Green Finance Institute

eama

Guide to Electric Vehicle Infrastructure

June 2024

Technical knowledge can be a barrier to investment in all emerging sectors. Materials such as this guide can build confidence amongst finance providers to unlock the capital required for a nationwide charging network in the UK.

Rhian-Mari Thomas
CEO, Green Finance Institute

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Glossary

AC	Alternating Current
BSI	British Standards Institution
CCS	**Combined charging system:** a charging plug and vehicle communication standard for DC fast charging.
CHAdeMO	A charging plug and vehicle communication standard for DC fast charging. An abbreviation of CHArge de MOve ("charge for moving") derived from the Japanese phrase "o cha demo ikaga desu ka" or "How about a cup of tea?", referring to the time it would take to charge a car.
Chargepoint	"Chargepoint" is the colloquial but more commonly used term for a charging station or unit. It has no official definition, but for the purposes of this guide it is defined as the dedicated piece of equipment used to supply power to an EV.
Charger	A charger is not the same as a chargepoint. A charger is primarily a rectifier that converts AC from the mains in order to supply DC to the batteries. The charger may be located within a chargepoint (Mode 4) or built into the vehicle (used when supplied by Mode 2 or a Mode 3 chargepoint).
Contestable element	The element of the connection work which can be undertaken by an ICP or IDNO. This is from the point of connection on the existing distribution network, up to the point of demand or generation. Non-contestable works are downstream works on the existing distribution network to facilitate the point of connection. Although they must be completed by the DNO, an ICP can manage the DNO's completion of these works to offer a turnkey solution.
CPO	**Chargepoint operator:** a company that operates a portfolio of chargepoints.
DC	Direct Current
DNO	**Distribution network operator:** operator of the electric power distribution responsible for distributing electricity to most end users.
ECA	Electrical Contractors' Association
ENA	Energy Networks Association
EV (or BEV)	**Electric vehicle (or battery electric vehicle):** a vehicle powered entirely by an onboard battery.
EV Charging Station	The charging station is the physical system where EVs are charged. It may contain one or more chargepoints, and the terms may be used interchangeably when the station contains only one chargepoint. A charging station is defined in the standard BS EN 61851-1 as follows: **AC EV charging station:** all equipment for delivering AC current to EVs, installed in an enclosure(s) and with special control functions . **DC EV charging station:** all equipment for delivering DC current to EVs, installed in an enclosure(s), with special control functions and communication and located off the vehicle.

EVSE	**Electric vehicle supply equipment:** all the EV charging equipment that sits between the fixed wiring of a building (or similar) and the vehicle itself.
ICE	**Internal combustion engine**: a vehicle powered by petrol or diesel.
ICP	**Independent connection provider:** an accredited company that can build electricity networks to agreed standards and quality required for them to be owned by either DNOs or IDNOs.
IDNO	**Independent distribution network operator:** a company licensed by Ofgem to own and operate electricity networks.
IEC	International Electrotechnical Commission
IET	Institution for Engineering and Technology
IC-CPD	In-Cable Control and Protection Device
ISO	International Organisation for Standardisation
NAPIT	National Association of Professional Inspectors and Testers
NICEIC	National Inspection Council for Electrical Installation Contracting
OIML	International Organization of Legal Metrology
OZEV	Office for Zero Emission Vehicles
PHEV	**Plug-in hybrid electric vehicle:** a vehicle containing an electric motor powered by batteries and an ICE powered by petrol or diesel.
RCCB	**Residual current circuit breaker:** a device used to detect and trip against electrical leakage currents, ensuring protection against electric shock caused by indirect contacts.
RCD	**Residual current device:** an electrical safety device that monitors electrical current and automatically switches it off if there is a fault.
RFID	**Radio frequency identification**: a form of wireless communication that incorporates the use of electromagnetic or electrostatic coupling to uniquely identify a user, for example to initiate charging at a chargepoint.
Smart Charging	A charging cycle of an EV that can be altered by external commands.

> As passionate advocates for the transition to low- and zero-carbon mobility, we help our clients through that journey and, ultimately, to make decisions about where, how and on what they spend their money. This no-nonsense guide is an invaluable starting point.

Chris Pritchett
Partner, Head of Energy & Mobility
Foot Anstey LLP

Forewords

There are currently 1 million Battery Electric Vehicles (EV) in the UK and 50,00 public chargepoints. It has been estimated that by 2030 there will be 11 million EVs on UK roads, which the Government expects to require 300,000 public chargepoints.

As the numbers of EV drivers increase, those without access to off-street parking will need charging solutions, depot charging for commercial vehicles and rapid charging for on the go charging in cities and along transport routes. Government and private sector investment in electric vehicle charging infrastructure will be considerable. It presents a huge engineering and construction challenge, but also a great business opportunity for industry and key step on the path to Net Zero.

The key considerations of EV charging system design are recommending the correct product for the Customer's needs, assessing the electricity network capability of the site or property, understanding the Regulatory environment – providing guidance and information, and integration with other technologies now and in the future.

BEAMA and the Green Finance Institute have produced our third edition of the Guide to EV Infrastructure, which will provide practical information for local authorities, designers and installers of electric vehicle infrastructure.

Mark Williamson
Electric Transport Infrastructure Manager
BEAMA

The UK charging infrastructure market is maturing, with more senior finance and debt entering the capital mix. However access to technical knowledge, and simplifying lengthy investment processes remains a common barrier. As we approach the 2035 deadline, there is still an increasing urgency to upskill investors to accelerate the pace of capital being deployed into charging infrastructure.

Since the last update of the guide, the deadline for the phase out of the sale of new internal combustion engine (ICE) vehicles has been pushed back to 2035, the ZEV mandate has become law and the last public capital available to local authorities has started to be deployed in the form of the LEVI Fund. With these recent developments, a huge opportunity presents itself as new private investors continue to enter the market.

We are delighted to continue our partnership with BEAMA to update the 2022 guide. We hope this guide helps to bridge the knowledge gap faced by stakeholders looking to finance charging infrastructure and helps to unlock more private capital to accelerate the roll out of the UK's charging network.

Juliet Flamank
Associate Director
The Green Finance Institute

Acknowledgements

BEAMA and the Green Finance Institute (GFI) are grateful to all their members and supporters who contributed their time and expertise to this guide. A full list of BEAMA's Flexible Energy Systems group members can be found **here**, and members of the GFI's Coalition of Decarbonisation of Road Transport can be found **here**. Our specific thanks go to Mauro Tortone at p27 Network, Alex Georgianna at Steer Group, Henry Cooke, Mark Henderson at Gridserve and Chris Pateman-Jones at Connected Kerb for their reviews.

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As CPOs such as ourselves continue to raise funds for deployment of EV charging infrastructure, it is critical for investors to fully understand the different EV charging technologies which exist and the nuances between the use cases they serve.

Chris Pateman-Jones
CEO, Connected Kerb

1. Introduction

This guide is intended to support anyone wishing to understand the fundamentals of electric vehicle (EV) charging; whether providers or installers of equipment, policymakers, or potential financiers who wish to enhance their technical knowledge and consider opportunities for their stakeholders.

This guide is a direct follow up and update to the BEAMA EV Infrastructure Guide published in 2015 and 2022.

The guide explains core concepts and product types and discusses how they are used so that the reader may gain a strong appreciation of all the infrastructure-side elements involved in charging EVs, allowing them to understand different business models.

Fundamentally this guide seeks to enable the development of a UK wide charging infrastructure network, to ultimately deliver on the UK's transition to zero emission vehicles.

About BEAMA

BEAMA is the UK trade association for manufacturers and providers of energy infrastructure technologies and systems. Its members' products deliver low-carbon energy and environmental services safely, securely and efficiently to UK homes, businesses, transport and grid networks.

About the Green Finance Institute

The Green Finance Institute is an independent organisation that tests, demonstrates, and scales the financial solutions needed to accelerate the transition to a net-zero and nature positive economy. We partner with financial organisations, corporates, NGOs, policymakers, academics and civil society experts to create and scale innovative solutions that deliver practical outcomes for communities and economies.

26%

Transport is responsible for more UK greenhouse gas emissions than any other sector

2035

The deadline for phasing out sales of new ICE cars and vans in the UK

£2.5bn

has been invested by the Government in the transition to EVs since 2020

> The transition to EVs will be one of the defining moments of this century as we finally take serious action to reduce climate change. This document will guide people to make informed choices about the charging infrastructure that unlocks the opportunities.
>
> **Richard Earl**
> Director of Research & Development EO Charging and Chair, BEAMA EV Infrastructure Group

2. Market context

Fleet electrification is pivotal in the global drive to net zero.

Transportation is responsible for 26% of UK greenhouse gas emissions, more than any other sector[1]. In addition, air pollution – in part caused by fossil fuel use in vehicles – is responsible for more than 40,000 excess deaths in the UK every year[2].

In response, the UK has introduced some of the most progressive regulatory objectives and announced significant amounts of funding for the sector, through the Transport Decarbonisation Plan[3] and the Electric Vehicle Infrastructure Strategy[4].

To date this sector has received financial support from the Government including the plug-in car grant scheme and various chargepoint grants. These have helped to establish the market for zero emission vehicles. Since 2011 the annual sales of EVs have increased from fewer than 1,000[5] (less than 0.1% of total registrations) to nearly 315,000 by the end of 2023 (16.5% of total registrations)[6].

The current UK legislative objectives and available funding include:

- In 2021 the Government announced the deadline for phasing out sales of new internal combustion engine (ICE) cars and vans in the UK by 2030, and for all new vehicles to be zero emission at the tailpipe by 2035.
- In March 2022 the Government published its updated Electric Vehicle Infrastructure Strategy, which pledged up to £1.6bn of public funding for charging infrastructure.
- In June 2022 new rules came into effect mandating the installation of EV chargepoints in the majority of new homes and commercial buildings.
- In 2023 the Government announced a new deadline for phasing out sales of new ICE cars and bans in the UK by 2035.
- In January 2024, the zero emission vehicle mandate, the government's pathway towards all new cars and vans being zero emission by 2035, became law.
- Current live or future funds available include The On Street Residential Chargepoint Scheme (ORCS), the Local Electric Vehicle Infrastructure (LEVI) Fund and the Rapid Charging Fund (RCF). Information on these funds can be found in section 5.

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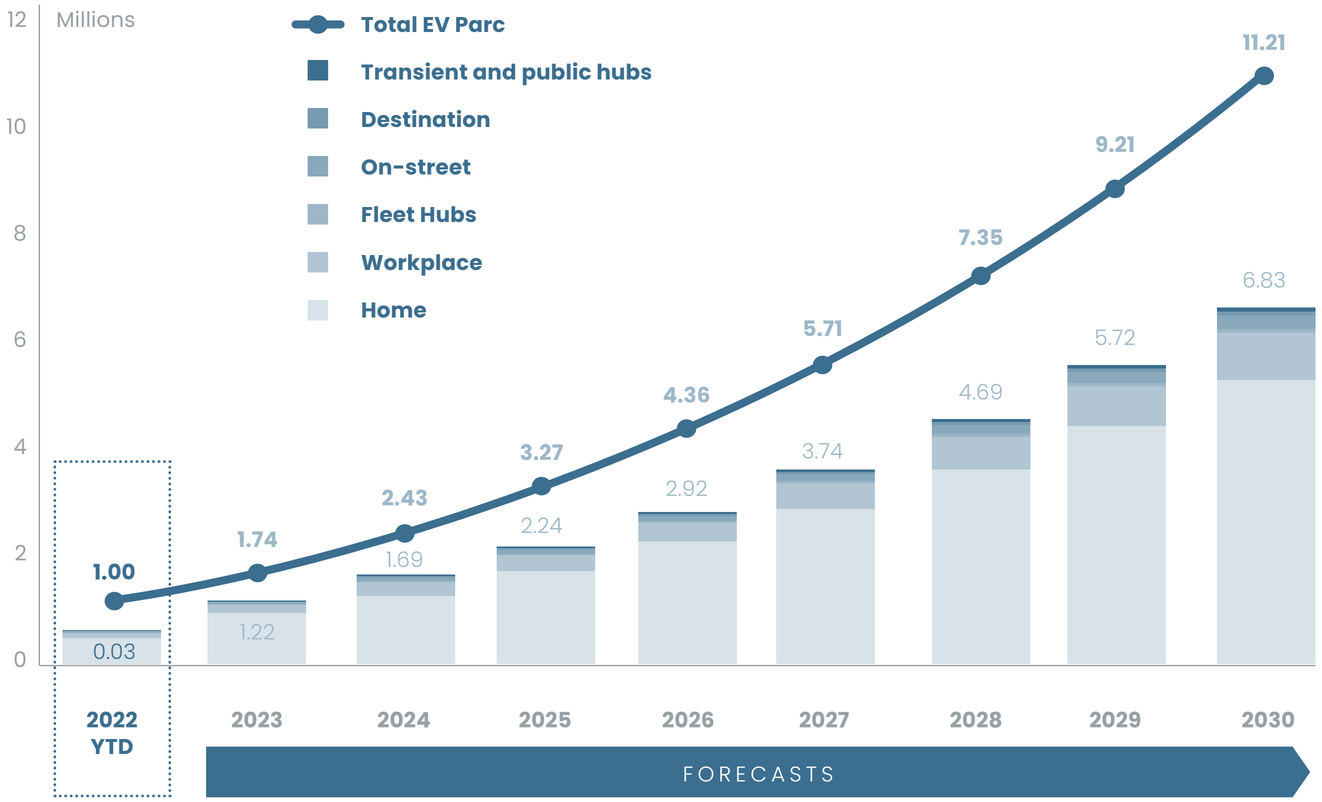
It is estimated that by 2030 there will be 11 million EVs on UK roads, which the Government expects to require 300,000 public chargepoints[7]. The majority of the early adopters of EVs have installed home chargepoints, but as the numbers of EV drivers increase, those without access to off-street parking will need charging solutions. A recent survey by Zap-Map highlighted that whilst 82% of EV drivers have access to charging at home, 93% of EV drivers use public charging networks, most commonly motorway service areas and chargepoints at supermarkets[8]. It is therefore clear that there will be sustained growth in demand for public charging infrastructure.

Figure 1: Forecast EV parc and chargepoints[9]



As of 30 March 2024, there were 59,590[10] public charging points in the UK, suggesting that a significant acceleration in the speed of deployment is required as well as substantial capital investment, estimated to be at least £20bn by 2030[11]. The Government's pledged £1.6bn can only go so far, and the majority of the investment required will be funded by private sector funds including infrastructure finance facilities and Environmental, Social and Governance (ESG) focused funds.

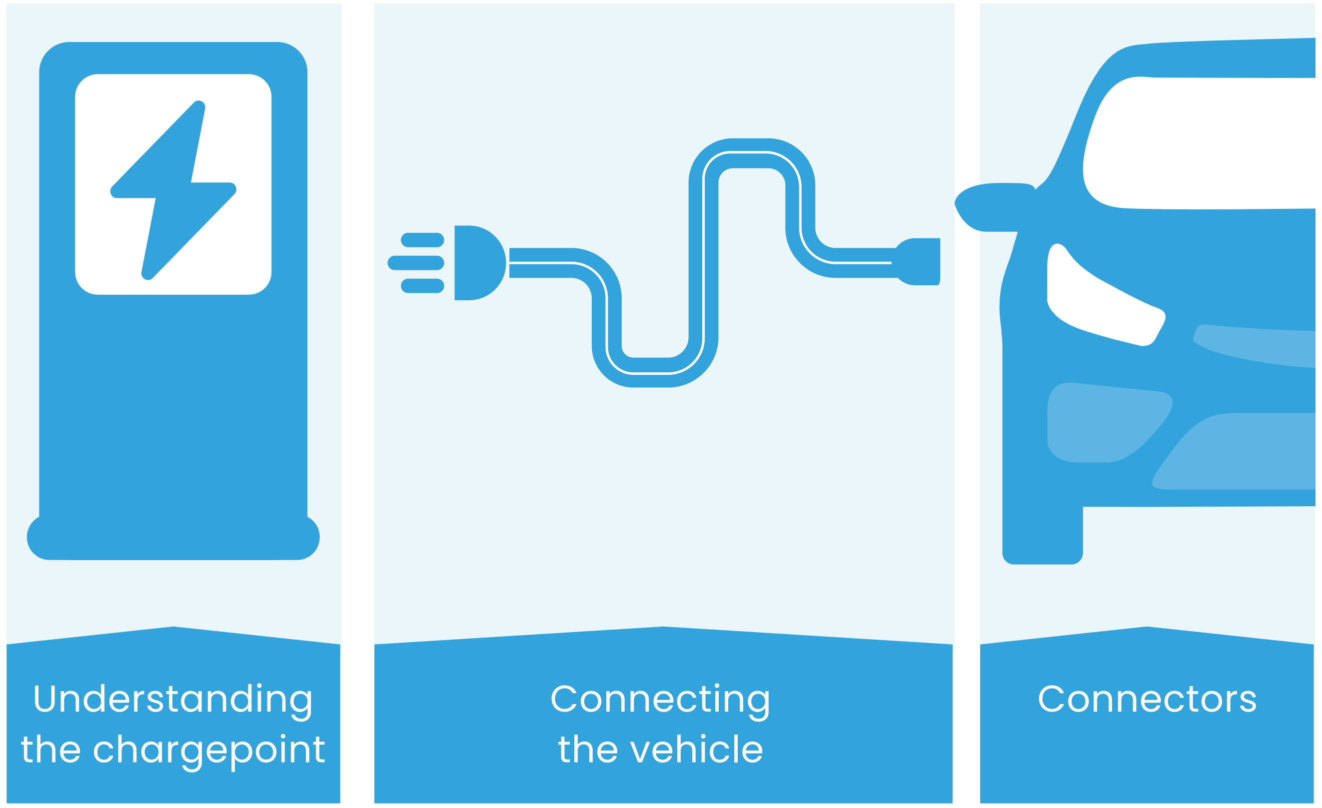
How and when EVs are charged will become important to the UK's energy security as well as our efforts to mitigate climate change. Different locations are suitable for different types and speeds of charging activity, resulting in a variety of business models from "free to use" chargepoints at destinations such as shopping centres, to premium-rate ultra-rapid chargepoints at key points on the strategic road network. As the UK's EV fleet continues to grow there will be an ongoing need for a diverse public charging network suitable for a number of different use cases. These will be discussed in section 4.

3. Charging equipment

The following section is intended to explain the fundamentals of EV charging equipment, from the electricity grid to the vehicle.

Charging equipment, referred to as Electric Vehicle Supply Equipment (EVSE), connects an EV to the mains electrical supply.

The term EVSE refers to all equipment that sits between the fixed electrical wiring of a building or street and the EV; that is, all cables, connectors, protective devices, communication equipment or accessories installed specifically for the purpose of delivering energy to the EV. Charging can be carried out from a dedicated charger, whether fixed or portable, or from non-specialised infrastructure.



3.1 Understanding the chargepoint

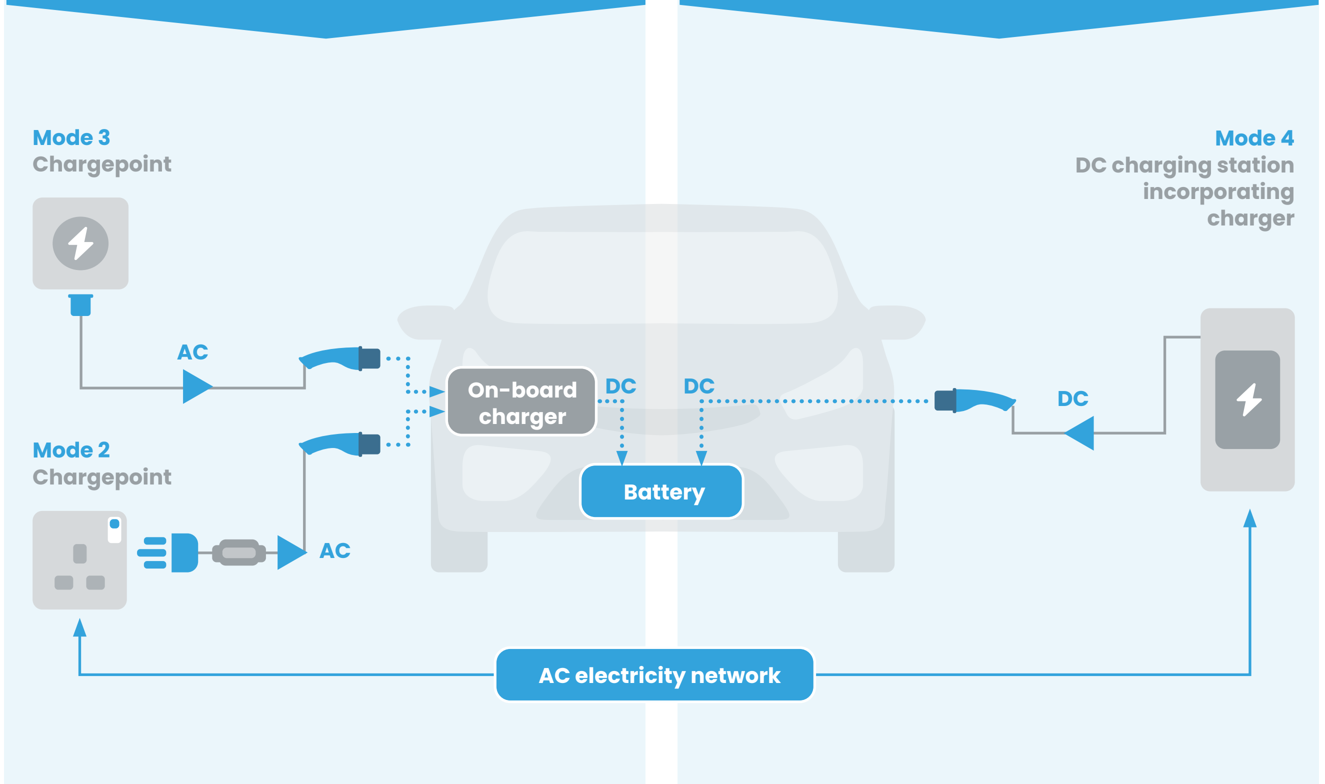
There are a number of different modes of EV charging explained over the following pages but, at a high level, there are two distinct types of charging: alternating current (AC) and direct current (DC). Power is supplied from the grid as AC, but an EV battery is always charged using DC. The current therefore needs to be converted from AC to DC, and where this takes place depends on the type of chargepoint.

AC charger

The mains AC from the grid is supplied to the vehicle, and equipment built into the vehicle converts the current to DC to charge the battery. Space and weight considerations tend to limit the power of chargers built into the vehicle.

DC charger

The mains AC is converted to DC current by the charger within the chargepoint before it is supplied to the vehicle. Because the DC charger is not part of the vehicle, it is less limited by space or weight and can accommodate much greater charging currents. The charging times for the batteries can be much shorter.



AC systems tend to be low to medium power while DC systems are higher power – there are contrary examples, but this is the general rule.

3.2 Connecting the vehicle

The chargepoint connects to the vehicle via a cable, which carries the electric current. Many AC chargepoints (public or private) are built to connect to a cable that is stored separately, usually in the vehicle. This is called an untethered cable. Other AC chargepoints have a tethered cable. Current building regulations for new-build properties require that chargepoints "be fitted with a universal socket (also known as an untethered EV chargepoint). Alternatively, in exceptional circumstances, such as for a self-build property, if the vehicle requirements are already known, a tethered EV chargepoint may be acceptable"[12].

The requirement for most chargepoints to be untethered is intended to deliver interoperability between cables and vehicles, so that consumers are able to charge any type of EV with a single cable type. This is to future-proof charging infrastructure in the built environment to the best extent possible. Consumers looking to install a chargepoint in their existing property still have the choice of tethered or untethered, depending on personal preference.

DC chargepoints employ tethered cables and include a connector plug for a DC-specific socket on the vehicle.

The AC and DC sockets on the vehicle are normally combined into a single socket with separate pins for AC and DC connections, although some vehicles have separate and different sockets for AC and DC. The plug and socket systems are designed to make it impossible to incorrectly connect a DC supply to an AC input or vice versa.

As well as providing the connection between the electricity supply and the vehicle, a chargepoint performs various safety, control, and communication functions. These are supported by separate connections within the connector and socket.

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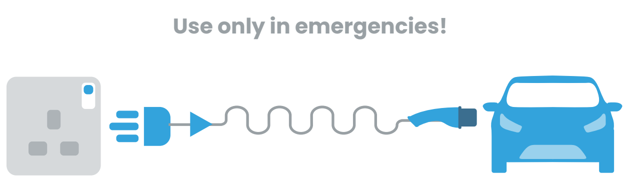
June 2024 Guide to Electric Vehicle Infrastructure | **Equipment**

The BS EN 61851-1 standard defines four different modes for EV charging

Mode 1

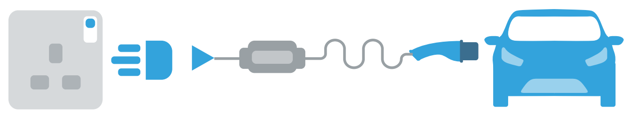


Mode 1 (AC) (not recommended for use) – no longer found on production vehicles
Non-dedicated circuit and socket outlet

Mode 1 connects to a non-specialised infrastructure (for example an existing household circuit) using a cable with no control equipment. Although protected by a BS 1362 fuse, residual current device (RCD) protection cannot be guaranteed and BEAMA does not recommend Mode 1 for EV charging.

Mode 1 charging should only be used when no other option is available and should be considered a means of emergency charging.

Mode 2



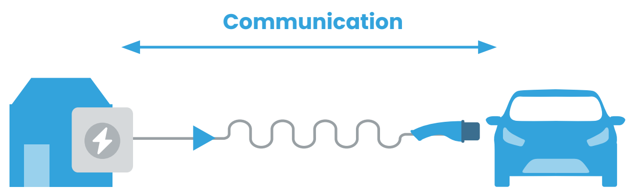
Mode 2 (AC)
Non-dedicated circuit and socket outlet, cable-incorporated RCD

- AC Charging
- 'In-cable' control and protection functions
- Limited to 3kW (13A) in residential use or 7.4kW (32A) for industrial

Mode 2 makes use of non-specialist infrastructure such as the BS 1363 domestic socket incorporating a BS 1362 fuse or the BS EN 60309-2 industrial plug and socket. However, the Mode 2 cable that connects the vehicle to the electrical supply also incorporates an In-Cable Control and Protection Device (IC-CPD) which provides RCD protection downstream of the unit.

In residential applications, Mode 2 charging power will often be limited by vehicle protocols to charging at 1.4kW to 2.3kW (6-10A). Regular Mode 2 charging should ideally be carried out using a dedicated EV circuit, although occasional charging from a non-dedicated circuit may be used if no other charging solution is available.

Mode 3



Mode 3 (AC)
Dedicated EV charging system with dedicated outlet

- AC charging
- Control, communications and protection functions incorporated in the chargepoint with smart charging potential and other functions
- Wide range of charging capabilities, single- or three-phase AC up to 50kW

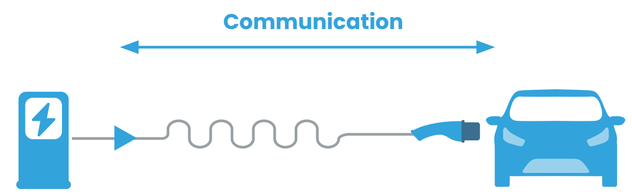
Mode 3 is a specialised system for EV charging used in residential, commercial and public charging and always runs from a dedicated circuit.

Mode 3 normally operates at 7.4kW (32A) in residential applications, but this may vary: 3.7kW (16A) systems are found in some older installations, and power may be significantly higher in commercial or public applications.

Mode 2 and 3 compatibility:

The vehicle itself does not distinguish between Modes 2 and 3. A vehicle's ability to charge from both or only one of these is therefore determined by the cables available and whether they come as standard with the vehicle or have to be purchased separately.

Mode 4



Mode 4 (DC)
Dedicated EV charging system with dedicated outlet

- DC charging
- Option of CHAdeMO or Combined Charging System (CCS) connectors and communication protocols
- For domestic, public and commercial charging applications
- Wide range of charging capabilities from 24kW to hundreds of kW

Mode 4 provides a DC charge to the vehicle and carries out the control functions within the chargepoint.

Mode 4 chargepoints can operate at considerable speeds, though may be constrained by the vehicle's battery management system, the specifics of the site and its electricity supply rather than by the chargepoint itself.

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3.3 Common types of connectors

3.3.1 Infrastructure side

Connector type	BS 1363	BS EN 60309	BS EN 62196-2 Type 2	CHAdeMO	CCS (CCS Europe/Combo Type 2)
					
Mode	1 and 2	2	3	4	4
Notes	Standard UK domestic plug and socket-outlet system	Standard UK industrial plug and socket-outlet system	Specialist EV. Type 2 is a recognised connector for all EVs	Typically 50kW, though the standard recognises up to 400A (150kW) This is the predominant DC charging connection in Japan. In the UK it is limited to a few EV brands, mostly Japanese or Korean in origin	Typically 50-350kW, though the standard recognises up to 500kW This is the European and UK standard for DC charging and is found on nearly all new EVs in the UK

3.3.2 Vehicle side

Connector type	IEC 62196-2 Type 1	IEC 62196-2 Type 2	CHAdeMO socket	CCS socket
				
Modes	1, 2 or 3	3	4	4
Maximum power of the connector	32A single-phase 7.4kW	Typically 7-22kW, though the standard recognises 63A three-phase 43kW 70A single-phase 16kW	DC charging technology continues to develop, and the maximum power increases as technology advances	DC charging technology continues to develop, and the maximum power increases as technology advances
Notes	This is the predominant AC charging connection in the US. In the UK it is limited to a particular set of vehicles – early EVs and some PHEVs	This is the European and UK standard for AC charging and is found on all new EVs in the UK	With mode 4 charging, the charger always uses a tethered cable	With mode 4 charging, the charger always uses a tethered cable

3.3.3 Cables

Type 2 to Type 1 cable

Type 2 to Type 2 cable

3.4 Determining charging time

The basic theoretical calculation for charge time is simple:

Amount of charge required (kWh) ÷ **Charging power** (kW) = **Time to charge** (hours)

The rate at which a charging station can deliver electricity to the vehicle can vary. For example, a 22kW chargepoint will not always deliver 22kW of charge in one hour. Actual power delivered can be impacted by any of the following:

- Available network capacity
- Battery size
- State of charge of the battery
- Maximum charge rate of the battery (see Figure 2)
- Temperature of the battery
- Power rating of the onboard charger (AC only)
- Power rating of the charging cable
- Power rating of the chargepoint

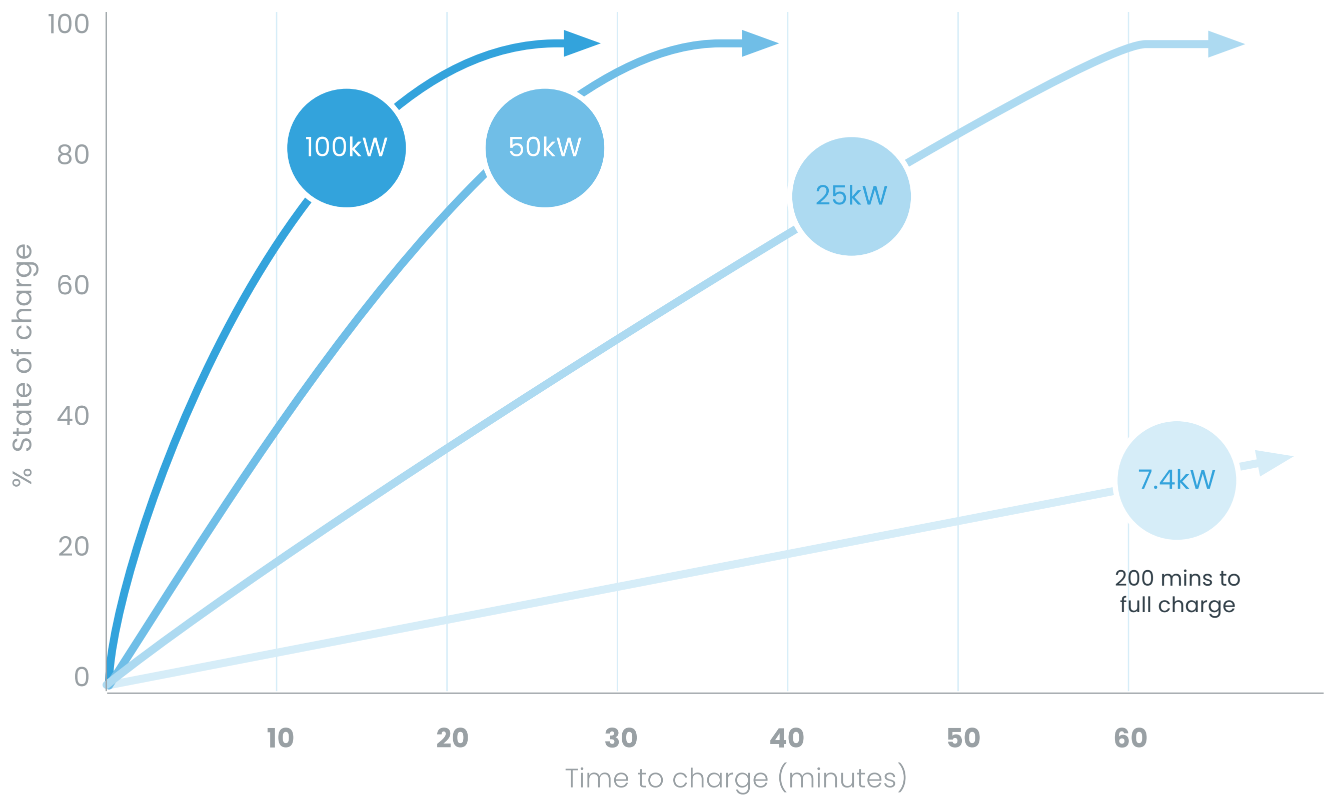
For AC charging, the external charger and the vehicle's on-board charger will each have a maximum rating. The vehicle's battery will be charged at the lower of these figures. On occasion, a non-tethered cable may be the limiting factor (for example if the cable is not correctly matched to the vehicle). In DC charging there is no separate charger on the vehicle to limit the rate of charge, so the battery will charge at the rate denoted by the DC charger. However, for both AC and DC, external factors such as the temperature of the battery and state of charge will impact the speed of charging.

Whether AC or DC, the rate of charge drops as the battery nears 100% – see graph Figure 2. This has a very limited impact in chargepoints below 10kW but for high power chargepoints it is a significant factor in calculating the time to charge a battery from 80% to 100%. There are two reasons for this:

1) As the battery reaches full capacity, it takes longer for electrons to locate empty cells (the classic analogy is to compare this with how much longer it would take to find a seat in a cinema that is at 80% capacity compared to one that is at 10% capacity).

2) Charging a battery for an extended period of time increases its temperature and the strain put on it, so battery management systems within the vehicle can limit the charging speeds after a certain capacity (usually 80%) to protect the battery and ensure longevity.

Figure 2: Impact on charge rate as battery fills
This chart indicates the varying charging rates for different powered chargepoints.



3.5 Other electrical connections and elements

The following sections lay out the key steps a project owner needs to follow when considering the installation of new EV chargepoints, and explain the key elements of infrastructure involved.

3.5.1 Electrical and civil considerations for installing new EV chargepoints

EV chargepoints are typically connected to electricity network infrastructure owned and maintained by Distribution Network Operators (DNOs) or Independent Distribution Network Operators (IDNOs).

The network capacity used by an EV chargepoint varies from one charging station to another depending on the location, number and load of chargepoints, other onsite facilities and the integration with other energy systems such as solar generation or battery storage systems.

The electrical infrastructure of the network (switchgear, transformers and cabling) is unique to each site and determined by factors such as the funds available, resilience needs, supply chain conditions, scalability plans and, most importantly, technical specifications (especially the voltage and capacity of the grid connection).

Before construction begins, technical specifications and design of the infrastructure between the electricity network and EVSE will be determined by an independent connection provider (ICP) or DNO.

3.5.2 Key project considerations

Network-side infrastructure should be designed to last for many years and cope with future demand and technological advances. Therefore, the design aim should be to install EV foundations once, allowing equipment to be upgraded without additional groundworks.

Additionally, designs need to avoid legacy issues such as congested footways, underground hazards or long lead times for repairs. The knock-on effects of poor design planning can lead to delays in civil works, spiralling costs, contractual disputes, and on-site damage. Consideration of the civils infrastructure at the beginning of a charging infrastructure project can avoid many of these problems. Key considerations and steps in the process of delivering civil infrastructure, from load assessment to connection, are described on the next page.

Network connections should work with different configurations and for all manufacturers. **Maintenance considerations** include future needs for upgrading units, minimising disruption, and ease of access to equipment. **Cabling considerations** include the availability of power, the cable bending radius, the length of cable from the power source, selection of the most appropriate route and cable containment system, and the expected manual handling of cables.

How many vehicles need charging at any one time?

What is the surrounding access for vehicles and existing amenities?

How many chargepoints are required immediately, and what is the likely future demand?

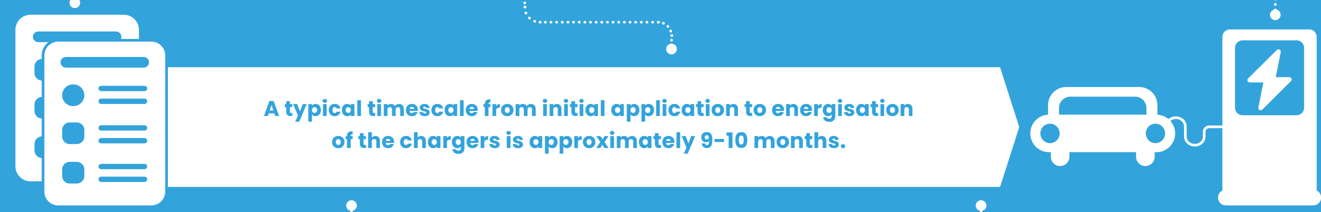
What is the development's proximity to the power source?

Key steps in civils infrastructure delivery

1. Undertake load assessment (how many chargepoints, of what power, used simultaneously) – this can be completed with the assistance of a DNO without cost but may take time, or a specialist utilities consultancy firm (quicker but more expensive).

3. DNO or ICP will then complete a design drawing as part of the approval process and will install the new equipment (e.g. a transformer) and complete cabling. These costs are covered by the customer.

5. Customer or CPO connects their charging equipment to the newly installed cables and buys electricity, paid for by the consumer plugging in their vehicle to charge.



2. As part of the load assessment, the DNO can provide a quotation for the design and construction of the required infrastructure. The load assessment can also be shared with an ICP who can also provide a quote for the contestable element of the project*.

4. Once built, ownership of the electrical infrastructure normally transfers to the DNO or IDNO[13].

*For further information contact your local DNO, or an IDNO or ICP

Civils infrastructure being installed

A barrier around a public rapid chargepoint

There are many other issues relating to electrical connections, engineering and safety that are of critical importance to infrastructure providers and investors. BEAMA will publish a White Paper to follow this Guide that considers these issues in more detail.

3.5.3 Engineering factors

The Energy Networks Association (ENA) has defined grid connection codes relating to import and export control. These are particularly important for load management and bidirectional EV charging. Of particular relevance are:

- Engineering Recommendation (EREC) G99[14] (Requirements for the connection of generation equipment in parallel with public distribution networks).
- Engineering Recommendation (EREC) G100[15] (Technical Requirements for Customers' Export and Import Limitation Schemes).

EREC G99 is intended to provide requirements for the connection of power generating facilities to the distribution networks of licensed DNOs. In this context, bidirectional (V2X) EV chargepoints and any associated solar photovoltaic systems, wind turbines or battery energy storage systems are classified as generators and are subject to the requirements of EREC G99. When assessing an application for connection, the DNO will consider the sum of the power ratings of all forms of generation to be installed.

Investors, installers and users should ensure compliance with the most recent iteration. More information can be found at www.energynetworks.org.

3.5.4 Wiring

With few exceptions, electrical power is provided to the EVSE (and accordingly to the EV) using wires governed by the British Standard 7671, the Wiring Regulations, which are co-published by the Institution for Engineering and Technology (IET) and BSI. All new and amended electrical installations are to conform to the requirements of BS 7671:2018+A2: 2022.

BS 7671 s.722 relates specifically to EV charging installations[16].

This smart chargepoint communications controller board is an OCPP communications gateway for smart chargers connecting ISO 61851 controllers to back-offices via Ethernet, Wi-Fi or LTE Cellular networks.

This AC charge controller, for single- or three-phase EV chargers, interfaces with control boards such as the one pictured above to support smart charging.

This local controller enables dynamic load management by relaying messages between the charging station's management system and the chargepoint.

3.5.5 PEN fault protection

Many UK electricity supplies combine the earth and neutral into one Protective Earth and Neutral (PEN) conductor using a supply system known as Protective Multiple Earth (PME). It becomes unsafe if the PEN conductor is disconnected from the Earth. If someone simultaneously touches something connected to the PEN conductor (such as an EV plugged in to a chargepoint) and something at true Earth potential (such as a metal fence), the residual current circuit breaker (RCCB) will not operate, and the person could receive a fatal electric shock. To protect against this, it is necessary to either provide a dedicated earth to the chargepoint (which is expensive) or fit a PEN fault protection device that will automatically disconnect the PEN when a dangerous voltage is detected.

Some of the latest chargepoints incorporate PEN fault protection into the device. BS 7671:2018+A1:2020 s.722.411.4.1 and the IET Code of Practice for Electric Vehicle Charging Equipment Installation[17] provide further guidance. BEAMA published its own Technical Bulletin[18] on this issue in 2022.

3.5.6 Consumer units

For the installation of dedicated EV charging circuits, consult the current edition of BS 7671 amendment 2 and refer to the IET Code of Practice for EV installation.

3.5.7 Transformers

The quantity and ratings of transformers required depend on the capacity of the grid connection and the voltage at which the connection is secured. Installers should match the rating of the transformer to the load profile of the charging station and the maximum load anticipated at any point. It is good practice to load transformers at around 75% and, if the network has multiple transformers, to keep a spare transformer on site.

All transformers placed into the market in the UK and Europe must follow Ecodesign regulations[19] for transformer losses.

Ecodesign compliant 1000kVA Distribution Transformer with a switchgear.

EV feeder pillar.

We need to install the appropriate infrastructure for the expected volumes of electric vehicles considering local demographics, supply and possible future technology changes.

Colin Herron CBE
Professor of Practice,
Newcastle University Group

4. EV chargepoints and charging stations

This section outlines the locations and types of public and private chargepoints.

Key considerations when designing a charging experience are: deciding the type and location of the solution; establishing who the expected users of the equipment are and their reasons for use; determining how much range needs to added; and the expected dwell time. The table below summarises the likely suitability of various chargepoint types for specific locations.

Most early adopters of EVs in the UK had access to off-street parking. Consequently, a significant proportion of current charging takes place at private chargepoints, either at home or the workplace. As EV ownership in the UK increases, most EV users are expected to use more than one method to charge their vehicle. With around a third of the UK not having access to off-street parking[20], a diverse mix of public charging will continue to provide a growing proportion of the UK's charging needs. This demands a reliable, nationwide rapid charging network, vital to give confidence to drivers that longer journeys can be completed easily.

Most suitable ⚡⚡⚡ **Least suitable** ⚡	**Mode 2:** AC charging	**Mode 3:** AC charging – dedicated equipment	**Mode 4:** DC charging – dedicated equipment
Private charging – home	⚡⚡	⚡⚡⚡	⚡
Private charging – workplace	⚡	⚡⚡⚡	⚡
Private charging – fleet depot	⚡	⚡⚡⚡	⚡⚡⚡
Public charging – on street	⚡	⚡⚡⚡	⚡⚡
Public charging – off street destination	⚡	⚡⚡⚡	⚡⚡⚡
Public charging – rapid and forecourt	⚡	⚡	⚡⚡⚡

These 24kW DC chargers are an example of an asset type designed to deliver an identified use case. They provide essential charging services to car dealerships and some fleet operators, but are not usually used for residential or forecourt charging.

4.1 Private charging solutions

4.1.1 Home and workplace

For private charging, at home or the workplace, factors such as ease of access, available power supply and the type of charge required will be the key considerations. The charge required will be dictated by the length and frequency of journeys being undertaken, how long the vehicle can dwell at the primary charging location, and how many vehicles need to be charged simultaneously. Due to the time spent at these locations, typically overnight at home or the working day at the office, slower chargepoints are usually adequate and more cost effective.

Solutions available for home and workplace locations are mostly single-phase AC chargepoints, available from 3.6kW to about 7kW. A 22kW chargepoint is unusual for a home but may be used in some workplaces.

A home charging solution.

This wall-mounted unit is a customisable (3.7kW, 7.4kW, 11kW or 22kW) AC chargepoint with Type 2 connector cable or socket option. It can be wall- or floor-mounted, depending on the requirements of the location, with an RFID reader, a socket or an integrated cable with plug, an MID-compliant meter and integrated load management.

This wall-mounted chargepoint is available as a 7kW or 22kW model, with a choice of cables (model shown is 22kW three-phase charger with tethered cable).

There are several different types of chargepoints on the market for purchase and use in private locations. The difference between the units will come down to aesthetics or any additional functionality offered. Some are built to allow users to upgrade power online when required, without changing the actual hardware product. If a second vehicle needs to be charged, operators can add another chargepoint next to the existing one and manage the power between the two using dynamic load balancing software.

Other chargepoints are built to be used as a standalone product or in conjunction with other products, such as solar panels or battery storage systems, including functions allowing users to charge at a rate that matches their surplus microgeneration or to control whether surplus generation is stored, used elsewhere in the building, or exported to the grid.

The cost of charging an EV is typically added to the domestic or commercial electricity bill. However, there are software solutions available that enable users to separately pay for electricity used for vehicle charging. These solutions enable more versatility in managing charging costs – for example by allowing employees who take company vehicles home overnight to easily reclaim charging costs.

Some chargers come with a built-in RFID reader to allow controlled activation of charging, for both private and workplace use. Note that the RFID card is used to initiate charge (not for payment functionality).

Some wall-mounted units may actually be pole-mounted.

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4.1.2 Fleet depots

Businesses looking to electrify their fleets operating from a depot will have different considerations than businesses installing solutions at office locations. The type of operation and duty cycle, available network capacity and physical space in the depot will be key factors in determining charging requirements.

Compared to home and workplace charging, depot charging stations will be expected to be used more frequently. With faster turnaround, higher powered chargepoints may be required. However, if fleets can charge overnight, lower powered chargepoints may be sufficient and more cost effective due to the lower network capacity required. The power rating needed is also affected by the size of batteries that need charging.

These solutions can be wall-mounted, pole-mounted or standalone. Depending on the power required, they may be either AC or DC chargepoints.

Charging solution at a van depot.

Example of single and dual socket AC chargepoints up to 22kW, supporting dynamic and static load balancing when multiple chargers are installed in a depot, car park or workplace.

Private on-street AC charging solution. Shown in use.

4.1.3 Private on-street AC charging

Some users want to benefit from the convenience and the domestic electricity tariffs that come with private domestic charging (including the lower VAT rate of 5% added to domestic electricity bills compared to 20% on the public network) but do not have facilities for off-street parking. Facilities for these users include chargepoints (ranging from 7kW to 22kW AC) that can be sunk into the pavement or road in residential on-street settings.

The pictured system lies flush with the surface into which it has been fitted to avoid pavement or roadway obstruction when not being used. It is designed for use by residents only and not the wider public. The chargepoint can be accessed by use of a 'lance' – a connection device that the user inserts into the chargepoint and has a tethered Type 2 connector with which to charge a vehicle.

This solution may require dedicated on-street parking bays and is therefore not suitable for all on-street charging.

Where there is additional parking pressure, a hub of multiple 22kW AC chargepoints may be more suitable.

Private on-street AC charging solution. Shown hidden.

4.2 Public charging solutions

4.2.1 Key considerations for public charging solutions

Considerations for public charging solutions vary from those for private charging, as they are often installed and provided by chargepoint operators (CPOs) and commercial businesses to be used by the general public, typically for a fee. The key criteria for selecting suitable locations for public charging solutions are listed here. The relative importance of each of these criteria will depend on what type of charging solution is being considered.

Access to land

For public charging, it is rare that the CPO owns the land that the charging station is being built on. It is therefore important that the CPO ensures sufficient planning permissions have been granted and contractual agreements are in place to protect ongoing revenue streams and that this is a sufficient contract term to generate a return. These contractual agreements between a landowner and the provider, called wayleaves, allow the provider access rights to the land to install, maintain or repair their equipment.

Accessibility

An important consideration is the accessibility of the installed charging stations. This should allow and encourage inclusive usage, especially by users with reduced mobility or other special needs. Industry groups and other bodies such as the charity Motability[21] worked with Government to publish a specification for the accessibility of chargepoints.[22]

Visibility

Ensuring a charging station is installed in a location that is visible to drivers is key to ensuring it is used and to addressing 'range anxiety' concerns – where there is concern that a vehicle will not have the charge sufficient to reach the desired location. This may require additional signage for certain charging stations. Chargers can also be added to various databases, such as Zap-Map[23], which shows EV drivers the location of available chargepoints.

However, there are certain locations, such as in local conservation areas, where chargepoints are encouraged, or required, to be visually discreet. This would not impact the chargepoints' utilisation negatively, as users of this type of solution are typically regular, habitual residents who live on the street and therefore know the charger is there.

Security

Physical security of the infrastructure is another important consideration, as damaged charging stations or infrastructure limit utilisation rates and therefore revenue streams. Damaged stations also impact consumers' trust and their ability to rely on charging infrastructure.

Furthermore, safety and security of the users of the infrastructure needs to be considered; there have been calls by organisations such as WalkSafe[24] for installers to take simple and effective steps such as lighting, so that drivers feel safer when charging their cars in public.

Available power

Network capacity upgrades may be required in certain locations where there previously has not been infrastructure requiring high power, or where a faster chargepoint is intended to be installed.

Ofgem has committed to supporting the rollout of EVs in Britain[25] by contributing to plans that ensure the infrastructure and technology is in place for the rapidly growing number of EVs on the road. This includes investing in network capacity, with billions more in network investment expected to follow as part of its next network price control, which is to run for five years from April 2023. Investment is already taking place, with £300m approved by Ofgem in May 2021[26], half of which will be used to develop EV infrastructure, including rapid chargepoints.

Some sites may not require network upgrades before installation, so exploring where current capacity exists is an important step in site location decisions in order to avoid unnecessary upgrade costs, which can be significant. Datasets that map grid capacity around the UK exist to assist with this information. Current examples include SP Energy Networks Distribution Heat Map[27] and Electricity North West Heatmap tool[28]. Also it is important to investigate the closeness of the connection point, as digging a long trench can be expensive.

User demand

Installation of charging solutions should be driven by user demand. However, it is important that charging infrastructure is not exclusively installed in areas that are more commercially viable as of today, as a full transition to electrified road transport will depend on a nationwide public charging network.

This means there may be periods, especially while the market is still maturing, when newly installed charging facilities experience fluctuating utilisation and cashflows. Short term revenue alone cannot drive the infrastructure rollout, so to ensure a just transition, some installations will need more public funding than others, or require user demand modelling that matches to sufficient longer term contracts to maximize private investment, and ensure longer term cashflows are captured in the business case.

Future-proofing[29]

There is a strong case for future-proofing installations by incorporating capacity[30] for additional chargepoints where possible and cost effective. On initial installation, the cost of hardware to provide for future capacity tends to be far less than the labour and other costs, particularly groundwork, associated with upgrading systems at a later date.

The Office for Zero Emission Vehicle (OZEV) Open Data project is intended to assist all drivers to locate available charging facilities[31]. Opening up chargepoint data will support the development of consumer-friendly apps and improve consumer experience.

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4.2.2 On-street residential charging

On-street residential charging solutions are provided for local residents, or their visitors, who do not have access to private at-home charging solutions. Dedicated parking bays, where used, will usually be spaced widely through an area rather than clustered, to provide equitable access to charging facilities and to preserve parking convenience in the medium term for drivers of ICE vehicles.

On-street residential charging is typically suitable for longer dwell users - drivers who live or work nearby and charge overnight. On-street residential charging is sometimes provided in the form of lower powered charging stations, including those attached to lampposts.

On-street residential charging solutions can be offered by CPOs independently or in collaboration with a Local Authority (LA). For more information about Government grants for LAs to assist in the installation costs of public charging provisions, see page 47. Whatever the delivery model, investors will still need to ensure that the DNO is involved early in the site selection process and that all the relevant permits and licenses are in place from the LA, for example the Section 50 licence, which is a permit to install new works on a public pavement. Investors should also consider security of tenure, sufficient length of contract and who holds control over tariffs.

A chargepoint on a residential street.

Local parking restrictions are a key installation consideration when selecting a site as the driver needs to be able to park there for the duration of their charge. LAs will analyse the density of EV ownership in the area, any existing or forecast chargepoint utilisation rates, and the quality of limited off-street parking options. If the chargepoint reduces the number of non-EV car parking spaces and is often empty due to low utilisation, local residents may complain[32].

There is therefore a balancing act for LAs to minimise disruption to residents while maximising utilisation in the short term. This issue dissipates as the number of EVs on the road increases. Minimising disruption for residents also means providing a solution which reduces pavement clutter; there are solutions on the market that do this, for example by blending with or connecting to existing street infrastructure, such as lamppost installations. However, LAs should factor in that these assets need to be future proofed with upgrades to power supplies, so that it does not increase dwell times and decrease utilisation rates.

A lamppost charger on a residential street.

4.2.3 Off-street destination charging

Destination charging is the term used to describe a charging experience where the user performs another activity (work, shop, sleep, use other nearby facilities) while leaving the EV to charge in a managed way.

Destination charging at shopping or leisure facilities, hospitality venues, on streets or at hospital or workplace carparks, are mostly AC. Short-stay charging, where the driver usually waits by the vehicle as it is charging, tends to be DC.

Public AC chargepoints tend to be rated either 3kW, 7kW or 22kW. Public DC chargepoints usually range from 20kW to 360kW, and in some cases even up to 400kW or 500kW. Lower-powered chargepoints are available in some places to accommodate two-wheel vehicles such as electric bicycles and scooters.

Many destination charging stations provide smart clustering and power management capabilities (further detail on page 52) to help reduce installation and operational costs. Chargepoints should ideally be able to support IEC 61851 functionalities (the standard that defines the functionality of a charging station – see section 8) and be ready for IEC 15118 when that specification comes into force. This will require a hardware component in the chargepoint that is impossible to incorporate later, as well as a physical powerline communication (PLC) chip and connector.

Some public charging solutions in dedicated retail carparks.

Public and commercial EV charging			
AC destination	**DC destination**	**DC fast**	**DC High Power**
7-22 kW	20-50 kW	50-150 kW	150 to 350 kW+
4-16 hours	1-3 hours	20-90 minutes	10-20 minutes




4.2.4 Rapid hub charging

Hubs of rapid chargepoints, such as those found at Motorway Service Areas (MSAs), are the form of charging infrastructure that most resembles the infrastructure for ICE vehicles. The customer experience of these is much the same, except that charge times are currently longer than refuelling times. As faster chargepoints enter the market and as vehicle and battery technology develops, the time taken to charge will fall. Drivers do not always charge the battery until full, and often charge only as long as it takes to get sufficient range to complete their journey, or for them to use the rest room and grab a coffee.

Existing MSA sites typically have one or two medium power chargers. To keep pace with demand there is a need to upgrade and accelerate deployment of chargepoints across the strategic road network, in order to achieve Government's stated objective to have at least six high-powered chargepoints at MSAs in England by 2023[33]. CPOs are investing in significant grid connection upgrades that enable sites of six-twelve chargers or more at speeds of up to 350kW. Engaging the relevant DNO early in the process is critical.

Given the longer EV charge times than ICE refuel times, provision of other services such as a coffee shop or toilet facilities will assist with higher utilisation rates, as well as providing another source of revenue.

To help manage the challenge of the power requirements for rapid hubs, some sites integrate microgeneration with public charging facilities, for example the Energy Superhub Oxford part-funded by the Government's Industrial Strategy Challenge Fund under its Prospering From the Energy Revolution programme[34].

Chargepoints with local microgeneration and storage.



Public rapid chargers with multiple cables.

350kW chargers at a motorway service station.

4.2.5 Forecourt charging[35]

Although ICE drivers will use their local forecourts to refuel, many EV drivers with the ability to charge at home or at work will not often need this provision. But those without home or work charging may want a 'petrol station of the future' close to where they live, and these facilities improve range confidence even among those who rarely need them. The forecourt will typically contain multiple high-power chargers. With an average charging time of around 30 minutes, visitors are offered retail experiences with coffee shops, convenience stores, lounge and meeting areas and Wi-Fi. Some locations also offer advice and support for customers, whether they are experienced EV drivers or newcomers.

These locations need to be newly constructed to meet the needs of today's drivers rather than reengineered existing buildings or forecourts. Away from the motorways, which are already catered for with existing locations, they will largely be on major A roads or near to large towns and cities, where off-street parking is less available.

GRIDSERVE's electric forecourt in Braintree.

4.2.6 Payment methods for public charging solutions

While private charging facilities do not require a payment function, the Government's 2022 EV Infrastructure Strategy[36] sets out a vision and plan for the rollout of EV charging infrastructure across the UK that includes measures to streamline the consumer experience of public charging by standardising payment methods. This includes plans to impose requirements for contactless payments to be available at chargepoints. In 2023 The Public Charge Point Regulations came into force and by the end of 2024, new public chargepoints over 8 kW and existing public rapid chargepoints over 50 kW must offer contactless payment options. Currently, several different methods of payment exist for public charging infrastructure, including payment via mobile phone apps, radio frequency identification (RFID) cards and contactless credit or debit cards.

Contactless credit and debit cards provide the easiest method of payment without the need to download any mobile application or obtain RFID cards in advance of charging. The effects of Covid-19 accelerated the cashless society meaning the ease of contactless payment benefits the EV driver through a simple, standard payment process. The CMA found in 2021 that only 9% of public chargepoints offer contactless payment facilities[37], although this number is growing.

◄ **A contactless payment terminal on a chargepoint.**

Mobile phone apps are increasingly popular, and the user interface allows for smart charging integration and a function to identify nearby charging facilities. Often these apps come with benefits for subscribers, such as access to a discounted rate per kWh for public charging.

RFID cards use radio frequency identification to access public chargepoints; a charge is initiated by tapping the card against the card reader at the charging station. These require management of an online account attached to the RFID card.

The Government plans to support fleet electrification by introducing payment roaming across the public chargepoint network[38]. Through The Public Charge Point Regulations 2023, at the end of 2025, CPOs must enable drivers to pay through at least one roaming provider at their public charge point[39]. Payment roaming would enable an EV driver to use various charging stations using a single mobile app, even if they are a customer of only one provider. This interoperability would streamline the consumer experience, making chargepoints more accessible to all EV drivers. Solutions available today include Zap-Map's Zap Pay and Octopus's Electric Universe, which allow EV drivers to use a single app to pay for charging across different networks.

The sector has experienced criticism for having too many different types of payment methods. As markets and regulation mature, payment methods may evolve. The ability to efficiently collect payments from customers is a crucial consideration for any business case.

4.3 Considerations for other systems

Electrification of large vehicles, such as heavy goods vehicles (HGVs), buses and coaches, is beginning to accelerate. HGVs, buses and other large specialist vehicles (such as refuse trucks) with very large battery packs will require higher power systems, including megawatt chargers, to recharge in a reasonable time – both to minimise vehicle downtime and make best use of legally required driver breaks. As with passenger vehicles there will be a mix of depot and on-route charging, and this will affect what solutions are required, with different powers required for different vehicle use cases. For further analysis of what charging solutions will be required for HGVs, see the following study by Element Energy, commissioned by Transport & Environment[40].

Once a charging infrastructure project has considered the appropriate solution for the use case and location, the project sponsor will have to consider the commerciality of their business case and look for available funding.

> As in all emerging sectors, we need to get markets up to speed with the technology. An understanding of how that technology generates revenue and of the risks to the revenue streams is vital to ensuring capital flows into the sector.
>
> **Mark Henderson**
> Chief Investment Officer, Gridserve

5. Finance Considerations

The following section is intended to support anyone looking to finance an EV charging infrastructure project.

To date, investment in charging infrastructure has been a mix of public and private capital. Profitable business models for public charging infrastructure without Government subsidies already exist in some locations, and private investment in the sector is growing as the sector matures. ChargeUK was set up in 2023, which brings together 24 CPOs in the UK with a total of 6bn in investment. Recent transactions include Griderve's £500m debt investment led by multiple banks including UK Infrastructure Bank[41], Infracapital's £200m investment in Gridserve[42] and Aviva Investors' investment of up to £110m in Connected Kerb[43]. Private capital providers such as mainstream commercial banks, private equity funds, traditional infrastructure funds, pension funds and private debt all have roles to play.

The key risk for potential financiers from the private sector when considering EV charging infrastructure projects is utilisation risk, which describes the risk that the infrastructure will not be used as much as expected, leading to lower revenues than forecast. Private finance in the sector will continue to increase as this risk is reduced.

However, in the short term, a just transition relies on a charging infrastructure network that is rolled out nationwide, not just in commercially attractive areas. Public financial support for LAs rolling out charging infrastructure may be required for some time in some areas.

Many parallels can be drawn between EV charging infrastructure projects and the financing of commercial toll roads and telecommunications infrastructure, both of which have relied on project finance with comparable risk factors and may be useful models for successful financing strategies.

5.1 Building a business case

Commerciality of a business case revolves around several decisions. Below is a non-exhaustive list of important factors which any stakeholder must consider before progressing with a charging infrastructure project at their identified site:

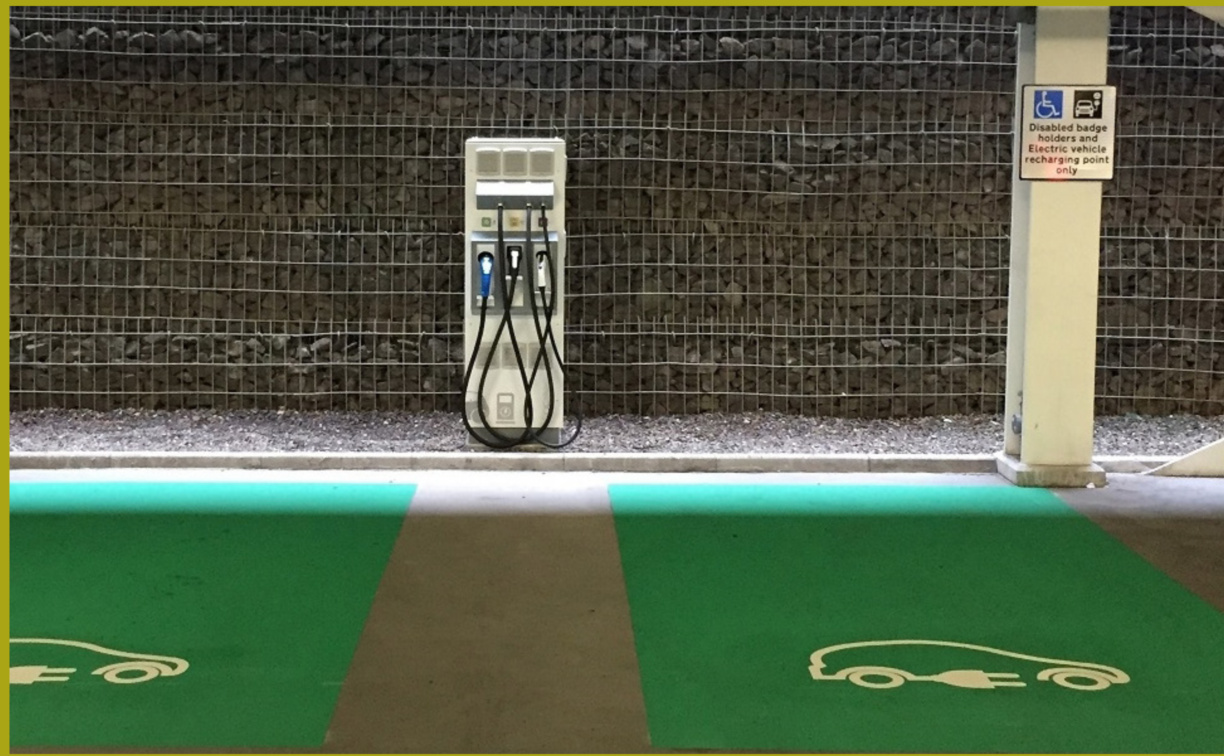
- **How long would a driver expect to spend at the location while charging?**
- **Are there other activities a driver will be doing while charging their vehicle?**
- **Will the car be there for longer than the time required to charge?**
- **How many vehicles could be charged in a 24-hour period?**
- **Who will manage the operations and at what cost?**
- **Is there additional revenue above margin on electricity, for example incremental spend in attached shops, advertising or overstay fines?**
- **How long, and secure, is the contract for the land?**
- **What is the risk to your ongoing business if you do not install a charging station?**
- **Are there opportunities to incorporate grid balancing technology, such as battery storage?**
- **What maintenance assumptions have been made, for example after acts of vandalism or accidental damage?**
- **Are upgrades to the grid capacity necessary for the speed of charge required?**
- **Does the installation need smart charging capabilities?**

5.2 Investment criteria

When considering a potential investment or lending decision, a financier will focus on the perceived risk of the project and how reliable the cashflow projections are.

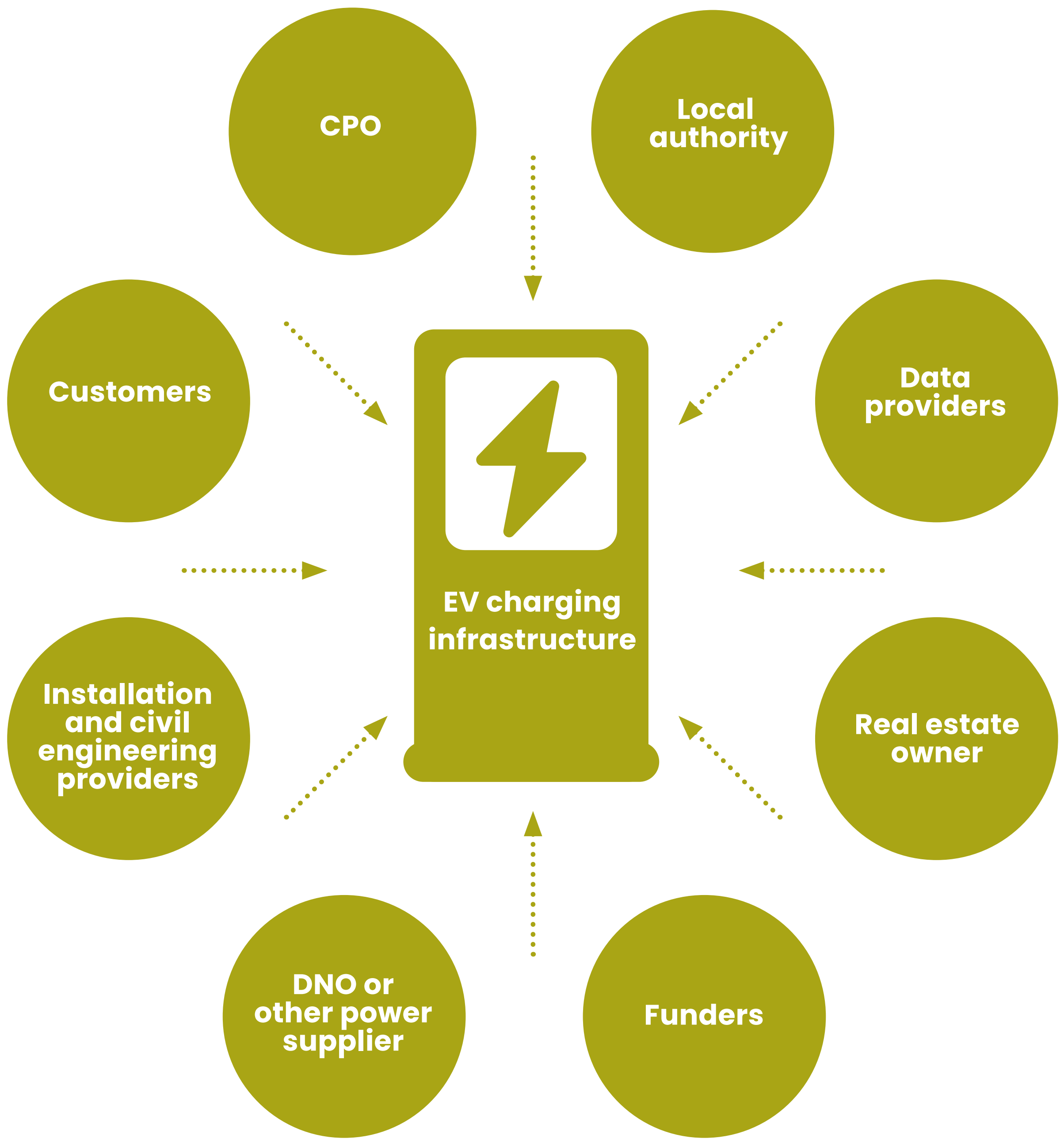
Below is a non-exhaustive list of questions which may be raised; the project sponsor will need evidence that the relevant risks have been thoroughly considered:

- **What is the project sponsor's track record and financial (equity) position?**
- **How reliable is the projection of utilisation rates?**
- **What influence, if any, does the sponsor have over utilisation?**
- **What experience does the management team have?**
- **How strong are the sponsor's rights over the real estate?**
- **How reliable is the sponsor's cost-efficient access to energy supply?**
- **How will the project sponsor and their CPO respond to adversity (demand volatility, technology evolution, regulatory adjustment, etc.)?**
- **Who has ownership of the equipment?**
- **Who has ownership of the revenues?**
- **What are the various sources of revenues?**
- **How robust are construction and connection costings?**



5.3 Project stakeholders

Though the roles and responsibilities of each can vary from project to project, the development of EV charging infrastructure generally involves a wide range of parties including:



5.4 Government support

The Government currently offers several grants for charging infrastructure across different locations and types of chargepoints.

5.4.1 Private charging infrastructure

For home charging, homeowners who live in flats and people in rental accommodation have access to the **EV ChargePoint Grant**[44], introduced in April 2022. This provides up to 75% of the cost towards the purchase and installation of a chargepoint at domestic properties across the UK, limited to £350 per grant.

For workplace charging, the **Workplace Charging Scheme**[45] is a voucher based scheme providing eligible applicants with support towards the upfront costs of the purchase and installation of EV chargepoints (inclusive of VAT), capped at £350 per socket or 40 sockets across all sites per applicant. As of February 2024, the grant has now been extended for state-funded schools. The grant provides up to 75%, up to £2,500 per socket.

5.4.2 Public charging infrastructure: on-street residential

The **On Street Residential Chargepoint Scheme (ORCS)**[46], is a £20m grant fund, giving LAs access to grant funding that can be used to part-fund the procurement and installation of on-street EV charging infrastructure for residential needs. Updates were made in 2023; funding is for up to 50% of eligible capital costs. A maximum grant size is of £200,000 and funding provided will not exceed £7,500 per chargepoint. Projects have been extended and must be completed by 1 March 2025 and should take between six and twelve months from making an application to installing the chargepoints; all applications must be submitted by March 2024.

The **Local Electric Vehicle Infrastructure (LEVI) Fund**[47] is a £450m fund for LAs to support local EV infrastructure. To access the fund, the LA must be planning projects that support the transition to EV use in a local area, with a focus on provision for those without off-street parking. £50m of the fund will be made available as revenue funding, specifically to allow LAs to recruit additional resources to design and deliver their local EV infrastructure strategy, which will help ease the current capacity constraints.

Tranche 1 of funding has now closed and as of February 2024, £185m has been made available with £14.2m of that already deployed to 5 LAs and 100 EV officers have been recruited. Funding for tranche 2 is open for applications between the financial year 2024 to 2025.

5.4.3 Public charging infrastructure: rapid and forecourt

The future £950m **Rapid Charging Fund (RCF)**[48] was announced in March 2020, in support of the strategy to support the rollout of a high-powered network for EVs in England. It is intended to future-proof electrical capacity at motorway and major A-road services areas by helping operators prepare the network for rapid charging facilities. The purpose of the fund is to ensure there is a rapid-charging network ready to meet the long-term consumer demand for EV chargepoints ahead of time. In February 2024, the government ran a consultation for the design of the fund. Government's response is expected to be published in second half of 2024.

5.5 Private finance

Outside of Government support there are mechanisms for financing an EV charging infrastructure project. As the market matures and becomes more commercially viable, access to private finance is expected to increase.

5.5.1 Asset Finance

Asset finance is a flexible alternative to a traditional bank loan, providing significant cash flow benefits for businesses looking to purchase a new piece of equipment, a vehicle or other fixed assets. Unlike traditional financing, the borrower must provide the lender with a security interest in the assets.

Independent Distributor Network Operator

As mentioned in section 3.5, the IDNO typically has ownership of the electrical infrastructure and the customer or CPO has ownership of the chargepoints. However, an innovative way of financing is for the IDNO's to also purchase the asset from the CPO. In return the IDNO offers an 'Asset Valuation' (AV) contribution – based on utilisation data – to CPOs, which helps them to reduce project costs. Once the electrical meter is fitted and plugged in, revenue is generated based on usage and the IDNO collects a % of the revenue until they are paid back their full investment. IDNO's are highly regulated and this type asset financing can be a way to manage investment risk on behalf of a CPO.

5.5.2 Loans

Loans are a popular tool to attract financing for net zero-aligned projects. When taking out a loan, the tenor or term of the loan and the interest rate are key factors to consider. There are two main types of interest rate mechanisms for loans provided by the private sector: fixed rate loans and floating rate loans.

The Public Works Loan Board (PWLB)[49] and UK Infrastructure Bank (UKIB)[50] are two sources available to LAs for loans to finance EV charging infrastructure projects. The UKIB is providing £22bn of infrastructure finance to address climate change and support regional and local economic growth across the UK.

Commercial and retail banks are another source of loans for both LAs and private enterprises, with many actively seeking green finance opportunities. Products such as sustainability linked loans will offer pricing benefits to the borrower for meeting agreed sustainability targets. The ability to renegotiate terms of loans may offer useful levels of flexibility.

There are also examples of innovative pay-on-use mechanisms which are emerging as alternative flexible funding solutions.

5.5.3 Bonds

A bond is a fixed-income instrument that represents a loan made by an investor to a borrower. Bonds are different from loans as they are a tradeable fixed rate instrument, whereas loans are non-tradeable instruments and may have fixed or variable rates.

Bonds designed to raise funds specifically for ringfenced climate and environmental projects are defined as green bonds. Green bonds are usually linked to assets and backed by the issuer's balance sheet, so they carry the same credit rating as their issuer's other debt obligations.

They are not regulated but tend to be subject to internationally recognised Green Bond Principles[51] and Climate Bonds Initiative standards[52], which define the approach to issuance and also set rules around use of proceeds.

Green bonds are currently experiencing a 'greenium', meaning that issuers are able to obtain a cheaper cost of funding by issuing debt with a specified use of proceeds that have positive environmental or social impacts. In H1 2021, yield curves were available for 36 green bonds and 80% of these priced on or inside their yield curve[53]. In simple terms, this means that 80% of the 36 green bonds achieved cheaper funding for the issuer compared to non-green (vanilla) bonds.

5.5.4 Community Municipal Investments

A Community Municipal Investment (CMI) – also known as a Local Climate Bond – is a regulated investment product launched by LAs to access cost-effective funding for specific decarbonisation projects[54]. It offers residents the opportunity to invest in their local area, through a crowdfunding platform, from as little as £5.

The instrument represents an opportunity to tap into a new source of capital – residents' savings. Based on public data from ONS, it is estimated that on average for every 100,000 people in the UK there is £4bn of cash and capital held[55], but this money tends to flow out of local communities. CMIs allow it to be invested locally, furthering community wealth building and helping bridge the funding gap for councils.

The Green Finance Institute, in partnership with Abundance, UK100, Local Partnerships and Innovate UK, launched the Local Climate Bond Campaign in 2021, to raise awareness and support councils in the issuance of CMIs.

Innovative New Models - Utilisation Linked Finance

The GFI have been developing Utilisation Linked Finance (ULF) as an innovative financial solution that can de-risk investment of charging infrastructure in areas that are typically deemed uncommercial due to low utilisation forecasts in the short to medium term, such as rural and seasonal areas.

ULF can be structured so that payments are linked to the usage of the chargepoint. Payments only commence once the chargepoints are revenue generating and in some cases there could be a pre-agreed utilisation threshold to reach before payments commence. As payments scale with utilisation, installers can have a greater level of comfort when deploying infrastructure, encouraging them to build now in areas where short-term demand is less certain. Public funding can also be incorporated to act as a guarantee in early years to ensure returns don't fall below a minimum threshold.

As of 2024 the GFI are exploring several possible transactions with stakeholders in the sector.

CONTENTS INTRODUCTION MARKET CONTEXT EQUIPMENT CHARGING FINANCING SMART CHARGING INNOVATIONS STANDARDS APPENDIX

6. Smart Charging

The following section explains how smart charging can improve the customer experience and assist with balancing the grid, reducing upfront grid upgrade costs and ongoing energy costs.

Smart charging ensures EVs are charged at a time suitable for both the driver and the electricity market, facilitating lower costs and carbon emissions, while mitigating pressures on the grid infrastructure. As EV ownership increases, smart charging will be important to avoid overloading the grid at peak times.

Smart charging means that the charging of an EV can be paused or the rate of charge adjusted in response to commands received from CPOs, Demand Side Response Service Providers (DSRSPs) or other flexibility providers. The grid, however, can have some influence on how chargers behave and managing charging behaviour enables CPOs to ensure the maximum charging is done aligned with access to renewable energy resources. A CPO can manage demand to protect the network, power availability and its own margins to protect the business case for funded sites.

A key feature of smart charging is that the user remains in ultimate control, setting the parameters to suit their needs while allowing some level of autonomy. This functionality allows users to benefit from flexible energy tariffs with cheaper pricing at certain times of day in return for the same overall level of charge and, typically, greener energy[56].

The Electric Vehicles (Smart Charge Points) Regulations 2021 came into force on 30 June 2022[57]. These mandate that most chargepoints sold in the UK for private use must have smart functionality, allowing charging when there is less demand on the grid or when more renewable electricity is available. The regulations also include other device-level requirements, enabling a minimum level of access, security and information for consumers. Connected Kerb led the first UK trial, the Agile Streets Project, for smart metered on-street EV chargepoints. As of April 2024 they are now rolling out the smart charging system nationwide[58].

6.1 Smart cables

A smart cable is an internet connected charging unit that connects to a standard socket outlet. It can offer many of the features of smart chargepoints but in a portable format. Where early adopters of EVs have upgraded to vehicles that can accommodate smart charging, smart cables have allowed them to benefit from this new technology without needing to replace their existing chargepoints.

◄ **A smart cable.**

6.2 Load management

Load Management (often referred to as Dynamic Load Management) is a software function that manages the consumption of the charging stations to ensure that a site or installation limit is never exceeded. For example, if available supply is limited to 100A then without load management it would only be possible to install four AC charging stations (4x32A = 96A). However, with load management it is possible to install more charging stations than the site limit would otherwise permit, as a load management algorithm distributes the available power across the charging vehicles. In this example, if there were ten vehicles connected to the 100A supply then the load management algorithm would limit each charging station to 10A.

6.3 Energy metering and displays

An EV charging system's smart functionality enables it to access and respond to a consumer's energy data. In many domestic and small business scenarios, this data is generated by and communicated from the smart meter. The availability of this data, and the smart charging it facilitates, allow consumers to make more informed decisions about their energy use. By helping consumers to select and switch providers or equipment, to choose when and how they charge according to affordability, carbon intensity or other concerns, smart metering displays help make EV charging cheaper, greener and a simpler, more intelligent and intuitive user experience.

EV charging integration with smart energy data will also support the grid to operate as efficiently and greenly as possible, providing network flexibility and resilience to allow more renewable energy generation. Flexibility will also enable more diversity of consumer offerings.

The International Organization of Legal Metrology (OIML) published in 2022 a Guide[59] to the metrological and technical requirements and the metrological controls and performance tests of EVSE.

6.4 Vehicle-to-Grid (V2G) technology

Vehicle batteries have a role to play in the energy system. As the UK's electricity generation becomes more variable and distributed with the move to renewable energy sources, our energy system will necessarily become more dynamic. The battery pack of some EVs could have a role to play in managing energy demand, and could be employed in two ways:

- By acting as a temporary energy source for the home when prices are high (and thus placing no additional demand on grid generation during a peak demand), or:
- By selling power back into the grid, either to support grid generation or to mitigate short term overloading on a local network.

In 2022, Octopus Energy and National Grid ESO ran the first successful integration of vehicle-to-grid technology. Following the trial, at the beginning of 2024 Octopus Energy launched Octopus Power Pack which is the UK's first vehicle-to-grid tariff[60].

7. Market development and innovations

The following section discusses new charging technology and some future use cases.

The technology described in this guide is essential to EV charging. The fundamentals of the technology are unlikely to change significantly, and the risk of obsolescence can be managed with proper planning. However, new technologies continue to come to market which offer additional complementary services. Developments include faster charging, vehicle-to-everything charging and wireless charging.

Investors and owners of charging infrastructure cannot be completely protected from technology obsolescence risk, but even as technology advances, the predicted trajectory of EV uptake and the upcoming 2030 phase out of new ICE vehicle sales means that there will be a strong demand for charging infrastructure for decades to come.

Once a grid connection in an accessible location is secured, individual parts of chargepoints above ground can be easily replaced when upgrades become available. CPOs who use data analytics and build this modularity and flexibility into their business plans from the beginning are significantly mitigating stranded asset risk for their businesses.

7.1 Vehicle-to-Everything (V2X) technology

As described in the previous section, current V2G technology allows the battery of an EV to export electricity back to the electricity grid. The next evolution in this technology is 'vehicle-to-everything' (V2X), which would include additional benefits to V2G technology, such as improvements in efficiency and accessibility. An EV could export energy beyond the grid to homes, buildings and other energy-consuming destinations. This offers additional flexibility to the energy system and a potential revenue source for businesses and consumers. V2X is an emerging technology with trials worldwide involving hundreds of vehicles, but it is not yet at mass deployment. By 2050, the capacity of V2X could significantly exceed 30GW[61].

7.2 Megawatt Charging System

The Megawatt Charging System (MCS) is a new commercial vehicle high power charging solution for commercial EVs, though it is also expected to have applications for buses, aircraft and other large EVs with battery packs large enough to accept a charge rate greater than 1MW. It is designed for charging up to 1250V and 3000A in conjunction with infrastructure for a 1000V/500A medium power supply using a CCS connector (vehicles equipped with MCS should be able to use existing CCS infrastructure, with all communication and safety requirements compliant with the CCS standard)[62].

7.3 Wireless charging

Wireless or induction charging is used where there is no cable connected to the vehicle: the vehicle can charge by being parked over an inductive pad. If widely adopted, this technology could help reduce street clutter, provide convenient and accessible charging and save time for users. The UK launched its first wireless charging trial in Nottingham in 2021 which concluded in 2023[63].

Wireless Charging of Electric Taxis (WiCET): The UK's first wireless charging electric taxi demonstration in Nottingham.

7.4 Dynamic charging

Dynamic charging is charging while the vehicle is in motion, using devices such as induction plates in the section of road or cables above the road (catenary charging). This technology has potential to improve the EV experience by reducing the need to stop to charge. If widely adopted, it could nearly eradicate range anxiety, remove stationary charging time and make charging simple, safe and accessible to all. However, this technology is still in its trial phase, and the impact of applying this technology to roads at scale will come with significant cost and disruption, and place high demand on the grid.

8. Product standards

This section contains a list of product standards, specifications and legislation relevant to the manufacture and operation of EV charging equipment.

Investors, procurers and operators of charging infrastructure should satisfy themselves of the compliance of both the product and the installation, for example through Competent Person Schemes such as those provided by National Inspection Council for Electrical Installation Contracting (NICEIC), Electrical Contractors' Association (ECA), National Association of Professional Inspectors and Testers (NAPIT) and OZEV.

This list is subject to change; standards can be amended and withdrawn as well as introduced. This list is correct to the best of our knowledge at time of publication. BEAMA maintains a list of relevant technical standards and specifications for its members, which is updated periodically. We will update this list when we next issue a new edition of this Guide.

Wiring regulations

BS 7671:2018+A1:2020	**Requirements for Electrical Installations.** The IET wiring regulations eighteenth edition.

Regulations

	Electromagnetic Compatibility Regulations 2016.
	Electrical Equipment Safety Regulations 2016.
	Electric Vehicles (Smart Charge Points) Regulations 2021.
	Public Charge Point Regulations 2023.

Publicly available specifications

PAS 1878:2021	**Energy smart appliances.** System functionality and architecture. Specification.
PAS 1879:2021	**Energy smart appliances.** Demand side response operation. Code of practice.
PAS 1899:2022	**Electric vehicles.** Accessible EV charging points. Specification.

Plugs, socket outlets and connectors

BS 1363-1:2016+A1:2018	**13A plugs, socket-outlets, adaptors and connection units.** Part 1: Specification for rewireable and non-rewireable 13A fused plugs.
BS 1363-2:2016+A1:2018	**13A plugs, socket-outlets, adaptors and connection units.** Part 2: Specification for 13A switched and unswitched socket-outlets.
BS EN 60309-1:2021	**Plugs, socket-outlets and couplers for industrial purposes.** Part 1: General requirements.
BS EN 60309-2:2021	**Plugs, socket-outlets and couplers for industrial purposes.** Part 2: Dimensional interchangeability requirements for pin and contact-tube accessories.
BS EN 60309-4:2021	**Plugs, socket-outlets and couplers for industrial purposes.** Part 4: Switched socket-outlets and connectors with or without interlock.
BS EN 62196-1:2014	**Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of electric vehicles.** Part 1: general requirements.
BS EN 62196-2:2017	**Plugs, socket-outlets, vehicle connectors and vehicle inlets – Conductive charging of electric vehicles.** Part 2: Dimensional compatibility and interchangeability requirements for AC pin and contact-tube accessories.
BS EN 62196-3:2014	**Plugs, socket-outlets, and vehicle couplers - Conductive charging of electric vehicles.** Part 3: Dimensional compatibility and interchangeability requirements for DC and AC/DC pin and tube-type contact vehicle couplers.

EV conductive charging systems

BS EN 61851-1:2019	**Electric vehicle conductive charging system.** Part 1: General requirements.
BS EN 61851-21-1:2017	**Electric vehicle conductive charging system.** Part 21-1: Electric vehicle on-board charger EMC requirements for conductive connection to an AC/DC supply.
BS EN 61851-21-2:2017	**Electric vehicle conductive charging system.** Part 21-2: Electric vehicle requirements for conductive connection to an AC/DC supply. EMC requirements for off board electric vehicle charging systems.
BS EN 61851-22:2002	**Electric vehicle conductive charging system.** Part 22: AC electric vehicle charging station.
BS EN 61851-23:2014	**Electric vehicle conductive charging system.** Part 23: DC electric vehicle charging station.
BS EN 61851-24:2014	**Electric vehicle conductive charging system.** Part 24: Digital communication between a DC EV charging station and an electric vehicle for control of DC charging.
BS EN 61851-25:2021	**Electric vehicle conductive charging system.** Part 25: DC EV supply equipment where protection relies on electrical separation.

EV communication

PD IEC/TR 61850-1:2003	**Communication networks and systems for power utility automation.** Part 1: Introduction and overview.
PD IEC TS 61850-1-2:2020	**Communication networks and systems for power utility automation.** Part 1-2: Guidelines on extending IEC 61850.
BS EN 61850-3:2014	**Communication networks and systems for power utility automation.** Part 3: General requirements.
BS EN 61850-4:2011+A1:2020	**Communication networks and systems for power utility automation.** Part 4: System and project management.
BS EN 61850-5:2013	**Communication networks and systems for power utility automation.** Part 5: Communication requirements for functions and device models.
BS EN 61850-6:2010+A1:2018	**Communication networks and systems for power utility automation.** Part 6: Configuration description language for communication in power utility automation systems related to IEDs.
BS EN 61850-10:2013	**Plugs, socket-outlets, vehicle connectors and vehicle inlets – conductive charging of electric vehicles.** Part 2: Dimensional compatibility and interchangeability requirements for AC pin and contact-tube accessories.
BS EN ISO 15118-1:2019	**Road vehicles - vehicle to grid communication interface.** Part 1: General information and use-case definition.
BS EN ISO 15118-3:2016	**Road vehicles - vehicle to grid communication interface.** Part 3: Physical and data link layer requirements.
BS EN ISO 15118-4:2019	**Road vehicles - vehicle to grid communication interface.** Part 4: Network and application protocol conformance test.
BS EN ISO 15118-5:2019	**Road vehicles - vehicle to grid communication interface.** Part 5: Physical layer and data link layer conformance test.
BS EN ISO 15118-8:2020	**Road vehicles - vehicle to grid communication interface.** Part 8: Physical layer and data link layer requirements for wireless communication.
BS EN ISO 15118-20:2022	**Road vehicles - vehicle to grid communication interface.** Part 20: 2nd generation network layer and application layer requirements.

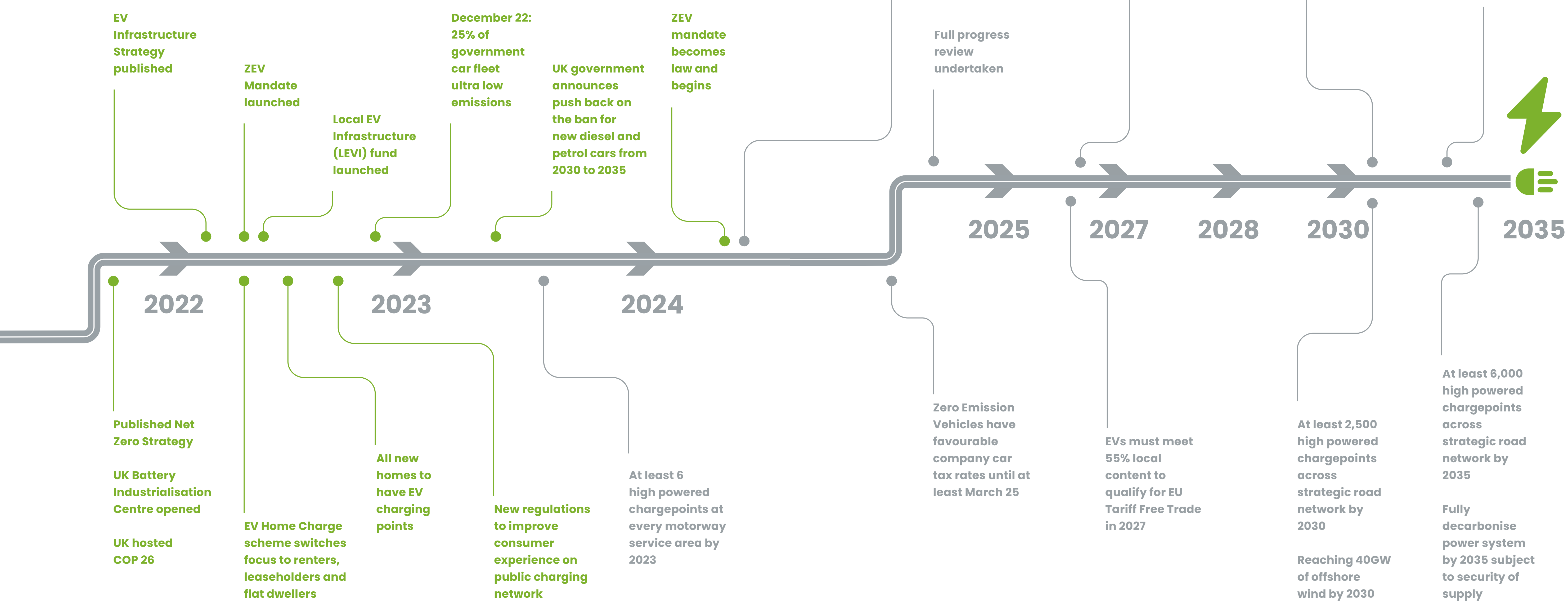
EV Wireless Power Transfer (WPT) systems

BS EN 61980-1:2021	**Electric vehicle inductive charging systems.** Part 1: General requirements
PD CLC IEC/TS 61980-2:2020	**Electric vehicle wireless power transfer (WPT) systems.** Part 2: Specific requirements for communication between electric road vehicle (EV) and infrastructure
PD CLC IEC/TS 61980-3:2020	**Electric vehicle wireless power transfer (WPT) systems.** Part 3: Specific requirements for the magnetic field power transfer system

9. Appendix: understanding the policy and regulatory landscape

The timeline below was published alongside the Government's EV Infrastructure Strategy in March 2022[64] and lays out the critical activity and milestones on the UK's path to electrified road transport.

Our 2035 delivery plan



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