

Public charging stations shall use at least Mode 3 charging as mentioned per the IEC 61851 -1:2017 classification earlier. In this mode several communication functions are employed to ensure public safety. These include for example verifying protective earth connection in addition to the connection between the EV and EVSE.

Therefore, Mode 3 is characterized by bidirectional communication between the vehicle and the EVSE. In addition, it uses a dedicated charging outlet in compliance with IEC 62196 "Plugs, socket-outlets, vehicle connectors and vehicle inlets – Conductive charging of electric vehicles".

In terms of charging management communication, the Open Charge Point Protocol (OCPP) is widely adopted in different jurisdiction as open-source protocol used to the charging station and the charging network management. its main role is to allow any charging station of working compatibly with charging management software to authenticate the user, start the charging session and secure exchange of data.

3.1.2. Safety Requirement

Similar to the individual charging points, the public charging points shall be designed for outdoor use with ingress protection rating of IP54 according to the IEC 60529 to ensure resistance of enclosure against the intrusion of dust and liquids. Furthermore, it shall have an impact protection resistance level of an IK 10 against mechanical impact according to the IEC 62262.

Furthermore, the charging plug shall be at a height of 75 to 120 cm from the ground.

3.1.3. Equipment and Wiring Requirement

As highlighted earlier in the requirements for individual charging points, the EVSE shall follow the requirements of the IEC 62196 "Plugs, socket-outlets, vehicle connectors and vehicle inlets – Conductive charging of electric vehicles" along with its defined requirements, and tests. However, two additional DC contacts are added to (Type 2) into the Combined Charging System (CCS 2) for high-current DC charging using (Mode 4) charging, as shown earlier in Figure 2.

Furthermore, the electrical wiring shall follow the IEC 60364 standards to ensure these requirements. Specifically, as prescribed in IEC 60364-7-722.311 "It shall be considered that in normal use, each single connecting point is used at its rated current or at the configured maximum charging current of the charging station. The means for configuration of the maximum charging current shall only be made by the use of a key or a tool and only be accessible to skilled or instructed persons."

IEC 60364-7-722.311 also states that "Since all the connecting points of the installation can be used simultaneously, the diversity factor of the distribution circuit shall be taken as equal to 1 unless a load control is included in the EV supply equipment or installed upstream, or a combination of both."

An emergency button shall be attached to each charging point along with proper signage.

3.1.4. User Interface Requirement

In terms of user interface, a display is required to communicate to the user:

- Charing consumption
- Charging costs
- Charging states and errors, if any.

The use interface shall enable payment through the widely used instruments namely electronic payment.

It shall also allow access to 24/7 support service and customer complaint handling. In addition, it shall support the communication in at least two languages mainly Arabic and English.

3.1.5. Location Requirement

Further to the safety requirements mentioned earlier for the individual charging stations, there are location aspects that shall be considered as follows:

- Sufficient parking plots must be ensured for the charging station in relation to its capacity.
- Besides, the online presence of the location, the charging station shall have adequate guiding signs that can guide customers to the charging plot inside the facility or the land where the station is located.
- Proper ventilation, cooling, and shading in case of exposure to direct sunlight as per manufacturer recommendations shall be adhered with.
- kept away from areas with potentially explosive material. In some jurisdictions such as Jordan, charging stations are allowed to be in a petrol station provided that a concrete wall as tall as the charging station is constructed.
- Protected with a collision protection shield constructed around each point.
- Electrical wiring and connection shall be crossing neither walking lanes nor motorways.

3.2. Grid Connection Requirement

Similar to the requirements for private charging points, the following requirements are still applied:

- operating voltage shall be maintained within the operating voltage as per the distribution system requirements.
- The distribution company is required to assess the suitability of the grid capacity at the connection point and propose needed extensions if needed.
- The charging point shall continue to operate as long as the voltage remains within a certain range as highlighted earlier which is in a range +-10% of the nominal voltage as per the requirements of the Saudi Electricity Company.
- The charging station shall continue in operation as long as the grid frequency remains within allowed limits.

- No reverse power shall be fed into the grid.
- The charging station shall comply with the allowed power factor limits as per local requirements as presented earlier.

In terms of power quality parameters, the phase voltage unbalance shall be kept within limits.

For example, the Egyptian Distribution Code sets the limit at +- 5% from the average voltage of the three phases up to 1 kV and at 2% for higher voltages. It further allows for 10% deviation from the average voltage for up to 1 kV networks and 4% at higher voltages provided that this unbalance does not go beyond two minutes.

Table 7 Individual harmonic level limits for voltages above 1 KV and below 33 kV – Saudi Electricity Distribution Code

Odd Harmonics (Non-multiple of 3)		Odd Harmonics (Multiple of 3)		Even Harmonics	
Order 'h'	**Harmonic Voltage %**	**Order 'h'**	**Harmonic Voltage %**	**Order 'h'**	**Harmonic Voltage %**
5	6.3	3	4	2	1.5
7	4.4	9	1.2	4	0.8
11	2.7	15	0.3	6	0.6
13	2.3	21	0.2	8	0.5
17	1.7	>21	0.2	10	0.5
19	1.5			12	0.4
23	1.2			14	0.4
25	1.1			16	0.3
>25	(32.3/h) – 0.2			>16	(2.5/h) + 0.22

Similar to the requirements for the charging point, it is required for the public charging stations to keep the harmonic injection level in the allowed limits. These allowed can be defined by the standards, national codes and regulation.

For example, the Saudi Electricity Distribution Code defines the allowed max value for the total harmonic distortion for the individual level of each component for voltage as highlighted earlier below 1 kV. Whereas, for voltages above 1 KV and below 33 kV the individual limits are shown in Table 8.

The protection equipment shall provide protection against short circuit currents at the point of connection. A short circuit level at different loads can be considered a system design reference such as the one Provided the Egyptian Electricity Distribution Code in Table 8.

Table 8 Short Circuit level at different voltages - Egyptian Electricity Distribution Code

Short Circuit Current Level (kA)	(MVA)	Voltage level (kV)
13.1	500	22
18.4	350	11
21.9	250	6.6
50	36	<1

Similar to the protection requirements presented for individual charging points, the charging equipment shall protect against short circuit currents as well as thermal loading on the grid components. It shall further ensure protection against earth leakage current with an operating current rating not above 30 mA.

Additionally, the Residual current device shall be of class B to ensure proper functioning with DC leakage current. Regulations in certain countries may dictate additional earthing requirements.

3.3. Licensing Requirement

In designing the license and permit requirements, regulators and policy makers consider either of the following objective, as shown in Figure 7.

- Access to market
- Quality Control
- Responsibilities & Procedures

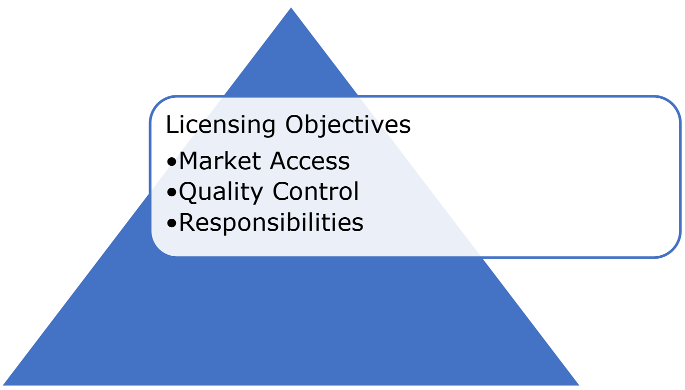


Figure 7 Possible different licensing Framework objectives

3.3.1. Market Access

In terms of market access, policy makers may choose to limit market access through defining certain eligibility criteria for licensed actors.

The eligibility criteria can aim at creating a level playing field between actors interested in the charging stations business. This can be done, for example, by preventing the network operator from getting into this business as to avoid potential discrimination against competing EV charging companies.

Additionally, eligibility criteria can be based on company scale. Requirements on the actor scale can further ensure a small number of companies in the business and thus reduce the administrative work. However, such option will create more entry barriers against new entrants. International experience shows wide scope of implementation. For Example, the Egyptian Electric Utility and Consumer Protection Regulatory Agency sets a minimum number of charging station for each licensed company in the business.

3.3.2. Quality Control

In terms of quality control, a qualification criterion can be set in place to ensure the financial and technical competency of the licensed companies. For example, the Egyptian Electric Utility and Consumer Protection Regulatory Agency (EgyptERA) sets a minimum requirement of 10 million EGP on the issued capital for the qualified company. Further technical requirements can be designed to ensure the technical competency of the qualified company. However, such constraint will limit the development of the market given that neither of the existing market players has previous experience.

3.3.3. Responsibilities and Procedures

In terms of responsibilities, clear procedures should be defined along with the responsibilities of each involved actor. As an example, the licensing framework in Egypt is discussed sowing the procedures and responsibilities of each involved party.

The interested actors in the EV charging business shall have a coverage plan for the next five years with a list of potential station locations. They can further consult the distribution companies on the connection costs that will be incurred to connect these potential stations to validate their business cases accordingly.

The plan shall be supported with a no-objection letter from the distribution company confirming the possibility of connecting the charging station at each specified location.

With this plan along with an application template, as shown in table 6, qualified actors can apply for the permit before starting the construction phase. The permit shall be given to the applying entity upon confirming the economic, environmental, and technical feasibility of the charging station.

After obtaining the permit, the permit holder can start the construction phase during which he should comply with the technical requirements.

In terms of compliance with the technical requirements, it is the role of the DISCO (or a third party) is to ensure the compliance with all the above requirements. The distribution company shall ensure that equipment along with its installations, configuration and performance have been following the relevant requirements as mentioned above.

After installation, the permit holder applies for a license to start the commercial operation. The distribution company shall also be notified to carry out the testing and commissioning of the charging station to ensure its compliance with the above requirements. Furthermore, the distribution company shall do regular audits to ensure the compliance of the charging station with the technical requirements during its operation.

Table 9 Permit/License Application template - EgyptERA

No.	Item	Requirement
1	Company Profile	Please Provide the following: Company Name: CEO:.............. Legal representative: …. Company Address:……… Tel.:....................... Fax:.................... Email:................. Commercial Registry No.:
2	Articles of Association	Please attach.

No.	Item	Requirement
3	Commercial registry	Please attach.
4	Tax ID	Please attach.
5	Prefeasibility study	Please attach.
6	Company Organizational chart	Please attach.
7	Authorized list of the signed contracts with every distribution company for the charging stations (If exists)	Please attach.
8	Environmental Approvals	Please attach.
9	List of Charging stations	Please attach.
10	Preliminary Approval from the distribution companies for the suggested locations of charging stations and the quantities of charging points	Please attach.

After the testing and commissioning, the distribution company installs the meter to be ready for the commercial operation. Afterwards, the license holder can start offering the EV charging services to its end customers according to the mandated terms and conditions.

In this regard, there are two models available worldwide from which regulators and policy makers can choose when it comes to the charging price/tariff. The first is have a fully regulated price which gives more certainty to the investments whereas the other one is to have a market-based price which introduces more competition and allows for differentiated value offerings. Regulators and policy makers can choose either of the two options based on the market status.

Another aspect of the end-customer terms and conditions is data confidentiality. All customers' data and information available with either the distribution company or EgyptERA shall be deemed confidential. EgyptERA and the distribution companies shall not circulate such data and information except with the authorized persons and bodies.

4. Transportation Perspective for Public Chargers

In order to maximize the potential of EVs it is important that suitable charging infrastructure should be in place. This requires the development of a charging network to ensure availability of sufficient capacity particularly in areas where there are few charging points accessible by the public.

4.1. Zoning Guidelines

Typical zoning guidelines employ four categories of charging locations:

a) Public spaces or destination charging.
b) Workplace charging, and
c) Motorways or enroute charging.
d) Home or overnight charging.

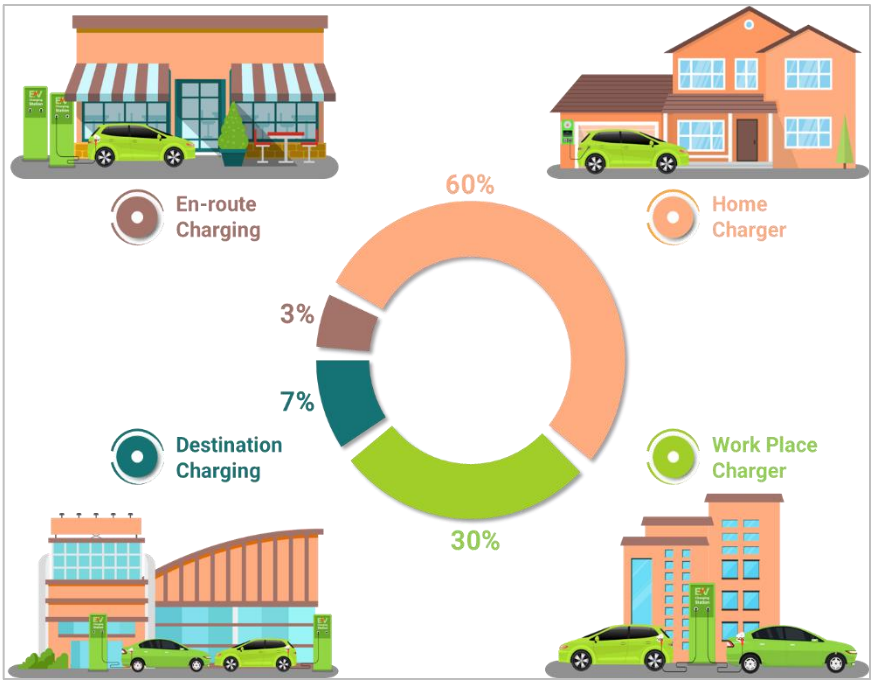


Figure 8 Typical zones for EVSEs[10]

The differences between the EVSEs zoning categories are summarized in Table 10.

[10] Source: From Autel.

Table 10 Different zoning categories of EVs chargers[11]

Zoning Category	Description
Destination charging	Approximately 7% of total charging time takes place at destinations or at public spaces such as: malls, cafes, restaurants, administrative offices, or parks. Usually, people tend to stay 2~4 hours, so they will commonly require a "top-up" charging. While 3-11 kW charging stations are okay for "topping up" an EV, real-world experience shows that such charging rates often don't serve the full needs or preferences of drivers. It is ideal to have at least 22 kW charging stations at these locations.
Workplace charging	For people without a charger near their home, being able to charge at work is the next best thing, therefore AC charging is recommended in both cases, either Home or Work, as people tend to stay long durations (6~10 hrs). If they have home charging and workplace charging, almost 90% of charging is done at home and work together. 6–11 kW charging ports may be fine, but if these are parking areas in which each parking space isn't dedicated to an individual, 22 kW charging ports would be more effective for maximizing EV charging access and convenience at a reasonable cost.
Motorways or enroute charging.	Charging stations along motorways are important for people driving long distances. In general, major points of entry/exit into a city should also have charging stations nearby. These should be fast charging locations with a minimum power capacity of 50 kW, but more ideally 100-350 kW. Such charging stations need to be highly visible and easy to access, especially for visitors coming from other cities or countries and unfamiliar with the area.
Home or overnight charging	Globally around 60% of EV charging is done at home if drivers have a place at home to charge. AC charging is recommended at that case, as people tend to stay long durations (7~10 hrs). If they have home charging and workplace charging, almost 90% of charging is done at home and work together. 6-11 kW charging ports are fine for home chargers.

4.2. Sites Requirements

4.1.1. Power Connections

Sites can differ in cost extremely based on the vicinity to a power source. As the Electric Vehicle Supply Equipment (EVSE) is close to a power source,

[11] Fishbone A., Shahan Z., and Badik P. Electric vehicle charging infrastructure: Guidelines for cities. Greenway, December 2017.

the less the installation cost will be. Since, E-Mobility markets in our countries still un-matured with less access to infrastructure and power connections, the average installation costs should not considered as a selection criterion for EVs[12].

4.1.2. Space Allocation

It is recommended to Install electrical vehicle supply equipment (EVSE) in parking spaces used by any commercial building, up to 10% of all parking spaces or at least 6 spaces should be ready for EVs, whichever is greater[13].

4.1.3. Safety

Public chargers must be properly installed and maintained to ensure both the safety of users and the environment. Safety measures should include issues such as accidental fires, electrocutions, damage to property, injury, or loss of life. The best way to minimize these risks is to invest in high-quality equipment and hire reputable contractors to install and maintain it. Here are some basic tips for maintaining a safe environment at charging stations:

- Install your charging station in a well-ventilated area.
- Protect the EV charging station by using adequate safety barriers such as: such as wheel stops, guardrails, and bollards.
- Make sure your charger complies with all regulations - The manufacturer of the charging station must provide detailed installation instructions and information on the legal requirements for installing the unit.
- Provide adequate lighting around the station - Installing outdoor lighting around charging station is a great way to make it more visible to drivers and pedestrians at night.

4.1.4. Signage

EV charging stations must achieve high level of visibility and accessibility. As such, the following are some key tips for charging station design:

- Colors: It is recommended to use strong colors to attract the eyes' attention.

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12 How-to guide: Starting an electric vehicle workplace charging program. City of Boston, 2020.
13 LEED for Building Design and Construction rating system. Version 4.1.

- Lighting: Other than the whole space lighting, it is recommended to include lighting around charging ports and/or control screens to facilitate visibility at night and trace whether the car is charging or not.
- Height: Charging station top should stand well above the height of an average car including a SUV
- Signage and Wayfinding consists of three types that should be all equipped and it is recommended to have a common visual scheme to reduce confusion:
    - ✓ Wayfinding Signage: assist in locating an EV parking space and increases awareness.
    - ✓ Regulatory Signage: identifies a space for a specific use and can enclose time limitations.
    - ✓ Parking Spot Stencils: increase visibility and ability to identify spaces.

Figure 9 shows some good examples of for signage considerations:

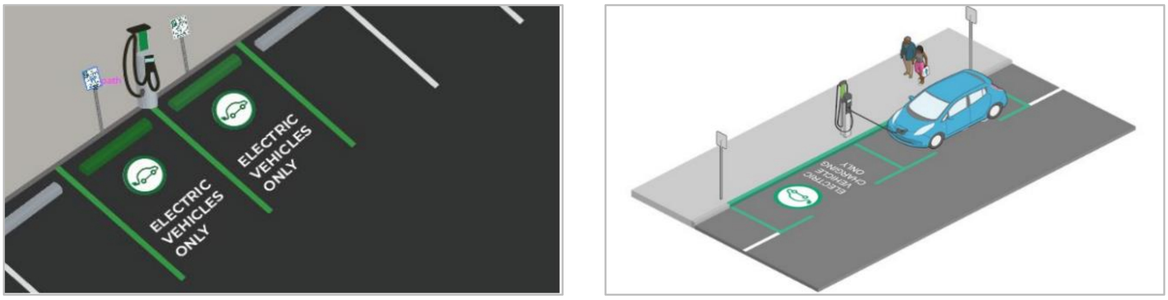


Figure 9 Recommended signage locations[14], (a) off-street (left), (b) curbside (right)

4.1.5. Accessibility

Accessibility refers to the ease and ability that a driver can safely plug in an EV to the EVSE, and the ability to reach all additional necessary components. All pedestrian routes must also be safe and accessible to drivers of all physical abilities.

4.1.6. Handicapped

EV charging requires drivers with disabilities to exit their vehicle, traverse to the charger, and carry the connector back to their vehicle charging inlet (which may be on the opposite side of where they enter/exit their EV). Since EV's do not have a standard location for the vehicle charging inlet,

[14] The Americans with Disabilities Act with its amendments.

maneuverability around the entire EV is needed. The following aspects should be taken into consideration to serve drivers of all physical abilities:

4.1.6.1. Number of parking spaces

The first column in Table 11 indicates the number of electric vehicle stations being provided on site and the second column indicates the number of accessible charging stations that are to be provided for the corresponding number(s) of charging stations:

Table 11 Recommended number of handicapped parking spaces for EVs[14]

Total no. of parking spaces provided in parking facility	Minimum number of required accessible parking spaces
1 to 25	1
26 to 50	2
51 to 75	3
76 to 100	4
101 to 150	5
151 to 200	6
201 to 300	7
301 to 400	8
401 to 500	9
501 to 1000	2% from total
1001 and over	20, plus 1 for each 100, or fraction thereof, over 1000

4.1.6.2. Accessible routes

EV chargers with accessible mobility features must be connected to an accessible route.

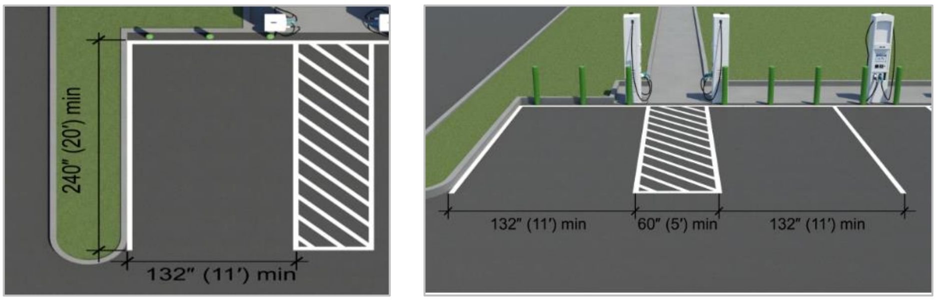


Figure 10 Recommended space and accessible routes aside[14]

4.1.6.3. Unobstructed side reach

All operable parts should meet the requirements for an unobstructed side reach (not be higher than 48 inches above the clear floor or ground space and no farther than 10 inches away. Placing operable parts higher than the 15-inch minimum is recommended.

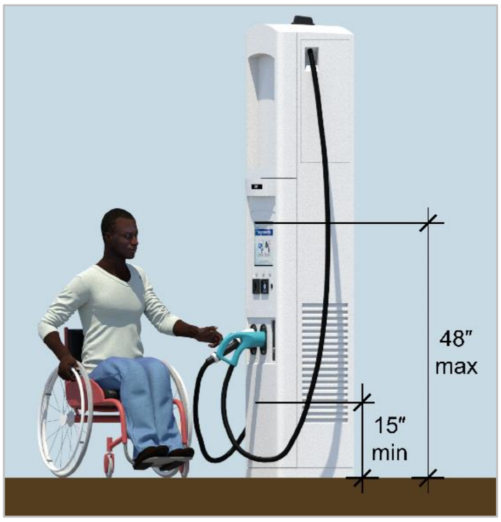


Figure 11 Locations and accessible charging ports

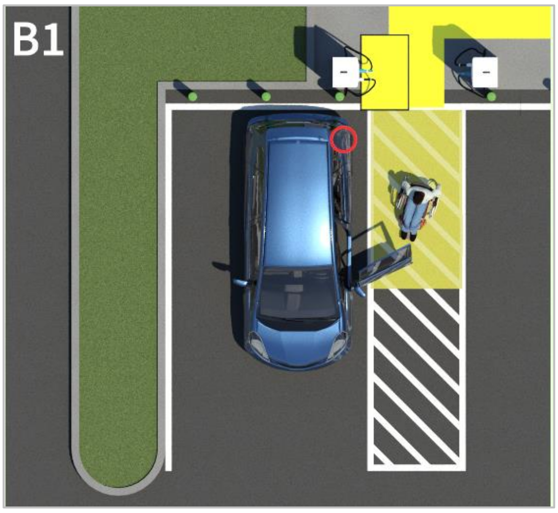
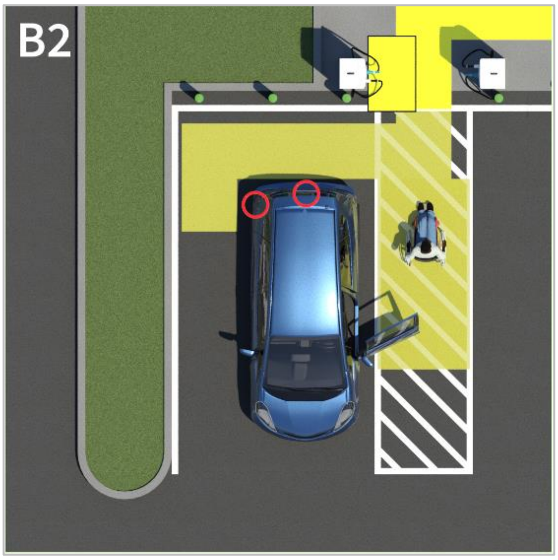
4.1.6.4. Charging ports location with respect to vehicle charging inlets

Generally, a person with a disability driving an EV will need the access aisle positioned on the driver's side.

4.1.6.5. Maneuvering scenarios

The scenarios shown in Table 12 indicate how a vehicle's orientation changes depending on the location of the vehicle charging inlet. This is particularly important for DC chargers with short and heavy charging cables. AC Level 2 and few DC chargers that have sufficiently long, and light cables may not have this issue.

Table 12 Different charging maneuvering scenarios for handicapped[14]

	B1 depicts an ideal scenario with the most common EV charging inlet location, which is on the driver side rear. When the vehicle is backed into the vehicle charging space, the driver side door is aligned with the access aisle and the vehicle charging inlet is close to the EV charger. The EV charger is located at the same level as the charging space and access aisle by depressing the curb to the same level as the asphalt. The EV charger has been rotated so that the clear floor or ground space is on the same side as the access aisle and not obstructed by bollards. Bollards are used instead of wheel stops to provide ample maneuverability around the vehicle
	B2 depicts a vehicle backed into a charging space, but the vehicle's charging inlet is located on either the rear or passenger side rear. While the access aisle is still aligned with the driver side door, the vehicle now needs to be spaced at least 36 inches (3 feet) away from the bollards in order for mobility device users to pass between the vehicle and bollards and reach a charging inlet located on the opposite side of the vehicle.

5. Business Models

In this part, a very brief overview on the global best-practices of EV charging stations in terms of projections, policies, technologies, and business models. Since China and the United States are the world's two largest markets for E-Vehicles. The data presented in Table 13 will be limited to those countries.

Table 13 Comparison of EV charging business in China and the U.S.

Thematic area	China	United States
EV deployment and sales	2.7 million EVs (2021) – 16% global market share Nearly 6.5 million EVs (2022)	0.47 million EVs (2021) – 5% global market share
Growth in 2022 vs prior year 2021	141%	102%
EV charging infrastructure	330,000 public charging points (2018)	67,000 public charging points (2019)
Role of charging infrastructure in EV purchasing decisions	EV purchases were directly linked to the availability of public charging points especially in China where many Chinese households lack access to a dedicated parking lot. Moreover, having a household chargers require a lot of permits and paperwork in China.	Lack of public fast chargers are one of the main reasons that hinder EVs purchases in the U.S.
EV charging policies	The Chinese government supports the development of EV infrastructure by setting national targets, unified standards, and financial incentives for EVs' purchases and EVSE.	The US federal government has a limited role in deployment EVs. State and local governments play the key role though. Tax credits for EV charging operators, dedicated EV charging corridors on highways, and mandated standards are key factors in the deployment of EVs.
Utility rates	Utility rates for public chargers (i.e., $0.15 to 0.28/kWh) are relatively low and many operators have complained	Highly decentralized electric utility rates (i.e., $0.12 to 0.27/kWh) with a wide market uptake of subsidized Time-of-

Thematic area	China	United States
	that the low utility rates are not making the EV charging business is financially viable. EVs' owners are very sensitive to raising the charging rates.	use pricing mechanism to respond to grid requests; however, financial incentives on the purchased EVSE positively affect the financial viability of the business.
Charging technologies	Both China and the U.S. have a growing network of DC charging points with a common rated capacity of 24 kW, 50 kW, 100 kW, 120 kW and few points with a rated capacity of 350 kW and 400 kW. These fast chargers have charging times ranging from one hour to as little as 10 minutes for a battery from 20% to nearly full charge.	
DC charging standards	One nationwide - China GB/T	Three standards - CHAdeMO, CCS SAE Combo, ad Tesla
Cost of a 50-kW charging point	Ranging from EUR 6,000 to 8,000. Nearly half of that amount is for the infrastructure cost.	Ranging from EUR 10,000 to 20,000 – excluding infrastructure cost.
EV charging business models and incentives to promote the market	**Independent companies** Located in large urban areas and leading EV cities. Earning equipment subsidies and land grabbing are key to financial viability. **Utility companies** Owns significant number of charging stations. Utilities are responsible for infrastructure upgrading as a part of its social responsibility.	**Independent companies** Raised funds from global cars' manufacturers. Available in thousands of locations. **Utility companies** Power companies with generation assets are boosting their electricity sales – improve grid operation. New technology to build new corporate image. Responsible for infrastructure upgrading.

The world's two largest markets for EVs are China and the United States in terms of the global share of EVSE and number of licensed EVs. Both countries had taken concrete steps towards promoting the E-mobility within their borders. In a descending order of importance, these actions are setting national plans and targets, mandating specific standards, and financial incentives for the purchase of EVs and EVSE. Utility rates for EV charging in both countries are nearly the same, independent operators in China are concerned towards the business viability; however, subsidies on equipment as well as the high-utilization rate are key for financial viability.

Annexes

Annex 1 - List of Reference Standards

Standard	Description
IEC 61851	IEC 61851 -1:2017 electric vehicles conductive charging system – Part 1: General requirements. IEC 61851-23:2014 Electric vehicle conductive charging system - Part 23: DC electric vehicle charging station. IEC 61851-24:2014 Electric vehicle conductive charging system - Part 24: Digital communication between a d.c. EV charging station and an electric vehicle for control of d.c. charging.
IEC 60529	IEC 60529:1989/AMD2:2013/COR1:2019 Corrigendum 1 - Amendment 2 - Degrees of protection provided by enclosures (IP Code).
IEC 62262	IEC 62262:2002 Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK code)
IEC 60364	IEC 60364-1 Low-voltage electrical installations – Part 1: Fundamental principles, assessment of general characteristics, definitions.
IEC 61000	IEC 61000-3-2 Electromagnetic compatibility (EMC) – Part 3-2: Limits – Limits for harmonic current emissions (equipment input current ≤ 16 A per phase). IEC 61000-3-12:2011+AMD1:2021 CSV Consolidated version Electromagnetic compatibility (EMC) - Part 3-12: Limits - Limits for harmonic currents produced by equipment connected to public low-voltage systems with input current >16 A and ≤ 75 A per phase.
IEC 62196	IEC 62196-1:2022 Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of electric vehicles - Part 1: General requirements. IEC 62196-2:2022 Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of electric vehicles - Part 2: Dimensional compatibility requirements for AC pin and contact-tube accessories.
IEC 60309	IEC 60309-1:2021 Plugs, fixed or portable socket-outlets and appliance inlets for industrial purposes - Part 1: General requirements.

Annex 2 - Important Definitions

Charger/EVSE	A device with one or more charging ports and connectors for charging EVs. A charger is also called electric vehicle supply equipment (EVSE) or EV charger.
Charging Network	A collection of chargers located on one or more property(ies) that are connected via digital communications to manage the facilitation of payment, the facilitation of electrical charging, and any related data requests.
Charging Network Provider	The entity that operates the digital communication network that remotely manages the chargers. Charging Network Providers may also serve as Charging Station Operators and/or manufacture chargers.
Charging Port	The system within a charger that charges one (1) EV. A charging port may have multiple connectors, but it can only provide power to charge one EV through one connector at a time.
Charging Station	One or more EV chargers at a common location. A large site can have multiple charging stations, such as in various parking lots and parking garages.
Charging Station Operator	The entity that operates and maintains the chargers and supporting equipment and facilities at one or more charging stations. This is sometimes called a Charge Point Operator (CPO). In some cases, the Charging Station Operator and the Charging Network Provider are the same entity.
Combined Charging System (CCS)	A standard connector interface that allows direct current fast chargers to connect to, communicate with, and charge EVs.
Connector	The device that attaches EVs to charging ports to transfer electricity. Multiple connectors and connector types (such as J1772, CHAdeMO, Tesla, and CCS) can be available on one charging port, but only one vehicle will charge at a time. Connectors are sometimes called plugs.
Contactless Payment Methods	A secure method for consumers to purchase services using a debit, credit, smartcard, or another payment device by using radio frequency identification (RFID) technology and near-field communication (NFC).

Direct Current Fast Charger (DCFC)	A charger that uses a 3-phase, 480-volt alternating-current (AC) electrical circuit to enable rapid charging through delivering a direct-current (DC) electricity to the EV.
Electric Vehicle (EV)	An automotive vehicle that is either partially or fully powered by electricity.
Open Charge Point Protocol	An open-source communication protocol that governs the communication between chargers and the charging networks that remotely manage the chargers.
Open Charge Point Interface	An open-source communication protocol that governs the communication between multiple charging networks, other communication networks, and software applications to provide information and services for EV drivers.
Plug and Charge	A method of initiating charging, whereby EV charging customers plug a connector into their vehicle and their identity is authenticated, a charging session initiates, and a payment is transacted automatically, without any other customer actions required at the point of use.
Site	A parcel of land bounded by a property line or a designated portion of a public right-of-way.
Vehicle Charging Inlet	The inlet on a vehicle that a connector is plugged into. Also referred to as a charging port or charging door.
Vehicle Charging Space	A space to park a vehicle for charging. A vehicle charging space can be a marked parking space, or an unmarked area adjacent to an EV charger.