November 2020

Electric Vehicles: Future-proofing Railway Station Car Parks

CATAPULT
Connected Places

Contents

1

1 Introduction

This report has been prepared by the Connected Places Catapult, in collaboration with the Energy Systems Catapult and Dr Keith Bevis of the University of Hertfordshire, to consider the futureproofing of railway station car parks. This report is relevant to organisations involved in the planning of new car parks or upgrading existing car parks. Whilst the focus of the report is on railway station car parks, much of the report is also applicable to other car park types.

The focus on this report is on Electric Vehicles (EVs), how the automotive landscape is likely to evolve, and how this could influence the infrastructure and design aspects of railway station car parks.

The report is structured as follows:

- **Section 2** outlines EV policy considerations.
- **Section 3** presents anticipated national EV trends, in terms of user uptake, vehicle capability, and charging demand.
- **Section 4** discusses likely use cases for EV charging at railway stations.
- **Section 5** considers potential EV user charging habits.
- **Section 6** discusses overall charging point provision and design considerations.
- **Section 7** presents conclusions and next steps.

2

2 EV Charging – Policy Considerations

Introduction

Government policy is a major driver of the switch to electric vehicles (EVs). This section sets out some of the key policies which will have an impact on EV charging at railway stations. It outlines current and proposed policies for plug in vehicles at a national and local level. Policies in this section will affect the demand for charging (both how many vehicles are sold, and what alternative opportunities for charging may exist) and may impose specific requirements on station design.

National Policy

The UK Government has introduced a series of policy measures to promote the development of the EV market. Specifically, it set an ambition in 2015 to "ensure almost every car and van is a zero-emission vehicle by 2050". The ***"Road to Zero Strategy"*** was then published in 2018 setting out the Government's ambition for at least half of new cars to be ultra-low emission by 2030 and for a ban on the sale of new petrol and diesel cars by 2040, as part of the Governments Air Quality Plan. On 4 February 2020, the Prime Minister announced that government is consulting on bringing forward the end to the sale of new petrol and diesel cars and vans from 2040 to 2035, or earlier if a faster transition appears feasible, as well as including hybrids in the ban for the first time.

The Climate Change Act 2019 requires the UK to meet net zero greenhouse gas emissions by 2050, going beyond the 2008 Act which required the UK to reduce greenhouse gas emissions (GHG) by 80% compared to 1990 levels. This is a particular challenge for the transport sector given that in 2017, GHG emissions from road transport made up around a fifth of the UK's total GHG emissions which has grown by 6% from 1990 to 2017, partly as a result of a 29% increase in road transport over that period. Whilst the increase in emissions has not matched the increase in road transport as a result of improvements in vehicle efficiency, this shows that there are significant challenges in decarbonising road transport.

There are a number of proposals, policies and regulations relating to electric vehicles to support these ambitions, as summarised in the subsections below.

National Infrastructure Commission's National Infrastructure Assessment[1]
This recommends the roll out of charging infrastructure sufficient to allow consumer demand to reach close to 100 per cent electric new car and van sales by 2030.

Charging Infrastructure Investment Fund[2]
A fund which aims to catalyse the rollout of electric vehicle charging infrastructure that is required to support the electrification of vehicles.

Automated and Electric Vehicles Act 2018[3]
Makes provision for regulations to specify the provision of EV charge points, how they operate, their type and specification.

The Alternative Fuels Infrastructure Regulations 2017[4]
Includes requirements to ensure EV charging points comply with technical specifications and customer experience standards which enable a minimum level of access and information for consumers.

Planning practice guidance: Air quality (2019)[5]
In response to the UK Air Quality Action Plan, Planning Practice Guidance has been issued to provide local authorities with guidance on considerations for planning applications relating to addressing local air quality. This states:

> "Considerations that may be relevant to determining a planning application include whether the development would: Lead to changes (including any potential reductions) in vehicle-related emissions in the immediate vicinity of the proposed development or further afield. This could be through the provision of electric vehicle charging infrastructure;"

1 https://www.nic.org.uk/assessment/national-infrastructure-assessment/revolutionising-road-transport/
2 https://www.gov.uk/government/publications/charging-infrastructure-investment-fund
3 https://www.legislation.gov.uk/ukpga/2018/18/contents/enacted
4 https://www.gov.uk/guidance/regulations-alternative-fuels-infrastructure
5 https://www.gov.uk/guidance/air-quality--3

The National Planning Policy Framework (NPPF)[6]
Sets out the Government's economic, environmental and social planning policies for England. The policies set out in this framework apply to the preparation of local and neighbourhood plans and to decisions on planning applications. They are a framework by which local plans are made, with the more detailed local policies based upon.

The NPPF provides high level policies that relate to ensuring provision for electric vehicles in new development proposals is considered, however it does not prescribe any specific rules with regards to the number or type of charging facilities should be provided. Relevant extracts include:

Paragraph 105:

"If setting local parking standards for residential and non-residential development, policies should take into account:

(e) the need to ensure an adequate provision of spaces for charging plug-in and other ultra-low emission vehicles."

Paragraph 110

"Within this context, applications for development should:

(e) be designed to enable charging of plug-in and other ultra-low emission vehicles in safe, accessible and convenient locations."

Draft Building Regulations for Electric Vehicle Charging in Residential and Non-Residential Buildings[7]
Proposes changes to building regulations to require EV charging for new buildings, refurbishments and existing non-residential buildings.

This document, which was issued for consultation, states that for new buildings other than dwellings where a minimum of 11 parking spaces are provided, both:

a. a minimum of one electric vehicle charge point must be provided;

b. a minimum of one in every five parking spaces must be provided with either:
   i. an electric vehicle charge point;
   ii. enabling infrastructure.

The intent is to make it easier to install charge points in the spaces with cabling routes in the future and ensure drivers can have confidence the building will have at least one charge point at the location. The document estimates that installing a charge point upfront in an average non-residential carpark is around £1,100 less expensive than retrofitting a charge point at a later point. Furthermore, the installation of cable routes at the time of construction in non-residential car parks can make the installation of charge points around £1,000 less expensive than a retrofitted charge point where these were not provided.

6 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/810197/NPPF_Feb_2019_revised.pdf
7 https://www.gov.uk/government/consultations/electric-vehicle-chargepoints-in-residential-and-non-residential-buildings

The document also offers the following definition of passive provision for a charge point:

- Sufficient physical space for a new electrical connection at a metered supply point, such as a consumer unit or feeder pillar.
- A dedicated, safe, unobstructed route for electrical cabling from the electrical supply point to the future connection location (using electrical containment systems).
- A future connection location (as specified above), clearly identified and labelled/signed.
- Provision to facilitate the safe installation of an EV charge point meeting the standards in BS 7671 (the IET wiring regulations). This may require a suitable location to be identified for an earth electrode.

It is also proposed that existing non-residential buildings with more than 20 car parking spaces must install at least one charge point by 2025.

This document was issued as a proposal for consultation and is awaiting a government response, so the requirements are likely to change in the future.

Permitted development rights
Alongside planning policy to encourage the installation of EV charging, the Town and Country Planning Act also provides active encouragement of EV charging facilities through providing them with permitted development rights. This means that planning permission is not required for the installation of EV charging in many situations. A more detailed summary of the permitted development rights is included in Appendix 1.

Planning for the Future White Paper
The Government has published a white paper which proposes future reforms to streamline and modernise the planning process, bring a new focus to design and sustainability. This process should be monitored as it evolves.

Local planning policy

Many local authorities are now specifying that new developments must provide EV charging facilities as a condition of planning permission. It is worth checking the relevant development planning documents for requirements around EV charging. Station operators may choose to follow these even where planning permission is not required for a car parking scheme, as they reflect local needs and best practice.

Based on our observations, local planning policy is not always specific about the number of or type of spaces that should be provided. In such circumstances, an estimate of potential demand for EV charging at the specific car park might be needed, but this is not straight forward as the future uptake of EVs is uncertain, as is the proportion of EV drivers that will want to charge at the car park.

Summary and implications

The following key points should be considered from this section:

- The sale of new petrol and diesel vehicles will eventually be banned, potentially by 2035.
- It is likely that building regulations will require a minimum charge point provision in new non-residential car parks. The current proposal is for a minimum of one space to be equipped with a charge point, with at least 20% having enabling infrastructure.
- Existing public buildings with large car parks are expected to be required to provide at least one charge point. However, this may not be enough to meet demand and electric vehicle users may be reluctant to rely on a single charge point being available.
- Various measures are in place to facilitate and fund the rollout of charge points, both private and public, and to ensure that these are useable by all vehicles.
- Local planning policies do not yet impose specific requirements beyond those of the proposed building regulations. These policies are likely to change in the future.
- Overall, supply of public charging facilities is expected to improve as a result of these policy measures.

3

3 Anticipated EV Trends

Introduction

This section sets out predictions for EV adoption, capability and performance between now and 2050. Understanding how the vehicle parc in the UK will change is crucial to be able to adequately plan infrastructure for a drastically different automotive landscape.

CVEI model

Much of the content of this section is drawn from Energy Systems Catapult's (ESC's) Consumer, Vehicles and Energy Integration (CVEI) project, which included development of a model for EV charging[8]. The CVEI model provides an integrated, holistic means of quantifying and qualitatively assessing the impacts on and from infrastructure, consumers, vehicle uptake and use, policy measures and commercial models across the UK's energy system.

8 Consumer, Vehicles and Energy Integration, https://es.catapult.org.uk/case-studies/consumers-vehicles-and-energy-integration/

A simplified schematic of the model can be seen in Figure 1. Some of the key modules that make up the model include:

- ESME (Energy System Modelling Environment, ESC's primary least-cost optimisation national modelling tool[9]) - used for net zero energy system design and analysis.
- MEDT (Macro Electricity Distribution Tool) - used for electricity distribution network analysis.
- MCPT (Macro Charging Point Tool) - used for EV charge point analysis.
- ECCo (Electric Car Consumer Model) - used for EV analysis[10].
- An optional Vehicle to Grid (V2G) module used for V2G related analysis.

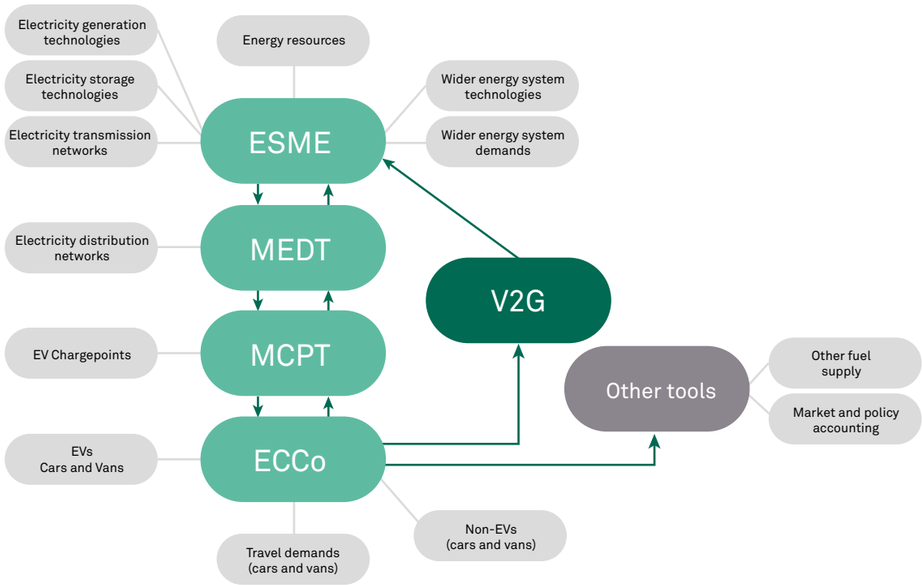


Figure 1 – Simplified schematic of the CVEI modelling capability: the main tools, their interactions and where key elements of the energy and transport system are represented

9 National Energy System Modelling, https://es.catapult.org.uk/capabilities/modelling/national-energy-system-modelling/

10 The main function of the ECCo module is to provide the levels of ULEV (ultra low emission vehicle) uptake and their parc size up to 2050. At its core is a rational consumer choice model, populated with behaviour coefficients taken from an extensive consumer survey of attitudes to EVs that has been updated in 2015. (The model was originally developed for the ETI in 2011 as part of the Plug-in Vehicle Economics and Infrastructure Project) For further detail see: https://es.catapult.org.uk/wp-content/uploads/2019/11/CVEI-Summary-of-approach-conceptual-design-and-key-research-questions.pdf

The model uses a large range of datasets as inputs, including data from the DfT, OLEV (Office for Low Emission Vehicles), vehicle OEMs (Original Equipment Manufacturers) and charge point manufacturers to name a few. The model can be configured to represent several narratives and scenarios regarding policy and the broader environment. For the context of this report, the modelling framework was constrained to achieve Net-Zero emissions targets by 2050. The ULEV (ultra-low emission vehicle) narrative that was developed as part of the CVEI project was used for the purposes of this analysis, in which:

- A transition to EVs is supported by central government via significant vehicle grants and infrastructure support.
- Government leverages private investment in infrastructure, providing regulated returns.
- Centrally planned roll-out of infrastructure opens opportunities for Demand Management via both User-Managed Charging (UMC) and Supplier-Managed Charging (SMC) schemes.
- Six different charging points are available, i.e. home, public, rapid, work, on street residential and depot.
- Internal Combustion Engine (ICE) vehicles are eventually removed from sale after 2040 with the aim of meeting the Road to Zero ambitions[11].
- V2G technology is unavailable (the V2G module was disabled), but a proportion of the plug-in vehicles on the road are engaged in smart charging at domestic charge points.

This all sits within the wider context of the ESME-based Patchwork scenario where economic wealth is fuelled by innovation[12]. There is a more comprehensive reduction of gross emissions due to limited possibility for negative emissions.

The vehicle market shifts towards EVs after 2020, requiring substantial upgrades to the electricity networks. Industry adopts hydrogen early and overall energy usage drops 30% relative to today. Wind energy becomes the dominant electricity generation source, with roughly 73% of all electricity generation coming from intermittent generation sources. This means that there is value to be found in storage and flexibility services and demand shifting[13].

Plug-in vehicle adoption

Globally, plug-in vehicle numbers are growing, and the total stock reached 7.2 million units in 2019. 67% of these were fully battery electric vehicles (BEVs)[14]. This is also seen within the UK vehicle parc where, according to the Society of Motor Manufacturers and Traders (SMMT), in the year to date (June 2020) BEVs and PHEVs (plug-in hybrid electric vehicles) account for 7.7% of new vehicle registrations, when in 2019 this stood at 2.1%[15].

11 CVEI Market Design and System Integration Report, https://es.catapult.org.uk/wp-content/uploads/2019/11/CVEI-Market-Design-and-System-Integration-Report.pdf (August 2019)

12 Innovating to Net Zero, https://es.catapult.org.uk/reports/innovating-to-net-zero/

13 Report 2 - Storage and Flexibility Net Zero series - Vehicle to Grid, Energy Systems Catapult (April 2020)

14 Global EV Outlook 2020: Entering the decade of electric drive?, International Energy Agency (2020)

15 https://www.smmt.co.uk/vehicle-data/evs-and-afvs-registrations/ , (June 2020)

Energy System Catapult's CVEI model has been used to establish a credible UK car (and van?) parc out to 2050. In Figure 2 the pathway produced by the model shows how the UK's passenger car parc will need to change in order to reach 97% EV by 2050 to achieve the Net-Zero targets. The graph shows the full profile of the UK car parc in use in each year (which includes new sales and the expected retirement rate of vehicles). These outputs also align to numbers published by McKinsey, who estimate that by 2040 70% of all vehicles, not just passenger cars, sold in Europe will be electric[16]. These outputs feature PHEVs primarily as transition vehicles, with BEVs dominating the market, particularly in the latter portion of the transition.

UK Car Parc Profile by Powertrain Type

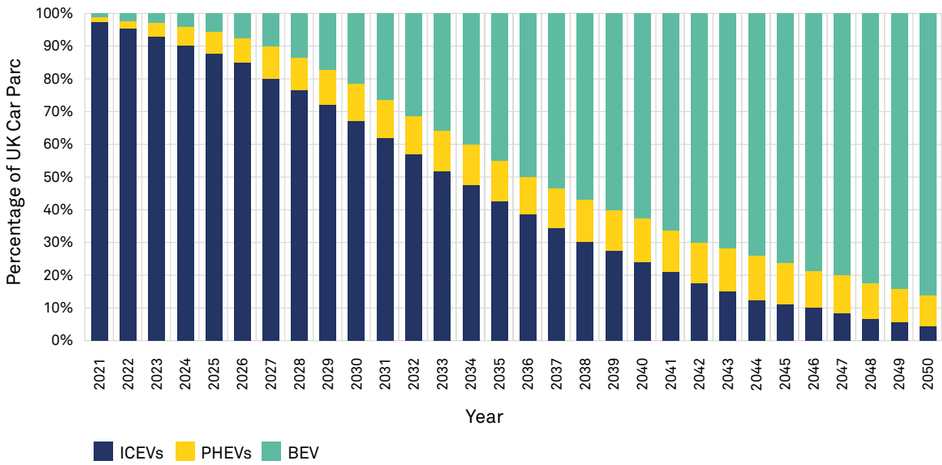


Figure 2 – UK car parc profile of ICEVs, BEVs and PHEVs produced by the CVEI model

Figure 2 provides a credible basis for assessing the potential demand for EV infrastructure. Even though local variations and clusters will be seen, a national picture can provide a good understanding of when to expect a high number of BEVs on the road.

It should be noted that these results were produced on the assumption that the sale of new ICE vehicles will end in 2040.

Limiting factors for EV deployment

Some of the commonly raised concerns that may hinder the deployment of EVs are:

- Consumers without access to off-street parking may lack access to charging infrastructure.
- Materials required in the manufacture of electric vehicles may have limited availability, resulting in costs becoming prohibitive.
- Hydrogen fuel cell vehicles may become more attractive than BEVs.

16 Recharging economies: The EV battery manufacturing outlook for Europe, James Eddy, Alexander Pfeiffer, and Jasper van de Staaij (May 2019)

As of 2018, 33.4% of England's homes did not have access to either a garage or off-street parking, according to the National Housing Survey[17]. This means that car owners in these locations will be reliant on public infrastructure for charging. Fast and rapid charging is expected to play a key role in giving these consumers the confidence to buy EVs: infrastructure at stations can play a part in this.

A McKinsey article from 2018 discussed the availability of resources required for battery manufacturing[18]. Lithium and cobalt are in high demand and the price of these metals more than doubled between 2015 and 2018. These cost changes could have drastic impacts on the affordability of EVs, as the battery cost represents a significant proportion of the total vehicle cost[19]. This might become a roadblock to mass market uptake; however, it is predicted that advancements in battery technology will go some way to mitigate these concerns[20]. The Advanced Propulsion Centre in the UK has a timeline of the expected technology evolution which provides more detail as to how this will be achieved. This roadmap shows an expected drop in the $/kWh of energy storage of around 64% between 2017 and 2035[21], alongside almost a quadrupling of the energy density of the storage. As well as the cost implications, with increasing demands for these materials there are also concerns and issues with the mining process; long lead times, ecological and social concerns. There are, however, ongoing projects around the world looking to mitigate these issues. For example, the Faraday Institute's ReLib project which seeks to develop the technology, economic and legal infrastructure to make recycling of almost all the materials contained in lithium ion batteries from the automotive sector a reality[22].

Currently, development of Hydrogen Fuel Cell Vehicles (FCVs) is focused on the freight sector, with HGVs the most likely vehicle segment to adopt the technology and adapt operations to use the necessary infrastructure. Earlier analysis done as part of the CVEI project showed that there might be some potential for FCV uptake amongst car drivers after 2030, focused on fleet users where longer ranges are expected, but battery electric technology is still expected to dominate for passenger cars. Further detail on the role hydrogen will play in the energy future of the UK can be found in the Innovating to Net Zero report published this year[23] as well as in the Decarbonising Road Freight report from 2019[24].

17 DA02201 : parking and mains gas - dwellings, https://www.gov.uk/government/statistical-data-sets/amenities-services-and-local-environments
18 https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/three-surprising-resource-implications-from-the-rise-of-electric-vehicles (May 2018)
19 Automotive Batteries, https://admin.ktn-uk.co.uk/app/uploads/2019/04/Automotive-Batteries-Report-Summary-April-2019.pdf (April 2019)
20 Automotive Batteries, https://admin.ktn-uk.co.uk/app/uploads/2019/04/Automotive-Batteries-Report-Summary-April-2019.pdf (April 2019)
21 Technology Roadmap 2017: Electrical Energy Storage, https://www.apcuk.co.uk/technology-roadmaps/
22 Faraday Institute: ReLib project, https://faraday.ac.uk/research/lithium-ion/recycle-reuse/
23 Innovating to Net Zero: UK Net Zero Report, https://es.catapult.org.uk/reports/innovating-to-net-zero/?download=true (March 2020)
24 Decarbonising Road Freight, https://es.catapult.org.uk/wp-content/uploads/2019/12/Decarbonising-road-freight-report-v08-spreads-version.pdf (December 2019)

Expected charging demand

It is also important to consider consumer charging behaviour, as once the vehicle parc is dominated by electric vehicles the available infrastructure at any location will play a part in consumers consideration of using certain facilities. Charging behaviour and therefore electricity demand will also have an impact on electricity grid connection requirements and investment costs.

The CVEI model uses data from various sources, including the data collected from the consumer trials undertaken within the wider project. The data is used, in part, for developing charging demand profiles for the six different types of charging point location. These locations are

- home,
- work,
- on-street residential (P Street),
- public car parks (P Central),
- rapid charging stations, and
- depots for fleet vehicles.

The CVEI model shows a pathway of charge point deployment that can be seen in Figure 3. The graphs shared as part of this report are outputs of the ULEV narrative described in the previous section. A sensitivity analysis can be performed to understand how utilisation of different types of charge points can change based on different assumptions about consumer behaviour and preferences on charging locations, changes in the policy landscape and effect of different business models.

As can be seen most charge posts are expected to be installed at individual homes (that have access to off-street parking). By 2050, approximately 95% of the total number of charge points will be installed at homes with access to off-street parking. These are the results for the specific scenario outlined. Under other system circumstances there would be variance in the locations of charge post installations. For example, in the Transport on Demand narrative, where a large proportion of mobility as a service is deployed[25], 78% of all charge points would be installed at homes with off-street parking. In this narrative public charging infrastructure becomes much more prevalent. This is a reminder that the policy and industry landscape that unfolds will have an impact on the infrastructure required to support EV use in the UK.

Even though, for the ULEV narrative, home charging is expected to cover the majority of the charging demand for users with available off-street parking, destination and opportunity charging events will still occur and easily accessible public charging infrastructure will be required to support mass EV uptake. The location of these charge posts, the additional services offered, and the way users can access charging facilities (e.g. payment methods) will affect consumer choice and will likely drive decisions on where to charge.

25 For further details on the specifics of this narrative see the CVEI Market Design and System Integration Report, https://es.catapult.org.uk/wp-content/uploads/2019/11/CVEI-Market-Design-and-System-Integration-Report.pdf (August 2019)

Locations of Charge Points over time

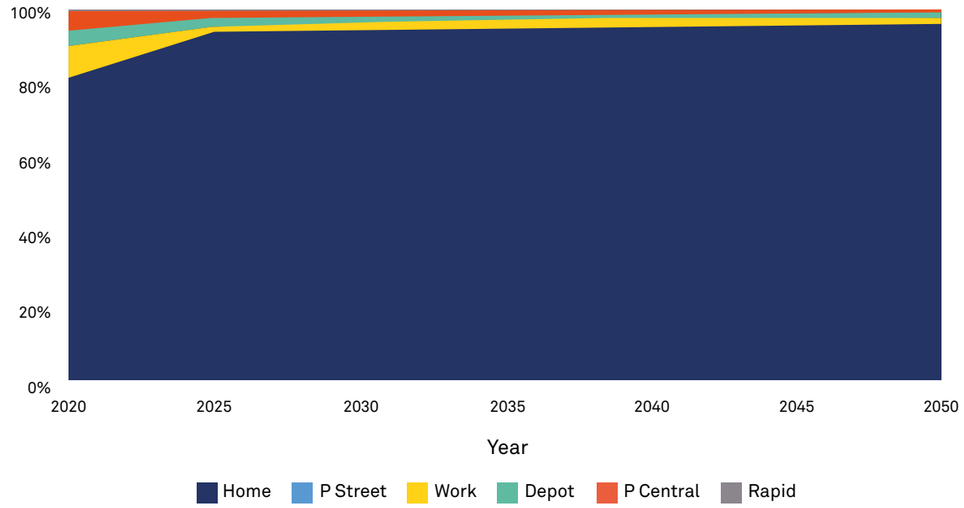


Figure 3 – Percentage of charge points at specific locations (at national level) over time from CVEI model

For the purposes of this report the two charge point location types presented are public car parks and rapid chargers as the two that best fit the application at a railway station car park. The model produces predicted pathways for the charge point powers at the different locations. Public car park chargers are assumed to change from 7kW to 22kW and rapid chargers move from 50kW to 150kW by 2025 under the parameters of this ULEV scenario. The numbers of charge posts deployed of these types can be seen in Figure 4.

Number of Charge Points

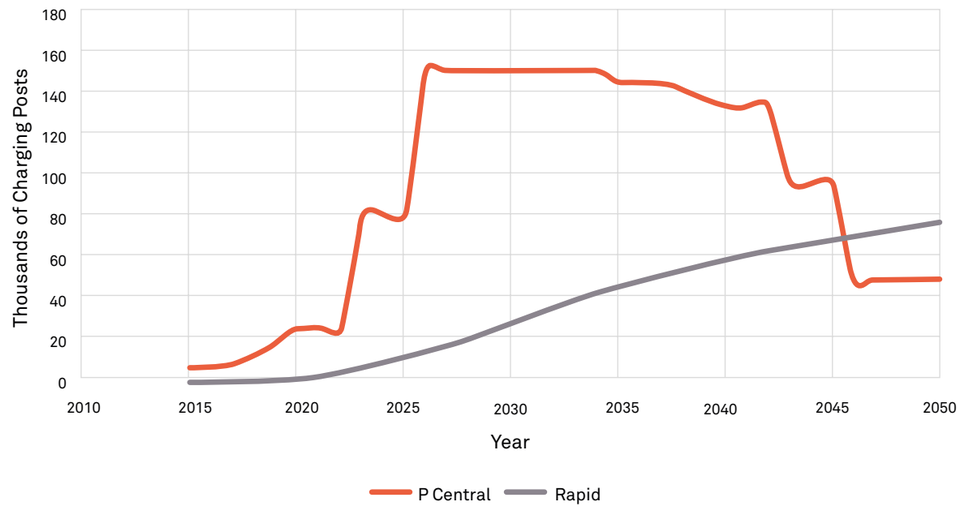


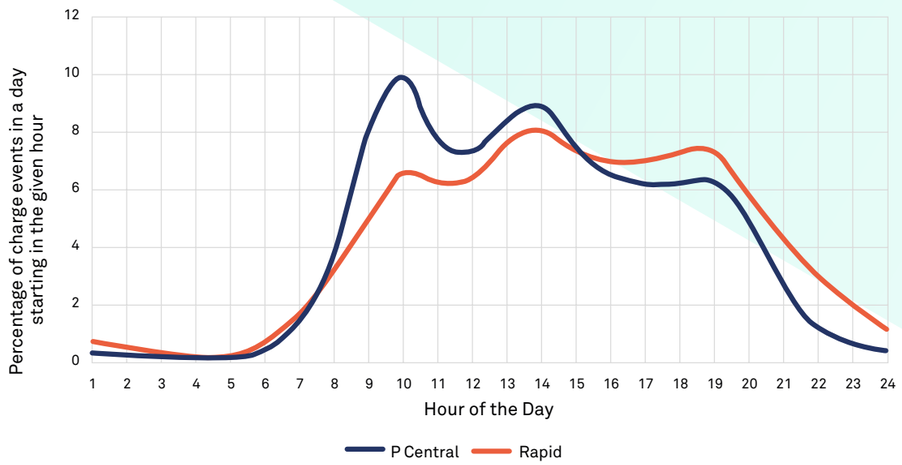
Figure 4 – Number of charge posts at national level

The charging profiles for these two charge location types over a 24 hour period can be seen in Figure 5. These profiles are used as inputs to the ECCo model of the CVEI analytical framework. The profiles for these locations are derived from data collected as part of the National Travel Survey and analysed by the ETI; for further details see the CVEI Summary of Approach and Conceptual Design and Key Research Questions document[26]. The charging profile in Figure 1 shows the percentage of charge events in a day that start in the given hour.

These profiles are intended to represent the full spectrum of public and rapid chargers across the UK. It is possible these will be different at locations with specific user behaviours. For long stay car parks, such as airport parking, there are likely to be more people leaving vehicles overnight. This would lead to a higher demand through the night hours. This would increase the potential for the deployment of smart charging and vehicle-to-grid services, discussed in more detail later.

Percentage of Charge Events starting in a given hour

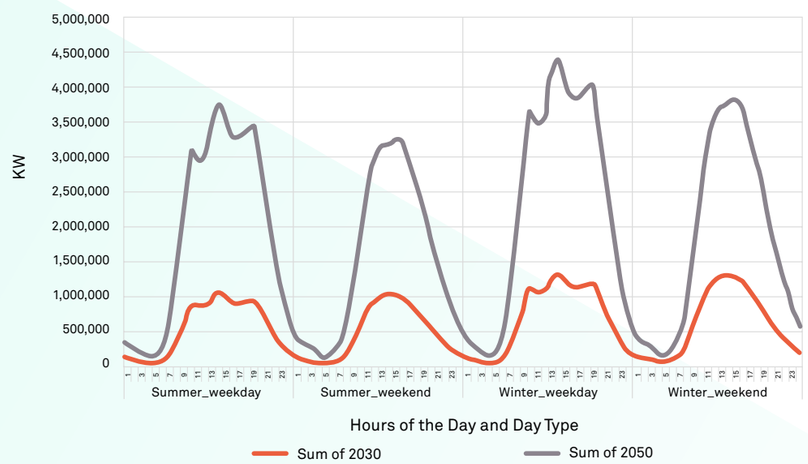
Figure 5 – Charging demand profiles as percentage of charge events starting in a given hour, from CVEI model



Charging profiles are then used to assess the corresponding electricity demand. The CVEI model suggests the demand for electricity as an energy source for passenger vehicles will be roughly 57 times greater by 2050 than it currently is to be able to meet Net-Zero emissions targets. Figure 6 shows the electricity demand at public parking and rapid stations over 24hrs of four typical days for 2030 and 2050. Electricity demand is focused through daytime hours for these types of charge points, which reflects the typical periods of the day for which public car parks are utilised. However, there is still demand during the overnight period. To meet the additional demand that will be required by 2050, the appropriate network connections and infrastructure would need to be in place. The design of the charging infrastructure would need to account for the increased demand with measures put in place to avoid future additional costs due to lack of available power capacity needed to meet demand, especially for rapid charge points.

Hours of the Day and Day Type

Figure 6 – Predicted electricity as a fuel demand in the UK for cars from the CVEI model over four different types of day modelled (none consecutive).



26 CVEI Summary of Approach and Conceptual Design and Key Research Questions, https://trl.co.uk/sites/default/files/articles/content/D1.1.-Summary-of-approach-conceptual-design-and-key-research-questions.pdf

Vehicle performance and range

Currently achievable range

A publicly available EV database lists the specification of the BEVs available on the market globally; as of July 2020, this shows that vehicle ranges span between 55 to 465 miles, with an average range of 195 miles[27]. This is a result of a wide variation in battery sizes: the average usable battery capacity of the models currently available is 61kWh for a BEV and 10.5kWh for a PHEV[28].

Trends in battery performance

Improvements in battery performance may influence infrastructure requirements by altering the range and charging speed of vehicles. Speed of charging is important to understanding user preferences: very rapid charging could make en-route charging more attractive relative to home or destination options, offering convenience approaching that of a petrol station. Range is also expected to have an impact: the longer the range, the less the vehicle needs to use public charging, but installing a larger battery comes with compromises. Cost, size and weight are key constraints for manufacturers, so if batteries become smaller and cheaper, vehicle range can be expected to increase.

A summary of the expected trends in battery performance is shown in Table 1.

27 EV Database Cheatsheet – EV Range, https://ev-database.uk/cheatsheet/range-electric-car (July 2020)
28 https://ev-database.uk/cheatsheet/useable-battery-capacity-electric-car

Table 1 – Battery technology trends and expected impact on vehicle performance

Attribute	Current State	Expected Trend	Expected Impact
Cost	**Significant cost** The battery is the single most expensive component of an EV, making up 35-45% of the cost[29]. Manufacturers pass this cost on to consumers, who pay a premium for longer range.	**Moderate decrease** The cost of batteries fell by 87% between 2010 and 2019. Projections suggest that the cost will continue to fall, though not as quickly: by a further 36% by 2024 and around 60% by 2030[30].	**Longer range more affordable, but not universal** Falling costs will make EVs more attractive to owners, and long-range models especially will become more affordable. However, the battery will still represent a significant cost, so we see a place in the market for medium range vehicles.
Size & weight	**Significantly heavier than fossil-fuel equivalent** On the latest EVs, clever packaging means that passenger space feels like any other car of the same size. However, this can't hide the weight: for example, the Peugeot e-208 weighs around 365kg (33%) more than a similar petrol model.[31]	**Moderate decrease in short term, unclear from mid-late 2020s.** Batteries are likely to get a little smaller and lighter: one model suggests a 30% decrease in weight between 2020 and 2030[32]. Beyond this, any significant gains are likely to come from new battery chemistries. Lithium-Sulphur batteries would be significantly lighter but may actually take up more space, and prototype units have performed poorly when recharged repeatedly. Lithium-Air batteries have the potential to be smaller and lighter than both but are at a very early stage of development.	**No dramatic change imminent, longer term uncertainty** Incremental improvements are likely over the next 10 years, but battery size and weight will remain an important design consideration for the foreseeable future. This is especially true if reduced costs lead to larger batteries being installed.
Charging speed	**50 - 150 kW, but affects battery life** Most electric vehicles on sale today support charging speeds in the range 50-150kW. This rate is a compromise between speed and damage to the battery: rapid charging wears batteries out.	**Potential improvement from mid-late 2020s / early 2030s** Lithium-titanate batteries already offer high speed charging, but their lower energy density and higher cost means they are not commonly used in electric cars. In the future, solid state lithium-ion batteries (currently at prototype stage) are expected to result in significant improvements to battery lifespan, which could make faster charging practical. Toyota, who own many patents relating to solid state batteries, recently stated in an interview that their prototype can be fully charged from empty in 15 minutes[33]. This implies a charging rate of around 150 - 300 kW (based on the battery capacity of today's vehicles). However, the same interview warned that this technology has a high cost which may limit market share. Looking further into the future, use of graphene in the cell also offers the potential for faster charging, but development of technology based on this is at a very early stage.	**Home and destination charging still attractive** Battery technology development could make rapid charging much more convenient but will not replicate the petrol station experience for some time. As a result, we still see a demand for destination charging: it will always be convenient to charge somewhere that you are parked anyway. However, long distance travel by electric vehicle could become far more attractive than it is today.

29 https://www.mckinsey.com/industries/oil-and-gas/our-insights/recharging-economies-the-ev-battery-manufacturing-outlook-for-europe
30 https://about.bnef.com/blog/battery-pack-prices-fall-as-market-ramps-up-with-market-average-at-156-kwh-in-2019/
31 https://www.parkers.co.uk/peugeot/e-208/hatchback-2019/active-electric-50kwh-136-auto-5d/specs/
32 https://trl.co.uk/projects/cvei-stage-1-reports
33 https://www.autonews.com/automakers-suppliers/solid-state-batteries-track-toyota

Charging infrastructure technology

EV charging technology is advancing at a rapid rate, with much innovation to provide faster, more convenient solutions to meet the diverse needs of different EV consumers. The following sections provide an overview of charging infrastructure technology and its implications for infrastructure designers. Appendix 2 contains more detailed information about the applicable standards and specifications.

Conventional wired connections

By far the most common type of charging connection is the "Type 2" connecter (IEC 62196) which is now a European standard and is expected to remain widely used for the foreseeable future. It offers speeds of up to 43 kW, making it well suited to destination charging but relatively slow for en-route charging. Because of this, most electric vehicles also support rapid charging using the CCS (combined charging system) connector or, less commonly in Europe, CHAdeMO. CCS is capable of supplying power at up to 350 kW, much faster than today's vehicles can accept, while the latest version of CHAdeMO supports 500 kW (and a future release will be even faster).

There have been some signs that CHAdeMO could become a legacy standard, with a key user Nissan recently choosing the CCS standard.

When the BMW i3 was introduced into the UK and it became apparent there would continue to be vehicles in the UK car parc with one or other of these connectors, an OLEV requirement was brought into play requiring any new publicly available Rapid DC charger to be equipped with both connectors. This remains the current position. However, it must be anticipated that once the legacy of CHAdeMO equipped vehicles begin to retire from the parc, manufacturers will lobby to have this requirement removed in order to reduce their manufacturing costs.

Smart charging and vehicle to grid

Smart charging (SC) involves controlling a vehicle's charging based on external factors, such as the cost of electricity or availability of transmission capacity. Vehicle to grid (V2G) takes the same idea a step further, allowing vehicle batteries to be discharged and send electricity back to the grid at times of high demand. Electric vehicles will place new demands on the National Grid, and it is widely believed that these technologies will be essential to ensuring that it is able to cope. As a result, smart charging is being championed by the Government at the Office for Low Emission Vehicles and DfT through various projects and funding calls. The EV Energy Taskforce also emphasised the importance of smart charging as an enabler to transition to low carbon transport.

For charge point owners, SC and V2G offer commercial opportunities: electricity price varies over time, so altering charging patterns can lead to greater profit margins. Since vehicles are expected to be parked at railway stations for a relatively long time, there is the potential to take advantage of this without any inconvenience to the user.

Technology for SC is largely already in existence and increasingly being deployed: for example, all charge points funded by the Electric Vehicle Homecharge Scheme support the Open Smart Charge Protocol. This provides an interface between the network operator and the charge point management system, managing congestion of the grid by communicating forecasts of its available capacity. EV users can indicate their vehicle's charging needs to a central system and the network operator will ensure that the grid's limited capacity is maintained. Smart charging capability has a relatively low cost and relatively high maturity level, so we recommend that compatible charge points should be specified for installations at railway stations[37].

V2G technology is currently largely in the early demonstration stages in the UK, for example the work being undertaken by OVO Energy[38]. There are still some barriers to be overcome, for example:

- Most plug-in vehicles (and the type 2 charging standard) do not yet support V2G.
- Because vehicles are discharged as well as charged, longer plugged-in times will be required to gain the full benefits.
- Changes to the electricity and flexibility markets would need to occur before V2G can be deployed at scale in the UK.

The benefits are similar to, but potentially larger than, smart charging alone.

Railway station car park site operators have the potential to be an industry leaders in the adoption of new charging technology. However, given the barriers outlined above, the feasibility of V2G deployment is uncertain at this point.

Novel charging technologies

Wireless charging or 'induction charging' has only relatively recently been applied for charging EVs. It works in the same way as a wireless mobile phone charger, but on a much larger scale. A charging unit is sunk into the ground which emits an alternating electromagnetic field. Cars fitted with a suitable receiving unit can then park above the charging unit to generate current that will then charge the battery. While convenient, wireless charging is less efficient than a wired connection and currently has a much higher cost. However, it does have potential for certain special applications: we discuss this further for buses and taxis in section 4.

Both Volkswagen and Tesla have recently demonstrated prototype robotic charging systems. These systems are of interest to manufacturers for two main reasons: to support deployment of automated vehicles, and to assist users with the more cumbersome cables required for very rapid charging. It is too early to draw conclusions about whether these will be useful in railway station car parks. If they are, it is likely that they will require similar infrastructure to a conventional charge point.

37 Electric Vehicle Charging Requirements: Long-term parking (Document no.: 1D202-EDP-TM-REP-000-000003)
38 OVO Energy Vehicle-to-Grid Trial, https://www.ovoenergy.com/electric-cars/vehicle-to-grid-charger

Costs associated with charging

At present, the cost of charging an EV at public charge point is dependent on the charge point network, the type of charger and the location. Cost of charging at home depends on the electricity tariff of the household.

Battery sizes vary significantly from one EV to another, just as fuel tank sizes vary on ICE vehicles, and users rarely fully empty the battery or fuel tank. Therefore, it is less relevant to talk about the cost of a full charge, and more relevant to talk about the cost per mile to charge (or the cost per kilowatt hour, which then enables a comparison with electricity prices to the home).

Fast charging costs at public charging points will generally be somewhere between the cost of home charging and rapid charging, although the situation is complicated by the fact that some operators provide this through subscriptions.

Utilisation of charging points at railway stations is expected to be heavily influenced by the type of pricing. If customers need to pay no additional cost beyond the parking price, utilisation may be very high. However, if the price of electricity is more than they would pay to charge at home (assuming that is an option for them) then utilisation may be much lower.

Summary and implications

The following key points should be considered from this section:

- The number of plug-in vehicles is expected to grow substantially between now and 2050. By 2030, approximately 22% of vehicles in the UK will be battery electric and 12% plug in hybrid. Electrification will continue and by 2050 this becomes 87% BEV and 10% PHEV. Although plug-in hybrids are not a long-term solution, their smaller battery size means that they might have a significant effect on charging demand.
- Whilst it is expected that most charging will happen at home, the availability of high-quality public charging is essential to support the uptake of electric vehicles. Within a station car park the cost of charging over and above the cost of parking may be critical in influencing the utilisation of charging points.
- While there are technical and resource challenges associated with mass adoption of battery electric vehicles, they remain the most credible zero-carbon technology for passenger cars. Hydrogen may have a limited role (and a larger role for commercial vehicles) but will not remove the need for charging.
- BEVs are expected to fall in cost and improve in capability. However, charging will remain slow in comparison to filling up with petrol, meaning that there is still a role for destination charging. Avoiding the need to make extra stops represents an improvement in convenience for users when compared to internal combustion engine vehicles.
- Smart charging has real benefits, both commercially and to the energy system as a whole, so new charge points should support it. Vehicle to grid technology is less mature and its development should be monitored between now and the opening date. Railway station operators have the potential to be leaders in this area, but the necessary conditions for success do not yet exist.

4

4 Station parking use cases

Introduction

This section looks at some of the reasons why people will drive to railway stations, and what implications those might have for charging.

Long stay railway station car park users

Long stay users are expected to generate most demand at many stations. The journey purpose of these users will be varied: some will be making a regular trip (e.g. to work), others will be travelling as a one off. Almost all will be parked for at least a few hours, and some may stay considerably longer.

Most BEV users will have enough range to be able to do a round trip from home to the station without charging, but this does not mean all will. For those without access to charging at home, reliable access on a regular rail trip could help make it practical to own an electric vehicle. Potential charging patterns of these users are discussed in detail in section 5.

The users who do choose to charge need to be confident that they can find a space reliably and will need to leave their vehicles plugged in for as long as they are parked. Charging speed is not especially important, as long as vehicles can receive enough charge before their driver returns.

Users for nearby destinations

Many railway stations are close to other traffic generators. The station operator may take measures to discourage non-railway users from parking at the station. However, if spare parking capacity is available this could be an alternative revenue stream for the station.

Users for surrounding facilities may have different journey types to railway users. If other destinations struggle to facilitate demand for EV charging, railway stations could help to meet that demand. This is particularly true where stations are near residential or commercial areas: as mentioned in section 3, access to fast charging hubs is important if drivers without off-street parking are going to adopt EVs.

Taxis and private hire

Taxi and Private Hire Vehicle (PHV) drivers are potential frequent users of rapid charging infrastructure. They typically travel high mileages on every working day without spending a significant length of time parked at a destination. The high mileage, sometimes combined with local authority incentives, makes them likely early adopters of EVs. However, maintaining productivity is vital to drivers.

Like car drivers, taxi/PHV drivers are expected to prefer home charging (either private or using a public charge point near home) when available. There appear to be no national statistics for taxi/PHV mileage, though surveys report typical annual mileages in the range 15,000 and 60,000 miles per year[39,40,41]. This suggests a daily mileage of 60 - 240 miles, which is already within the range of many EVs. However, some days will be longer than average, and some taxis are shared between multiple drivers, so it is likely that at least occasional charging will be required during their shift. In the shorter-term drivers may choose to use PHEVs. These are likely to require at least one charge during the working day if most driving is to be done in electric mode.

In the UK, the authority with the most experience of providing infrastructure for electric taxis/PHV is Transport for London. New vehicles are now required to be zero emission capable, which in practice means battery electric or plug in hybrid. Their guidance for charge point installation offers the following suggestions for good practice of immediate relevance to railway station car parks[42]:

- For taxis, it is beneficial to have rapid charging infrastructure close to transport hubs.
- For all users, it is good practice to have facilities such as toilets, indoor space and food and drink outlets available for drivers to use while they use a rapid charger.
- Rapid charging infrastructure is most useful when installed as part of a hub, with six or more charge points in the same place. This gives users confidence that they will be able to charge when they need to.
- Charge points should be open to all users if possible.

39 https://www.insuretaxi.com/2019/05/2019-taxi-driver-survey-results/
40 https://trl.co.uk/sites/default/files/RR374.pdf
41 http://lruc.content.tfl.gov.uk/london-electric-vehicle-infrastructure-taskforce-delivery-plan.pdf
42 http://lruc.content.tfl.gov.uk/london-electric-vehicle-charge-point-installation-guidance-december-2019.pdf

Car parks at larger railway stations have the potential to make a large contribution to the attractiveness of electric taxis/PHVs in the areas which they serve. However, as demonstrated in London, the requirement for EV charging is highly influenced by the local authority (both as a result of licencing rules and the wider charging network). Railway station car park operators should discuss requirements for electric taxis and PHVs with the relevant authorities for each station.

Other relevant examples of successful or experimental practice include:

- Stockholm's main airport has implemented a priority queuing system for zero emission vehicles, which is believed to be a significant factor in encouraging EV uptake in the region[43]. If a UK-based station operator chose to adopt a similar system, it could help to drive adoption of electric taxis in the areas that it serves.
- A trial of wireless charging at a taxi rank is taking place in Nottingham[44]. The cost of this is currently high (£3.4 million for 10 taxis and 6 charge points) but could fall if the technology is more widely adopted.

Drop off/pick up and short stay (private vehicles)

Short stay users are expected to fall into three main groups:

- People dropping off/picking up friends and relatives.
- Incidental visitors: people whose business takes them to or near the station, but not to travel (e.g. delivery drivers).
- Destination visitors: visitors who choose to visit the station in order to use station facilities (including charge points and shops, but typically not rail services).

43 Hagman, Jens; Langbroek, Joran H M (2019): Conditions for electric vehicle taxi: A case study in the Greater Stockholm region. International Journal of Sustainable Transportation (13:6, 450-459)
44 https://www.gov.uk/government/news/electric-taxis-to-go-wireless-thanks-to-new-charging-tech-trial

The attractiveness of station charging for each of these user groups is set out as follows:

Dropping off/picking up friends and relatives

Will they need to charge?
No reason to expect journey to station to be any longer than long stay users. The vast majority will be comfortably within the range of today's EVs.

Will they want to charge?
Many drivers will only be at the station for a few minutes, so charging is impractical. For those who arrive early and wait, it might be possible to get a worthwhile amount of charge from a rapid charger. This is likely to be more expensive than slower charging options at home or other destinations, so would probably only be used as a last resort.

Charging requirements
Only a small minority of this group will choose to charge. The few that do would benefit from easy access to a few rapid charging bays.

Incidental visitors

Will they need to charge?
Some higher mileage drivers will need to charge during the working day, though not necessarily at the station. While railway stations will offer one option, they will be competing with alternatives such as retail outlets and converted petrol stations.

Will they want to charge?
We expect drivers will charge their vehicle while taking a break. Railway stations could be an attractive option as they are regularly visited, provide access to facilities and should provide a good (and reliable, if enough capacity is built) charging experience.

Charging requirements
There could be some demand for rapid charging from this user group, but the level will be highly dependent on alternative options, commercial decisions by the station operator (e.g. food and drink prices) and user preferences.

Destination visitors

Will many people do this?
On the existing rail network, many stations are retail destinations in their own right.

There is evidence that provision of rapid charging near home helps to encourage adoption of EVs by users without private parking. These people could make short trips a railway station to charge and may provide an income stream at times when facilities are otherwise quiet.

For people choosing to stop off on a long journey, motorway services are likely to be more convenient, so people will only make the diversion to a railway station if it is more attractive in some way.

Will they need to charge?
Users visiting the stations only to use shopping facilities are likely to be making relatively local journeys and, at city centre stations, many will not arrive by car. Some of those that do may choose to charge, but it is likely to be less attractive for them than it is for the long stay users. This is due to the higher cost of rapid charging and the likely irregular nature of the journey.

Charging requirements
As with the other short stay groups, some access to rapid charging is likely to be useful, but this will depend on many local factors and could be difficult to quantify.

Buses

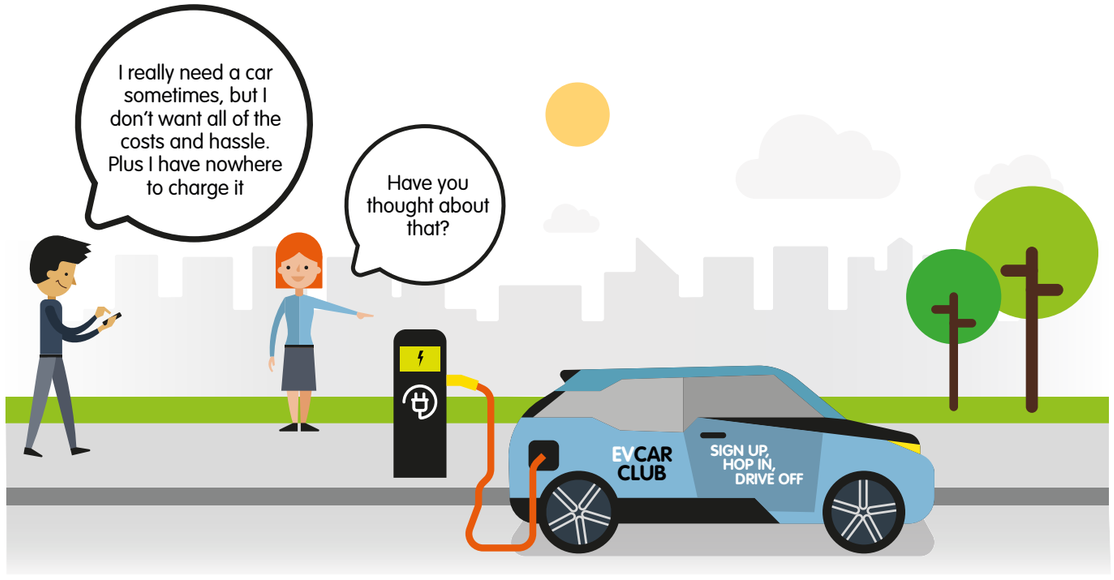
Unlike private cars, battery vehicles are not the only credible option for zero emission buses. The demands of a typical bus duty cycle are can be challenging to achieve with batteries, making hydrogen fuel cells an alternative proposition. This means that there is a lower level of certainty about the future charging requirements for buses.

To achieve a useful charge while a bus is stationary at the end of the route, charging needs to be rapid and automated. Whilst wireless charging systems have been demonstrated in locations such as Milton Keynes, conversations with stakeholders indicate that the higher efficiency of using overhead contacts is the general direction of travel in bus charging.

It is not yet clear whether battery electric buses will become the dominant technology. If they do, they may (but may not) require charging facilities at the ends of the route. Given the level of uncertainty, both in technology and future bus routes, it may be difficult to specify charging facilities at railway stations at this stage. However, it is recommended that potential bus charging developments are discussed with the relevant highway authority and / or bus operating companies at an early stage.

Car clubs

Car clubs are short-term car rental services that allow members access to locally parked cars. Users can pay by the minute, hour or day. They offer an alternative model to private car ownership and may help users reduce their carbon footprint as a result. They may also help accelerate the transition to EVs as they offer many of the benefits of EV use but without the upfront investment, or the need to install a charge point at home.



Railway stations are well suited to car clubs to provide a mobility solution at the user's destination. However, car clubs need space to park their vehicles where they are visible and members can access them conveniently. Investigation will be required into each station location to establish the current usage pattern and projected growth trajectory of car clubs in the area. The appropriate number of EV charging enabled spaces that are reserved for car club use at railway stations should then be established.

Summary and implications

The following key points should be considered from this section:

- For railway station users who drive their own vehicle to the station, charge points are required in the long stay car park. These do not need to be especially fast, as long as users away for a day trip can expect to return to a fully charged vehicle.
- Large railway stations are favourable locations for rapid charging hubs. The most important users of these would be taxis and private hire vehicles: rapid charging at a station could allow many drivers in the area to move to battery electric or plug-in hybrid sooner than would otherwise be possible. Other groups who may benefit include local residents, delivery drivers, and people making a stop-off on a longer journey.
- There would be significant benefits to car clubs having vehicles based at railway stations. Car clubs can help to solve the "final mile problem": enabling users to reach their destination after making most of the trip by public transport. This is especially of relevance to Parkway stations, which serve distributed populations. Car clubs would benefit from having dedicated charging bays at the station.
- Many station car parks are near to other destinations. If non-railway users park at the station, charging demand might be significantly affected.

5

5 EV user charging habits

Introduction

This section considers the possible charging patterns of EV users once the vehicles are widely deployed. These are used to estimate the proportion of users who may wish to charge between 2030 and 2050.

Charging opportunities for EV owners

There are three main types of charging opportunity for plug-in vehicle owners:

- At or near home (including public on-street charge points). For those who have convenient access to it, we expect this to be a preferred option: private charge points are usually cheaper to use (once the installation cost has been paid for), vehicles visit regularly and are parked for long periods of time.
- At a destination where the vehicle would be left parked anyway. We expect this to be the second most desirable option, since inconvenience to users is minimal.
- At a destination requiring a special stop, such as a rapid charging hub near home. A study by ESC found that the availability of these facilities is important to encouraging people without on-street parking to buy an EV.

For designers of station charging facilities, understanding the alternative options which users have for charging is essential for demand estimation. As discussed in section 3, an average BEV on sale today has a range close to 200 miles, so almost all users will be able to make a round trip from home to the station without charging. Whether they choose to charge at a station depends on both the facilities at the station and the other options which they have access to.

The content of this section has been written with long-stay demand in mind, but also has implications for demand for other types of charging facility.

Plug in vehicle user subgroups

For analysis, we have split plug-in vehicle users into six subgroups, as shown in Figure 8:

Figure 8 – Plug in vehicle user subgroups

BEV home chargers Drivers of purely battery electric vehicles who typically charge at, or near, home. They may top-up using a public charger on a long journey or if the electricity is subsidised.	**BEV habitual destination chargers** Drivers with no access to a charger at home, but who charge when visiting a regular destination (e.g. a station or workplace car park).	**BEV opportunist chargers** Drivers who have no fixed pattern of charging. This group either has no access to charging at home/work or prefers not to use it.
PHEV reluctant adopters People who have bought plug-in hybrid vehicles to benefit from tax incentives, but rarely bother to charge.	**PHEV home chargers** Plug-in hybrid owners who charge at home, but prefer to use their engine than to charge from public charge points.	**PHEV economisers** Plug-in hybrid owners who supplement home charging with public charge points when it will save them money and is convenient.

For PHEV owners, we have not considered owners who will charge at public charge points but not at home. At present, we suspect these users are quite rare: PHEVs have a relatively small battery capacity, so a vehicle used in this way would need public charging very frequently. If charging facilities are readily available at virtually all destinations in future, this might become viable, though this will also make BEVs more attractive.

Attractiveness of railway station car parks to each subgroup
Each subgroup has access to different alternatives for charging. How likely they are to charge at a railway station car park depends both on how attractive these alternatives are, and how attractive the station facilities are. High quality, good value facilities will increase demand, but should also have a positive effect on public perception of the railway.

Attractiveness of charging facilities partly depends on inherent features of the facility, such as the length of time people typically park and how regularly they visit. However, some factors are also in the control of the station operator, such as the cost and availability. In Table 2, we suggest how attractive each group might find the station facilities depending on their cost and quality relative to other public charging facilities.

Table 2 – Attractiveness of railway station charging to various user groups

How competitive is the cost/quality of station charging?

Group	Not as attractive as other public charge points	About the same as other public charge points	Better than other public charge points	Highly incentivised (e.g. free electricity)
BEV home chargers				?
BEV habitual destination chargers (regular station users)	?	✓	✓	✓
BEV habitual destination chargers (occasional station users)				✓
BEV opportunist chargers	?	✓	✓	✓
PHEV reluctant adopters				?
PHEV home chargers				?
PHEV economisers		?	?	✓

Key:

✓ Attractive option for this user group

? May be attractive to some members of this user group

(blank) Unlikely to be attractive to this user group

Rationale and discussion
BEV home chargers are likely to visit their home at the beginning and end of a trip. This is likely to be a convenient and cheap place to charge and is difficult for public facilities to compete with.

BEV habitual destination chargers are further split into two groups here: those who are regular station users (i.e. the station car park could be a habitual destination) and those who are not. For regular users, station charging facilities will be attractive. How often this group needs to charge depends on vehicle range and how frequently the station is visited.

For BEV habitual destination chargers who are not regular station users, the station will not be a default option for charging. However, if the facilities are significantly better than other options, they may still choose to use them. It is worth noting that slower charging is better for battery health and likely to be cheaper than rapid charging, which gives the station facilities (where vehicles are parked for longer periods) an advantage over places like supermarkets.

BEV opportunist chargers are likely to find station charging very attractive. Unless the facilities are significantly worse than those available at other destinations, we expect a high proportion of these users to take advantage of the opportunity to top up.

By definition, PHEV reluctant adopters and home chargers rarely use public charge points unless there is a strong incentive to. PHEV economisers will charge if it is convenient and in their financial interests. They have charging at home, but the shorter range of PHEVs means that some may not have enough electric range to do a round trip. Unlike BEV users, they will never need to charge at facilities perceived as expensive or poor quality.

Future size of user subgroups

A survey of EV users[45] suggested that 85% currently have access to charging at home. This number is expected to fall as EV use rises: only 67% of English households have access to off street parking[46], and not all of these will be able to install a charging point. However, some people will have access to on-street charging, which fills a similar role. Also, car ownership is likely to be higher in households with off-street parking, meaning that more than 67% of cars will come from these households. For this analysis, we assume that the eventual proportion of plug-in vehicle owners with access to charging at home will be between 50% and 85%.

Estimating the number of habitual destination chargers is more difficult. The most obvious destination for regular charging is a workplace, but only around a quarter[47] of cars and vans are used for commuting on a typical working day and not all workplaces will have charging facilities. Supermarkets increasingly provide charging, but typical supermarket visits are not long enough to receive a full charge unless rapid charging is used (which would be more expensive). In the absence of detailed information about user parking habits and charging preferences, we have taken the 20% of EV owners with access to workplace charging today as a lower estimate[48] (Zap-Map, 2019) and an arbitrary 80% as an upper estimate.

All BEV users which do not fall into one of the two categories above are classified as opportunist chargers.

Table 3 summarises the estimated proportion of BEV owners in each group:

Table 3 – Expected proportion of BEV users in each subgroup

Group	Assumed proportion of BEV	Summary of reasoning
BEV home chargers	50% - 85% of owners	The lower estimate of 50% assumes around three quarters of people with access to off street parking are able to charge at home. In reality, many people without on-street parking will be able to as well. EV adoption is likely to rise amongst those without access to home charging, so the current rate of 85% is taken as an upper bound.
BEV habitual destination chargers	20% - 80% of those without home charging (3% - 40% of BEV users)	The wide range here reflects uncertainty about user habits and charge point provision. 20% of EV drivers already have access to a charge point at work, and we hope this will improve as charging infrastructure develops. However, not all users will routinely park away from home for long enough for receive a full charge, or would have to use a (more costly and damaging) rapid charger to do so.
BEV opportunist chargers	All those not falling into other groups (3% - 40% of BEV users)	We expect that most people will take advantage of charging at home or a regular destination if able to, as it is likely to be more convenient and potentially cheaper.

45 https://www.zap-map.com/engine/wp-content/uploads/2019/11/Zap-Map-Survey-Key-Issues-2019.pdf
46 https://www.gov.uk/government/statistical-data-sets/amenities-services-and-local-environments
47 150 car/van driver commuting trips per employed person per year in 2019 (https://www.gov.uk/government/statistical-data-sets/nts04-purpose-of-trips) 26.7 million employed people in England in mid-2019 (https://www.nomisweb.co.uk/query/asv2htm.aspx) and 30.7 million cars and light goods vehicles. Implies 0.37 commuting trips per vehicle per day or 0.26 two-way trips per vehicle per weekday.
48 https://www.zap-map.com/engine/wp-content/uploads/2019/11/Zap-Map-Survey-Key-Issues-2019.pdf

There is limited evidence regarding the number of PHEV drivers in each group. A blog post from a fleet management consultancy suggested that real-world fuel consumption in fleet use is little better than a petrol car, though details of the methodology are not available. This suggests that many of today's users might fall into the 'PHEV reluctant adopter' group. However, we expect the size of this group to fall over time, as fuel savings replace Government incentives as a reason to purchase a PHEV. In contrast, a trial carried out as part of the CVEI project found that 58% of PHEV users charged away from home during an 8-week period, despite having access to a home charge point . This figure may be higher than is achieved in reality, since trial participants had free access to a public charge point network (while having to pay for fuel and electricity at home). However, since running a PHEV on electricity is likely to be significantly cheaper than petrol, there should still be a reasonably strong economic incentive to charge where necessary. Also, the trial was carried out in 2018/2019, and we expect the public charge point network to improve over time.

For PHEV users, we assume the following distribution between the groups:

- 10% are "PHEV reluctant adopters" who will avoid charging even when there is a financial incentive to. This relatively small proportion reflects an expectation that government and corporate policies will disincentivise this behaviour.
- 50% - 100% of the rest (45% - 90% overall) are "PHEV economisers" who will charge whenever there is convenient charging and a financial incentive.
- The remainder are "PHEV home chargers", who will charge at home but rarely or never use public charge points.

The CVEI model discussed in Section 2 gives the following estimates for the share of plug-in vehicles in the fleet:

- In 2030, 22% BEV and 12% PHEV
- In 2050, 87% BEV and 10% PHEV

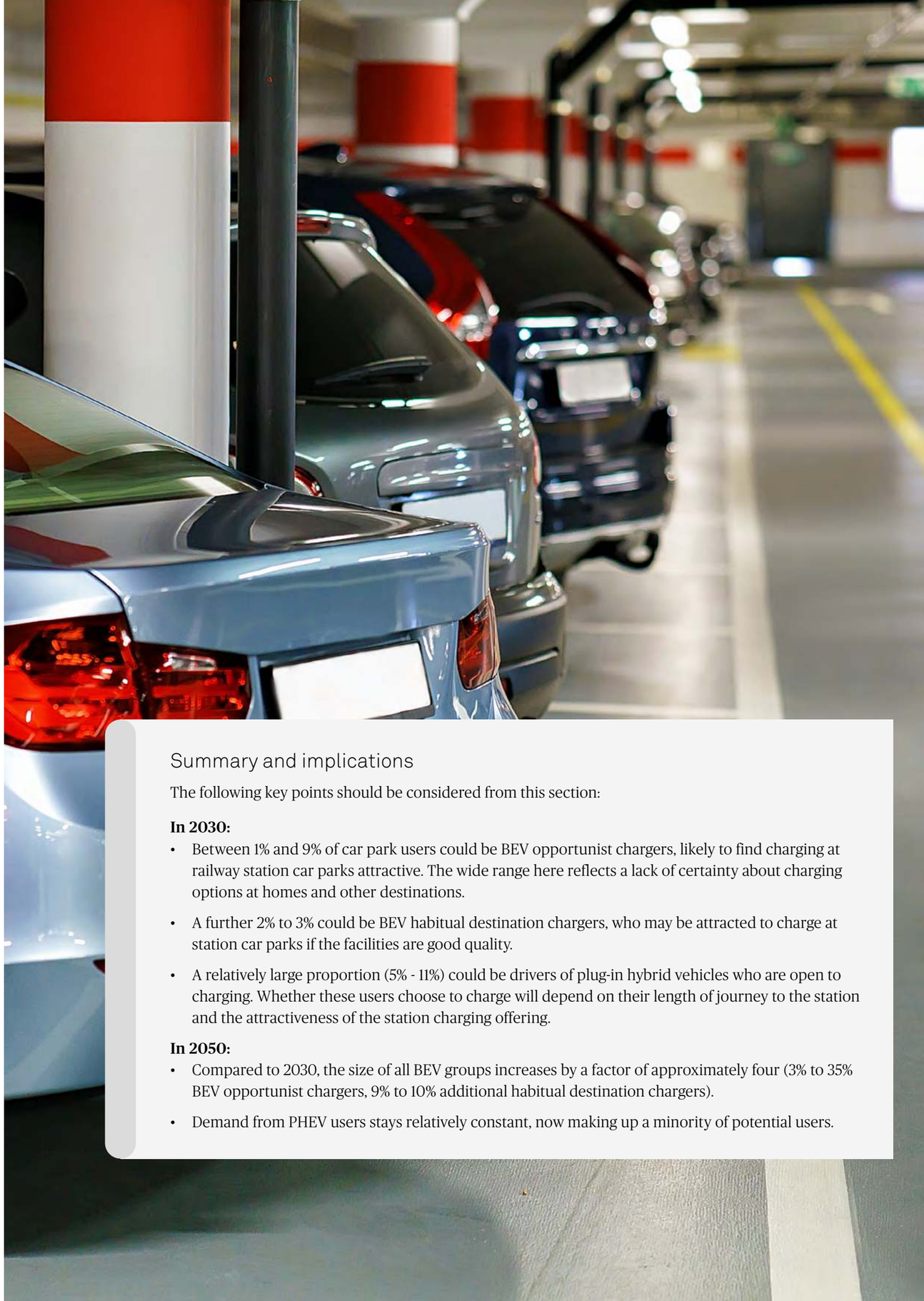
In Table 4 below we consider the size of each group as a percentage of all drivers in 2030 and 2050 under two different scenarios. Scenario 1 uses inputs at the end of the range likely to lead to higher demand for charging, while Scenario 2 represents the other extreme.

Table 4 – Size of subgroups as a proportion of all vehicle owners

Group	2030		2050		Likey to use station charging?
	Scenario 1	Scenario 2	Scenario 1	Scenario 2	
BEV home chargers	11%	19%	44%	74%	**Unlikely unless electricity is subsidised:** likely to be cheaper and more convenient to charge at home.
BEV habitual destination chargers	2%	3%	9%	10%	**Mixed:** Stations may be a habitual destination for some users, but highly dependent on site-specific factors. Habitual chargers at other destinations may use station charging if the facilities are more attractive.
BEV opportunist chargers	9%	1%	35%	3%	**Likely:** Station charging will be a good option for these users, who do not regularly park for long periods near charge points.
PHEV reluctant adopters	1%	1%	1%	1%	**Unlikely:** this group rarely charges.
PHEV economisers	11%	5%	9%	5%	**Mixed:** depends whether the distance to the station is long enough to require charging.
PHEV home chargers	0%	5%	0%	5%	**Unlikely:** this group prefers to charge at home.

It is possible that the mix of vehicles using station car parks may change at a different rate to the national average. There is some evidence to suggest that the demographics of rail users and EV users are similar: men from households with above average incomes are overrepresented amongst both[51,52]. This suggests that the proportion of plug in vehicles using station car parks could be higher than these estimates suggest.

51 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/590562/rail-passengers-factsheet-2016-revised.pdf
52 Trommer, Stefan; Jarass, Julia; Kolarova, Viktoriya (2015): Early adopters of electric vehicles in Germany unveiled



Summary and implications

The following key points should be considered from this section:

In 2030:

- Between 1% and 9% of car park users could be BEV opportunist chargers, likely to find charging at railway station car parks attractive. The wide range here reflects a lack of certainty about charging options at homes and other destinations.
- A further 2% to 3% could be BEV habitual destination chargers, who may be attracted to charge at station car parks if the facilities are good quality.
- A relatively large proportion (5% - 11%) could be drivers of plug-in hybrid vehicles who are open to charging. Whether these users choose to charge will depend on their length of journey to the station and the attractiveness of the station charging offering.

In 2050:

- Compared to 2030, the size of all BEV groups increases by a factor of approximately four (3% to 35% BEV opportunist chargers, 9% to 10% additional habitual destination chargers).
- Demand from PHEV users stays relatively constant, now making up a minority of potential users.

6

6 Charge Point Provision and Design Considerations

Introduction

This section discusses overall charging point provision and other design aspects in relation to car parks.

Space allocation

When discussing demand for charging in car parks, it is tempting to assume that the percentage of spaces with active charge points should match the percentage of vehicles requiring charging. However, this ignores the possibility of non-charging vehicles parking in the charging bays. Several possible strategies exist to mitigate this:

- **Designated bays:** spaces are designated for plugged in EVs only. This is highly effective where the proportion of charging bays and the proportion of plug-in vehicles is small. Unfortunately, we expect this strategy to be less effective in the future. If the number of charging bays exceeds demand, the usable capacity of the car park is significantly reduced. Also, by 2050, almost all vehicles will be plug-in vehicles, and the restriction will be meaningless.
- **Organised allocation:** the car park operator could allocate vehicles to bays based on whether they need to charge. This could be done though a system of variable lights/signs or when pre-booking parking. This way, parking bays can be reserved for users who need them (but be reallocated when the car park is busy and charging demand is low). From a user's perspective, booking ahead provides certainty that a charge point will be available, though some users may find it inconvenient.

- **Courtesy allocation:** rely on non-charging drivers helping others by not parking in charging bays while other spaces are free. This could be supported by 'nudge' tactics and signage. If this strategy is adopted, it is important to ensure that there are enough spare charging spaces to allow for some being wasted: plug in vehicle users place a high value on knowing there will be a space available when they need it.

The strategy adopted has potential to significantly affect infrastructure requirements. Especially in the early stages EV adoption, when charging demand will be at its lowest, a relatively small proportion of non-charging users parking in charging bays could dramatically increase the number of spaces required.

One way to mitigate this is placing charge points so that they can be accessed from several spaces. Guidance from the Energy Saving Trust[53] suggests placing charge points between two rows of cars, where they can be accessed from up to 8 spaces. This approach automatically produces cable routes to allow for more charge points to be added in future, though we would advise designers to think carefully before counting these towards any passive provision targets (while they allow more charging sockets to be installed, they do not allow for more charging spaces).

Level of demand

There is no doubt that there will be a demand for long stay electric vehicle charging facilities at stations. While EV range and charging speed is likely to improve, they will still not match internal combustion engine vehicles and as a result we do not expect a direct switch from petrol stations to rapid chargers. This means that home and destination charging will be required.

Compared with other destinations visited by members of the public, railway station users will park for relatively long periods of time. Many of them will also be making journeys as part of a routine trip, such as a commute. Both of these factors make the stations a good place for charging: there is plenty of time to charge, and users can plan ahead knowing when their next visit will be. This should be considered when comparing planned charging provision with the national recommendations and guidance discussed in section 2, which have to take many kinds of parking facility into account. We also note that guidance and regulations for electric charge points is relatively new and likely to change in coming years.

As prediction of demand for EV charging at any particular station car park is complex and depends on many factors. It is hoped that the analysis presented in Section 5 provides some initial guidance.

Car club spaces

As discussed in Section 4, there would be benefits to allocating some private spaces in the car park to car clubs. These would help improve access to the area around the station by railway users and would also have benefits to the surrounding area. Discussions would need to be held with potential operators to understand their charging requirements: normal long stay chargers are likely to be enough for most spaces, but there may also be a limited need for rapid charging for these higher utilisation vehicles.

53 https://energysavingtrust.org.uk/sites/default/files/Local%20Authority%20Guidance%20-%20Positioning%20chargepoints.pdf

Rapid charging provision

As discussed in section 4, larger stations would make favourable locations for rapid charging hubs. Most demand for these is likely to be indirectly related to rail passengers: likely users include taxi and private hire drivers, people making deliveries to the site, and local residents. Therefore, the expected level of demand depends more on the local context. We would encourage station car park operators to consider providing a rapid charging hub at larger stations. This would help to drive adoption of EVs in the local area.

Other design considerations

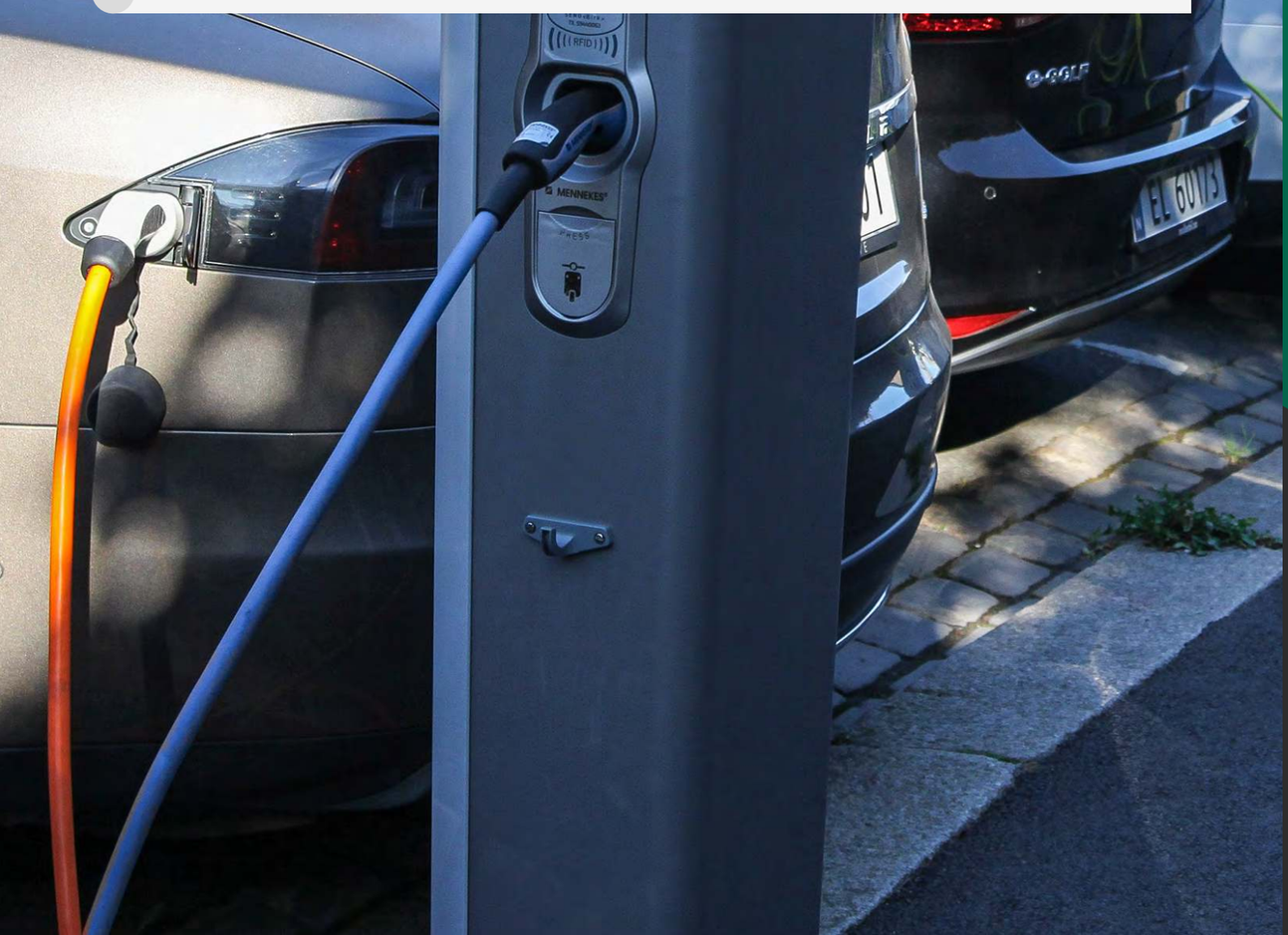
Other topics which should be considered when designing charging facilities include:

- **Accessibility**. Generally, placing charging stations near the entrance to buildings increases their visibility and their convenience for drivers, though it could also tempt non-charging users to park in them unnecessarily. Wherever spaces are placed, providing clear wayfinding is an important consideration. It is also important to ensure EV charging bays are accessible to all including in spaces facilities suitable for those with disabilities and children, with adequate sizing, dropped kerbs, tactile paving and avoidance of potential trip hazards. Further requirements are also defined in Building Regulations Approved Document M2: Accessibility to buildings other than dwellings.
- **Pedestrian access.** Where charging points are located on the footpath, the pavement must remain accessible to all users, including disabled people. It is also advised to avoid locating charging points at the back of the footpath, to prevent cables creating a trip hazard for pedestrians and to ensure there is still sufficient space not to impede access along the footpath such as to those in wheelchairs. BS8300-1 provides further guidance on how to design for accessibility and inclusivity in public spaces, including parking spaces. BS8300-2 also defines requirements for ensuring payment counters are accessible, which should be a consideration for EV charging points to ensure that any screens are at an appropriate height.
- **Payment**. This has been a challenge for users, who often have to use multiple apps and subscriptions for different charge point operators. There is now a move towards a roaming type system, similar to roaming arrangements for mobile phones. This has been very popular in Europe, starting in the Netherlands with the Open Charge Point Alliance. It means that users can charge their vehicles at any charge point run by participating operators. When the station operator selects a charge point operator, participation in schemes like this should be considered, as it will be an important factor in encouraging people to use the facility. We note that there is now a legal requirement to provide "ad-hoc access", without a pre-existing contract, under the Alternative Fuels Infrastructure Regulations (2017). This is sometimes priced at a premium rate.
- **Reliability and operational issues.** Any failure of the charge points and any delay in corrective action will be seen as a failure by station management. Contracts need to include high levels of service and clear methods for replacing unsatisfactory network operators and their charging kit.

Summary and implications

The following key points should be considered from this section:

- The required number of charging spaces is dependent on how they will be allocated to users. Enforcing that charging bays are for Evs only is not a long-term solution, as this will apply to virtually all vehicles by 2050. Bays will be most efficiently used if the car park operator allocates users to spaces or zones based on their charging need. Alternatively, it is possible to provide extra charging spaces on the understanding that some will be used by vehicles which do not really need them: this could be achieved by positioning charge points so that they are accessible from multiple spaces.
- There is considerable uncertainty about the level of demand for charging in the future. It may be worth carrying out further research to narrow the range of expected values. Suggestions for the form that this could take are provided in the conclusions section.
- Railway stations would make favourable locations for rapid charging hubs, and provision of these should be investigated in more detail. In particular consideration should be given to providing rapid charging for taxis and private hire vehicles.
- Allocating some spaces at stations to car clubs could help to improve “last mile” options, especially at Parkway stations.



7

7 Conclusions and next steps

Conclusions

Charge points in the long stay car park are possibly the most important type of EV provision for railway stations. There is no doubt that charging at destinations will be in demand.

The analysis in this report provides a relatively wide range for possible demand for EV charging. This demand would be affected by many external factors, as well as some that are within the control of the car park operator. The latter include:

- Charge point pricing. If the intention is to include the cost of charging within parking charges, virtually all plug-in vehicles might use the facility. At the other extreme, pricing at a premium compared to other public charging locations is likely to deter all users except the ones who really need to charge.
- Car park space allocation. If users can freely choose their own spaces, it may be necessary to allow additional capacity for vehicles which park in a charging space unnecessarily.

As well as demand estimates for the long stay car park, several opportunities to deliver additional benefits have been identified as part of this report. These most significant are:

- Providing rapid charging facilities. These would be especially valuable for encouraging the adoption of electric vehicles amongst taxi and private hire drivers. They could also help to encourage electric vehicle use by delivery drivers and local residents.
- Providing dedicated spaces and chargers for car clubs. These will improve access to the local area station users as well as having wider benefits.

Uncertainties and proposed ongoing monitoring

As noted above, the estimates of demand in this report cover a wide range of possible outcomes. In some cases this is a result of natural uncertainty about the future, while in others it is down to a lack of research to draw on. Future research and monitoring could help to narrow the range of possible outcomes, reducing the risk associated with charge point provision.

Currently, there is significant uncertainty in the number of EVs which will be arriving at railway stations in future design years. Ongoing monitoring of real-world vehicle ownership and sales data is recommended.

Once the number of EVs is known, the proportion of EV owners with access to charging at home is probably the single most important factor in our model. This report's predictions are based on the levels of off-street parking in the national housing survey, but this has some drawbacks as a tool for assessing home charge point availability. In particular:

- Not everyone who has off-street parking will be able to install a charge point.
  - In the national housing survey, off-street parking includes garages, which many people do not actually use for parking.
  - People who rent their home may find it difficult to get funding or permission to install a charge point.
  - Not all off-street parking is accessible from the household's electricity supply.

In some places, public charging is provided in residential areas. It is not yet clear how widely this will be rolled out and what proportion of people will find it a convenient option.
Data on real-world access to charging by EV owners, broken down by housing situation, could be used to reduce the level of uncertainty in this estimate. This can only realistically be gathered by a survey, though some data may already be commercially available. Data of this type could also provide insight into how quickly plug-in vehicles are being adopted by users without their own charge points.

For those who will not be able to charge at home, demand for charging at a station depends on the alternatives which are available. There is already some data available about access to workplace charging and we suggest that it is worth monitoring trends in this. However, charging at regular non-workplace destinations is likely to be important to many plug-in vehicle owners. Patterns of use will change over time: ideally, we would monitor the proportion of users who regularly charge using the same public charge point to give an estimate of the size of the BEV habitual destination charger group. This data will be held by charge point operators but is likely to be considered commercially sensitive.

Price and quality of charging at a station have already been identified as important factors affecting demand. Equally important are the commercial decisions made by other charge point operators, as charging will become an increasingly competitive market. Station car park operators should monitor what the major charging networks offer over the next few years to understand the significance of free charging and various subscription/payment options.

This report has largely taken a 'bottom up' approach to estimating demand, based on assumptions about vehicle owner behaviour and the number of plug-in vehicles sold. An alternative would be to take a 'top-down' approach, looking at trends in actual user behaviour at stations where good quality charging facilities are already available. Currently, the number of these sites is limited, but a survey could provide useful insight. Ideally, this would the place in a time of stable travel behaviour and gather data on:

- The proportion of BEVs and PHEVs parking at the station, to be compared with vehicles registered in the local area.
- The proportion of these vehicles which occupy a charging bay.
- The types of journey commonly made from the station.

Data of this type could be used to refine a bottom-up estimates, or (if carried out at several sites) build for an empirical model for estimating demand.

The one subject not covered in this report has been the coronavirus pandemic. Much of the data used in this report had been collected before the pandemic. Work patterns and therefore travel patterns have changed considerably. How those behaviours change once the pandemic has receded are as yet unknown. Inevitably it will be some time before the data sources used initially can be reliably revisited. So, whilst the report has been at pains to suggest that all predictions should be revisited in order to reduce the uncertainties there is a caveat that any new data must be reviewed for its stability in what may still be a very volatile environment.

Possible future trends

- In chapter 6 above, in a discussion on the allocation of parking spaces mention was made of signage and lighting to assist drivers to the right space. With the recent introduction of 5G communications there is more scope for 'Internet of Things' type innovations to take place. It is reasonable to expect some form of automatic guidance to be available (within next ten years) so the driver can be led directly to the allocated space.
- The first commercially available EV chargers were designed primarily to act as kerbside chargers, consequently with a maximum of two connectors. With increasing demand for charging, especially within carparks, it is reasonable to expect the technology to advance, thus providing for more connections to a single charging device. Taken to an extreme, the development of technology might reduce the technical content of a parking bay to little more than a connector. All other functions: communications, billing, switching and recording would be handled elsewhere. At this point the constraint on the number of charging sockets becomes a choice related to the available power supply.
- Energy storage has been mooted for some car parks to smooth the power consumption and limit peak demand. Methods of storage and capacity of installations are growing and may be able to reduce the peak demand at a site. In addition, a number of car parks have been fitted with canopies of solar panels. These certainly stress the idea to the users that locally generated electricity reduces their load on the grid. However, given the area involved and the charging rates for vehicles, these panels are a relatively small contribution. Serious provision of solar power for EV charging requires supplementary solar farms to be added.

Appendices

Appendix 1
Permitted development rights

This Appendix provides a detailed summary of permitted development rights for charge point installation.

Installing an electrical charging outlet

Schedule 2, Part 2, Class D of The Town and Country Planning (General Permitted Development) (England) Order 2015 (as amended) states that planning permission is not required for the installation of a wall mounted electrical outlet for recharging of electric vehicles as long as the area is lawfully used for off-street parking.

For installation to be classed as permitted development, the electrical outlet (and its casing) must not:

- Exceed 0.2 cubic metres
- Face onto and be within two metres of a highway
- Be within a site designated as a scheduled monument
- Be within the curtilage of a listed building.
- Installing an upstand with a mounted electrical charging outlet.

Schedule 2, Part 2, Class E of The Town and Country Planning (General Permitted Development) (England) Order 2015 (as amended) states that planning permission is not required for the installation of an upstand with an electrical outlet mounted on it for recharging electric vehicles, as long as the area is lawfully used for off-street parking.

For installation to be classed as permitted development, the electrical upstand and the outlet must not:

- Exceed 2.3 metres in height from the level of the surface used for the parking of vehicles. This limit is 1.6 metres where in the curtilage of a dwellinghouse or block of flats
- Be within two metres of a highway
- Be within a site designated as a scheduled monument
- Be within the curtilage of a listed building
- Result in more than one upstand being provided for each parking space.

For Class D and E, when the electrical outlet is no longer required as a charging point for electric vehicles, the wall (on which the outlet was mounted) or the land (on which the upstand was placed) must be returned to its previous condition (prior to the installation being carried out) as soon as possible.

Appendix 2
Standards and specifications for charging infrastructure

This appendix provides a detailed summary of charging infrastructure technology, the standards it is based on, its current use and how it is evolving.

Charging infrastructure speeds and applications

Wired charging points are typically classified according to their power rating: slow (typically 3.6kW), fast (typically 7 or 22 kW) and rapid (typically 50kW or more). There are also wireless chargers, most commonly available with speeds of 3.3kW, 6.6kW and 20kW.

Slow chargers are most commonly rated at 3.6kW (16 Amp). They are often used to charge overnight or at a workplace and will take between 6 and 21 hours to fully charge a pure electric car, depending on the battery size. They may also be suitable for long stay car parks where vehicles are parked for long periods of time.

Fast chargers are typically rated at either 7kW or up to 22kW (single or three phase 32A). A 7kW single phase charger will typically take between 3-7 hours to recharge depending on battery size. 7kW chargers are popular at workplaces and home and also tend to be installed in destinations such as car parks, supermarkets and leisure centres. Many electric vehicles currently on the market are not able to charge at 22kW from this type of charger as they do not have the necessary onboard equipment.

There is more variation in the rapid charger types currently installed. These are commonly used at short stay locations such as motorway services, fast food restaurants and some supermarkets. Commonly installed types include:

- Rapid AC three phase chargers are typically rated from 43kW (63 A) and capable of charging vehicles to 80% in 20–40 minutes.
- Rapid DC chargers provide a power output at 50 kW (125 A) using either the CHAdeMO or CCS charging standards (see below). Both standards types can charge an EV to 80% of capacity in 20 minutes to two hours depending on battery capacity and starting state of charge.

- The Ultra-Rapid DC chargers provide a power output at 100 kW or more, with many offering 150kW.

  - Chargemaster are in the process of installing 400 ultra-rapid 150kW chargers by 2021 and EoN are also rolling out a network of 175kW Ultra rapid DC chargers.
  - Tesla offer a supercharger network for their customers with power outputs of up to 150kW.
  - Recently, Ionity have been installing 350kW Ultra-Rapid chargers capable of providing 80% charge in less than 20 minutes
  - There are R&D programmes in China and Japan underway looking at 900kW charging facilities.

Wireless chargers work by having the charging unit sunk into the ground which emits an alternating electromagnetic field. Cars fitted with a suitable receiving unit can then park above the charging unit to generate current that will then charge the battery. There is currently a £4 million Innovate UK trial of this technology. A number of standards are being used or in development, including IES TC 61980-3, published in February 2019.

Wireless charging is likely to be significant due to the convenience it provides for specific users (for example. taxi drivers, disabled users, buses etc) and helping to reduce clutter where there is not space to place a traditional charge point.

Connector types

Table 5 summarises the commonly used charge point connector types and their features.

Table 5 – EV charging connector types

Connector types	Description	Charge time and power requirements	Future considerations
Type 1	The Type 1 plug isn't very common these days. It was common amongst early electric cars such as the Mk1 Mitsubishi Outland PHEV in 2014. It is commonly used for slow or fast charging but isn't suitable for rapid charging.	3-7 kW AC Single Phase (Slow/Fast Charge) Approximately 12 miles range per 30 minutes of charging.	Likely to continue to be used for home charging but not for any public charging stations. Home is likely to be dominated by the Type 2 and CCS.
Type 2	The Type 2 connector (IEC 62196) also referred to as 'mennekes' is suitable for slow, fast and rapid charging. The Type 2 is now the European standard, so it is the most prevalent option on the market - everything from the Renault Zoe to the Tesla Model S feature the Type 2.	3-43 kW AC Single Phase/ Three Phase (Fast Charge) Approximately 75 miles range per 30 minutes of charging.	The Type 2 (IEC 62196) commonly referred to as mennekes has been specified by the European Commission as the official EV charging plug in Europe for AC charging. It is likely to maintain popularity in the future for fast and rapid charging.
CHAdeMO	It is most suited to rapid charging applications and is more commonly used by Japanese vehicle manufactures, including in the popular Nissan leaf. As a result, it is currently the most widely available standard at rapid charge points in the UK. However, its design means that cars require an additional plug to have this on top of the legally required Type 2 plug.	50 kW DC Three Phase rapid charge Approximately 85 miles range per 30 minutes of charging.	There have been some signs that CHAdeMO could become a legacy standard, with a key user Nissan, now choosing the CCS standard. Japanese manufacturers who traditionally chose CHAdeMO are now switching to use the CCS standard including Nissan, Honda, Kia and Hyundai. It is however the only standard currently capable of supporting V2G and CHAdeMO version 3.0, also known as 'ChaoJi', released in April 2020 which now supports 500 kW 'ultra-fast' bi-directional charging. This uses chilled cable technology, and future releases are expected to support up to 900kW.
CCS (Combined Charging Standard)	The CCS plug is similar in capabilities to the CHAdeMO above, in that it is best suited to rapid charging. However, unlike the CHAdeMO it builds on the Type 2 design, albeit with added connections on the bottom of the plug. CCS connectors are most common on German car models, being used by BMW, Mercedes and Volkswagen, but they are also spreading to other manufacturers that sell cars in Europe.	50kW - 350 kW DC Rapid charge Approximately 85 - 200 miles per 30 minutes of charging	The CCS standard (IEC 62196-3) is the favoured charger standard in Europe for DC charging. It is The CCS standard is expected to reach full Vehicle to Grid (V2G) capability by around 2025. Following this, the new standard will also need to be integrated into the communications hardware and software in the cars, chargers and the grid.

Virtually all Electric Vehicles that currently on the market in the UK support charging using the Type 2 standard, though not necessarily at full speed. Most also use another technology for rapid charging, often depending on the vehicle manufacturers country of origin. For example, European vehicle manufacturers prefer the CCS (Combined Charging Standard), whilst Chinese and Japanese vehicles typically use CHAdeMO. Table 6 shows the connector types used by some of the most common models of electric vehicle.

Table 6 – Connector types for popular electric vehicles

Make	Model	Connector types (s)
Audi	e-tron	Type 2 and CCS
BMW	i3	Type 2 and CCS
Hyundai	Kona Electric	Type 2 and CCS
Jaguar	I Pace	Type 2 and CCS
Kia	e-Niro	Type 2 and CCS
Nissan	Leaf	Type 2 and CHAdeMO
Mitsubishi	Outlander	Type 2 and CHAdeMO
Renault	Zoe	Type 2
Tesla	Model 3	Type 2 and Tesla Type 2
Audi	e-tron	Type 2 and CCS

ChaoJi is a new type of plug, based upon the CHAdeMO 3.0 protocol that was released in April 2020, which is a move to harmonise with China's GB/T rapid charging standard and to create a new generation of ultra-high powered charging, to also cater for commercial vehicles.

Developed by the China Electricity Council (CEC) and the CHAdeMO Association, this new protocol allows DC 500kW charging (maximum current 600A), utilising liquid cooling technology with bidirectional charging. Based upon trials, it has been quoted as being able to charge for a range of up to 250 miles in less than 10 minutes. The protocol has also been designed to also offer up to 900kW charging, with a peak of 600 amps and 1500 volts for heavy-duty vehicles, such as trucks and buses.

The testing requirements for CHAdeMO 3.0 specification are expected to be issued within a year. The first ChaoJi EVs will be likely commercial vehicles and expected to be launched in the market as early as 2021, followed by other types of vehicles including passenger EVs.

CHAdeMO have also been trying to enable convergence by making this new protocol back compatible with other charging standards and have presented their thoughts on how convergence may be achieved between different charging standards from 2025 onwards[54].

Another area of interest to manufacturers is automated charging. There are several reasons for this, including the fact that cables for rapid charging are becoming more cumbersome as power ratings increase and a desire to support the delivery of autonomous vehicles.

54 https://www.itf-oecd.org/sites/default/files/docs/charging-infrastructure-standardisation-developments-yoshida.pdf

VW recently presented such a system for an e-Golf, as a research facility in the test phase called e-smartConnect. The DC quick charging process starts with a communication between vehicle and electric filling station. The vehicle transmits its data to the charging station, which transmits in return the target position for the automated parking. The charging socket of the vehicle has to be in a target area of 20 by 20 centimetres. Afterwards, a camera on the robot detects the exact position of the charging socket, which is accurately defined to a millimetre. Following, the robot-gripper picks the DC-Connector and links it with the charging socket of the vehicle. After having linked the DC-Connector, the charging process starts. Once the battery is fully charged, the robot automatically unplugs the DC-Connector.

Tesla have also been doing a similar trial. In their implementation, the charging cover opens automatically when the parked vehicle is ready for loading. The charging system detects this, and a snakelike robot arm searches its way to the socket. Once the connection between the robot and the vehicle is made, the charging process can be started. Detailed technical information about the charging system has not published yet. Tesla has an advantage when implementing this type of system since all of their cars have the charging socket in the same place.

Smart charging and vehicle to grid

Two of the technologies often discussed in connection with the UK's charging infrastructure are managed or smart charging and Vehicle-to-Grid (V2G). Smart charging is where the time in which a vehicle is charged is not purely dictated by when the vehicle is plugged in. Rather it can be altered to begin and end at a time of low electricity prices which better suits the user (in terms of energy cost, as in a Time of Use tariff) or the energy system at large (the energy supplier would directly manage the charging within consumer set boundaries). V2G chargers are slightly different in that not only can the timing of a charging session be moved to best suit the interested parties but the charger is two way meaning that the vehicle can supply energy to the system rather than merely drawn down from it.

Smart charging is being championed by the government at OLEV and DfT[55] through various projects and funding calls. The EV Energy Taskforce also emphasised the importance of smart charging as an enabler to transition to low carbon transport.

It is widely believed that this type of charging flexibility will be crucial to have an energy system that can cope with the needs of the EV charging demand. Even though smart charging might not be suitable for vehicles parked at railway station car parks for short period of times when it is expected that a short charge might be needed, it could offer benefits for vehicles parked for longer periods of time and more importantly overnight. The ability to shift demand could offer benefits to both the rail customers and the charge point operator as lower electricity prices or local generation from renewable sources can be exploited. Further work would be needed, based on consumer segmentation and traveling profiles, to understand the value smart charging can offer to railway station operators.

55 https://innovation.ukpowernetworks.co.uk/wp-content/uploads/2020/05/Delta-EE-Survey-Report-for-Shift-UK-Power-Networks.pdf

V2G technology is currently largely in the early demonstration stages in the UK, for example the work being undertaken by OVO Energy[57]. The main selling point of this technology revolves around the additional flexibility type services it can offer to the energy system, and the various value streams this can generate for customers, charge point operators and aggregators. As the energy system moves to rely more heavily upon intermittent renewable energy generation this is likely to be of value. This largely relies upon longer plugged-in times to provide the type of immediate response required from this type of service. Similar to smart charging, V2G could potentially enable station operators to access additional value streams through vehicles that are parked at the station for longer periods of time.

Energy Systems Catapult have produced a study into the impacts of smart charging and V2G technology on the energy system and the benefits that they could offer[58]. Changes to the electricity and flexibility markets would need to occur before V2G can be deployed at scale in the UK. Add to this the fact that currently there are very few V2G capable vehicles available on the market for consumers immediate potential for this technology is limited. This does not mean that the energy system, the market and vehicle offering will not develop over the years rather that the progression of this technology should be reviewed to reassess whether it would be applicable to stations in the future.

58 https://www.itf-oecd.org/sites/default/files/docs/charging-infrastructure-standardisation-developments-yoshida.pdf

Visit our website
www.connectedplaces.org.uk

Follow us on Twitter
@connectplaces

Email us
info@connectedplaces.org.uk

CATAPULT
Connected Places