Scoping and Discovery Report

Accessible EV Charging

For Motability the Charity

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Executive summary

The accessibility of charging infrastructure for Electric Vehicles (EVs) has been identified by Motability, the national disability charity, as a priority area, to prevent disabled drivers, passengers, and pedestrians being disadvantaged as the UK phases out the sale of petrol and diesel vehicles. Designability is working with Motability on their wider project aiming to make EV charging accessible, and will lead on user engagement.

This report describes the scoping and discovery work carried out by Designability in preparation for a future phase of user engagement.

Designability's researchers carried out desk research and engaged with topic experts drawn from Motability Charity and Motability Operations, the company under contract to the charity which leases vehicles to disabled people and their families, as well as external contacts. Focussed field work was also carried out to contribute to an understanding of the usability of current EV charging infrastructure and hardware.

Research was gathered in the context of accessible EV charging design, on the topics of users and their journeys; charging infrastructure; charging hardware and components; user interfaces; vehicles; and the built environment. Topics to clarify and explore during user testing were identified for each of these. Usability considerations of EV charging were also drawn together from both previous user research and field studies, to inform future user engagement, design and guidance work.

The key questions identified at the start of the Scoping and Discovery were answered as follows.

1. The groups within the disabled population who should be prioritised in user testing and product design were identified as: physically disabled drivers and passengers of EVs, particularly those with mobility impairments and limited dexterity and strength; independent drivers who charge EVs; disabled drivers and passengers who will charge EVs and who have the greatest accessibility needs; those who are particularly reliant on public charging infrastructure.
2. The aspects of the charging components and the built environment that should be prioritised were identified as: lamp post, pillar and rapid charging units, including their cables, connectors and interfaces; in both on and off-street parking/charging settings, with consideration for obstacle-free space, level access, signage and information and protection from weather.
3. The types of infrastructure that should be considered when proposing potential design solutions and guidance, to have the greatest impact on disabled people, were identified as: public charging infrastructure, including off-street and kerbside settings, whose solutions may also apply to other types of charging infrastructure in physically similar settings.

Closely aligned topics were also identified, which may influence or be influenced by future design work, namely: information services and customer assistance; accessing and paying for the charging process; and emerging and future technologies including wireless charging.

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Purpose

This Scoping and Discovery report describes initial research work carried out by Designability to support and inform Motability's wider Accessible Electric Vehicle (EV) Charging project, and in order to define the work to be carried out by Designability during a future phase of user engagement.

Background

Motability the Charity has identified a lack of attention paid to the accessibility of electric vehicle charging infrastructure, in the context of the planned ban on the sale of petrol, diesel and hybrid vehicles in the UK by 2030 (recently brought forward from 2035). The vision for this project is that EV charging infrastructure in the UK becomes accessible for disabled people so they are not disadvantaged in this future shift.

Designability's current role in the project is to lead on user engagement. Following the completion of a 4-week scoping exercise (Phase 1), Designability has carried out 8 weeks of in-depth research work (Phase 2: Discovery) whose purpose is to inform Phase 3 (User Engagement). The aim is that findings from Phases 1, 2, and 3 will be drawn into a final phase of concept design and guidance work.

Objective

The objective of Scoping and Discovery was to answer the following key questions:

1. Which groups within the disabled population should user testing and product design focus on?
2. Which aspects of charging components and the built environment should we target when proposing design changes?
3. Which types of infrastructure should be considered when proposing potential design solutions and guidance, in order to have the greatest impact on disabled people?

Activities

Designability's researchers carried out desk research and engaged with subject experts to answer these key questions. Focussed field work was also carried out to gather further information about the usability of existing EV charging infrastructure and hardware which will inform the later design work.

Summary of research findings

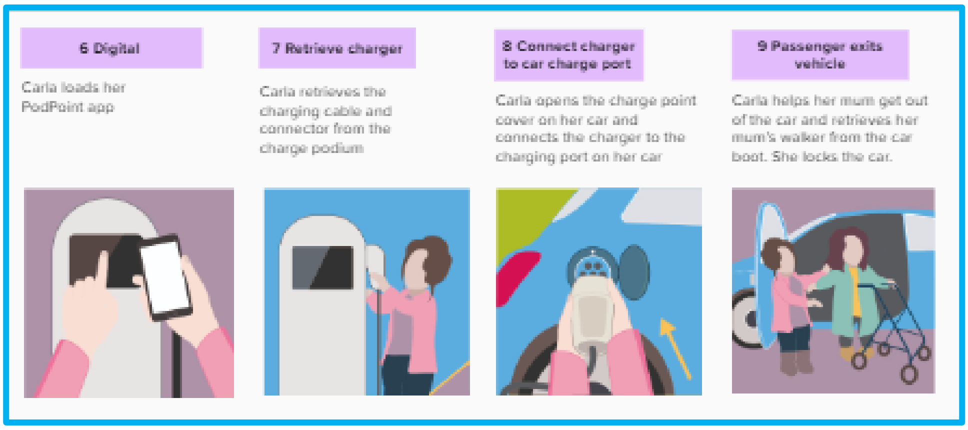
The findings from the information gathering activities during Scoping and Discovery are summarised in the following sections, which describe the research and identify what is still to be learned, or explored in further detail, during user engagement.

Designability will develop a set of use cases that describe, between them, the range of users and situations (including e.g. user characteristics, journeys, vehicles, charging infrastructure), that need to be considered in order to develop suitable design concepts and guidance for accessible EV charging. These will be refined by future user engagement work so that the use cases are highly relevant and detailed. In order to communicate the use cases, we will create “user journeys” to describe them.

User journeys

User journey mapping is a valuable tool in the design process. User journeys depict step-by-step actions a user carries out in order to achieve a specific task e.g. electric vehicle charging. They often comprise of a series of images (with descriptions) which capture key touchpoints along a journey. The intention of user journeys is to tell cohesive stories about how people could interact with a product or service, to highlight pain points, user feelings and opportunities to enhance the user experience. User journeys can also be utilised later during the design process, as a quick means of assessing the suitability of design ideas against various user characteristics, scenarios, and environments. It provides a tool which designers can use to measure how inclusive and accessible a design really is, given that a particular design feature may work well for one person and scenario, but be difficult to use by someone else.

A series of user journeys will be created to highlight key opportunities and problems to solve in our design phase. These user journeys will be informed by our user engagement work and based on real life experiences of people we engage with.



Extract from a draft user journey created by Designability to demonstrate how the tool is used

1. Users and their journeys

This section describes which users and journeys we will prioritise during our design and guidance work, and indicates which aspects of users' characteristics and experiences we will be exploring in the user engagement, in order to find out information from users that we cannot derive from desk-based research.

Who do we consider to be the primary and secondary users of EV charging?

For Designability's work, the primary users in the context of accessible EV charging are:

- A disabled person who charges the EV (whether a driver or passenger), including entering and exiting the vehicle and manoeuvring around the vehicle in order to charge it
- A disabled person who is a driver or passenger in the vehicle and who needs to enter, exit and manoeuvre around the vehicle without charging it

The secondary users are:

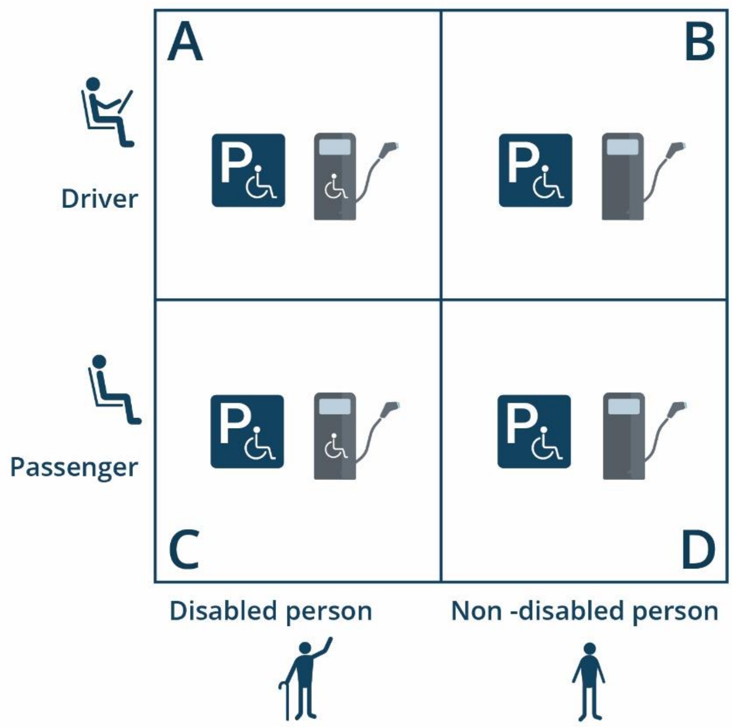
- Any person at or near the charge point unit who could be affected by the charge point unit, whether or not a vehicle is currently being charged. This includes passing pedestrians, e.g. those with mobility or visual impairments, who need to navigate past a charge point.
- Any non-disabled person who charges the EV, whether a driver or passenger. (This is a trivial design case, as these people are likely to be able to use any type of charger, regardless of its accessibility for disabled users)

The accessibility of EV charging (in the context of Designability's work) can be broken down into two core areas:

1. The usability of the charge point unit itself
2. The accessibility of the parking space and built environment around the charge point unit

The usability of the charge point unit could describe more than one design solution; we are not assuming a one-size-fits-all "accessible" solution.

When considering the question **"Who is charging the EV?"** in relation to an EV that has been provided for use by a disabled person, we can think of this as four potential cases, as shown below:



Considering accessibility requirements based on who is charging an EV

In all cases (A, B, C and D), a disabled person could be present during parking or charging, so providing an accessible parking space would be necessary if that disabled person had a mobility impairment, so that they could enter and exit the vehicle and manoeuvre around it. In the less common case that the disabled person did not have a mobility impairment, e.g. upper limb amputees, then an accessible charge point unit in a standard parking bay could be appropriate.

We anticipate that in situations A, B, C and D, the vehicle's owner or user would have a Blue Badge and therefore be eligible to park in an accessible parking space.

In case C where a **disabled passenger charges the vehicle**, this could be a scenario where a physically disabled driver and a disabled passenger travel together. The disabled passenger charging the vehicle could therefore be a person with conditions which preclude holding a driving licence, e.g. a significant visual impairment.

Case A includes the case which requires the greatest accessibility provision, where an **independent disabled driver** is charging the EV alone and the parking space and the charge point unit must both be accessibly designed.

In cases B and D where a **person who is not physically disabled uses the charge point unit**, there is potential for them to use a standard charge point unit in an accessible parking space, if such a combination were made available. If information services were to provide sufficiently detailed information about the accessibility of individual charge point units, this could mean that:

1. **An accessible charge point unit in an accessible parking space** could be more reliably available for those who could only use that combination, for example independent drivers of WAVs

2. Non-disabled people who can use **standard charge point units in accessible parking spaces** could have greater numbers of charging options available for their use

This approach will be considered carefully since it involves potential risks as well as benefits (which will be explored with users, as described at the end of this section).

For example, it could be tempting to simply create an accessible parking space around an existing charge point unit, but existing EV charge point units are often not situated near pedestrian car park entrances or amenities, so would not necessarily be appropriately accessible.

There will also need to be consideration of **which spaces are used by which users.**

For example, how might a non-disabled driver of a small, un-adapted EV, who is travelling with a disabled passenger, be appropriately discouraged from using an accessible bay with an **accessible** charger when they could use an accessible bay with a **standard** charger? This can be also considered in the context of the guidance in section 7 of BS8300-1:2018 [1], which states:

> *"To assist in minimizing the likelihood of misuse of designated accessible parking spaces … a range of parking spaces for a variety of specific uses could be provided in larger developments, including… larger bays for minibuses, camper vans and cars with caravans or trailers…" and "Where electrical charging points are available, these can provide choice for users and can be provided to standard spaces, parent and child spaces, Blue Badge parking spaces and larger spaces."*

(There is also the potential scenario where the disabled person who was not charging the vehicle chooses to stay in the vehicle during a short charge by a non-disabled person, and therefore does not need to enter, exit or move around the vehicle. In that instance a standard EV charging space and standard charge point unit could be used; however there is no design incentive to address that scenario.)

Priority user groups

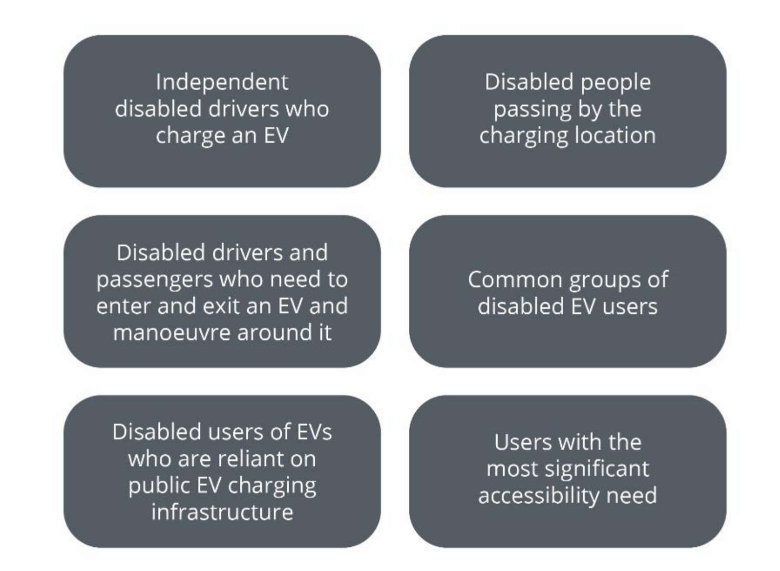
In order to inform our accessible EV charging design requirements, we will consider some key user types in order to understand common and edge-case scenarios, and rather than consider specific conditions, we will consider the abilities of the users and what this means for the design of accessible public EV charging. This approach means that we can aim to meet the needs of large numbers of users, as well as less common user groups who have more specific accessibility needs.

Designing well for carefully chosen groups with specific needs will enable us also to meet the needs of a wider group. For example, creating plug in solutions which only require limited dexterity is beneficial to those with reduced dexterity while also being easy to use by other groups with less significant needs. Some conflicts may occasionally arise where different needs conflict with one another, but this will be managed or mitigated as far as possible.

For the purposes of this work, we are considering **disabled people who have physical impairments** to be the core focus of our design work, since we know these users are likely to have the most common or significant needs in terms of accessible design for EV charging.

We are however also considering a wide range of user characteristics in our user journeys and when developing design requirements, in order to design for as broad a range of users as possible. These could include for example age, cognitive impairment, neurodiversity, literacy level, urban or rural location, responsibility for any dependent children or adults, employment status and familiarity with technology.

We will gather further details about the following key users groups in the context of this work by engaging with users, as described at the end of this section.



Priority user groups

We will prioritise our primary users, specifically: **independent disabled drivers who charge an EV themselves** since their ability to travel independently by EV relies on being able to use accessible public charging infrastructure themselves; and **disabled drivers and passengers who need to enter and exit the EV and manoeuvre around it** since they are likely to be present on every occasion when the vehicle is charged.

Secondary users who are not disabled will not be designed for specifically, since they should be able to use any charging provision that has been designed to meet the needs of disabled users. However, **disabled people passing the charging point**, e.g. those with visual or mobility impairments will be considered. Secondary users who are driving past a charging point will only be considered from the perspective of the safety of the driver and/or passengers charging the EV and moving around the vehicle.

Common types of disabled vehicle users include those with some types of physical impairments.

A study by the Research Institute for Disabled Consumers (RiDC) into the accessibility of plug-in electric vehicles" [3] indicated that their survey respondents *"were heavily skewed towards people with a mobility impairment (75%) and/or dexterity/limited strength impairments (27%)"* and that this was aligned with the general population of disabled drivers.

Data from the nationally representative National Travel Survey about travel in England in 2018 (reported in NatCen's secondary analysis report [4]) indicated that 46% of disabled people had access to a car as its main driver, 10% not as the main driver, and 14% as non-drivers in households with a car, i.e. potential passengers. This proportion could be used to estimate of the proportion of drivers and passengers, while acknowledging that the data are from 2018 and the proportions may be different by 2030.

The same analysis report indicates that the most common mobility aids used by disabled people whose disability reduced their ability to carry out day-to-day activities included walking sticks, powered mobility scooters and manual wheelchairs (and “other” walking aids, e.g. walkers), so these will be considered. Powered wheelchairs were more rarely used, but people using powered wheelchairs will be considered as part of the edge case users who have the most significant needs.

Users who **rely on accessible public EV charging infrastructure** include those who cannot reliably use accessible EV charging at their home (so would need on-street or at other types of local charging locations) or who have travelled out of range of their home, and will therefore be prioritised. Ricardo’s report on EV charging infrastructure for disabled people [5] estimated that by 2035 potentially 1.35 million disabled drivers (approximately half of disabled drivers) may depend to some extent on accessible public charging infrastructure.

Users who have **the most significant accessibility needs** in this context include:

- those whose mobility aids take up the greatest space when manoeuvring around a vehicle;
- those with the tallest and shortest height including standing and seated positions in wheelchairs or scooters when charging the vehicle;
- those with the largest and smallest hands;
- those with the most limited* dexterity, grip strength, reach, muscle control, hand function (including use or availability of less than two hands, and/or use of a prosthesis), mobility, balance, vision, hearing, concentration and energy.

*We will consider suitable ergonomic datasets, including older people, disabled people, males and females, and use professional judgement to determine whether to use e.g. 5th percentile or other appropriate values in order to design pragmatically. As a hypothetical example, it would be better to propose a technically feasible physical charging concept that could be used by the majority of disabled people, rather than a less technically feasible, maximally accessible, physical concept that that could in theory be used by people with 5th percentile strength, if in practice those in the 5th percentile for strength were unlikely to use such a charger themselves and instead would choose a personal assistant (PA) or use on-site assistance to charge their vehicle.

We are also aware that the users of accessible EV charging will include disabled people with a range of interest in and familiarity with technology. Since many disabled drivers and passengers use Motability Scheme vehicles, which are all new vehicles leased for 3 years, there will be Scheme customers who will be new users of EVs when their lease renews, rather than at a time of their choosing. We can therefore anticipate that the earliest adopters of accessible EVs will include both confident and less confident users of technology.

Priority journeys

Having established that the design requirements will be prioritised based on types of typical user and those who have the greatest accessibility needs, their journeys will also have some influence on their needs. Types of journey that which we will consider within our user journeys will be drawn from the following, since these are either commonly occurring or significant in the context of accessible EV charging:

Prioritised journey types

The most **time-critical journeys** are expected to include:

- travel for work or study (e.g. for commuting, classes, job interviews);
- essential appointments (e.g. for outpatient appointments or benefit assessments)
- life events (e.g. weddings or funerals).

A 2021 report by ONS on disabled people's outcomes [6] states that around half of disabled people aged 16 to 64 years (52.1%) in the UK were in employment in July to September 2020, and the secondary analysis report of the National Travel Survey 2018 (England) [4] indicates that 68% of the surveyed disabled people who commuted to work travelled by car or van as a driver or passenger in 2018, so supporting working disabled people to be able to use public EV charging infrastructure will be important for that group.

Some (but not all) disabled people will have a greater number of health-related appointments than the average member of the public; eligibility for a Blue Badge or for Motability's Scheme depend on eligibility for certain types of benefit (higher rate Personal Independence Payment (PIP) or Disability Living Allowance (DLA)) so benefit assessments, while infrequent, are essential and are likely to be relevant to most people who could benefit from accessible EV charging, and at March 2020 there were 2.44 million Blue Badges held in England [7].

Life events such as weddings and funerals can demand not only punctual arrival for a one-off event, possibly in an unfamiliar location, but also wearing clothing (as for work) that users would be particularly keen not to get dirty for example when handling charging cables. Journeys of this type can therefore be used to illustrate some important pain points in the user journeys.

Common types of journey are expected to include shopping and personal business, based on a 2017 Department for Transport report on the travel behaviours and attitudes of disabled people [8]. The report also indicated that people living in rural areas travelled more miles per year by car than those living in urban areas, regardless of whether they were disabled, and that disabled people living in rural areas were more likely to have a driving licence than disabled people living in urban areas.

Journeys which include the **most unfamiliar EV charging experience** will have unique challenges, including finding, paying for and physically charging an EV in an unfamiliar setting. Such journeys could include the use of a newly-installed local charge point unit of an unfamiliar brand or charging at several different types of charge point unit during a one-off long distance journey such as a holiday.

Examples of journeys whose length or frequency require **preferred types and timings of charging** will be important to understand. For example medium-distance commuters with regular travel patterns might require daily overnight slow charging close to home or at work; those making many short, frequent journeys may require fast and/or top-up charging at a range of different locations; and people making short shopping trips or stopping at motorway services may require rapid and/or top-up charging where the user does not want to spend long at the charging location.

What we will find out from working with users

Engaging with users will enable us to test some of our reasoning that has arisen from this discovery work and to gather rich, detailed examples of real-world experience to inform the user journeys that we will use to capture the needs that our design concepts will seek to meet. Specific topics of interest include:

- Exploring the user characteristics and journey types described in this section to inform our user journeys
- Understanding the current parking and refuelling experiences of drivers with complex solutions, i.e. wheelchair accessible vehicles, for those both with and without EV charging experience
- Understanding who charges (or would charge) and EV, and why, and whether this is by choice
- Exploring reactions to the idea of providing different combinations of EV charging spaces and charging units; for example a standard charging unit in an accessible parking space, an accessible charging unit in a standard parking space, or both aspects being accessible
- Seeking to understand what the most significant edge cases might be in practice, for example what solutions are desirable for current independent disabled drivers and whether non-physical solutions such as assistance are the preferred option for some users

2. Public EV charging infrastructure

There are various locations in which EV charge points are situated, and these can fall under private or public infrastructure. In Scoping we identified public charging infrastructure as a key priority, and we explored this in more detail in Discovery.

Ricardo's report on EV charging infrastructure for people living with disabilities [5] highlighted public infrastructure as a priority area of focus in making charging infrastructure more accessible for disabled users. It is estimated that by 2035 34% of disabled drivers/passengers will not have access to off street parking at home and 14% will be wholly dependent on public charging. Further to this, the RiDC report on the accessibility of plug-in electric vehicles [3] highlighted accessibility of charging units (for example, lack of consideration for wheelchair users), accessibility of charging cables (which are heavy and sometimes excessively long) and environment (e.g. slippery surfaces, lack of cover) as key barriers to electric vehicle charging.

What is public parking?

Public parking can be defined as anywhere in which a member of the public can gain access and make use of parking without expressed permission. Public parking includes free, paid or limited (e.g. a maximum 2-hour stay) parking. Public parking locations can be managed privately (e.g. supermarkets) or by the local authority, and must comply with The Road Traffic Act [9]. Examples include supermarket car parks, hospital car parks, on-street public parking, motorway service stations, and park-and-ride car parks.

What is private parking?

Private parking requires expressed permission to use or is owned privately by the user, this includes; residential parking (including driveway, on-street, car park), workplace parking, parking where you must be a customer to park (e.g. hotel, pub car park), allocated parking bays - reserved for an individual person (can be disabled bay or non-disabled bay e.g. workplace, resident),

There is also the concept of community parking, which is offered by services such as the *Just Park* smartphone app. The service allows owners of private parking, with access to EV charging to offer their parking space and charger to members of the public for a fee. Despite members of the public having access, they do need express permission to park in these locations and as such fall under private parking and are out of scope for this work.

Priority types of charging infrastructure

As anticipated, the primary focus of our research and design work will be around public charging (e.g. supermarket car park, on street parking). However, the findings are likely to be relevant to some types of private infrastructure (e.g. hotels or residential car parks) where the charging types and physical settings are similar to those found in public charging settings.

What we will find out from working with users

User engagement can be used to provide further information on topics such as:

- How do users' experiences differ between public and private parking, where charging unit speed and type are determined by location and infrastructure?

- How do users' experiences differ between different charge point types e.g. lamp post, pillar, rapid, and what are their preferences?
- Understanding journey charging vs destination charging behaviours, such as how far away from the home are disabled EV users willing or able to park.

3. Charging hardware and components

A comprehensive review of existing and emerging EV charging components has been carried out to understand their technical capabilities and limitations, and the various types of charging unit and where they are found. This desk- and field-based research has enabled us to focus on specific charging units and components for the future user engagement and design work.

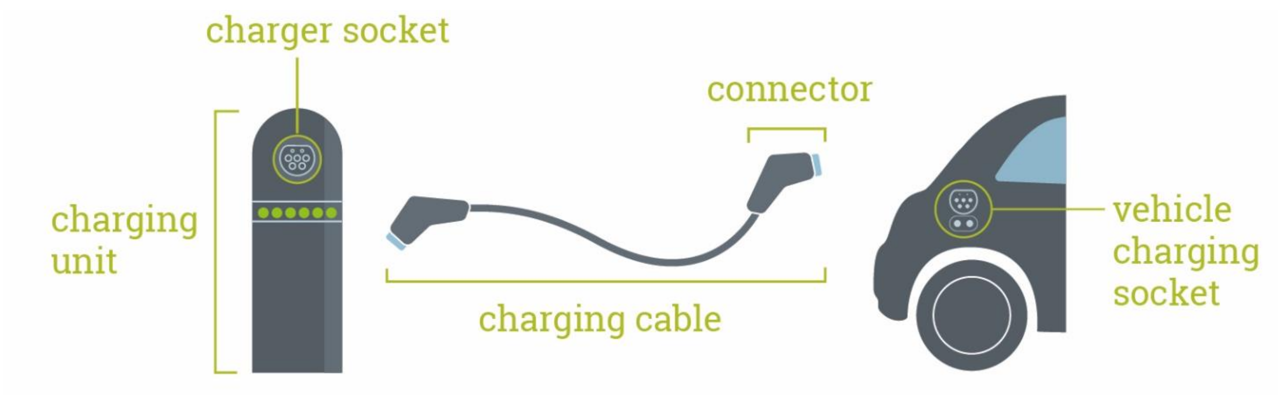
The national network of EV charging providers comprises numerous industry players. The infrastructure is fragmented, where privatisation has led to a free market for companies to develop and install EV charging units with little regulatory oversight or scrutiny. There is also little evidence that disabled people have been considered in the design of EV charging points. Disabled people have seemingly been overlooked while the industry accelerates ahead, but with 2.45 million disabled drivers and passengers in the UK, and a predicted 2.72 million by 2035 [5] the industry must take action to avoid leaving disabled people behind. The impending ban on new petrol and diesel vehicles by 2030 and the Equality Act 2010's [10] requirements on employers and service providers to make 'reasonable adjustments' [11] that will allow disabled people to access the same opportunities and services as non-disabled people make for a strong argument that the industry must be responsive to the needs of disabled people.

Destination versus journey charging

Charging can be divided into two categories: "destination" and "journey" charging units. "Destination" settings are where the user has a longer period to charge and therefore the charge rate is slower e.g., hotel, residential charging. "Journey" charging points are intended to form part of a user's journey, where faster (or top-up) charging is appropriate, e.g. at motorway service stations or some retail outlets.

Description of charging units

Charging units deliver power to an EV. There are various types of charging units available which provide different intensities and therefore rates of power. The appropriate charging unit for a particular location is determined by various infrastructural and contextual determinants, such as available power supply, location type (destination or journey), whether aesthetic discretion is required (e.g. at a protected or heritage site), space available, and demand from members of the public.



Illustrative overview of EV charging terminology (Designability)

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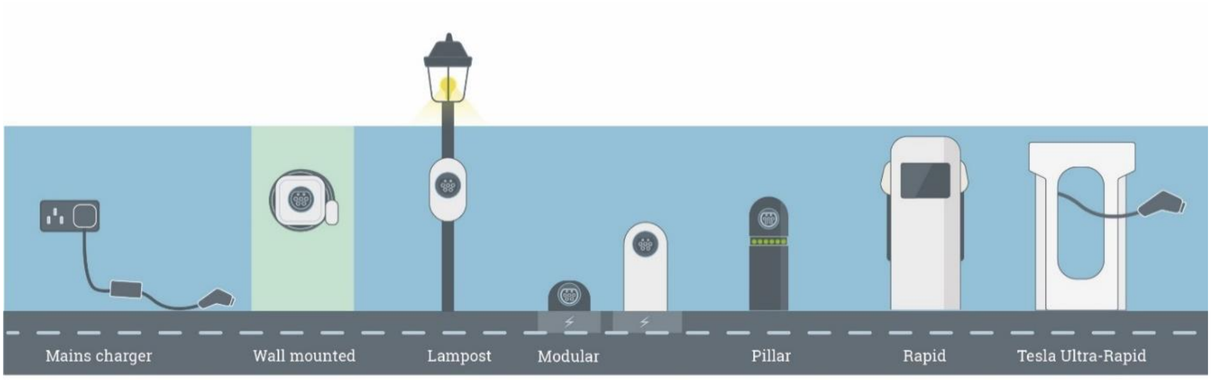
Types of charging unit

The range of charging types is summarised below.



Illustrative overview of types of EV charging units

Mains charging

EVs can be connected directly into mains power using a charger with a mains plug. Most vehicles come with a mains compatible charger as standard. These chargers are usually used in a residential setting but some public networks, e.g. *Source London,* provide mains powered charging units.

Wall-mounted

In addition to mains charging, charging units can be installed on a wall with tethered charging cables or sockets for untethered chargers. Depending on the type, these units allow for slow or fast charging which can deliver up to 7.2-22kWh of power. These are typically found in residential (on and off street) and workplace settings, although they can sometimes be found in public car parks. This type of charging is encouraged, particularly overnight as demand for power is at its lowest which in turn places the least strain on the national grid network. The government provide financial support to install charge points in their home via the *Electric Vehicle Home Charge Scheme (EVHS)*.

Pod Point Solo wall charge (source: www.autocar.co.uk)

Andersen Wall charger (source: electrek.co)

BP Chargemaster Wall charger (source: bpchargemaster.com)

Lamp post

A charge unit type which offers a discreet solution that is minimally invasive, low cost and fast to install, and removes the requirement to dig up a pavement, is lamp post charging units. These require an untethered charging cable to use. Many public street lamps have been converted to LEDs in recent years to make them more energy efficient and in turn this frees up power which can be utilised for slow EV charging. It is difficult to estimate the number of lamp post chargers in the UK but a significant number (1,200) have recently been installed in London, by *Siemens* and *Ubitricity* [12]. Lamp post charging delivers a maximum power supply of 5.8kW.

An Ubitricity/Siemens lamppost charger installation (source: www.current-news.co.uk)

Closeup of an Ubitricity smart charging (source: www.electrive.com)

A City EV charging unit (source: www.autocar.co.uk)

Pillar

Pillar or free-standing charging units tend to be located close to kerbs to prevent cables trailing along the ground. These are commonly situated in public car parks, workplace car parks and residential streets. They are intended for destination charging so offer a slow charge, delivering a 3-7kW energy supply.

Companies such as *Urban Electric* offer telescopic charging units which offer a discreet solution and protect the unit from risk of damage.

An Urban Electric telescopic charger (source: www.electrive.com)

A Pod Point charger (source: www.current-news.co.uk)

A close-up of a Pod Point charger (source: www.matine.co.uk)

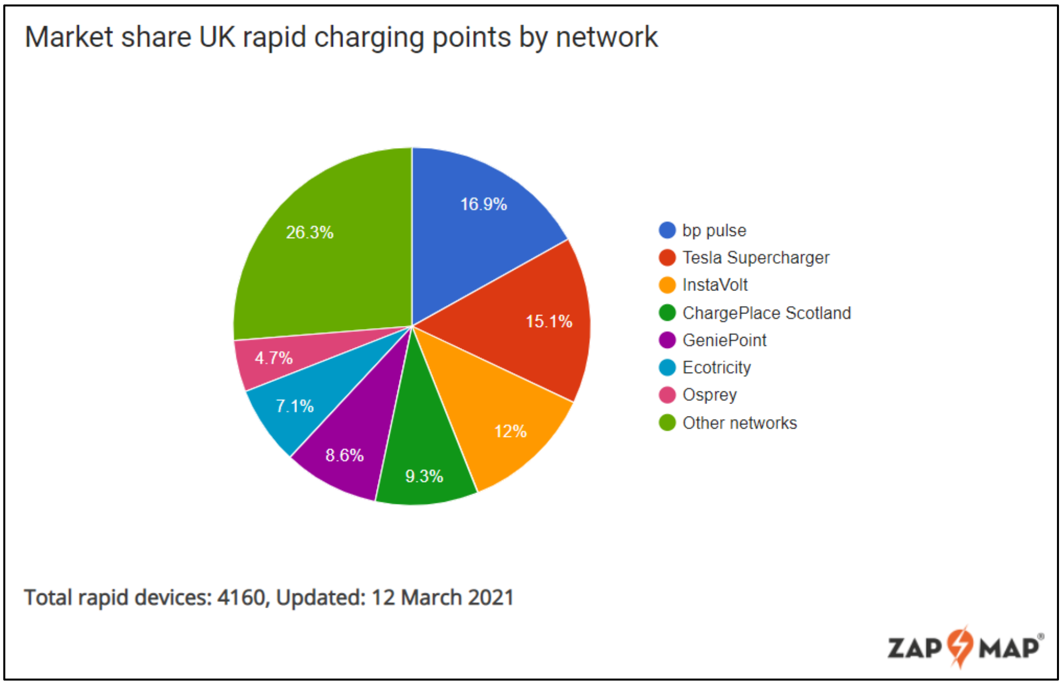
Rapid and ultra-rapid charging units

Rapid charging units offer the fastest way to charge an EV. Rapid units are typically found at service stations, at motorway services and at some major supermarkets. Rapid charging units deliver 43-100kW of power in 20-60mins and ultra-rapid charging units deliver over 100kW of power in less than 20mins, making them ideal for journey charging, where it is inconvenient to wait at the charging location for long periods of time. *BP Pulse, Tesla* and *InstaVolt* are the most widely available rapid charging units in the UK.

Polar Chargemaster rapid charger (source: bpchargemaster.com)

Tesla Ultra-rapid charger (source: www.electrive.com)

InstaVolt rapid charger (source: instavolt.co.uk)



Most prevalent rapid charging unit providers in the UK (source: www.zap-map.com)

Priority charging units

After reviewing various charging unit types and with our focus being primarily on public charging, the charging unit types which we believe present the greatest opportunity for disabled people are:

- **Lamppost charging units** which deliver a slow rate of charge. These should be considered for users who do not have residential parking, those who live in urban areas and for settings requiring a discreet solution. *Connected Kerb* is developing modular on-street charging units which present the opportunity for these units to be replaced with induction chargers in future (see the Closely Aligned Topics section of this report for more information), which could be much more accessible than using plug-in cables.
- **Pillar charging units** since the most prevalent charging units in the UK are fast chargers which are most often pillar charging units. These units offer a cost-effective solution for destination charging and have the broadest outreach.
- **Rapid charging units** since these have presented some of the most negative user experiences, particularly for users with physical disabilities which affect mobility, and there is therefore a wealth of opportunity to enhance the user experience.

The appropriate charging unit type (and rate) is defined by the context in which it is situated. Further research in our user engagement phase is required to understand the journeys disabled people make and want to make, and where convenient charge points could be situated, both in destination and journey contexts. This information will further support us in prioritising charging units to focus on, based on real user insight.

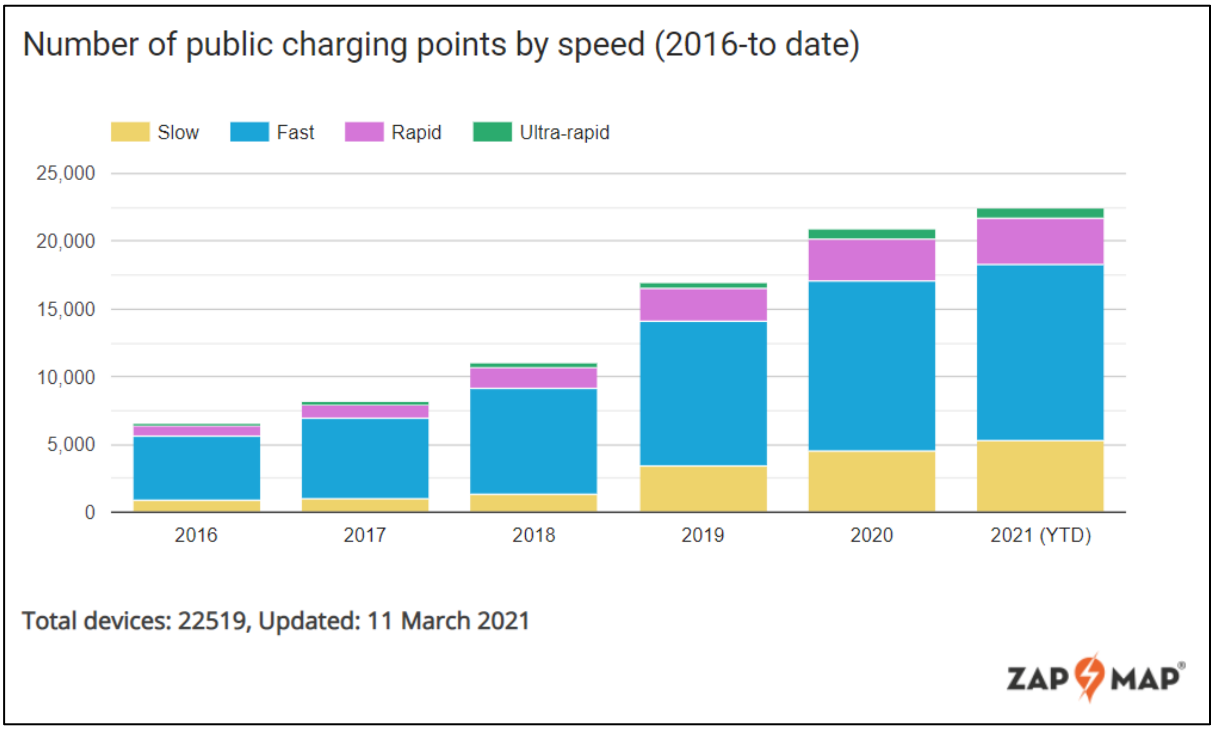
Charging speed and duration

There are four rates of charge that are delivered through EV charging units: slow, fast, rapid and ultra-rapid. Slow and fast chargers run on Alternating Current (AC). AC is converted to Direct Current (DC) in the vehicle which contributes to the longer charging time. Rapid chargers run DC directly into the vehicle, the AC to DC conversion happens in the charging unit which increases the charge rate. Some vehicles are only suitable for slow-fast charging and not rapid. The table below summarises the charge unit rates of charge and time to charge.

Charging unit type	Current	Time to fully charge battery
Slow	3 kWh	8-10hours
Fast	7-22kWh	3-4hours
Rapid	43-100kWh	20-60mins
Ultra-rapid	100kWh+	<20mins

Charging unit capacity and time to charge (source: www.zap-map.com)

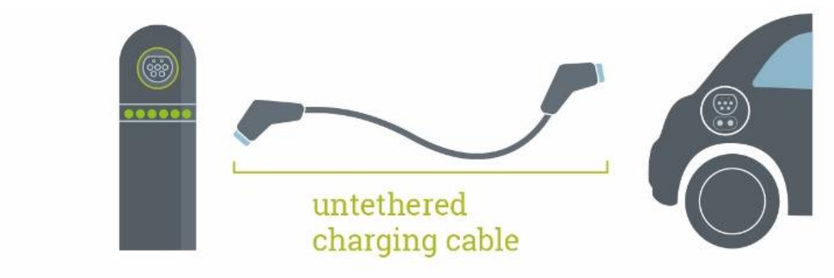
Fast charging is the most prevalent speed found in charging units, as shown below:



The increase in the number of public charging points, by speed (source: www.zap-map.com)

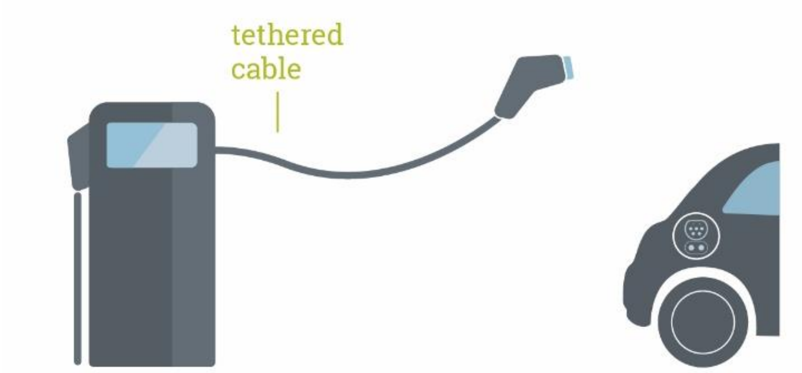
Cables

Cables can be described as tethered or untethered. Untethered cables are not attached to the charging unit and need to be connected to the charging unit.



Example of a fast pillar charging unit with an untethered cable (Designability)

Tethered charging cables are hardwired to the charging unit. Rapid charging cables are always tethered to the charging units for safety. In some instances, residential chargers have tethered cables for convenience.



Rapid charging unit example with a tethered cable (Designability)

Slow and fast power are delivered via single-phase charging cables, comprising two internal wires to deliver 2 kW (domestic) to 22kW of power, which equates to total charging time of between 3-10 hours. There are 16 or 32 Amp charging cables available which can charge the vehicle at different rates depending upon the vehicle battery capacity. The wiring results in a lighter weight cable than the tethered charging cable, although the weight of a standard Type 2 cable, 5m long is 2.5-3kg, while the longer cables (up to 20m) can weigh 12kg.

Example of an untethered 32A charging cable (source: www.evconnectors.com)

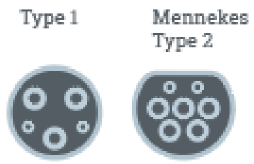
To deliver a rapid or ultra-rapid charge, cables deliver power via a three-phase charging cable comprising 3 internal wires and have internal cooling system to control heat emission, both of which make this cable type heavier than untethered cables. These cables deliver 43-150kWh of power, giving a charging time of between 20mins-1hr.

A person inserting a rapid charging connector into the vehicle socket (source: www.bp.com)

Charging connectors and sockets

EVs can come with a standard 3-pin UK plug charger which plugs in directly to a standard domestic wall socket (with the other end usually being a Type 2 connector which connects to the vehicle). Domestic chargers can also be installed in residential (and some workplace) settings to deliver slightly faster charging and are usually set up with or compatible with Type 2 charging cables.

Slow and fast charging units feature sockets for, or tethered charging cables Type 2 connectors. Type 1 connectors are being phased out in favour of the type 2 connector. Most slow-fast charging units in the UK with sockets are only compatible with Type 2 connectors (in the few vehicles that require a Type 1 cable in the UK, owners tend to have a Type 1 to Type 2 adaptor charging cable).

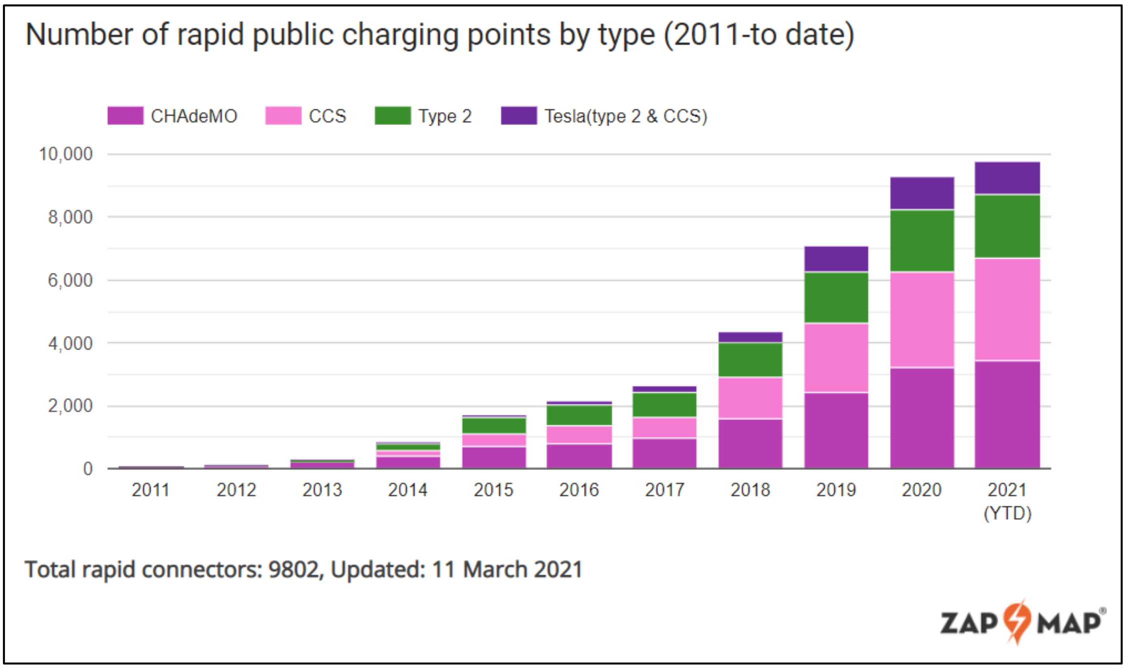


Configuration of charging ports on Type 1 and Type 2 connectors (Designability)

Rapid chargers feature tethered cables with CCS or CHAdeMO charging connectors. Most rapid and ultra-rapid charger units feature one of each connector. Some rapid chargers provide a Type 2 socket for 32amp charging cables.

Configuration of charging ports on CCS, CHAdemMO and Type 2 connectors (Designability)

The prevalence of charging points for different types of rapid charging is shown below.

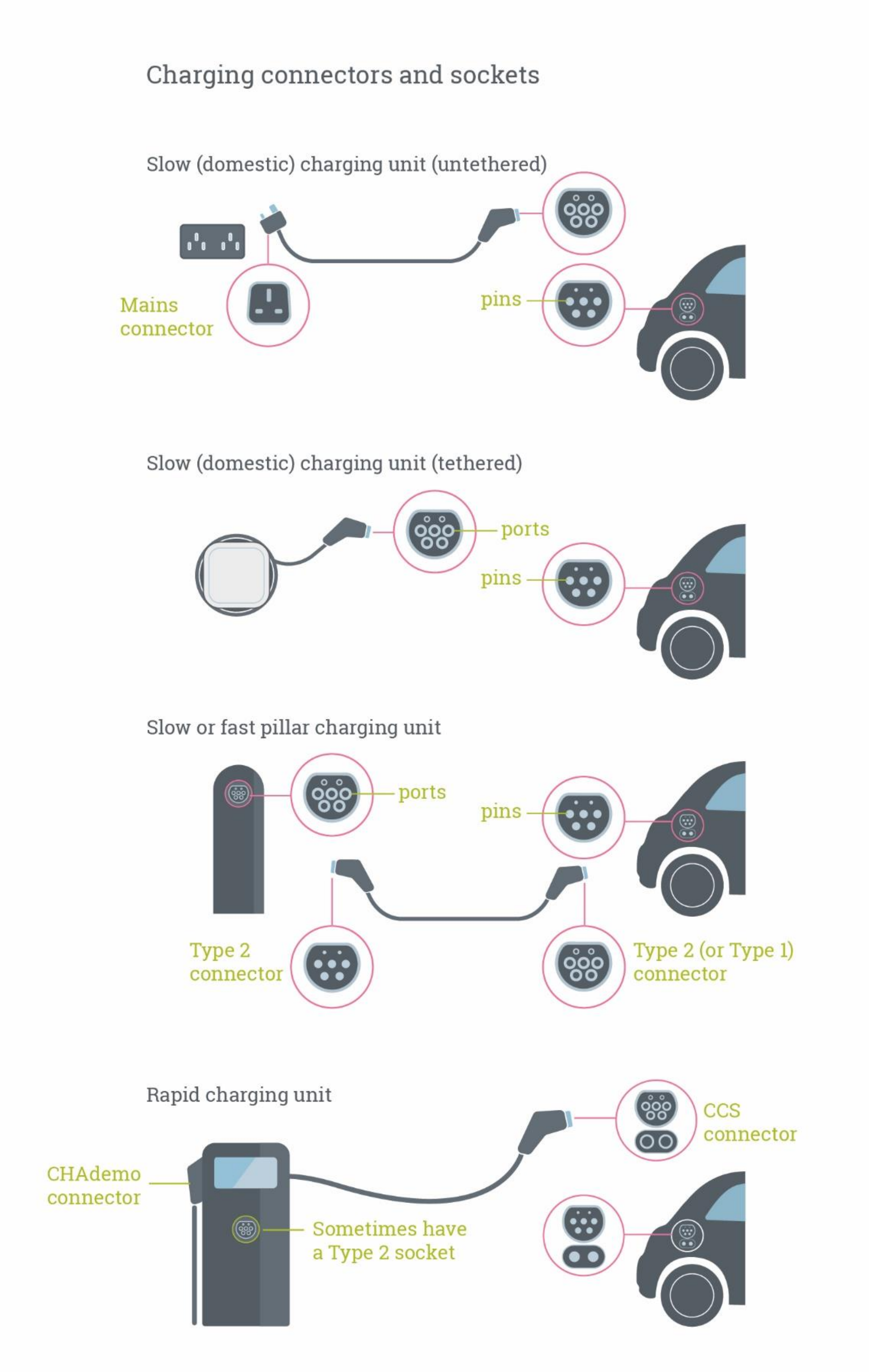


Number of rapid charge points in the UK by type (source: www.zap-map.com)

Type 2 and CCS connectors are also known as "universal" connectors in the UK. The network industry are moving toward universalising these connectors in a move to make charging infrastructure simpler and more accessible. Further to this the CCS connecter is effectively a Type 2 connector with additional ports for rapid charging so vehicles which adopt this model have one charging socket which accepts both CCS and Type 2 connectors. Type 2 and CCS (“universal”) connectors will therefore be prioritised in our work going forward.

Although Type 2 and/or CCS connectors will be the highest priority in terms of features, it is also worth considering provision CHAdeMO chargers as these sockets are often found in Japanese manufactured vehicles e.g. Mitsubishi. It is common for owners of Japanese vehicles to have a Type 1 to Type 2 adaptor cable to charge via a Type 2 socket (which are more widely available), however this is not possible for CHAdeMo since these cables are tethered. Despite some Japanese manufacturers adopting universal socket compatibility in newer vehicles there will still be existing vehicles in the market with these connector types and so demand will remain for these connectors for the near future at least.

Examples of existing configuration of charging connectors and sockets are illustrated below, and an overview of connector types and their associated types of charging unit is provided in the Appendix.



Examples of examples of existing charging unit connector configurations (Designability)

What we will find out from working with users

Experiences

- Explore charging behaviours of current disabled EV users: where and when do people charge their vehicle? What would the ideal place be to charge (day/night-time)?
- Explore any existing experiences of using accessible charge points. Strengths, weaknesses, opportunities.
- Understand how disabled drivers currently charging or refuel their vehicles.
- Gather more case studies around how different disability types impact on charge point usability.
- Understand common/typical journeys made by disabled drivers/passengers and explore what their journey aspirations are.
- Understand where the most convenient locations for charging are/would be
- What are needs and preferences for charging a distance away or on a longer journey (for disabled people)?
- Determine where the greatest needs are in terms of public infrastructure.

Components

- For disabled EV drivers or passengers with experience of charging, what are their experiences (including pain points and opportunities) around specific aspects of using the charging unit, for example:
  - Access and payment
  - Physical interaction with components (interface, connector, cables, connecting to vehicle)
  - Process and understanding the order of steps
  - The most pressing changes which must be made to make charging units more accessible
- Understand the process of how independent EV drivers charge their vehicles when they are alone.
- What are the opportunities to make charging units more accessible?
  - For people with significant accessibility needs?
  - Where a greater number of disabled people benefit?

4. Vehicles used by disabled people

Disabled people currently use a wide range of vehicles in terms of size, fuel type and adaptations. While vehicle design is out of scope for Designability's work on this project, aspects of EVs that can affect the charging experience, such as the location of the charging socket on the vehicle, must be considered when proposing design concepts and standards guidance for accessible charging.

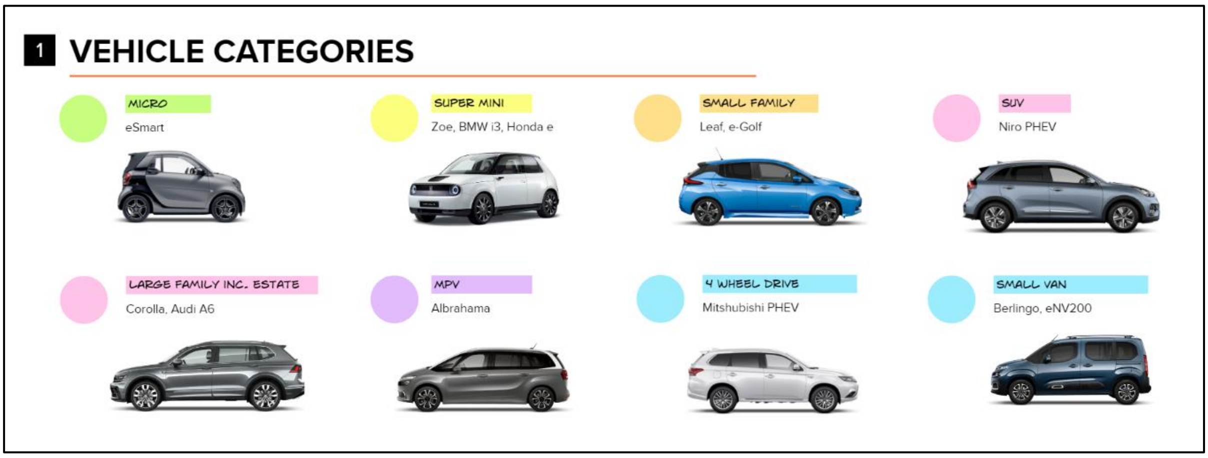
The Phase 3 (Discovery) research into the vehicle types and their use by disabled people can be summarised as follows:

- Passenger vehicle types/categories
- Electric vehicles overview
- Charging considerations for EVs
- Wheelchair Accessible Vehicles (WAVs)
- Adaptations made to vehicles to accommodate the needs of disabled people
- Large vehicles and those with the largest adaptations
- Vehicles used by disabled people that are not adapted

Passenger vehicle types/categories

The range of passenger vehicles available for use on public roads in the UK can be sub-divided into the broad categories shown below, based on size and shape and type of use.

Disabled drivers and passengers could use a vehicle in any of these categories, although those that are adapted for wheelchair access are typically larger vehicles e.g. large family cars or small/medium passenger carrying vans.



Overview of standard passenger vehicle categories (Designability)

The small to medium sized vehicles are generally most common amongst the driving population as a whole (for both disabled and non-disabled people).

Electric vehicles overview

The Electric Vehicle (EV) market in the UK currently comprises a small but increasing range of vehicles across the standard vehicle categories, which are either fully electric or use a combination of Internal Combustion Engine (ICE) and electric motors to propel the vehicle.

Designability is only considering 'plug-in' electric vehicles which can be charged using a charging cable. For this reason, Hybrid Electric Vehicles (HEVs) are excluded as they are "self-charging" and do not require plugging in. Only the following types of EV are therefore relevant to Designability's work on this project since they all use plug-in cables for charging.

Battery Electric Vehicle (BEV)

Battery driven electric motors are the only means of propelling a BEV so there is no combustion engine for liquid fuel (petrol or diesel). Therefore, once the battery is out of charge, the vehicle has no means of propulsion and the battery requires re-charging.

Existing BEVs are predominately small and medium sized vehicles. Some larger electric vehicles and vans are now beginning to enter the market e.g. *e-Transporter*, but choice is limited.

BEVs with greatest range (miles between charges) are typically either premium vehicles or medium/small SUVs e.g. *Tesla* and *Jaguar-LandRover* (large, premium/luxury) or *Kia eNiro* (SUV).

Nissan Leaf – BEV (small family car)
(source: https://www.motaclarity.co.uk/motability-cars/nissan/leaf)

Plug-in Hybrid Electric Vehicle (PHEV)

PHEVs are predominantly powered by liquid fuel supplying a combustion engine, but have a small battery and sometimes motors to provide a small electric range at lower speeds. Most vehicle manufacturers have PHEV models now, available in a wider range of vehicles categories than BEVs

With the planned ban on new fossil fuel vehicles from 2030, PHEVs are likely to be entirely replaced by BEV at some stage, however that could be some time off when current production and vehicle life span is considered and there could still be PHEV vehicles on the roads in 20 years' time (2040).

For the purposes of this project, although PHEVs are not reliant on being charged, the plug-in charging experience is the same as for BEVs.

Mitsubishi Outlander – PHEV (4 wheel drive)
(source: https://www.motaclarity.co.uk/motability-cars/mitsubishi/outlander-phev)

Extended Range Electric Vehicle (E-REV)

E-REVs feature the same battery and motor technology as BEVs but with the addition of a small petrol/diesel generator that tops up the battery to increase range and longer journeys, therefore they can technically be run without charging.

Few electric vehicles use E-REV technology and there are only a handful of examples on the market, which are mostly smaller cars e.g. *BMW i3.* E-REVs will be phased out in line with the ban on new fossil fuel vehicles, but as with PHEVs there may be some examples around for some time yet.

BMW i3 - E-REV (super mini)
(source: https://bpchargemaster.com/bmw/bmw-i3)

Electric vehicle adaptations

The number of disabled electric vehicle users (BEV, PHEV or EREV) is currently very low.

The current assumption is that those disabled people using EVs are in the majority of vehicle users who have no vehicle adaptations. Adaptations made to EVs for driving controls, for access and stowage are likely to be similar to those made to non-EVs, albeit dependent on the vehicle make and model.

Electric WAVs

Some models of EV which could potentially be used as WAVs are now entering the market, but there are known issues with converting existing EVs for wheelchair access [14] - namely the position of the battery and electric motors in the vehicle floor, which is usually modified and lowered for wheelchair ramp access.

Nissan e-NV200 Electric WAV (source: https://www.brotherwood.com/wheelchair-accessible-vehicles/electric-wheelchair-accessible-vehicle-nissan-env-200/)

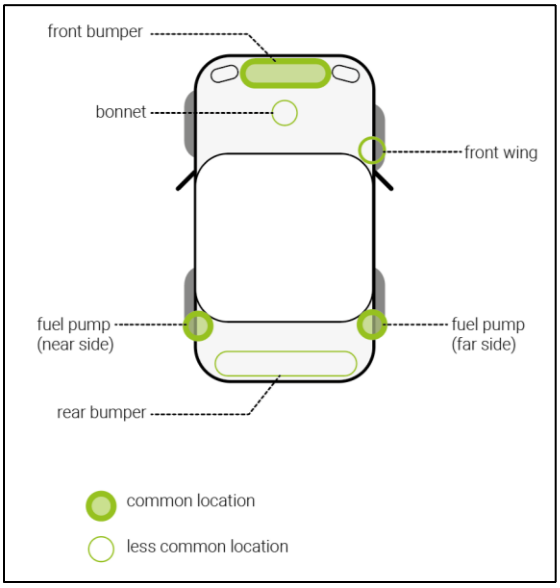
Charging considerations for EVs

When considering the vehicle-related aspects of achieving accessible EV charging, the **most important aspects** that could affect the design and guidance are:

- The location of the charging socket on the vehicle
- The orientation that the driver must park the vehicle in, to enter and exit the vehicle and manoeuvre around it, and the potential conflict with using the charge point when the vehicle is in this position; the need to charge the vehicle adds an additional level of requirement above that needed to park in any accessible parking bay.
- The largest vehicle footprint, including external adaptations and space to manoeuvre around the vehicle.

Location of the vehicle charging socket

The positions of different charging sockets on EVs are summarised in the image below.



Vehicle charge socket locations (Designability)

Parking orientation to enable a disabled person to enter and exit the vehicle

The orientation in which the vehicle is parked to allow driver and passenger access can conflict with any orientation demands placed on the driver by the charging hardware:

Nose to kerb

If the vehicle parks 'nose to kerb' in a parking bay, to allow rear access (e.g. for wheelchair via ramp), then a vehicle charging socket located on the front of the vehicle, close to the charge unit, requires less movement/effort compared to a socket located towards the rear of the vehicle.

Tail to kerb

If a vehicle parks 'tail to kerb' in a parking bay, to allow side access (e.g. passenger hoist or side lift), then a vehicle charging socket located on rear of the vehicle, close to the charge unit, is most convenient.

Location of charging equipment

The Institution of Engineering and Technology (IET)'s code of practice [21] suggests charging equipment locations to accommodate the different socket locations on EVs, but this does not take into consideration the parking orientations potentially required by disabled vehicle occupants.

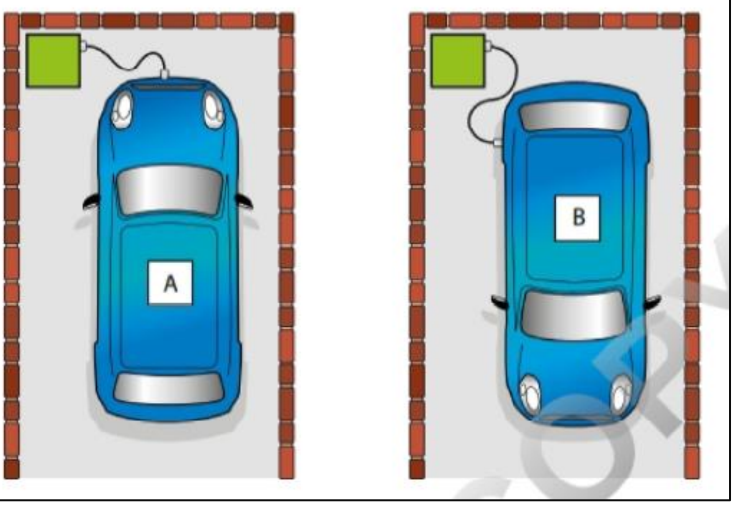


Figure 4.1 Charging equipment location relative to parking space

Suggested EV charging equipment locations relative to parking spaces [21]

Considering the combined requirements of vehicle features related to charging, charge point positions and user needs, demonstrates that 'standardised' charging socket locations on vehicles (front bumper or rear wing) could be a useful idea for those who can choose to park their vehicle in any orientation. However, those users who need to park their vehicle in a specific orientation to enable safe access, e.g. WAV users, may still be at a disadvantage.

Wheelchair Accessible Vehicles (WAVs)

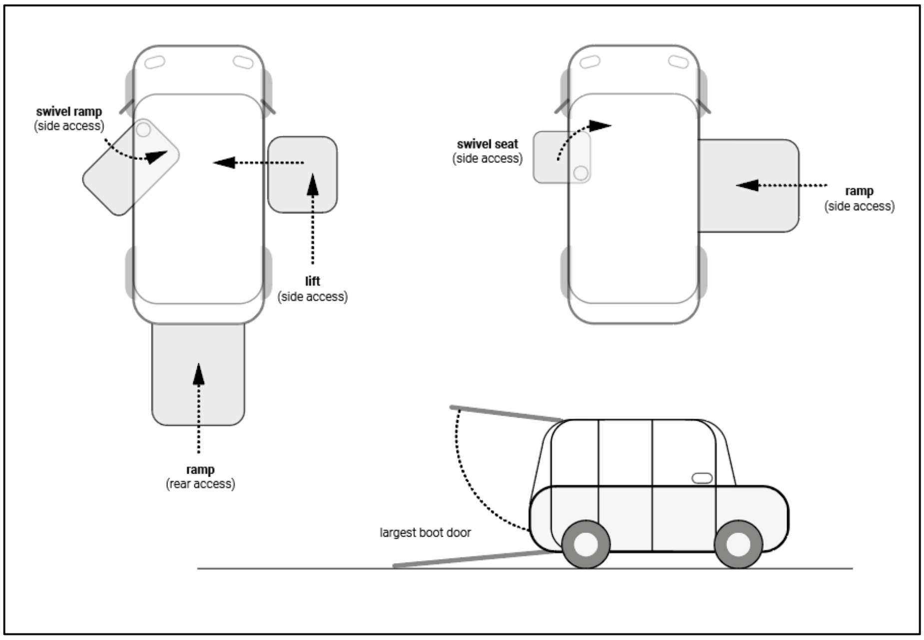
WAVs represent some of the most complex driving solutions provided by Motability. In the context of this work, they include both some of the largest vehicle dimensions and users with the most significant accessibility needs and must therefore be considered in the context of accessible EV charging design.

A WAV enables a driver or passenger to enter the vehicle while seated in a wheelchair, rather than stowing a wheelchair in the vehicle and then transferring into the vehicle separately.

WAVs are available with different combinations of access adaptations, for example:

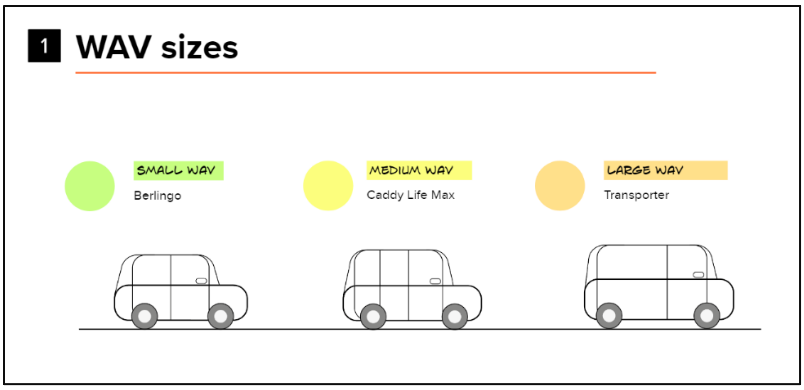
- **Ramp or lift** (at the rear or the side) for entering and exiting the vehicle when seated in a wheelchair. The wheelchair user may then travel while seated in their wheelchair or transfer onto a driving seat.
- **"Drive from"** is where the driver enters the vehicle in a wheelchair and then drives the vehicle while seated in their wheelchair – again access is via ramp or lift
- **"Up front"** describes the scenario where the vehicle is adapted so that a passenger can access the vehicle in their wheelchair, and then travel in the front of the vehicle, beside the driver

If a vehicle is adapted to include a wheelchair hoist to help with lifting and storing the wheelchair (not the occupant), this is classified as a *stowage* adaptation and the vehicle is not classified as a WAV.



Summary of common adaptations deployed outside the vehicle footprint (Designability)

WAVs are available in a range of sizes, depending both on the required adaptations and the other needs that the user may have, e.g. number of passengers or transporting large items.



WAV sizes and vehicle examples (Designability)

WAVs can be considered as either small, medium or large, and some examples are given above. Motability also provide some intermediate vehicle sizes, which they describe as either medium-small or medium-large.

Adaptations made to vehicles to accommodate the needs of disabled people

As well as WAVs converted to allow access for wheelchair users, there are other less complex adaptations that can make a vehicle more comfortable for use by a disabled occupant, whether driver or passenger.

Motability place these adaptations into three categories:

- **Driving:** controls for speed, steering, signalling, handbrake (automatic only)
- **Access:** person hoists, swivel seats, transfer plates
- **Stowage:** wheelchair hoists and roof stowage

Most of the access and stowage adaptations are present on vehicles that do not have direct wheelchair access like WAVs. However, driving controls can be present on any vehicle, whether a WAV or not.

Driving controls are the most basic of adaptation, and do not impact the extra space that may be required around the vehicles for access and stowage.

The Motability guides on WAVs and vehicle adaptations are a useful reference describing the variety of different options available to disabled people depending on their needs [22,23].

Large vehicles and those with the largest adaptations

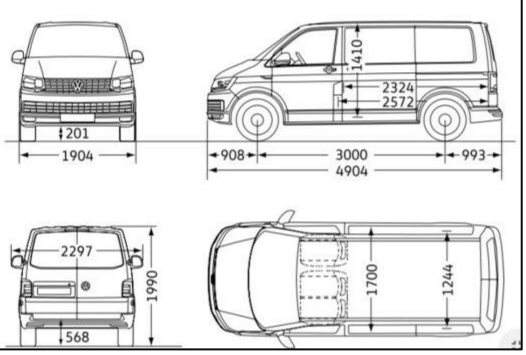
The larger the vehicle and/or the more space required for large access and stowage adaptations, or to move around the vehicle, the more space is required when parking and using the vehicle. This also therefore applies when needing to access the vehicle and charge an EV.

The fundamental requirement for large WAVs, regardless of whether the person charging the vehicle is disabled, is therefore accessible parking provision at charging locations suitable for these largest vehicles and adaptations.

Large WAVs are typically converted passenger-carrying vans, and can be as long as 5 meters in length before considering any adaptations. For example, the *VW Transporter* measures 4904mm long and 1904mm wide.

Short wheelbase low roof.

Roof height		Low
Wheelbase		3,000
Load compartment	length	2,572
	width	1,700
	width between wheel arches	1,244
	height	1,410
	floor area	4.3m²
	load volume	5.8m³
Side sliding door	width	1,017
	height	1,282
Rear wing doors	width	1,473
	height	1,305
Tailgate	width	1,473
	height	1,299
Turning circle (wall to wall)		11.9m



VW Transporter dimensions
(source: https://www.vanguide.co.uk/vw-transporter-dimensions)

BS8300:1 [1] provides a useful summary of space requirements at the side and rear of vehicle for some of the largest know adaptations:

Table C.2 — *Widths for access at the side and the rear of a vehicle or between vehicles in a car park*

Activity by a person in a self-propelled wheelchair	Space required [A)] mm
a) Opening a vehicle door (two-door vehicle)	1 080
b) Using a roof hoist with an assistant	1 450
c) Using an internal hoist with an assistant	1 200
d) Being helped by an assistant (width for the assistant) (see BS 8300-2:2018, Table G.1, Table G.2, Table G.3, Table G.4 and Table G.5 for widths of wheelchairs and electric mobility scooters)	800
e) Using a ramp at the side of a vehicle (max.) (height from ground to vehicle floor = 560 mm)	2 935
f) Using a ramp at the rear of a vehicle (height from ground to vehicle floor = 560 mm)	2 935
g) Using a side-lift (perpendicular)	2 400
h) Using a tail-lift (parallel)	2 400

A) Based on CAD measurements.

Space required for adaptations at the side and the rear of vehicles (source: BS8300:1 [1])

It is important to note that WAVs make up a small percentage of vehicles leased by or on behalf of disabled people, and the largest WAVs and vehicles with large adaptations are likely to represent an even smaller portion of that group; therefore, these are not common scenarios. However it is important to consider these due to their additional requirements for space when parking and charging.

Non-adapted vehicles used by disabled people

The majority of vehicles leased by or on behalf of disabled people are not adapted in any way.

These disabled vehicle users could include some manual wheelchair users who do not require adaptations, but are more likely to be people with mobility issues and other physical disabilities who may or may not use mobility aids.

It is likely that the vehicles that are not adapted in any way are chosen based on what people need the vehicle for e.g. how many passengers they need to carry and how much space they need for storage, as opposed to significant vehicle features that support their disability.

For this reason, these vehicles could be from any of the passenger vehicle categories highlighted above, and a better understanding of the exact vehicles used by this large group is required, to better understand their requirements for accessible EV charging.

What we will find out from working with users

- Access requirements for those people using the largest WAVs and those vehicles with the largest adaptations, including those who are also independent disabled drivers
- What requirements the vehicles disabled people use place on the built environment e.g. large WAVs and adapted vehicles
- What additional considerations need to be made for moving within an EV charging setting and accessing the charger for people using large/adapted vehicles - for example; cable length, charger position
- For those people who do not have adapted vehicles that require more space, what are the biggest issues and most significant accessibility considerations, for example people with reduced dexterity and mobility issues driving a small/medium sized vehicle/EV
- The experiences of disabled people who have previous experience of using and charging plug-in EVs (BEV, EREV and PHEV)
- How users' experiences of fuelling ICE vehicles can influence our understanding of the opportunities and challenges related to EV charging

5. Built environment around EV chargers

Section 2 of this report (Public Charging Infrastructure) provides a definition of public EV charging that will be the setting prioritised for the purposes of this project, and which will be explored further in a subsequent user engagement phase.

This section presents research findings on the topic of the built environment, comprising features of the physical external environment within these public settings.

The location or 'setting' of public EV parking provision, and therefore charge point setting, can be grouped into two main categories;

- **Off-street** parking - typically car parks
- **On-street** parking – kerbside

Off-street - bay parking

The majority of off-street chargers are sited in side by side car park spaces (termed here as 'bay' parking spaces), as opposed to at off-street 'kerbside' parallel parking spaces.

Bay parking spaces provide a great opportunity for safe, confident, access to public EV charging, where on-street charging is not suitable, available or preferable.

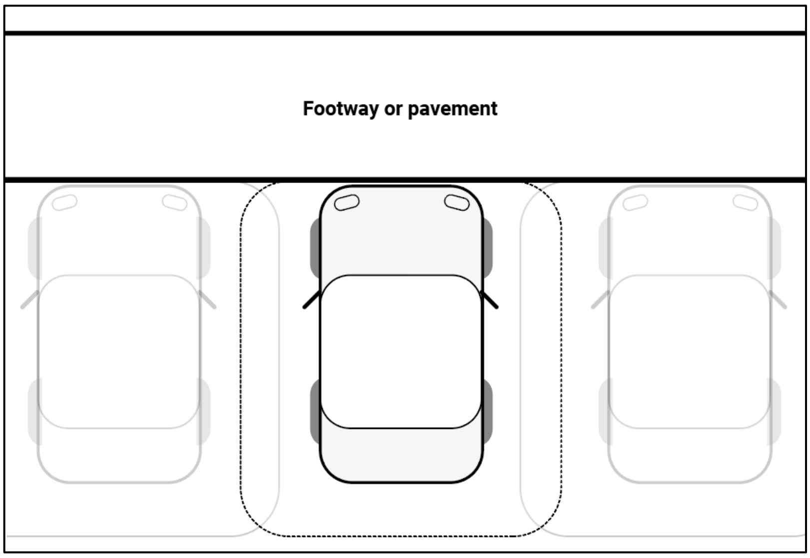
Public off-street charge points are typically found at these location types;

- Motorway services stations (including on major trunk roads)
- Supermarkets
- Fuel station forecourts
- Car parks, e.g. council-run (urban/suburban centre)
- Hotels/accommodation (restrictions apply)
- Retail/shopping centres (open air or multi-storey)
- Park-and-ride car parks
- Education settings, e.g. university campus (restrictions apply)
- Healthcare settings, e.g. medical centres
- Community venues with car parks, e.g. football club, leisure centre
- Charging hubs/forecourts (emerging)

An example of an off-street, bay parking, charging location

(source: https://www.combroconstruction.co.uk/services/ev-charging-points)

Design provision and guidance for the built environment around EV chargers will be similar for a variety of off-street parking location types.

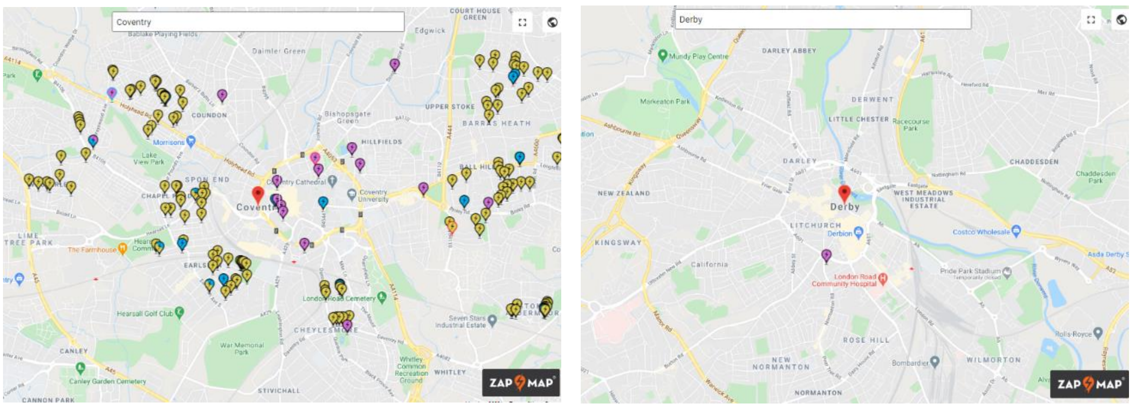


Typical off-street side by side, bay parking layout in car park (Designability)

On-street – kerbside parking

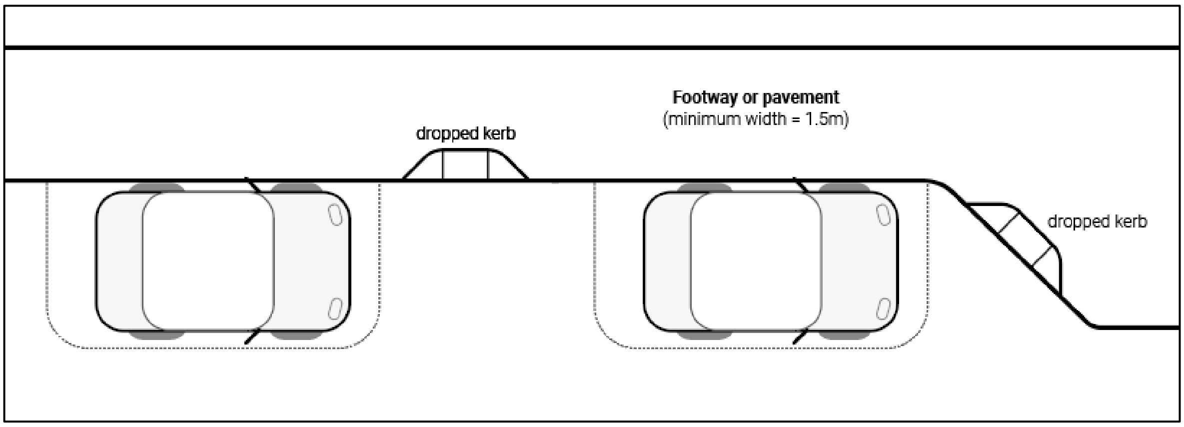
On-street parking is more common in densely populated urban centres, e.g. London, where larger car parks and off-street residential parking are less prevalent.

However, based on a review of Zap-Map's interactive online map of charging points in the UK, the existence of on-street charge points appears to be dependent on local authority buy-in or market factors. For example, the city of Derby has very few on-street chargers, but the similarly sized and nearby city of Coventry has many, due to a recent roll-out of lamp post chargers by *Char.gy*.



On-street parking search results for Derby (right) vs Coventry (left)
(source: https://www.zap-map.com/live)

It is likely that on-street chargers will increase in density and number across the UK as EV vehicle sales increase.



Typical on-street parking layouts, parallel parking (Designability)

Although BS 8300-1: 2018 [1] dictates provision of dropped kerbs or level access for on-street disabled parking spaces, many existing on-street parking spaces do not meet this requirement and so are not accessible for disabled vehicles users who require level access.

This therefore places a requirement for the existing on-street built environment to be modified to achieve access for disabled people using wheelchairs and/or for whom abrupt level changes are problematic.

On-street parallel parking, no-dropped kerb (source: https://www.wandsworth.gov.uk/news/news-nov-2020/brighter-borough-tops-london-s-league-table-for-ev-charging-points)

Angled on-street parking (where the parking space is located diagonally to the kerb, rather than parallel to the kerb) is far less prevalent than parallel parking, and although some consideration will be given to this parking orientation when developing future design requirements, it will not be a focus of the user engagement work for this project.

Relevant existing guidance on design for the built environment

The following documents contain relevant guidance relating to the built environment aspects of parking provision and/or accessible EV charging, and will be referred to during the design concept and guidance work.

- The Institution of Engineering and Technology's code of practice on electrical vehicle charging equipment installation [21]
- British standard BS 8300-1 code of practice on the design of an accessible and inclusive built environment (External environment) [1]
- British standard BS 8300-2 code of practice on the design of an accessible and inclusive built environment. (Buildings) [24]
- Harmonised standard BS EN 12414 on vehicle parking control equipment (requirements and test methods for a parking terminal) [25]
- The handbook provided by the car park accreditation organisation "People's Parking" [26]
- Transport for London's guidance for installing electric vehicle charge points [27]
- The Department for Transport's best practice guidance on improving access to public transport and creating a barrier-free pedestrian environment [28]

Design of an accessible and inclusive built environment

Whilst BS 8300-1 does not provide specific guidance on the design of fuel stations or EV charging units, it does highlight access requirements for disabled users and raises accessibility considerations that are relevant to the design of the built environment around EV charge points, particularly the provision of accessible parking and access for wheelchair users.

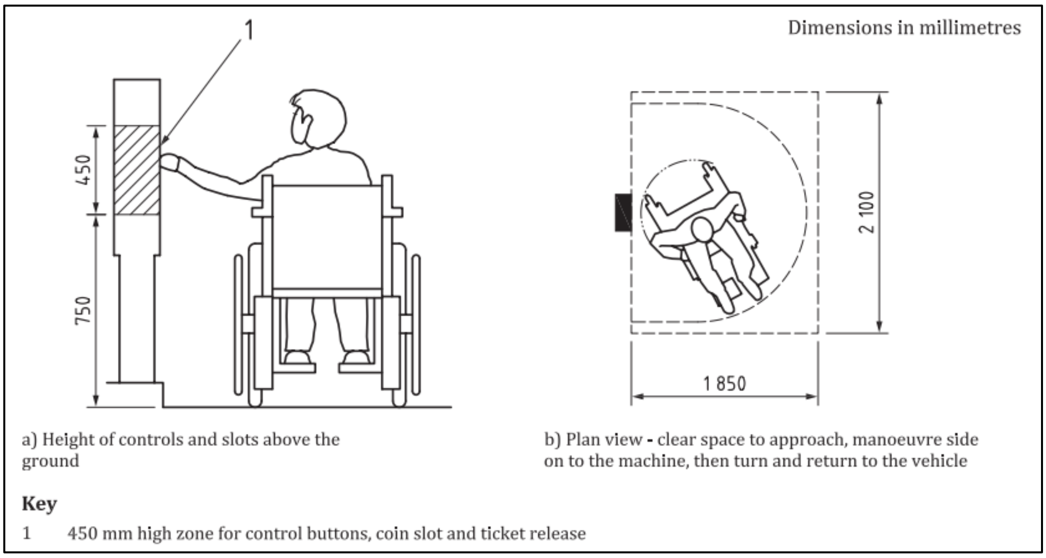
The key sections of this standard that are relevant to this project can be summarised as:

- Provision of designated accessible parking spaces
  - Designated on-street parking
  - Designated off-street parking
- Access to, and location of, designated off-street parking spaces
- Design and layout of designated off-street parking spaces
  - Access around designated off-street parking spaces
  - Markings for multiple designated off-street parking spaces
- Multi-storey car parks
- Parking meters, payment systems and ticket dispensers
  - Key dimensions relating to ticket dispensing machines for use by wheelchair users (screens and controls)
- Access routes for pedestrians and wheelchair users
- Hazards on an access route e.g. street furniture and bollards
- Information and signage

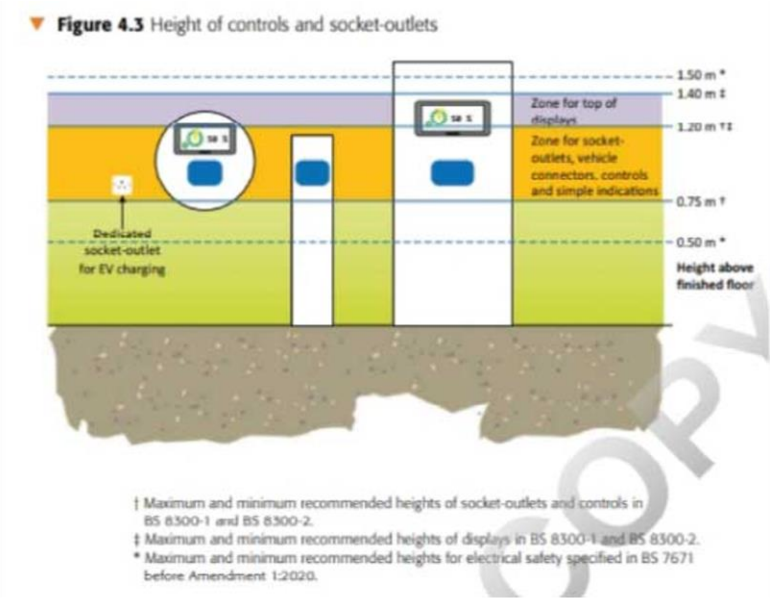
BS 8300-2 also provides an extensive range of dimensions determined by user trials which document the space allowances for wheelchair manoeuvring for manual and electric wheelchairs, electric mobility scooter and attendant propelled wheelchairs.

The height of machine controls for seated users is covered in BS8300-1 and used in the context of charging devices in IET's codes of practice [21].

This guidance can be directly applied to the design of EV charging units, although should also be reviewed in the context of using charging cables, which is different from pressing a button or retrieving a ticket.



Recommendations for suitable heights, positioning and spacing around a ticketing machine (source: BS 8300-1 [1])



Recommended height of controls and socket locations for EV charging units based on BS8300-1 (source: IET code of practice [21])

BS8300-1 describes in Section 8.3, in general terms, the signage requirements for accessible aspects for built environment, including accessible parking spaces, and should be used as a basis for our signage suggestions. It includes reference both to in situ signage and any signage used to navigate to accessible facilities. Further practical guidance and best practice examples relating to accessible parking in car parks, and which may also apply to EV charging locations in car parks and in other settings, are given in the People's Parking Handbook [26] which lays out what should be in place in car parks in order to gain accreditation from the People's Parking Scheme.

Content for signage may include the purpose of the space (e.g. accessible EV charging, a clear description of who is entitled to park in each space (e.g. Blue Badge holders) and any penalty for misusing the space. Factors relating to EV charging, such as charging type (slow, fast) or cost might also be included if appropriate.

BS8300-1 mentions clarity and legibility of signage, and these should be considered alongside branding so that drivers searching for specific brands of EV charging can readily find accessible EV charging spaces.

Key aspects of the built environment

The key considerations for the built environment around charging units, including parking provision can be summarised as follows;

- **Space around the vehicle** for the deployment of access and stowage solutions, and for the safe movement of all vehicle occupants, whether wheelchair users, ambulatory or people who use other mobility aids, such as walking sticks or crutches
- **Space for secondary users to move around the charging unit** when it is in use – clear access routes to facilities nearby the charging unit
- **Level access or suitable ramps** between different areas e.g. vehicle space and footway - to support those using wheeled mobility aids or those with visual impairments
- **Free from obstructions or obstacles** e.g. bins, bollards and signs that can reduce the space and ability to move around the charging unit
- **Clear signage and information** that is unobstructed and demonstrates best practise in terms of design, size and colour contrast for people with visual impairments
- **Protection from weather** e.g. precipitation, wind and direct sunlight

Other considerations include the **provision of seating if vehicle users need to rest**, and **access to the wider facilities available at any charging location** e.g. shopping centre or service station toilets. Due to charging times the wider accessibility of the built environment is essential although it does not fall within the scope of this project.

It is common to protect the charging unit should a vehicle lose control, by placing bollards on the edge of the parking area. This causes an obstruction between the vehicle and the charging unit, which inhibits access.

Bollards to protect EV chargers in South Gloucestershire's electric vehicle charging hub (source: https://www.youtube.com/watch?v=ODsnM9RY7_8)

Priority charging settings

We will prioritise both **off-street** 'parking bay' charging, and **on-street** 'kerbside' charging settings.

Off-street parking/charging locations can provide maximum accessibility for people charging EVs with the greatest need - e.g. largest vehicles (WAVs) and most need for space around the vehicle for movement and the deployment of access and stowage adaptations (ramps, lifts and hoists)

On-street charging offers greater flexibility in terms of locality (potentially more densely located across urban areas compared with off-street parking), but on-street charging supports a lower capacity of vehicles per area than off-street parking/charging locations. Universal accessibility cannot be achieved at on-street 'kerbside' parking/charging locations, predominantly due to limitations on space. However, an understanding of how the accessibility of on-street chargers can be improved, and a sense of how many people this could benefit, is important.

Physically accessible design solutions should not be considered without also understanding disabled people's attitudes towards the setting or location of the electric vehicle charging point.

What we will find out from working with users

- A deeper understanding of real-world challenges around the built environment when charging and/or parking
- How do disabled people use on and off-street parking currently, what challenges do they experience and how might this change as they begin to use these settings to charge EVs (opportunities as well as challenges)
- What are disabled people's preferences and attitudes are towards parking and fuelling/charging in these different settings, particularly on-street, and why
- What can we learn from people who currently fuel their vehicles (e.g. ICE at fuel station, or those already charging EVs) - main issues and any compensation strategies
- Impact of wider accessibility for disabled people at charging locations
- What do users want from signage in different settings, including aspects of positioning, content and clarity

6. Usability considerations

Throughout the discovery phase numerous usability insights and opportunities have been drawn from the following pieces of research:

- Designability field research (a design review of existing public charging units, described below)
- Designability desk research (a review of the top five charging unit interfaces)
- Designability interviews with subject experts
- Outcomes from RiDC's report on the accessibility of plug-in electric vehicles [3]

These insights will form the foundation of our design requirements gathering work and focus specifically on the topics of:

- **Charging units:** access (service), payment, user interactions and physical design.
- **Built environment:** location, positioning of charging unit, parking provision, accessibility and information (signage and road markings)

Field research reviewing existing public charging units

We carried out a design review of six existing charging unit designs using field research (limited to Bath and surround area due to COVID restrictions), in order to:

- Identify the strengths and weaknesses of existing charge points in terms of physical charging unit design and infrastructure
- Identify key usability opportunities to make charge points more accessible for disabled people
- Understand the process of accessing charging (services and payment options)
- Review (where applicable) graphical user interfaces

Photographs of EV charge points from field research in and around Bath

Our field research has highlighted key usability touchpoints to focus on in our work which are included in the usability considerations summary below..

Usability considerations summary

The following collated insights about usability will inform our user engagement activity and design concept and guidance work.

Charging units

Aesthetic and size: Some charge points are discreet in their design, whereas charging units should be easily visible and identifiable.

Interface position: Interfaces are often positioned too high up for seated users or angled upwards for standing users, making them inaccessible to wheelchair users.

Lighting: Lighting is usually integrated into the charging unit to indicate when it is charging or connected successfully (typically manifesting as a colour change, an element “lighting up” or dynamic lighting). This is a helpful feature but cannot always be easily seen when the user is some distance away from the charging unit (depending on their vehicle socket location).

Labelling: It is often difficult to identify the type of charging speed and connectors housed by a given charging unit.

Connectors

Retrieving the connector from the charging unit: Connectors usually require user to “lift and pull” the connector from the charging unit which requires good control, strength and dexterity.

Returning the connector to the charging unit: Connectors are reported as being difficult to locate back into the charging unit. For wheelchair users, reach may be a particular issue. As a result, cables and connectors are often found on the ground beside the charging unit.

Connector alignment: It can be difficult to know if the ports and pins in the connector or sockets are aligned correctly. Inserting the connector requires precision movement and good dexterity.

Confirmation of connection: It is often difficult to know if a connector is inserted fully into the vehicle’s charging socket. Most vehicles have an LED above the charge socket to indicate when charging but as mentioned above it can be difficult for a user to see connection indicator lights on the charging unit from a distance.

Size and ergonomics: Current connectors are large and with the added weight of the cable these could be difficult to handle, particularly with one hand (e.g. with limited use of one hand or while using walking aids.

Strength requirement: The connectors require a lot of (general and grip) strength to insert the connector into the vehicle charging socket.

Visibility: Users report finding it difficult to locate the charger connector into the vehicle socket in the dark (because of poor visibility due to lack of lighting).

Cables

Cable management: Rapid charging cables are tethered to the charging unit making them difficult to manage manually, particularly whilst carrying out multiple actions e.g. accessing an app on a phone or driving a manual wheelchair.

Cable weight: Rapid charging cables are heavier than slow and fast charging cables due to the addition internal wiring and cooling process. There is little that can be done at this stage to reduce the cable weight. Slow and fast chargers weigh around 3kg which would be very heavy to manage and manoeuvre. Cables can weigh up to 12kg for extra-long cables.

Cable length: Cables can be too long and create a hazard when trailed across ground. They can be cumbersome to handle and manoeuvre. Cable length can range from 2.5-20m. In some instances, people may not have a choice but to drive (wheelchair and scooter users) or walk over the cables to navigate around vehicle, risking damage to the cables. Further to this if cables are run across pavements this can cause accessibility issues and trip hazards for pedestrians.

Conversely, cables can also be too short, users report struggling to make the cable reach the charging socket, particularly if the vehicle charging socket is located toward the rear of the vehicle.

Dirty cables: Cables can become unsanitary due to being constantly trailed along the ground or left on the ground between uses.

Cable suspension: Some rapid charging units feature cable suspension mechanisms to help manage the weight of cables and also to prevent them trailing on the ground.

Cable connection process: It is not always clear on untethered cables which socket (vehicle or charging unit) you need to connect the charging cable to first.

Built environment

Shelter: In adverse weather the user could become uncomfortable if no shelter is provided, which is particularly important for people with reduced mobility, who may take longer to exit the vehicle and carry out the steps in the charging process.

Weather conditions: Weather conditions which could affect the user's ability to use the charger include sun glare which can affect the legibility of text and screens, and ice which could create slippery surfaces.

Obstacles: There are often obstacles in the way of charging units which affects accessibility, particularly for wheelchair or motorised scooter users. Bollards to protect the charging units from vehicle damage are often placed close to the unit. BS8300-1 [1] outlines advice for designing accessible parking solutions and details specific advice and recommendations around avoiding putting obstacles in the built environment. This is especially important in considering people who are blind or who have a visual impairment, and for some people with limited mobility.

Lighting EV users have often reported that they have difficulty seeing what they are doing at night-time, particularly when placing the connector in the vehicle socket. Disabled people and women are also more likely to feel vulnerable at night-time so may even avoid charging at these times.

Raised kerbs: Charging units are often located on raised kerbs, making access for wheelchair or scooter users, and people with limited mobility, difficult or impossible.

Location: Many charge points are situated in the corners of car parks furthest from the amenities. In field testing we observed two charging units which were positioned beside overgrown hedges which affected access and obstructed the view of the interface.

Signage and road markings

Blue badge spaces: Some EV charging spaces have 1.2 metre-wide hatched areas around the vehicle parking space which are intended to accommodate wheelchair users. Sometimes these are just seen on one side of the vehicle space, and some are only seen at the sides of the vehicle and not at the front or back of the space. There seem to be very few examples of EV parking bays which are marked as disabled bays.

Road markings: Some EV parking spaces do not have road makings. There is a requirement in The Traffic Signs Regulations and General Directions (TSRGD) [17] to mark EV vehicle spaces with “Electric Vehicles only” and a graphic of an EV. In instances where road markings have been implemented, they are often worn, and some have a shiny surface which could cause glare on sunnier days.

Signage: Charge points can be difficult to locate without the use of a map-based app. Signage to support user in locating the charge point is often discreet and minimal, and information around the charge point itself is often inconsistent.

Interface and information

Location: If the user cannot get a signal on their smartphone (or if it runs out of battery) they cannot access the charge point. A mobile phone signal could also be particularly unreliable in multi-storey, or underground car parks.

RFID: Some RFID card users report finding it frustrating that some cards need to be topped up with cash in order to use them, meaning it can store credit which may not be used.

Language: There can be confusing, inconsistent and unclear language, e.g. using “combo” in place of the more familiar “CCS” to describe connector type. Some charging units use technical jargon which may not be clear to a less familiar user.

Card payment: It is not always clear whether the units require a payment by swiping a card, contactless payment or an RFID card, and the location of the contactless payment reader can be unclear.

Recovery from error: There does not seem to be an option on many interfaces to “go back” if the user accidentally does something wrong.

Instructions: Some charge points lack instructions on the unit or screen. E.g. the *Evolt* charger requires user to know to swipe their RFID card to turn the power on.

Hierarchy: Some charging units contain several layers of text information, and there is often little consideration in terms of prioritising or grouping information.

Fonts: Text is often small, and some signage is placed low down or high up, where the user may not be able to get close enough to read it.

Ambiguous instructions: Some instructions are ambiguous, which can cause problems for users accessing charge points. For example, on some of the slow pillar chargers we reviewed in field research, the written and digital (app) instructions state "plug in your vehicle" but you must connect the charger cable to the charging unit first, not to the vehicle. Similarly, in field research, an instruction to "swipe your card" was presented at a rapid charging unit for which it was unclear if it was referring to an RFID or a payment card, and also unclear exactly where to swipe on the unit. Another charger stated "select charger" in the set-up process which is ambiguous in context as it could mean press "A" or "B" or that the user should retrieve the charger.

Delivery of instructions visual instructions can be effectively used in combination with text-based instructions, or even audio prompts, having options is more inclusive option for providing instructions, for example if a user's first language is not English or if the user has comprehension difficulties. These types of instructions were seen on Pod Point charging units.

Conclusion - usability considerations

These usability considerations and insights will form the foundations of our design requirements work, where we will be able to translate insights into opportunities for improving design. Our user engagement work will enable us to confirm our understanding and provide evidence for some of the usability considerations.

We will use human centred design tools such as user journeys and task modelling in our user engagement and concept design phases, which will allow us to delve into the next level of detail in terms of usability. These tools will allow us to explore and analyse how effective our ideas are, against usability needs. One tool which is particularly relevant to evaluating the design of interfaces is the 10 Usability Heuristics for User Interface Design developed by Jakob Nielsen [29], which is a set of design recommendations for designing accessible and user-friendly interfaces and interactions. This can be used to assess the usability of physical products as well as web design, and we will consider the principles of Nielsen's Heuristics in any interface and interaction design recommendations.

7. Closely aligned topics

In Phase 1: Scoping, we identified a number of topics which would not be the focus of our work but could potentially influence, or be influenced by, the core topics we are considering in our design work. These are described in more detail below.

Information services for EV charging

Information services are typically apps which provide details about the locations and types of EV charging units. *Zap Map* is the most widely used map service for identifying charge points across the UK. *Zap-Map's* EV guides cover all aspects of charging an electric car, including vehicle range, connector compatibility, charging times, cost, and how to charge each model. *Zap Map* is the most widely used information service app in the UK, providing information for 97% of charge points, and is used by more than 90% of EV users [13].

Customer assistance

Most charge units provide a contact telephone number for customer services support. Often this number is not prominent, and the wait times can be long. If chargers are out of use, network providers seem to rely on users reporting.

Existing fuel services for disabled drivers

There could be parallels with, or lessons to be drawn from, existing customer assistance currently provided for users of petrol or diesel vehicles. Disabled drivers or passengers who cannot fuel their own vehicle may travel to familiar fuel stations where they know support is available, since this service is not always available in practice if only one attendant is working at a particular fuel station.

- **Assistance button at fuel point**

  Some fuel stations have an assistance button to press beside fuel points to call for assistance for disabled drivers, but this can be hard to reach and require some disabled to leave the vehicle to reach it.

- **Fuel service app**

  The *Fuel Service* app and website provide maps detailing fuel stop locations in the UK where customers can request support with fuelling their vehicle. The driver requests support via the app or by phone and a customer service assistant will come over to help. This type of service can be a critical for some disabled people who depend on it to fuel their vehicle. It is not currently understood how widely disabled people use this type of service but many supermarkets with fuel stations appear to offer this service.

- **My Hailo**

  My Hailo is a service which is accessible via a key-fob, rather than an app. Pressing a button on the key-fob at an affiliated fuel stop calls an employee to come out and fill up your fuel tank for you. Again, it is unknown how many disabled people use this service or indeed how many fuel stations offer this as a service.

Accessing EV charging units

The process of accessing an EV charging service varies between providers.

Smartphone apps

Most charge points require the user to have access to an associated network app to be able to use their charge points, and with multiple charge point providers this means that the user is required to download multiple apps. Additionally to use the apps you need access to a smartphone, with internet connection to make a payment, which impacts significantly on charge point accessibility.

Some of the key apps required for accessing public chargers in the UK [15] are:

- Electro Highway
- Ecotricity
- Charge Your Car
- Polar Instant App
- GeniePoint
- Instavolt
- PodPoint
- Shell Recharge
- Charge Point
- ECarnie (NI)

QR codes

Some charge point providers provide a QR code on the charging unit so the user can scan the code with a smartphone camera. This brings up the webpage where the user can select their charger and pay for the charge. This solution also requires access to a smartphone and internet connection.

Payment

Accessing public chargers can be free, pay as you go or subscription-based, and varies between providers.

Free access

Some local authorities are currently offering free public charging for EV users in a bid to encourage uptake of this new technology and to reduce vehicle emissions. This means that some charging point providers have disabled the payment system so the user can simply plug in and charge without accessing an app. In most instances this will likely revert back to a payment system as demand for chargers continues to grow.

Contactless payment

Some network providers offer the option of contactless payment without the need to access a smartphone and app. This is more commonly seen in rapid chargers. The government announced in July 2019 that they want to see all newly installed rapid charging units to have a contactless payment option [16] which could significantly increase their accessibility to user groups who are not willing or able to use smartphones.

Some network providers (*Instavolt, Osprey* and *Shell,* and some *BP Pulse* charge point units) only take contactless payment.

Membership and subscription

Some network providers require an RFID card to access their charge points.

These RFID cards come at a monthly fee of around £7-9. You can connect a payment card to the RFID card or top up the card with credit.

Emerging and future technologies

Some promising new technologies and products are in development and beginning to enter the EV market. Whilst our work will primarily focus on imminent solutions which are currently feasible and scalable, we must remain mindful of opportunities around how these emerging technologies could integrate with our proposed designs, particularly where they provide significant potential for improved accessibility.

Induction charging

Perhaps one of the most promising technologies (particularly in considering disabled users and accessibility) is induction, or wireless, charging. There is already much development work in this area to support scale, infrastructure and rollout. The Society for Automotive Engineers (SAE) recently announced the release of the first global standard for wireless electric car charging [18].

Companies such as *Qualcomm Technologies* and *Plugless* are exploring and developing induction charging solutions for both static charging and dynamic charging (induction powered road networks), so that drivers can pick up charge whilst driving.

Qualcomm induction charge, (source: www.carmagazine.co.uk)

In a move towards being the first carbon-neutral city in the UK, Nottingham City Council successfully secured £3.4m of gov support in 2020 to install 5 induction charging plates outside the city's railway station. Ten taxis have been fitted with appropriate hardware to trial the scheme and if successful it could be rolled out [19].

Connected Kerb

Connected Kerb offers a two-part solution. Its smart IoT (Internet of Things) technology manages power across a network and the hardware power source is stored below ground to manage the power supply. This modular platform will enable migration of current charging infrastructure to a wireless format. The approach means that EV charge units could be replaced with wireless charging panels, once wireless charging makes charging units redundant.

Connected Kerb Armadillo (source: www.itthub.net)

This unique, modular approach means that the unit positioned above ground can be more discreet, since the power source (the majority of the hardware) is stored below ground. This also has the added benefit of making the unit itself lower cost and easily replaced, and removes the need for obstructive bollards (which can limit accessibility around the unit) to be used to prevent damage to charge point units.

Induction charging is an emerging charging solution which will take time to scale and finesse. It currently requires precision and accuracy to establish a suitable charging connection between a vehicle and the induction charger, and the charging speed is slow. However, this “hands-free” approach has the potential to offer a much more accessible charging option for disabled people than using “plug-in” charging cables.

Robotics (auto-coupling)

Auto-coupling robotics could offer an accessible solution to the difficulties that EV users (disabled or non-disabled) face in using EV chargers. *Kuka* are currently developing a robotic arm which could connect the charging connector to the vehicle charging socket, therefore removing the need for the user to carry out the process themselves. There are over 425,000 electric buses in the world, 99% of which are located in China. These vehicles are charged overnight at depots, where a mechanical, extendable arm connects to the vehicles charging point [20].

Kuka robotic arm for EVS charging (source: electrek.co)

An Excelsior Charge bus in China (source: www.wired.com)

What we will find out from working with users

- Prior experiences of identifying and locating adequate (accessible where required) parking spaces for EV charging.
- Experiences of solving problems or seeking assistance when using an EV charge point.
- Preferences and experiences around methods for accessing charge points (apps, RFID, web app or unit) and payment methods. Which methods are more accessible and preferable? Reasons why?
- Understand how disabled people currently fuel/charge their vehicle:
  - What works well, and which features do not work?
  - Who can do this independently?
  - If the person is unable to do this themselves who does this, or what support tools are used?
  - Understand steps in the in the charging or fuelling process

Next steps

Designability has completed the Scoping and Discovery research activities and has gathered significant subject knowledge and prioritised the aspects of EV charging to be studied during the next phase of work: user engagement.

Acknowledgements

During the discovery phase we engaged with subject experts, both internally at Motability and externally, in the areas of electric vehicle charging and infrastructure, disabled EV users, vehicle provision for disabled people and wider accessibility of roads.

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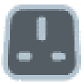
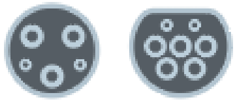
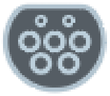
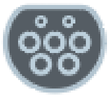
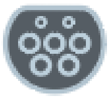
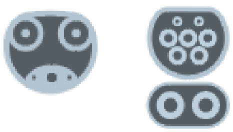
Appendix

Overview of types of charging and connectors

Mode	Charging type	Connector type *(inserted into the charge unit socket)*	Connector type *(inserted into the vehicle)*	Notes
2 (AC charging)	Slow	Mains 	Type 1, Mennekes Type 2 	Most vehicles come with a mains compatible charger as standard. Type 1 are being phased out (found in US and Asian EVs)
3 (AC charging)		Mennekes Type 2 		
	Fast	Mennekes Type 2 		
4 (DC charging)	Rapid	Tethered Some rapid chargers: Mennekes Type 2 	CCS2, CHAdeMO, Mennekes Type 2 	Only compatible with vehicles with rapid charging capability CHAdeMo connector is currently only found on Nissan Leaf and Mitsubushi PHEVs. Other manufacturers have moved toward "universal" CCS and Type 2 connectors.
	Ultra-rapid	Not applicable - tethered		
	Superfast (TESLA)		TESLA, CCS2 	Only compatible with Tesla models. Tesla is moving towards Type 2 and CCS charging in newer models. Ultra-rapid charging units can only be used by Tesla models.