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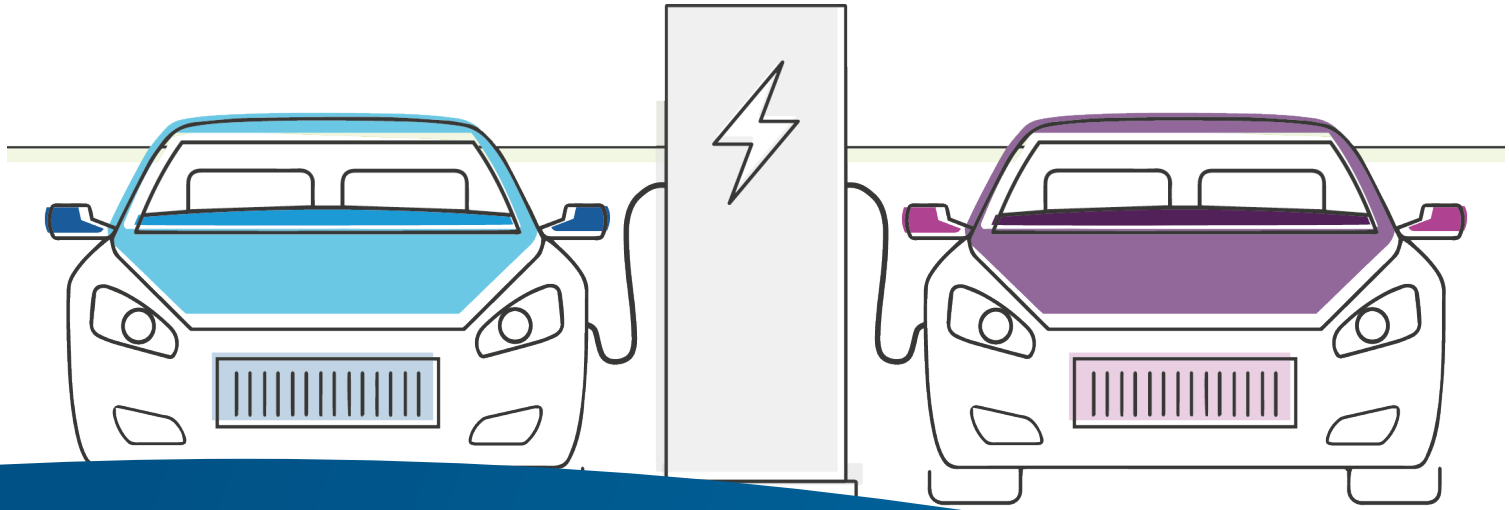


An Introduction to Plug-in Electric Vehicle Charging Infrastructure

Cenex Insight - June 2021

We will need more chargepoints as the transport system shifts to electric vehicles

Electric Charging Infrastructure

Electric vehicles (EVs) use electricity, via an electrically charged battery pack that powers the motor, to turn the wheels. They are recharged by plugging-in to dedicated charging units, usually termed 'chargepoints'.

Similar to traditionally fuelled vehicles, there is a socket on the vehicle for recharging. A cable is plugged-in to connect the chargepoint and the vehicle which enables electricity to flow into the vehicle's battery. Depending on their location and power rating, chargepoints may either have a fixed cable, or a socket for drivers to utilise their own cables.

Chargepoints can be deployed wherever there is a connection to the electricity grid, providing there is sufficient electrical capacity at that point of the grid. The type of infrastructure deployed corresponds to the users charging behaviour, whether the plug-in time is 20 minutes or several hours.

Taking a very rough EV efficiency of 3 miles range per kWh battery capacity, this works very effectively, meaning that the power of the chargepoint is directly equivalent to the range added (in miles) per 20 minutes of charging. The following table demonstrates this for different categories of charging power:

	AC or DC	Power / kW	Miles of range added per 20 minutes of charging*
Standard	AC	7 - 11	7 - 11
Fast	AC	11 – 22	11 – 22
Rapid	AC	43	43
	DC	50	50
Ultra-Rapid	DC	150+	150+

EV Charging Speeds and Miles of Range Added

For EV charging, chargers have power ratings (in kW) which reflect how much electrical energy they can transfer in a given time period. So, a 7 kW charger will transfer 7 kWh of energy every hour, or 0.12 kWh every minute.

Chargepoint Classification

The EV industry classifies charging systems into 1 of 4 modes:

Mode 1

The EV is plugged directly into a standard domestic or industrial socket. This has limitations on charging power, safety issues, and lacks convenience, and therefore is not recommended.

Mode 2

This also uses a standard domestic or industrial socket, but makes use of a cable with an in-cable control box, or ICCB. This offers improved safety over Mode 1 systems, but it's not recommended as a permanent solution.

Mode 3 and Mode 4

Both of these make use of bespoke equipment, for electric vehicle charging, which are designed for sustained charging at higher power with improved safety and convenience, and therefore are definitely recommended for EV charging systems.

The differences between Mode 3 and Mode 4 is that Mode 3 is an AC charging system and Mode 4 is DC, and with a different charging cable for each.

Mode 1	AC		Limitations on charging power, safety and convenience. **Not recommended.**
Mode 2	AC		Improved safety over Mode 1. **Not recommended as a permanent solution.**
Mode 3	AC		Designed for sustained charging at higher power with improved safety and convenience. **Recommended.**
Mode 4	DC		

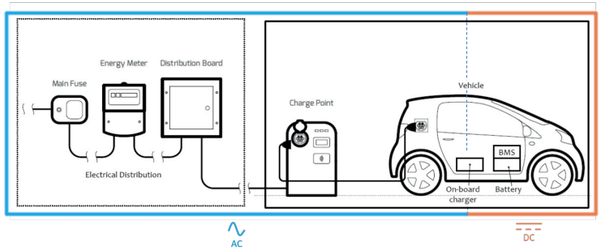
EV Charging Modes

Rectifying Electricity

Electrical energy can take two forms. Alternating current (AC) is where the voltage and current periodically reverses in direction. The electricity from the grid is AC.

Direct current (DC) has a unidirectional voltage and current, meaning the charge flows in one direction only. EV batteries store and use DC electricity.

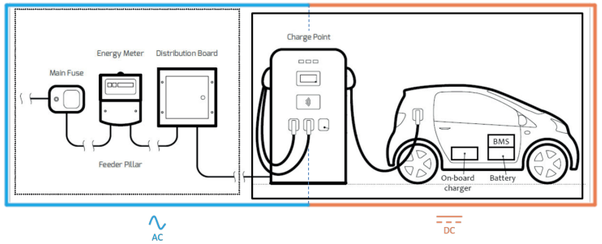
We can convert between AC and DC electricity and vice versa using power electronic devices, and while the task they perform is similar, the direction of conversion impacts the name given to the device.



Mode 3 AC Charging System

Alternating current is rectified by rectifiers to direct current, and direct current is inverted by inverters to give alternating current.

Onboard chargers rectify AC to DC electricity in EVs. Weight reduction is critical when designing a vehicle, therefore vehicle manufacturers tend to prefer to use smaller, lighter on-board chargers and leave the weightier elements in the chargepoint where weight isn't a critical factor.



Mode 4 DC Charging System

AC Charging

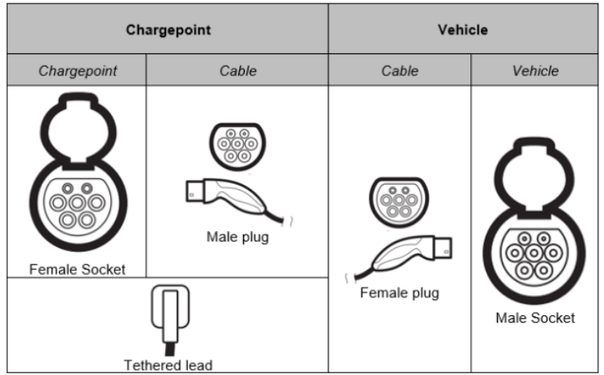
For Mode 3 AC charging, there are two dominant standards. Type 1 is used primarily in North America while Type 2 is the standard in the UK and Europe.

AC Type 2 chargepoints can have either a female socket (for drivers to plug their own leads into), or a tethered cable with a female plug at the vehicle end. Typically sockets are used in public situations whereas tethered leads offer greater convenience for private chargepoints.

The Type 2 cables that are carried by EV drivers – with a male plug at the chargepoint end and female plug at vehicle end – are limited to lower powers, therefore for AC charging at higher power, the chargepoint will need to provide a tethered cable. Hence why 43 kW rapid AC chargepoints have a tethered Type 2 cable.

In many cases, the same equipment can operate with either a single or three phase AC supply. For example, when wired into a single phase, standard electrical circuit in a home, a 7 kW rated charger can transfer 7 kW of electrical energy in an hour.

The same chargepoint installed at a location with a three phase electricity supply allows the same equipment to provide 22 kW power supply. This means it is important to understand what power supply you have at a location in order to understand the power a chargepoint will be able to deliver.



AC Charging Sockets and Plugs

DC Charging

There are two competing standards for DC charging. These connectors are more expensive and often used for higher power transfer, hence tethered cables are used for all DC chargepoints.

Combined Charging System (CCS)

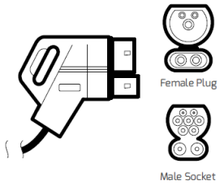
CCS is based on either the Type 1 (predominantly used in America) or Type 2 AC standards, with two additional pins for DC power transfer.

CCS Combo 2 is a Type 2 connector with two additional DC pins. This is becoming the dominant standard for DC charging in the UK and Europe, and is used by most vehicle manufacturers. The vehicle is fitted with a male socket which allows it to take an AC charge from a Type 2 connector and a DC charge from a CCS Combo 2 using a single socket.

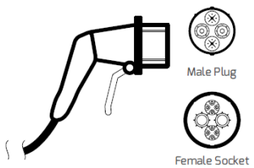
CHAdeMO

This standard is used by Japanese manufacturers Nissan and Mitsubishi to provide DC charging. It is a DC only standard and therefore vehicles with CHAdeMO will also need a Type 1 or Type 2 sockets in order to connect to and charge from an AC chargepoint. Note that unlike with Type 2 or CCS standard, the CHAdeMO vehicle socket is female.

DC charging cables and connectors, designed for higher loads, are heavier and more expensive than Type 2 AC equivalents. Those used for ultra-rapid charging will often be liquid cooled to dissipate heat generated during sustained high current charges.



CCS Combo 2 Socket and Plug (left photo)



CHAdeMO Socket and Plug (right photo)

Charging Locations

Typically, as parking durations decrease, charging power increases to deliver a useful amount of energy to the vehicle battery in the time available. The location types can be split into four categories:

Long stay locations

This location type includes residential areas, workplace locations, park and rides, travel hubs, fleet depots, and hotels; all locations where the vehicle is parked for a number of hours.

This charging behaviour can be beneficial for EVs as they can be “refuelled” slowly over a long period of time, while they are not in use. The most common type of charging for early private EV adopters is residential charging using a privately owned chargepoint.

This allows the driver to charge their EV when they are at home, using a domestic electricity tariff. However, this requires the driver to have dedicated off-street parking. Those without will rely on public charging infrastructure, either in long-stay or one of the three alternative options.

Typical charging power: 7 kW standard (7 miles of range per 20 minutes of charging)

Short stay locations

This type includes locations where the EV will be parked for a small number of hours including retail parks and shopping centres, leisure facilities, tourist attractions and workplace visitor parking.

As with long stay locations, this type of EV charging location provides an opportunity for charging whilst the vehicle is parked at a destination for a short length of time. As the parking duration is shorter, higher powered charging is recommended to deliver a useful amount of energy in the time available.

Typical charging power: 22 kW fast or even 50 kW rapid in some very short stay locations such as supermarkets.

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Charging Locations

Hub Locations

These are locations where the primary reason to visit is for recharging of the vehicle. Therefore, high powered charging is required to limit the time spent waiting.

They may also include some facilities for the driver, or be located in close proximity to short stay destinations. The prime example of a bespoke EV charging hub in the UK is the Gridserve Electric Forecourt in Braintree, Essex.

Typical charging power: 50 kW+ rapid. 22 kW fast charging may also be suitable for charging hubs located close to destinations.

Note that 50 kW is currently the most common rapid DC charging power, however this is expected to be superseded by 150 kW and 350 kW ultra-rapid charging in the medium and long term.

Transit

These are locations where the vehicle requires a charge to complete their journey. Typically, the parking duration for transit locations is shortest and therefore the highest power charging is required. Locations include existing fuel stations near to major roads and motorway services.

Typical charging power: A minimum of 50 kW DC rapid charging, 150 kW+ ultra-rapid if possible.

Electric Vehicle Fleets

EVs are often very suitable for company car or light commercial vehicle fleets.

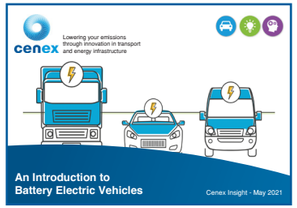
There isn't any one preferred solution for providing charging infrastructure as any of the options set out could be suitable depending on their use case.

For example, if the fleet is only used for a shift of 9 hours, long stay 7 kW AC standard charging at the fleet's "home" location will be sufficient. This could be a commercial depot or a member of staff's house for company cars.

At the other end of the spectrum, you have vehicles which are very heavily used over a long period. In this case it may be necessary to rely more heavily on hub or transit charging.

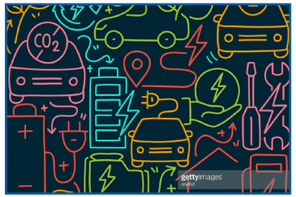
A good example is electric taxis, which are often double or triple shifted, and therefore require short, frequent top ups of charge in order to complete their operations.

Further Reading



An Introduction to Battery Electric Vehicles
https://www.cenex.co.uk/resources/an-introduction-to-battery-electric-vehicles/

UK EVSE Chargepoint Procurement Guide
https://www.r-e-a.net/wp-content/uploads/2020/03/Updated-UK-EVSE-Procurement-Guide.pdf



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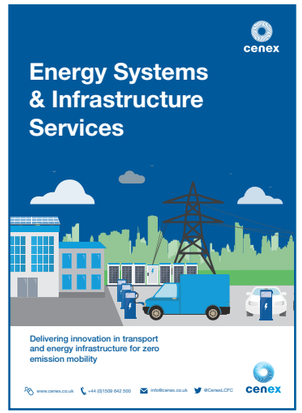

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