Independent, not-for-profit,
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EV Charging in Car Parks

A Study of Innovative Solutions to Charging EVs in Car Parks commissioned by Innovate UK

Innovate UK

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Table of Abbreviations

AC	Alternating Current
ANPR	Automatic Number Plate Recognition
AV	Autonomous Vehicle
BEIS	Department for Business, Energy and Industrial Strategy
BPA	British Parking Association
CAES	Compressed Air Energy Storage
CAPEX	Capital Expenditure
CCS	Combined Charging System
CCTV	Closed-Circuit Television
DC	Direct Current
DNO	Distribution Network Operator
DSR	Demand Side Response
EMS	Energy Management System
EPA	European Parking Association
EU28	28-member states of the European Union
EV	Electric Vehicle, specifically a Plug-in Vehicle, whether a Battery Electric Vehicle (BEV), Plug-In Hybrid Electric Vehicle (PHEV) or Range Extender Electric Vehicle (REEV)
EVSE	Electric Vehicle Supply Equipment
ICE	Internal Combustion Engine
IEA	International Energy Agency
IUK	Innovate UK
KTN	Knowledge Transfer Network
LED	Light-Emitting Diode
MaaS	Mobility as a Service
OLEV	Office for Low Emission Vehicles
OPEX	Operational Expenditure
P&D	Pay and Display
PCN	Penalty Charge Notice
PV	Solar Photovoltaic Electricity Generation
RFID	Radio-Frequency Identification
SMES	Superconducting Magnetic Energy Storage
TSO	Transmission System Operator
ULEV	Ultra-Low Emission Vehicle
V0G	Standard EV Charging systems
V1G	Managed EV Charging systems
V2G	Vehicle to Grid
kWp	Kilo watt peak, (highest production power of a solar PV system)

Executive Summary

- The number of Electric Vehicles (EVs) are set to rise rapidly in the UK with forecasts suggesting up to 30% of vehicles on the road could be EVs by 2030. Whilst the majority of EV charging will be done at home, it is anticipated that there will be a considerable demand for charging at public car parks. This represents a potential business opportunity for car park operators, and this report aims to explore the opportunities and provide the key information required to support the development of relevant business cases.

- There are more than 30 million car parking spaces in regulated (access controlled and fee paying) publicly accessible car parks across Europe, at least 5 million of which are in multi-storey car parks.

- EV charging is recognised as an emerging theme for car park operators but the low uptake rates demonstrate a lack of awareness and information on the topic and the options available for car park operators.

- There are a number of factors which should be considered when evaluating the suitability of a car park for EV charging (and the number of chargers required). These include:
    - Customer demographic & demand,
    - Car park location and size,
    - Dwell time of parking,
    - Existing infrastructure,
    - Space allocation,
    - Civil and electrical works,
    - Publicising the availability of the chargepoints,
    - Access and payment methods.

  (Details to support evaluation of these factors can be found in Section 1.2 of this report)

- For multi-storey car parks, chargers can be deployed according to the duration of stay expected, slow chargers could be deployed for long stay carparks, fast for medium stay and rapid for short stay.

- One of the key barriers to large scale roll out of EV charging in car parks is network constraints. Innovative approaches to charging EVs have focused on the challenge of managing demand from EV charging within local supply constraints through Demand Load Balancing (DLB). These ‘managed charging’ systems are commercially available for car park operators, recognising that car parks were not designed with the electrical supply capacity needed for multiple EVs to charge.

- In locations with local supply constraints, the alternatives to DLB include adding generation and stationary battery storage to car parks to reduce the demand from the local distribution infrastructure, or to invest in upgrading the infrastructure. Investment decisions will depend on whether the car park operator is the landowner or holder and the duration of any concession arrangements that apply, as well as on the existing supply availability on the local distribution network.

- With upcoming V2G chargers, bidirectional energy transfer between the EVs and the electricity network will be possible. In this case, the EV batteries can act as mobile energy storage, providing various grid services which can earn revenue for both the driver and the site operator. V2G charging at car parks and multi-stories is currently being developed as part of a number of UK innovation projects but is not currently commercially available at scale.

- Car parks are undergoing a transition towards ‘smart parking’, where sensors, cameras and other equipment are used to collect data on parking behaviour and to provide ‘value adding’ services to customers. These ‘modernisations’ also help meet the needs of EV drivers by providing guidance on EV parking locations and availability.

- The car parking sector is already anticipating changes to existing car park business models resulting from the likely emergence of autonomous vehicles, which will require more innovative approaches to charging, such as wireless charging systems.

1 Introduction

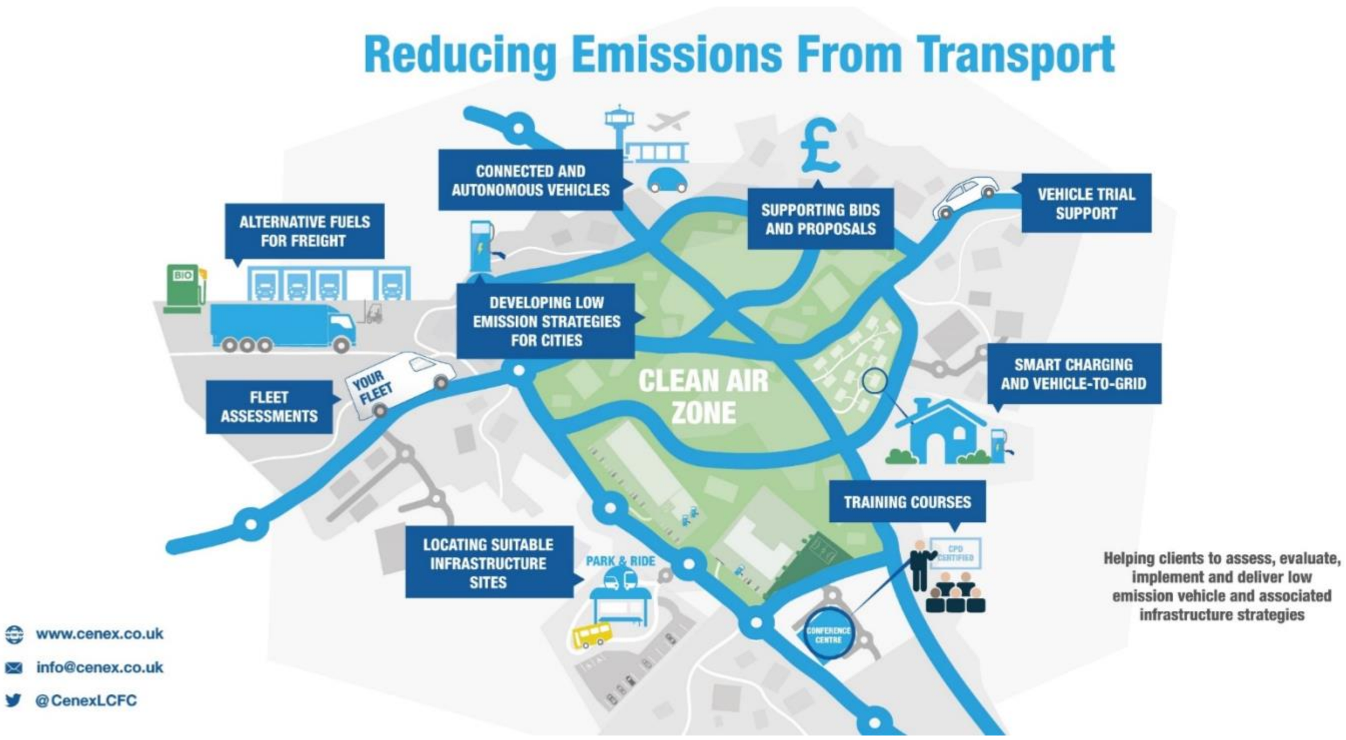

Figure 1: Cenex Core Activities Map

Cenex was established in 2005 as the UK's first Centre of Excellence for Low Carbon and Fuel Cell technologies.

Today, Cenex operates as an independent, not-for-profit consultancy specialising in the delivery of projects, supporting innovation and market development, focused on low carbon vehicles and associated energy infrastructure.

Independent. Not-for-Profit. Consultants.

We highly value our independence as it allows us to provide impartial advice and helps us build trust with our customers.

Being a not-for-profit, Cenex isn't driven by doing the work which pays the most or builds our order book, but by what is right for our customers and for the industry. This is reflected in everything we do, from the work we do and the advice we give, even to the prices we charge.

Finally, as consultants our aim is to be trusted advisors with expert knowledge – the go-to source of help and support for public and private sector organisations. We want to be people you can trust to help where and when it is most needed as our customers progress along their journey to a zero-carbon future.

To find out more about us and the work that we do, visit our website:

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Background

Electric Vehicles sales are expected to rise to up to 30% of global vehicle sales by 2030. Whilst the majority of EV charging is expected to be done at the home (particularly where off-street parking is available), there will be an increasing demand for public charging. Public charging is likely to be predominantly focused on areas with long dwell times or where people already park. On average, vehicles spend 96% of their life parked. Carparks traditionally serve as strategic locations from which the user can access their business or leisure activities, often on a daily basis. This therefore, presents a new business opportunity for car park operators.

Should the UK adapt its existing stock of car parks to accommodate electric vehicle charging infrastructure then the well documented public concerns around public charging infrastructure would be dramatically reduced. As EV uptake extends beyond early adopters, many potential city-based EV owners will not have access to suitable off-street parking or nearby on-street chargepoints and will need to look for alternative charging options. In this regard, car parks, including multi-storey car parks, could prove ideal locations in which to house multiple EV charging bays, providing both secure parking and charging.

Aims

The aim of this study is to provide sufficient background information to support car park operators in developing business cases for implementing EV charging. This is done through:

1. Setting out the existing opportunities and challenges associated with retrofitting chargepoints into public car parks.
2. Identifying innovations which could support or increase the scope for EV charging.

This report should also serve as a point of reference to encourage future innovation in this area and to assist in focusing future 'Innovate UK' investments. The analysis within this report will also consider the wider context of the innovation drivers influencing the car parking sector.

This study has been funded by Innovate UK as part of ongoing activities within the Ultra-Low Emission Vehicle field. The results of the study will be jointly disseminated by Innovate UK and Cenex.

This report is freely available via the Cenex website - www.cenex.co.uk

1.1 Electric Vehicle Market Development

Electric Vehicle (EV) adoption is forecast to rise dramatically over the next few years, primarily as a result of environmental policies (motivated by carbon reduction and air quality management) and the increased choice of EVs offered by vehicle manufacturers. Figure 2 illustrates forecasts for growth in EV adoption based on two different scenarios developed by the International Energy Agency (IEA). The first is the new policies scenario, whereby, the uptake of EVs is based on the policies that have been or will be deployed by global governmental bodies. The IEA EV30 ambition is for 30% of vehicles on the road to have electrified powertrains by 2030. This means a combination of hybrid electric (HEV) and plug-in hybrid electric (PHEV), as well as pure battery electric (BEV) and range extended battery electric vehicles REEV), with the latter 3 categories all expected to draw electrical energy by plugging-in to chargepoints. From comparison between the 'New Policies' scenario and the 'EV30@30' scenario it can be noticed that the new policies forecast produces a much less aggressive uptake of ULEVS going into 2030, with a total of ~125 million units (globally) compared to the EV30@30 Scenario of 220+million. Achievement of EV30@30 would, according to the IEA, require rapid scale up and geographical expansion of policy commitments, starting as soon as possible[1].

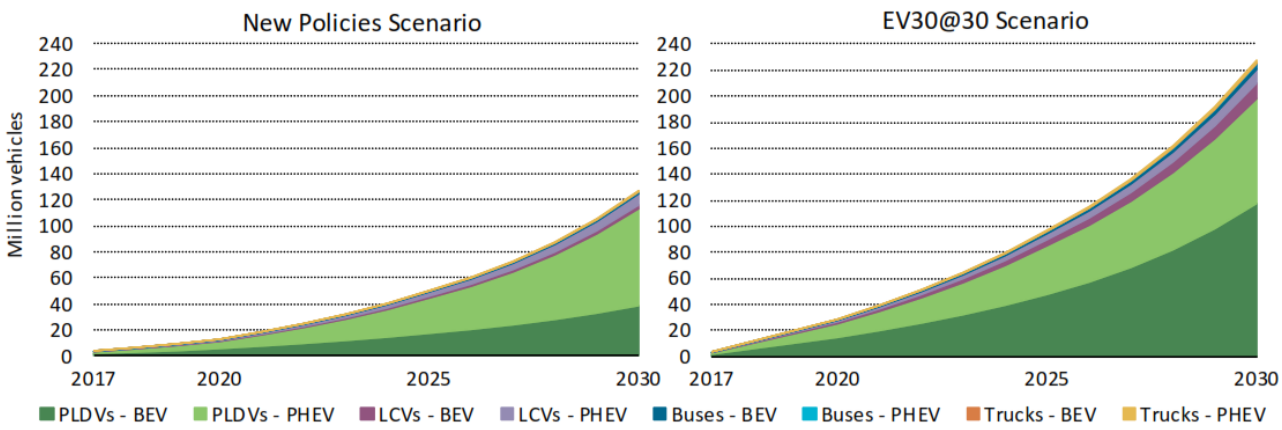


Figure 2 IEA Deployment scenarios for the stock of EVs to 2030

The current commercially available BEVs typically have battery capacity sufficient for a range of 80 to 350 km between charges, with a trend towards higher ranges for newer vehicles. Existing PHEVs are typically capable of running on electric drive for 15 to 45 km, and REEVs typically have an EV range of around 80 km with a further 100 or more km of range through a petrol/diesel-powered range extender engine. This enables drivers to carry out multiple short trips between charges, consistent with daily commuting or for leisure activities, often then only charging once or twice a week. For light commercial vehicles and taxis, with longer daily travel distances, additional energy and therefore more regular charging will be required.

For passenger cars, studies show that the average vehicle only spends 3% to 4% of time in transit throughout its lifetime, with roughly 80% of time spent parked at home and roughly 16% at destination parking[2]. On this basis the majority of passenger car EV charging is expected to take place at home. However, the requirement for charging at destination parking is evident and will increase in line with the increased uptake forecast for EVs.

1 IEA EV Outlook 2018

2 Association of Town & City Management, B. P. (2013). *Re-Think! Parking on the High Street: Guidance on parking provisionin town and city centres.* London: BPA.

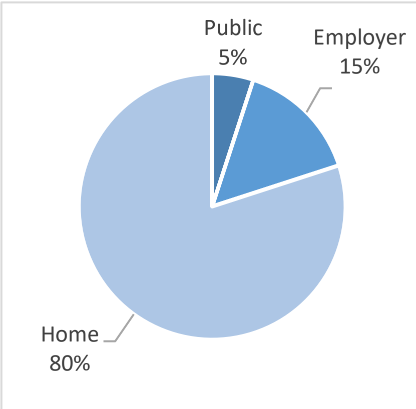
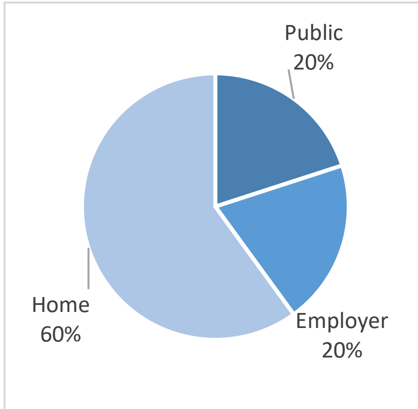
	Current (Early Adopters)	Future (Mass Rollout)
Distribution of Chargepoints for private EV drivers	 **Key Point:** Home Charging and Semi-Public dominates the infrastructure requirement.	 **Key Point:** Significant increase in requirement for public infrastructure.
Home and Semi-Public	• Most charging is done at home or at workplace locations	• Share of semi-public charging increases, dominated by long term parking at work and car parks.
Public	• Public charging infrastructure will not be built up densely, first installations mostly initiated by public authorities.	• Accelerated rollout as share of EVs and customers without off street parking increases.

Table 1 Chargepoint Infrastructure Implications of EV Market Development

Table 1 demonstrates that, as EV uptake increases the type and location of charging required also changes. Multi-storey and surface car parks provide one of the key means by which large numbers of EVs could be charged at a single location. This could take place during traditional daytime hours; however there is an opportunity for car park operators to access a new customer base and extend their operation outside of traditional working hours by providing overnight parking and charging for local residents and businesses. This public charging offer is considered essential if EVs are to be widely adopted by the 28% of households who lack the off-street parking needed for home charging[3].

Whilst making use of existing car parks for vehicle charging is an attractive option there are alternative locations which could compete with car parks as strategic locations for EV charging including:

- Workplace charging,
- Destination charging,
- Increased use of rapid charging.

Any significant increase in availability of charging in any or all of the above could reduce the size of the opportunity for car park operators, although it is likely that some market for this service would still exist.

3 “Spaced Out: Perspectives on parking policy”, RAC Foundation, July 2012

1.2 Defining the Key Considerations for Charging Facilities

Where municipalities operate public car parks, the addition of EV charging can be considered both an extension of environmental policy aims, as well as a practical necessity as EV numbers increase and motorists request charging in facilities under municipality control.

For private sector car park operators, the decision to have chargepoints installed and maintained can be considered as a business decision first and foremost, based on the desire to attract the customer pool of EV drivers, as well as any income that can be generated from the sale of energy for EV charging.

For car park operators, a range of factors feed into the decision-making process as to whether EV charging is a priority and what requirements should be set in terms of the type of chargepoints deployed. The key factors influencing these decisions are:

- **Customer demographic & demand:** Is there a reasonable number of EVs in circulation likely to need charging facilities, whether in the form of local commuters or those commuting into the area from longer distances for work or leisure? A key consideration of this is the demographic of the local area.
- **Car park location:** Does the location of the car park serve as a strategic destination where it will see consistent EV use across the year? For example, does the car park serve an airport, train station, shopping centre, sports facility, set of hotels, or any other destination likely to be regularly used by EV motorists?
- **Car park size**: Larger car parks in prime locations have more visitors and will therefore be statistically more likely to have EV motorists visit.
- **Dwell time of parking:** How long do cars and other vehicle types typically park? Medium and long-stay car parks typically need more chargepoints but of lower power outputs, as the cars can dwell for many hours plugged-in. For short-stay parking there may be a case for higher-powered charging. For the majority of car parks, the working assumption is that chargers will be unattended. However, where valet parking is already provided as a service, there may be a viable business model for concierge charging as an add-on service, which could be more easily facilitated by higher power charging.
- **Existing infrastructure:** When installing chargepoints, it is necessary to carry out a 'power availability' assessment of the current electricity use and the available capacity, both at the distribution board within the car park and the low voltage supply from the local substation. This requires communications with the relevant Distribution Network Operator (DNO). The aim of this assessment is to identify whether the current electricity supply that is servicing the car park would allow for the implementation of extra demand in the form of chargepoints. In cases where there isn't sufficient supply capacity available, car park operators have the following options:
    - Upgrade the cabling and/or low voltage supply,
    - Apply demand management approaches to prevent peaks in consumption that exceed capacity,
    - Add distributed generation and/or storage to reduce the draw from the local grid.

  DNO's typically take up to 12 weeks to carry out a supply upgrade. The costs associated with an upgrade are case specific, ranging from a few hundred pounds for minor upgrades to £100,000+ where substantial upgrades are required, such as installing a new substation. This topic is described in greater depth in section 4.2 of this report.

- **Space allocation**: Consideration needs to be given as to whether EV charging is located within dedicated parking bays and if so, where within the car park these bays are located. Dedicated bays represent a more attractive offer to the EV motorist as this implies a greater certainty of availability. However, this requires signage and markings, as well as enforcement. With EV numbers growing, but still limited in the UK, dedicated EV bays may have lower occupancy levels than the surrounding parking bays, which would lead to a loss of revenue with an associated opportunity cost per bay. The EVSE mounting method can also impact space availability; currently EVSE is typically wall mounted or floor mounted. Floor mounting can impact the depth of a parking space; however, this may be the only feasible option where no wall is available for mounting. The IET Code of Practice for EV Charging

Equipment Installation[4] provides guidance on a full range of relevant requirements from space to ventilation for electric equipment including chargers and more details on mounting methods can be found in section 3.2 of this report.

- **Civil and electrical works**: In addition to the immediate civil and electrical works required for chargepoint installations, additional work is required to provide power, signage and demarcation. For surface car parks the civils works can be expected to involve ground works to run cabling from the nearby distribution board to the chargepoints. For multi-storey car parks any additional electrical cabling could be run on the inner walls of the car park. Road markings and signage can be painted onto car park road surface, or put as signage on walls, or added as electronic signage. Typically, the civil and electrical costs can equate to up to 50% of the cost of installation.
- **Publicising the availability of the chargepoints**: The availability of publicly accessible chargepoints needs to be disseminated so motorists are alerted. This can be done through car park website information and signage but also by providing information to third party databases used to provide transport system information to other service providers. In the UK there is a government-funded 'National Chargepoint Register' but also commercially-funded databases including ZapMap. This could also support booking systems, allowing EV drivers to reserve a space ahead of time and thus ensuring availability. However, the resources and costs required to implement this need to be balanced against the potential benefits and 'effort savings' which can be achieved.
- **Access and payment methods**: Currently a range of approaches exist for access and payment for EV charging. The first approach is the membership model, whereby chargepoints form part of a common estate that can be regional or national in scope and members are able to access chargepoints using either a membership card, or a mobile App. In these cases, the control of access and payment processing for the chargepoint is managed by a back-office system referred to as the Chargepoint Management System. For some regions there are additional roaming platforms that allow membership schemes to be linked so that a member of one scheme can access the chargepoints that are part of the estate of another scheme. This 'interoperability' allows the motorist to roam between networks. The second approach, which is now a mandatory requirement for all public chargepoints, is as a means of 'Instant Access'\'Pay-as-You-Go', where charging can be carried out without membership. Options include 'chip and pin' payment, contactless payment or app-enabled e-wallets such as ApplePay. Some chargepoints that are serviced by a membership scheme may also have facilities that enable 'instant access' payment for non-members to charge their vehicles.

Key Points:

Section 1: Electric Vehicle Market Development

- EV uptake is a main driver for the implementation of chargepoints within parking structures as they serve as strategic locations with long dwell times. By 2030 the IEA is forecasting that EVs will reach 30% of EV sales globally.
- As the EV population increases public charging infrastructure is expected to become more important, however there are alternatives to car park charging infrastructure (including; workplace charging, destination charging and the increased use of rapid charging infrastructure) which may directly compete with car park charging business models.
- Before installing chargepoints within a car park, the local demand for charging (current and predicted) should be considered in order to identify the type and volume of charge points which should be installed.
- Booking, access and payment technologies are developing to drive a better customer experience when using public chargepoints; however these are still early stage and work is needed to support interoperability between systems.

4 www.theiet.org/resources/standards/ev-cop.cfm

2 Overview of Parking and Innovation

The focus of this report is on the opportunity for EV charging in public car parks. However, it is first helpful to set the scope by defining the types and features of car parks being considered.

2.1 Introduction to the Car Park Market

Q-Park, one of Europe's largest private car park operators, has estimated that the combined 28-member states of the EU parking market stands at 440 million spaces, the breakdown of which is shown in Table 2[5]. Many of these parking spaces are free to access; however this study focuses on the 30 million off street regulated (fee paying) car parking spaces which make up a subset of the final three categories.

Category	Definition	Number of spaces in EU-28
Residential & work	This includes private spaces allocated to a homeowner including on street private, driveways, private on street parking etc. For work parking this includes any spaces which are for the sole use of a business, its employees and any visitors.	155 m
On Street Public Space	This includes any on street parking which is not allocated and is for use by anyone, this may be pay and display or free depending on the model adopted	130 m
Off-Street Open Air/ Surface level parking	This includes any parking scheme where the entirety of the carpark is located off street and on ground level	115 m
Off Street Floors	This includes any off-street parking that encompasses more than one floor. This includes multi-storey car parks and multiple level subterranean car parking.	30 m
Off Street Purpose Built	This includes any purpose-built parking garage.	10 m

Table 2 Estimation of the breakdown of parking spaces in EU-28

Figure 2 provides a breakdown of the off-street parking spaces present in the EU-28, further to this the average revenue for each category has been plotted in Figure 3. This illustrates that the most valuable parking space on average are airport parking spaces followed closely by in structure parking.

[5] EU Car Parking Market", Q-Park, 2014

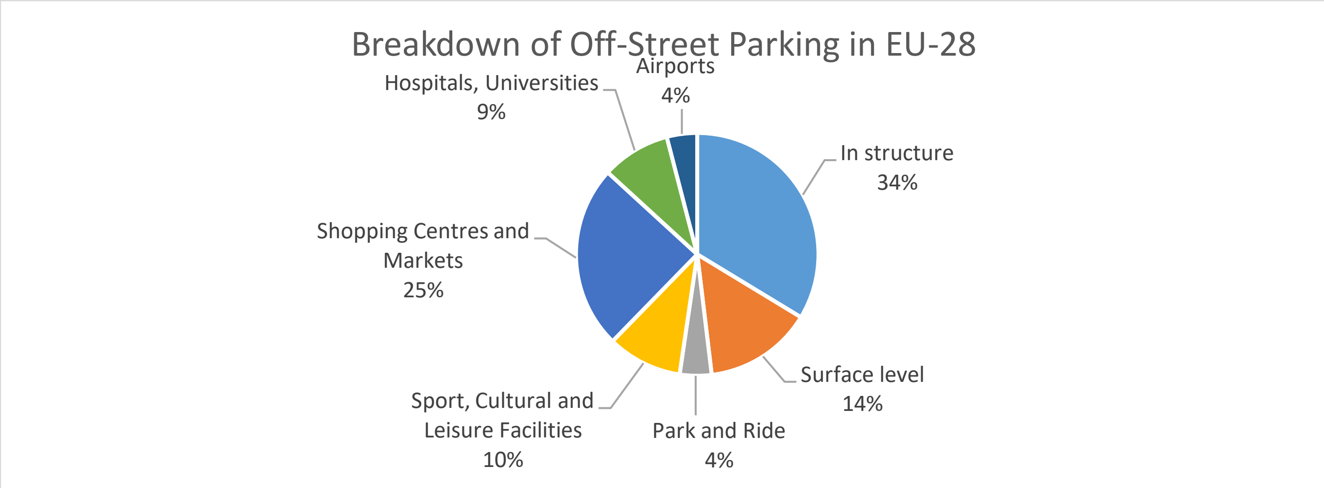


Figure 3 EU-28 Parking Stock Breakdown

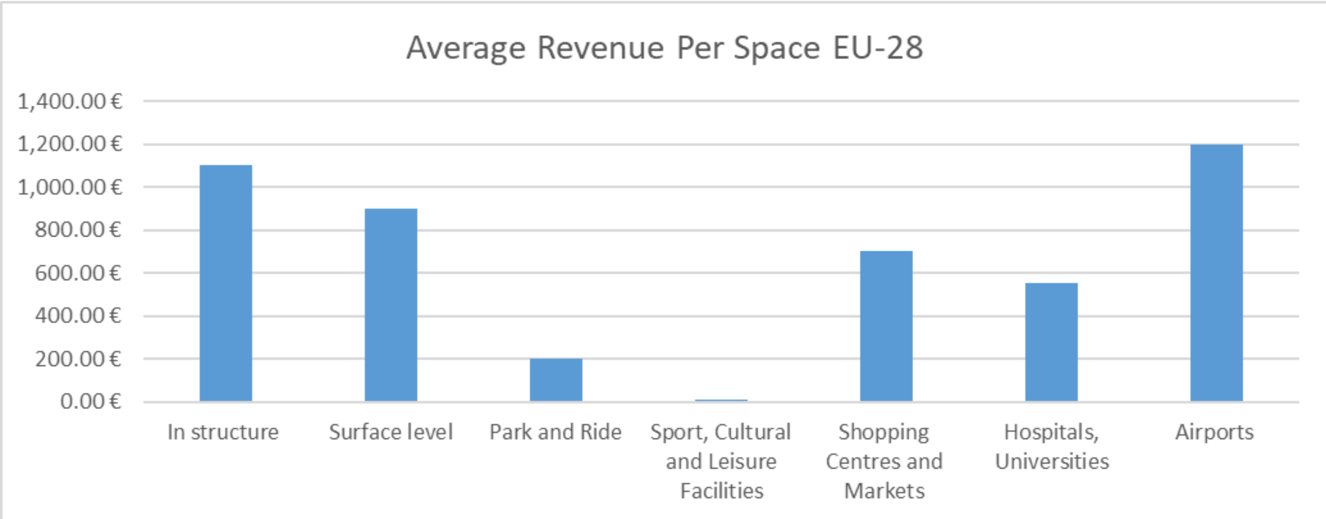


Figure 4 Most Valuable Parking Bays by Type in EU-28

Across the EU28, the largest private sector car park operators are Indigo-Infra Park (2. 1 million spaces), APCOA (1. 4 million spaces), Q-Park (835k spaces), Empark (530k spaces), Interparking (330k spaces), SABA (198k) and NCP (150k spaces)[6]. Indigo-Infra Park[7] reports that it owns only around 10% of its parking estate with about 90% being run under concessions let by public or private sector landholders, including shopping centres, hospitals and airports. According to private sector car park operators, concessions are typically let for time periods of 5, 7, 10 or 20 years. Municipalities may choose either to own and operate parking themselves or concession operation to private sector operations. In the latter case, any modifications to the site (such as installing EV charging) would be likely to require the agreement of the owner/landlord. This is particialary important because the use of the concession model may de-incentives the operator to make capital investments in infrastructure when the returns are subject to the concession being renewed by the concessionaire.

On a practical level the use of concessions for car parks can result in increased time to get approval for installations as well as impacting the duration of the install if landlord approvals are also required for DNO network upgrade works. Failing to have a good methodology for managing landlord approvals has historically resulted in some installations being cancelled or put on hold indefinitely. Therefore, it is

[6] S&P Global Data, Dec 2017

[7] "Infra Park Group, 2017 Full Year Results", Infra Park Group, 2018

important to understand where landlords many be involved in approval processes and to ensure that a robust approach is in place for managing this relationship.

2.2 UK Market Focus

Market research from 2013[8] estimated that there are more than 17,000 parking facilities in the UK, with around 48% of these facilities falling under local authority control. To facilitate even a small penetration of EVs into the UK vehicle stock, it can be argued that a significant proportion of these facilities will need to have at least a minimum viable level (2 or more outlets) of chargepoints availability. However, rather than seeing this as a requirement, car park operators could view this as an opportunity to encourage new customers and diversify their income streams by offering new services.

The main car companies active in the UK market include APCOA Parking, Euro Car Parks, National Car Parks (NCP) and Q-Park. Many of these operators have existing commercial relationships with chargepoint network operators (APCOA with New Motion, Q-Parks with Chargemaster, Tesla and Franklin Energy, etc), effectively leasing space for charging within the car park, separate from the car park operators. By Contrast, Councils have typically purchased chargepoints for the car parks they control with companies including APT, Rolec and Pod Point having supplied chargepoints.

Although they only account for 7% of the 17,000 sites identified in the BPA survey, multi-storey and underground car parks represent an important target for roll out of charging infrastructure.

As of September 2017, the UK 'Park Mark: Safer Parking Scheme'[9] had more than 5,000 award holding car parks. Table 3 shows the breakdown of available spaces within the scheme by car park type, as well as the number of EV charging spaces. From the table its noticeable that multi-storey car parks are currently leading the way in EV charging bays, but there is still a considerable disparity between the number of spaces available and the number being used for EV charging. Of the 504,739 available parking spaces only 403 (0.08%) are EV charging bays.

Car Park Type	Spaces	EV Charging Spaces
Multi-storey	504,739	403
Surface	146,319	73
Underground	44,912	142
Surface-Urban	708,757	178
Surface-Rural	92,730	4
Multi/Surface	24,343	4
Lift Operated	308	0
Roof Top	4,424	0

Table 3 Breakdown of Available Spaces and EV Charging Spaces by Car Park Type

By evaluating the data from the Park Mark Scheme, it can be seen that there is a large market for the rollout of EV charging capabilities within car parks in the UK. In addition, the diversity of structures (multi-storey, surface and underground) and locations presents an opportunity for different solutions to be deployed based on the dwell time of the location.

2.2.1 *Aging Parking Facilities in the UK*

The challenge of implementing any new technology into existing structures is that the targeted structure was not built with the new technology in mind. The British Parking Association (BPA) analysis identified that 20% of multi-storey car park sites are 40 or more years old. The age of the UK multi-storey car park estate is a challenge for EV roll out as;

- Many of the older car parks may lack the embedded electrical capacity needed to support the levels of charging required for a wholesale switch to EVs. This means that the cabling that is present within the carparks has been rated for parking related energy demands. For most this

8 "The size and shape of the UK parking profession", British Parking Association, 2013

9 http://www.britishparking.co.uk/Safer-Parking-Scheme-/-Park-Mark

includes lighting, electronic signage and lift facilities. Therefore, the electrical equipment may not have sufficient headroom to allow for EV charging to be incorporated.

- Many sites may not have sufficient low voltage capacity at the supporting substation(s) to increase electricity supply for the addition of chargers. The result of this is the requirement for a rollout of upgrades to the substations affected by low capacity levels. Whilst the short-term effect will be a large capital expenditure, the long-term benefits of future proofing the structure could be highly beneficial.

These challenges can either be overcome by investments to upgrade electricity supply or through energy management approaches (discussed further in section 5 of this report).

2.3 Innovation Themes in Car Parking

There is a consensus view within the motor industry that the key trends driving vehicle innovation are:

- shared ownership and use of vehicles,
- electrified powertrains,
- autonomous operation,
- connectivity based on vehicle communication with digitised infrastructure and other vehicles.

This is captured under the acronym of ACES, which stands for 'Autonomous, Connected, Electric and Shared'. The ACES transformation is also driving innovation in the transport infrastructure industry that supports mobility, including car parking. Consistent with this rationale, car park operator Indigo-Infra Park[10] differentiates between 3 major user-led disruptions:

- shared mobility,
- on-demand mobility,
- multi-modal mobility.

Outside of the automotive industry the key aspects of the ACES transformation are often referred to as 'Smart Mobility'. This definition seeks to capture the convergence of Information and Communication Technology (ICT), transport systems and energy management to enable new mobility service offerings. The trend toward the electrification and digitisation of road transport is driving innovation in supporting energy infrastructure as well as in telematics and intelligent transport systems, as illustrated in Figure 5. A concurrent transition to Smart Parking combines innovation in wayfinding (navigation advice for motorists and pedestrians leading up to and within car parks), ticketing\payment for car parking and the integration of novel technologies within the energy management of car parks. All three areas can be 'smart'-enabled by back-office ICT systems.

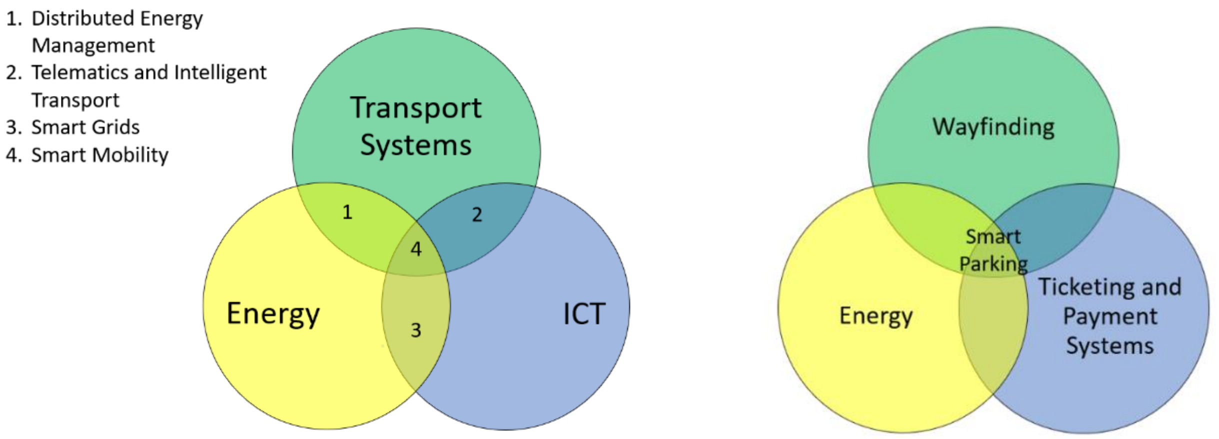


Figure 5 Smart Mobility and Smart Parking

10 "Infra Park Group, 2017 Full Year Results", Infra Park Group, 2018

The focus of this report is on EV charging, which falls within the energy management theme. However, as will be shown in this report, there is a trend toward Smart Parking solutions which simultaneously address overlap areas between wayfinding, parking equipment (access control and payment) and the energy solutions within car parks that will help support EV uptake.

A 2018 survey by the international Parking Institute (IPI) asked members to select the areas where trends are emerging in the parking sector. The need to accommodate EVs and EV charging infrastructure drew votes from 39%[11] of the survey audience, as shown in Figure 6. This is an increase of 19% versus the 2015 survey in which only 20% of members considered EV charging infrastructure to be an emerging trend in the parking sector. This indicates the increasing importance of EV charging in the modern car park.

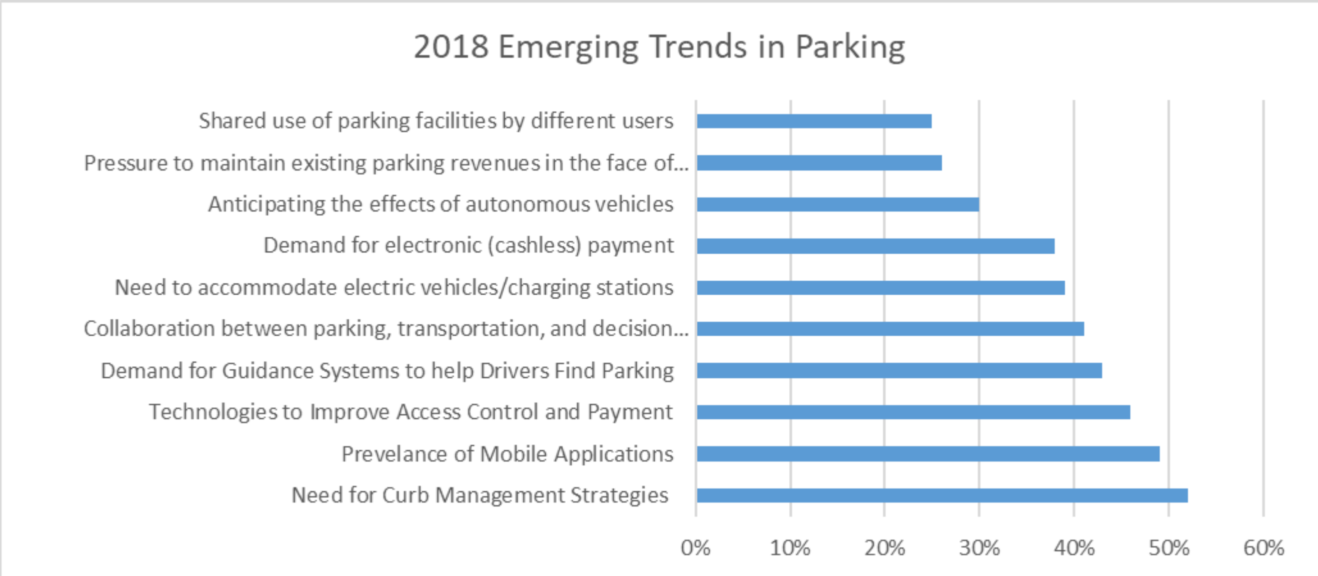


Figure 6 2018 Emerging Trends in Parking[11]

Key Points:

Section 2: Overview of Parking and Innovation

- Regulated (fee charging) car parks are common across developed-world towns and cities with more than 30 million car parking spaces in EU28 countries.
- Control of car parks is split between many local government (municipalities) and commercial operators, with several large specialist private sector car park operators controlling extensive car park estates and operating across national boundaries.
- EV market penetration would benefit from large numbers of chargepoints being deployed across these car park estates. Already, in the UK, small numbers of chargepoints are being added to multi-storey, underground and surface car parks in urban centres.
- Many car park buildings and structures were built long ago as a result there are electricity supply constraints which may limit the retrofitting large numbers of chargepoints to car parks without supporting investments or innovative approaches to energy management.

[11] 2018 Emerging Trends in Parking, Report on a survey conducted by the international Parking Institute. *Note: 'Curb management strategies' refers to the designation (permanently or temporarily) of curb side parking areas for different purposes, including loading/unloading, keep clear, customer only parking and other designations. As transport methods diversify, there is increasing recognition of the need for curb side management to update to match varying demands and usages.*

3 Overview of Charging Equipment for Car Parks

EV charging methods can be broken down into two main connector types; AC connectors and DC connectors. Figure 7 shows the most common connection types for both AC and DC Chargers.

Figure 7 Types of Slow, Fast and Rapid Connectors

The connectors depend on the vehicle and generally which region of the world it is from. Japanese vehicle manufacturers such as Nissan and Mitsubishi have favoured the CHAdeMo connector (which originated in Japan) for DC charging and Type 1 and 2 connectors for AC charging. European vehicle manufacturers have been standardising around the CCS connector for DC charging and the Type 2 connector for AC charging.

The main advantage of the DC charging is that it is possible to achieve higher power ratings for charging. While this is possible for AC charging, the need for the on-board converter to be large enough to cope with high power charging would make it too expensive and too large to use.

In the UK, type 2 connectors are used for all AC chargepoints, with DC chargepoints typically offering both CHAdeMo and CCS.

3.1 Charging Speeds

Currently EV charging systems are categorised by power output, as shown in Table 4.

Output Power Level	Minimum Power	Maximum Power
Slow/Standard	- kW	<7 kW
Fast	7 kW	25 kW
Rapid	43 kW	62 kW
Ultra-rapid	62 kW	500 kW (+)

Table 4 Charging Speed Bandings

3.1.1 *Slow Charging (<7kW)*

Slow charging utilises standard three-pin sockets. The limited power available from these sockets means that charging units experience long charging times; where the vehicle will be stationary for eight or more hours there is no requirement for higher rated charging systems to be installed. Slow chargers are currently in use in car parks across the country where there is evidence of long dwell times for electric vehicles. Slow charging also reduces the impact of charging on the building peak demand and the local distribution network, allowing for greater numbers of parking bays to be electrified. Airports, train stations and other destination multi-storeys would be an ideal place for the implementation of slow charging facilities. Typically, a slow charger can cost up to £300[12] for the hardware, although costs may be higher if billing and energy management is required.

3.1.2 *Standard Charging AC (3. 5-7kW)*

Standard charging is defined as charging that occurs between 3.7kW and 7kW using an AC power source. For typical EV battery sizes (15 to 60 kWh), these chargepoints can provide a full charge to a vehicle within 2 to 8 hours for 3.6kW chargers and within 3 to 5 hours for a 7kW. In real-world operation EVs will retain varying amounts of stored energy (state of charge) when plugging in so times to charge to full battery capacity will be quicker in most cases. Standard Charging (AC) fits the profile for longer dwell car parks that frequently have vehicles parked for more than 4 hours. Typically, the cost of chargers is dependent on the power rating of the unit. Table 5 shows the indicative costs of standard chargers, excluding installation costs. It is worth nothing that the cost of the unit can also include the cost of foundations including steel, this means that the cost of mounting a unit on the ground can be considerably higher than the wall mounted units.

Chargepoint Type	Cost Range[12]
Type 2 3.6kW Wall Mounted	£300-£500
Type 2 Wall Mounted 7kW	£750-1,500
Dual Type 2 Wall Mounted 7 kW	£1,700-2,700
Dual Ground Mounted 7kW	£1,700-5,000

Table 5 Indicative Costs of Standard Chargers (UK EVSE)

3.1.1 *Fast Charging (7-23kW)*

Fast charging typically enables charging up to 80% in 3-5 hours for a 7kW chargepoint and 1 – 2 hours for a 22kW chargepoint. These chargepoints are commonly found in areas where dwell commonly ranges between 1-4 hours such as supermarkets and shopping centres. Fast chargers would suit medium dwell car parks as they would allow a full charge to take place in the time period that the user would expect to remain.

Chargepoint Type	Cost Range[12]
Dual Type 2 Wall Mounted 22kW	£1,800-4,000
Dual Type 2 Ground Mounted 22kW	£3,000-5,000
Triple outlet 25kW Ground Mounted	£12,000 - £18,000

Table 6 Fast Charger Typical Costs

12 All costs indicated are gross costs (i.e not including incentives or tax breaks). Incentives, where available, may reduce the net cost to the customer.

3.1.2 *Rapid Charging*

Rapid charging utilises chargepoints rated between 43 kW and 62.5 kW. For the majority of EVs, these chargers can provide up to 80% of the vehicles charge in 20 to 40 minutes. However, for EVs with very large battery pack sizes, such as the Tesla product range, the charging time can be longer.

These charging facilities are suited to short stay car parks where the expected turnaround for vehicles is less than an hour, such as smaller supermarkets or fast food restaurants. In the context of car parks, one of the key challenges facing rapid charging infrastructure is that it sits difficultly between fast and ultra-rapid charging. Rapid charging has higher implementation costs when compared with slow and fast charging, however the charging time is relatively long compared to ultra-rapid charging. Therefore, in order to recover the initial investment of rapid chargers it is important to ensure that there is a high turnover of users which does not fit well with long or medium stay car parks.

Table 7 indicates costs of a typical rapid charger, excluding installation and civils etc.

Chargepoint Type	Cost Range
Duel Outlet 43-50 kW, Type 2 and CHAdeMo	£15,00-26,000
Triple outlet 43-50kW, Type 2, CHAdeMO and CCS	£16,000-30,000

Table 7 Rapid Charger Indicative Costs (UK EVSE)

3.1.3 *Ultra-Rapid Charging*

The charging methods discussed previously represent a significant behavioural change compared to refuelling an ICE vehicle. As a result, there is strong support, particularly from automotive manufacturers for faster charging methods which are more aligned with the speed of current refuelling methods (minutes). For this reason, several car companies[13] are supporting the development and roll out of ultra-rapid chargers with power outputs between 120 kW and 400 kW. These types of charger are considered best suited to supporting inter-city travel, as with the Telsa Supercharger network. Ultra-rapid charging is therefore, highly unlikely to be deployed within city centre multi-storey car parks. Currently the costs indicated by DBT suggest that an ultra-rapid charger ranges between €35,000 and €60,000[14] per unit, excluding installation or any supply upgrades that may be required.

[13] www.ionity.eu/ionity-en.html#whoweare

[14] European Leader in Fast Chargers - DBT Groupe. (2017).

3.2 Mounting Methods

Indoor multi-storey and basement car parks tend to favour wall mounted units, which take up less space and can be fed using cabling on the surface of walls and ceilings. However, for central areas within a floor, floor mounted chargepoints may need to be used as wall space is not available (Figure 8). Floor mounted chargepoints are also common across surface parking.

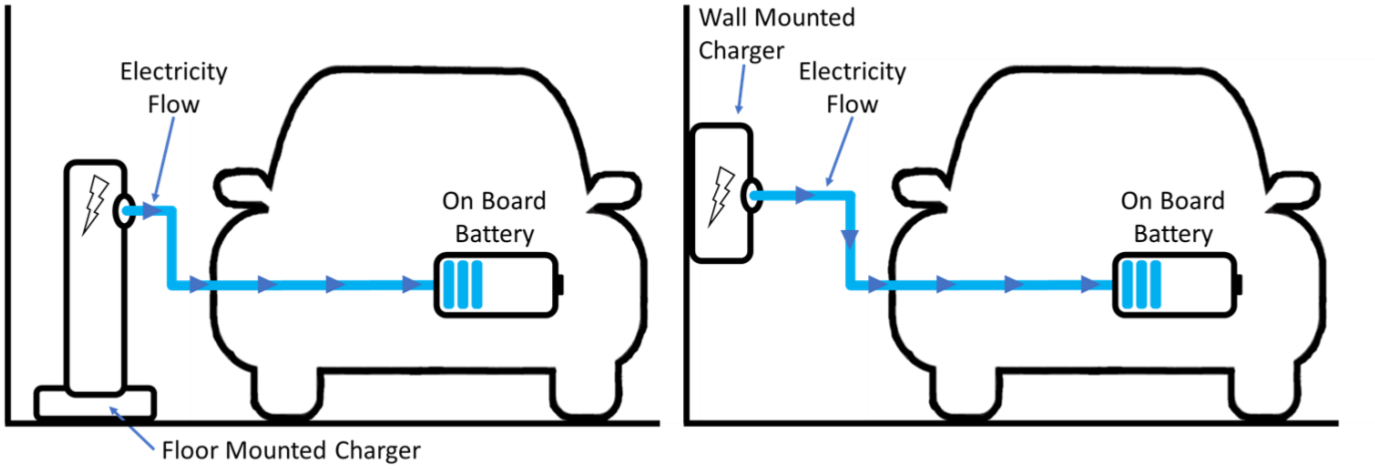


Figure 8 Typical Mounting Methods for EV Chargepoints

When it comes to locating chargepoints, ventilation and cooling become key factors. Air flow to charging equipment is critical for preventing overheating and ensuring safe and effective working of the power electronics. Trailing cables can also create trip hazards and unnecessary obstructions. This can be minimised for slow and fast charging by installing non-tethered units where users provide their own charging cables. This also reduces the requirement to provide both type 1 and 2 connectors to the chargepoint. Where tethered (non-detachable) charging cables are employed, provision should be made for safe storage when not in use. Furthermore, the placement of the chargepoint should not present any unnecessary obstructions to walkways, passages, fire escapes or any other areas that see high footfall.

In addition to the more standard approaches described, several innovative mounting methods have been developed specifically with car parks in mind. These are set out in the following sections.

3.2.1 *Ceiling Mounted Chargers*

For multi-storey car parks, mounting the charger on a bracket attached to the ceiling of the structure provides an alternative to wall or floor mounted units, as illustrated in Figure 9.

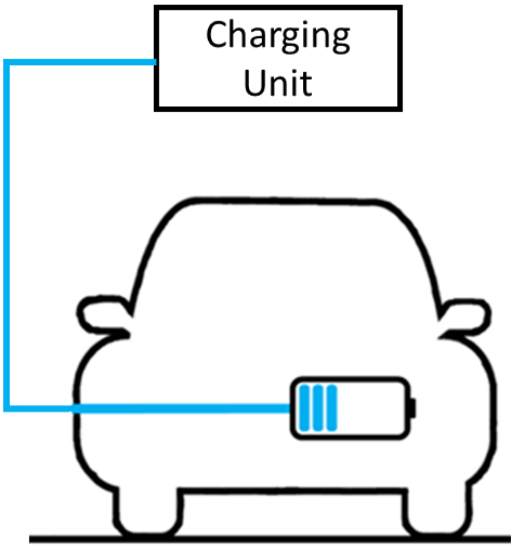


Figure 9 Ceiling Mounted Charging System

For this approach to be practical the connector cable needs to be extendable to reach the front, rear, or side of the EV, depending on where the vehicles charging socket is located.

The benefit of this approach is that no parking bay space is lost through the addition of the charger, making it an alternative where floor or wall units wouldn't be appropriate. However, the downside of this mounting approach is that it could be difficult to reach up to take hold of the connector and extend the cable to the location of the socket (particularly for wheelchair bound EV users). This layout also requires a tethered cable or for the unit to be mounted low enough to allow all users to have access. The potential reduction in head room above the bay is also a potential barrier to use of this mounting system as it may limit the type of vehicle which could make use of the bay.

To make it easier to stretch the cable to the vehicle, the unit itself could be mounted on a roller mechanism to allow movement along part of the length of the parking bay. However, this adds further complexity and cost to the charger. For these reasons ceiling mounted chargepoints in public settings are rare.

3.2.2 *Master and Slave Chargers*

Where there are several chargepoints being deployed, there is the option to use a "master and slave" configuration, where a central master unit is used to control a number of slave units. This typically allows up to 32 slave units to be controlled by the central master control unit. The main benefit of this approach is cost saving as functionality doesn't need to be replicated across all chargepoints. The intelligence in the master unit would control the power delivery to the vehicles dependant on how many vehicles are plugged in. In addition, the master unit could operate in a similar fashion to a central payment terminal that are frequently used in car parks today, potentially integrating energy and parking payment systems.

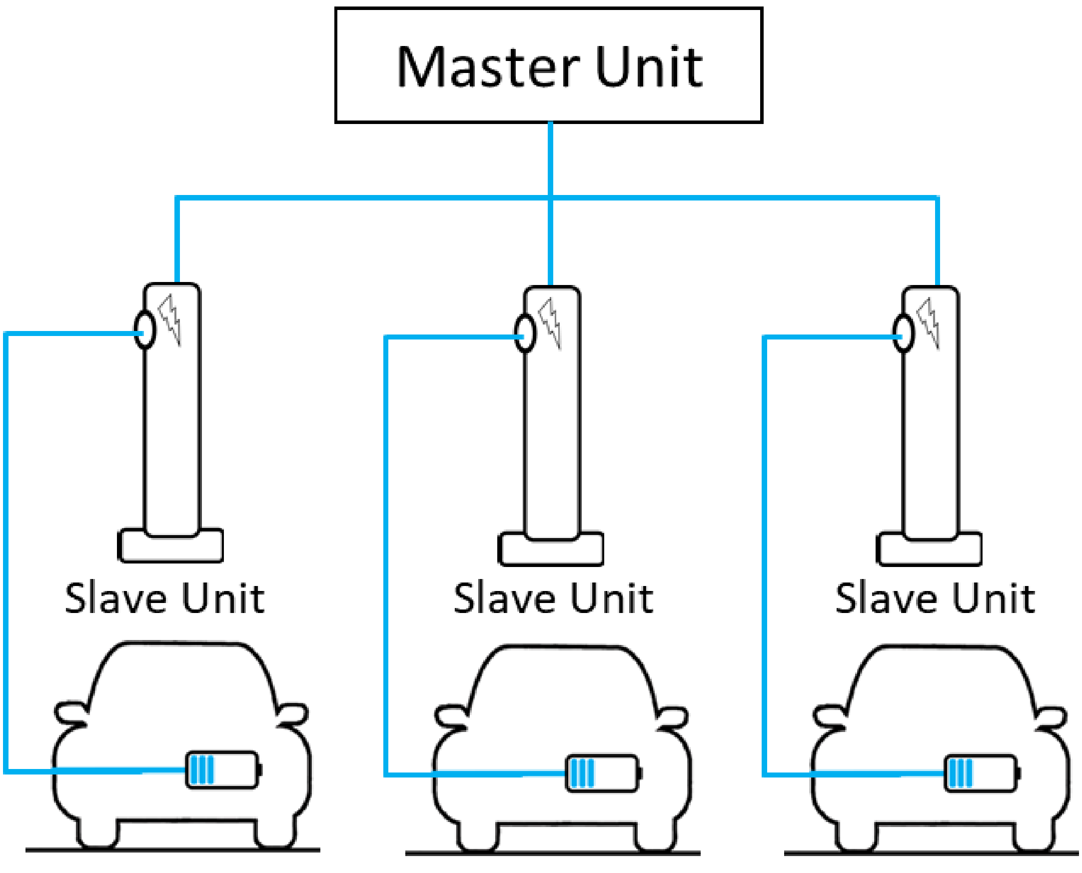


Figure 10 Master and Slave EV Charging Concept

3.2.3 *Inductive Charging*

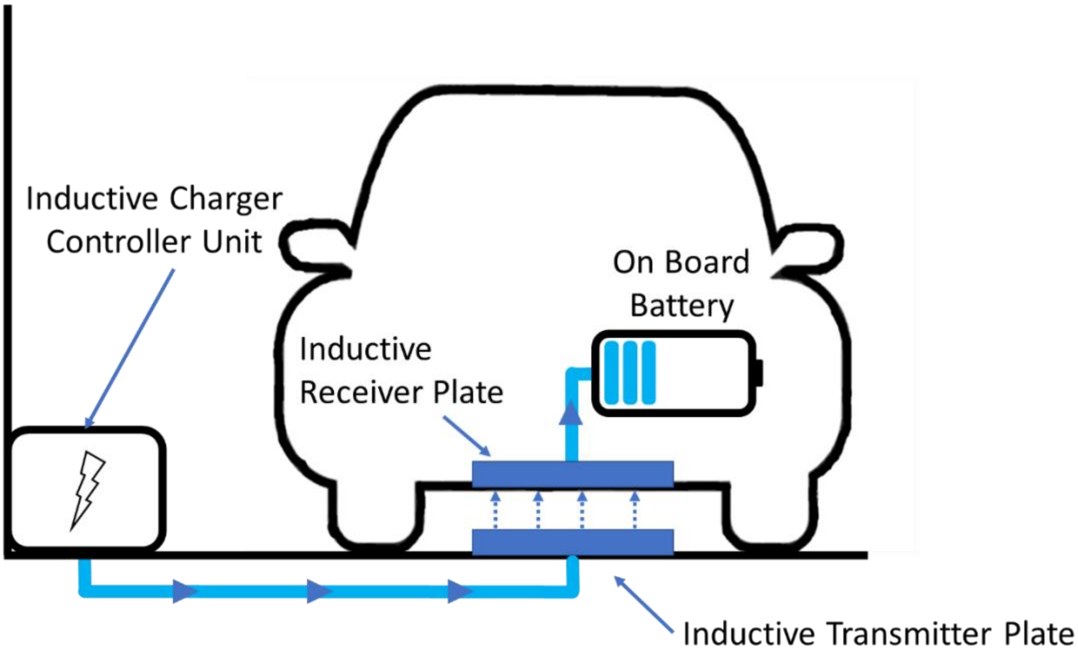


Figure 11 Inductive Charging Layout

Inductive charging offers an attractive alternative for motorists as it does not require a connector cable between the vehicle and chargepoint. This reduces the poor aesthetic and safety concerns of charging cables protruding from both vehicle and chargepoint.

Inductive charging is made possible by electromagnetic induction where a primary coil (inductive transmitter plate) is located on, or embedded in, the ground, and the secondary coil (inductive receiver plate) is placed under the EV. Current commercially available units are limited to slow charging, however, there are prototypes available that can achieve higher power transfer. The main limitation is that the higher power systems require larger, more incumbent transmission pads.

At present very, few existing vehicles facilitate inductive charging, meaning that vehicles require retrofitting of induction charging plates in order to make use of this charging method. Currently there are a number of different approaches for inductive charging, meaning that not all vehicles will be compatible with all inductive chargers. This presents a risk to early adopters of the technology.

Current inductive charging systems are also heavily dependent on the accuracy of the driver lining up the transmitter and receiver plates. Even small misalignment can result in reduced efficiency of power transfer, and significant misalignment may stop a system working at all. While industry is currently tackling this issue, the future use of autonomous self-parking cars is likely to offer increased parking accuracy and therefore, more efficient use of inductive charging, as the vehicles will be able to use 'Vehicle-to-Infrastructure' sensors to locate and align parking more accurately than a motorist could. At the current time of writing, the deployment of inductive charging in the UK is being held up by the lack of commercially ready induction charging compliant EV models.

Early forecasted figures put the cost of inductive chargers at a £850/kW for large applications (100kW+) and £400/kW for domestic (3.2kW) chargers[15].

[15] "A national power Infrastructure for charge-on-the-move", D. Nicolaides, PhD thesis, 2018

3.3 Considerations for Access

As the uptake of EVs increases, charging facilities must be able to accommodate all types of customers. This includes considerations for both able-bodied and disabled users. Standards for parking equipment (ticketing\payment machine) have already been developed, as illustrated in Figure 12. The IET propose that similar height considerations are made for charging equipment, where the mounting height of the charger is no more than 0.75m and the control screen is no higher than 1.2m above the ground. However, for chargepoints, particularly wall mounted units, once a vehicle is parked, access to the chargepoint can be restricted, with a wheelchair user potentially unable to move between parked cars to reach the wall to plug-in. Disabled parking bays tend to be more generously sized, but charging may remain an issue within these bays and there will be opportunities for design innovation.

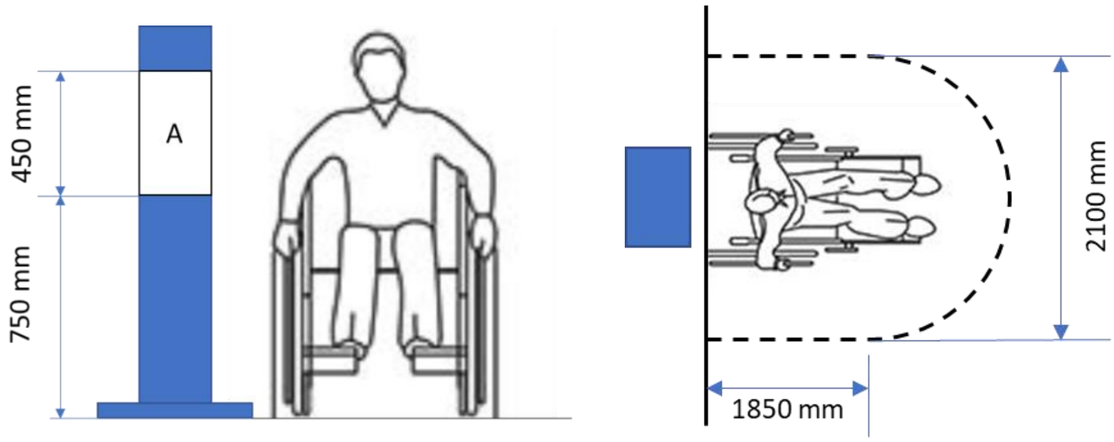


Figure 12 Height of Controls for Parking Equipment Accessibility

Key Points:

Section 3: Overview of Charging Equipment for Car Parks

- Chargers range from slow (3kW AC) to rapid charger (50-150kW AC/DC) with the future potential for Ultrafast charging (350kW+ DC)
- The required power ratings for charging equipment in multi-storey car parks is mainly defined by the typical dwell time of vehicles. Long stay car parks would, therefore, make use of slow chargers.
- As a concept, inductive charging provides a very applicable charging method to implement within multi-story car parks. At present the technology is not market ready, however, if it becomes economically viable then there is likely to be a good case for installation within car parks.
- The choice of mounting method depends on the proposed location of charging equipment within the type of car park and it is common for different mounting methods to be used across a single site. Wall units are favored for multi-storey car parks. Currently these are typically individual units in pairs or small groups.
- Master and slave units offer a means of applying intelligent control from a master to a large number of 'dumb' charge points, whilst keeping the overall costs down for the units.

4 Civil and Electrical Works Considerations

4.1 Civil Works Considerations

While charger types and mounting methods are important, it is often civil (ground) works which can be the most expensive part of installing a charging system, and in some cases the cost of civil works can make or break the viability of a project. In the case of new parking structures, a proportion of the civil works that are expected as part of the installation of chargepoints can be absorbed in the cost of the project and implemented in a way that does not disrupt the flow of the project as a whole. However, when retrofitting anything into an existing structure there is a requirement to ensure that the structure will be fit for purpose both before implementation and after retrofitting has taken place.

For the most part, the EV charging facilities that are in use in multi-storeys across the UK at present are placed on the lowest deck of the structure. This is typically because the distribution board of the structure is at ground level, allowing ease of installation. However, as the number of chargepoints being installed within the structure goes up, this will introduce additional costs and challenges.

Civil and electrical works ensure that the hardware is installed safely and effectively. However, civil work also has a part to play in the user-friendliness of an installation. These elements are explored below.

4.1.1 *Anti-Collision Barriers*

Anti-collision barriers are suggested by the 'IET Code of Practice on Electric Vehicle Charging Equipment Installation'[16]. This is to ensure that the chargepoint is not vulnerable to damage should a vehicle collide with it. Ideally the barrier will have secure anchorage to help it withstand impact. Example arrangements of anti-collision barriers are shown in Figure 13. Whilst barriers can provide added protection, they can also negatively impact the aesthetics of an installation. Many installations employ the use of a 'wheel stop', shown on the right of Figure 13. The installation of the wheel stop provides protection to ground mounted charging equipment by preventing vehicles from getting close enough to impact the unit.

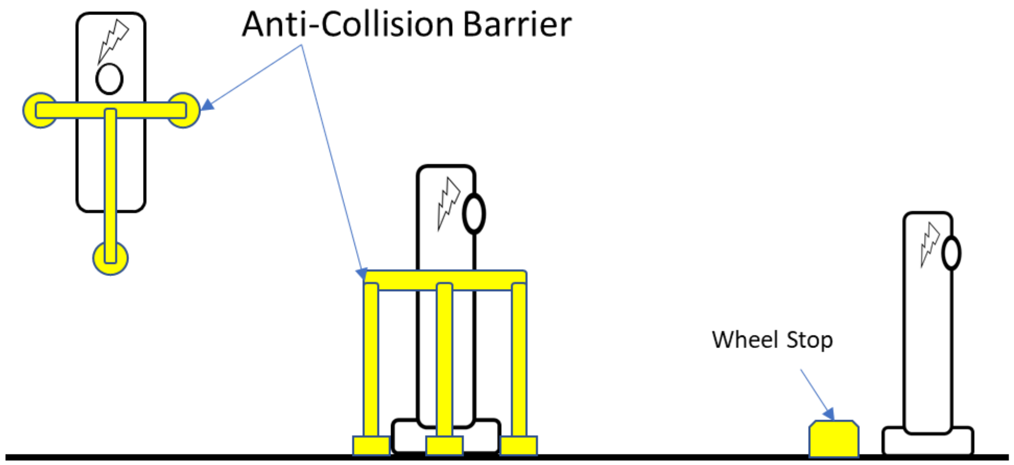


Figure 13 Configurations of anti-collision barriers

4.1.2 *Groundworks for Cabling*

The groundworks required for the running of power and communication cables depend on the nature of the installation. For surface car parks, powerlines are buried in the ground to protect against disturbance. However, for indoor structures, cabling can be run external to walls. For multi-storey installation of chargepoints, additional cabling will be required to take power to each of the levels. This could potentially require additional protection switches and/or distribution boards for each level of the structure. Further complications arise when utilising smart charging technology, there may be the requirement for data cables to be laid, which in some cases could increase the width of the cable trays/underground channels. This would in turn increase the cost of the installation, though it may be marginal. The increased costs can be avoided by making use of existing cable routes and installing chargers at locations that are within reach of the distribution points on each floor.

16 "IET Code of Practice on Electric Vehicle Charging Equipment Installation", IET, 2012

4.1.3 *Markings and Signage*

Where EV charging is provided for a limited number of bays. It is important to provide clear demarcation to prevent non-EVs from using the bays and to help EV drivers locate the charging bays. The most common approach is to paint signage within bays, as shown in Figure 14. However, smart signage and wayfinding are investigated in Section 7.1.2. There are currently standards that apply to the road markings of EV charging points but at this point they have been loosely interpreted, resulting in a range of marking schemes being employed. Further standardisation of the markings would allow for users to recognise the charging bays more effectively.

Figure 14 EV Chargepoint Road Markings

4.2 Electrical Works Considerations

The infrastructure requirements for EV charging fall into the three areas illustrated in Figure 15:

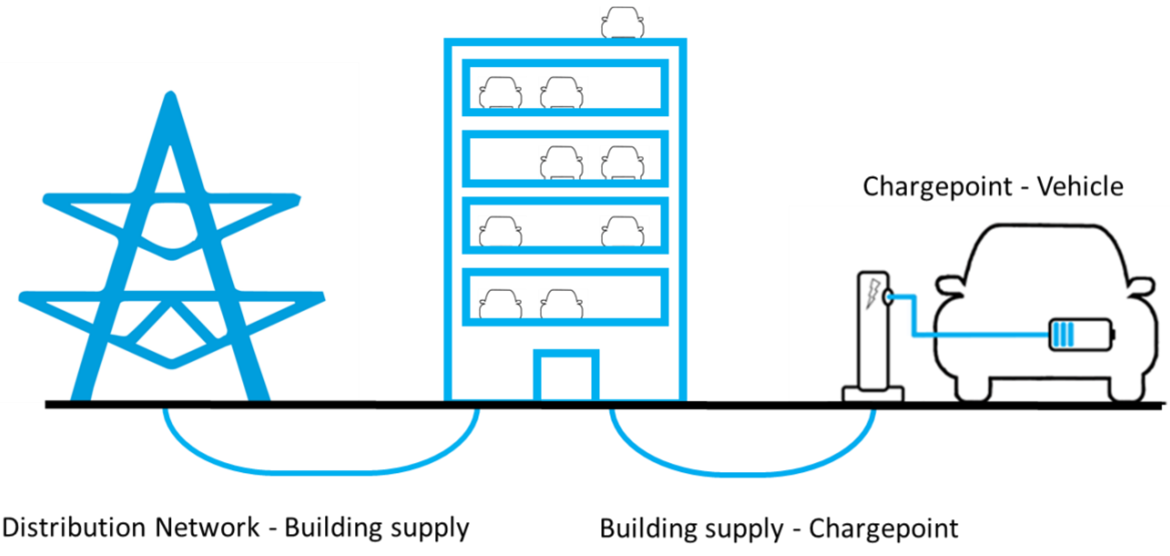


Figure 15 Infrastructure Requirements

The car park operator would be responsible for the safe installation of equipment between the building and the chargepoint. The 'IET Code of Practise on Electric Vehicle Charging Equipment Installation' provides guidance on the connection of EV chargepoints for both open air (surface carparks) and indoor carpark applications.

Another potential issue surrounding the clustering of EVs within car parks is the capacity available to the building from the local distribution network, should the provision of chargepoints result in the local substation requiring upgrading then the cost of upgrade is passed to the person/organisation that requested. This cost can be prohibitive and can potentially render the project financially unviable.

To give an idea of potential cost of installation an example real life project is discussed below:

For the Netform project, Encraft[17] assessed the electrical requirements for a new build multi-storey car park proposal planned for the HS2 Interchange Station in Birmingham. The 'from new' cost for electrical wiring was about £1,000 per 22 kW charger, combined with £16,000 per charger for the unit and installation cost. For retrofitting car parks, the electrical wiring costs may be lower as infrastructure will already be in place. Western Power Distribution provided Encraft with connection cost estimates based on available capacity on the low voltage distribution system. The cost for the car park adding charge points to up to 1,000 spaces £564 per charger. However, this jumped to £45.5M (£15k per charger) for 3,000 chargers as a major substation upgrade was needed to meet this electricity supply requirement, even considering a 60% diversity factor.

Key Points:

Section 4: Civil and Electrical Considerations

- Chargepoint installations in car parks require associated civil works for collision protection where chargers stand alone.
- Signage and road markings should be clear, making the charging bays easily identifiable.
- To retrofit car parks with chargers, electrical wiring upgrades may be needed to provide sufficient power capacity. For connection to the local low voltage distribution system, a single one-off upgrade cost may also be required, which would fall to the car park operator to pay.

17 Encraft, sourced April 2018

5 Load Management

Where standard chargers could be deployed in large numbers within existing car parks, there would be a risk that the electrical wiring within the car park and the local substation supporting the car park would be unable to cope with the additional electrical demand.

Technologies are being introduced to mitigate the challenges of additional electricity demand, or to turn the additional demand to profitable use. For example:

- **Smart charging (V1G)**, whereby the time that vehicles are charged, and the rate of charging can be controlled to provide additional services such as avoiding peak energy rate periods or limiting the peak demand from a group of charge points.
- **Vehicle-to-Grid (V2G)** also referred to as bi-directional dis/charging, refers chargepoints which, in addition to providing standard charging systems for EVs, are capable of discharging power from the vehicle back into the building or local network. This can be used to provide grid services, to support building electrical demand, or to provide services to EV drivers.

When considering the application of car parks, while each option may offer a range of different benefits, either system would allow car park operators to limit the peak demand of EV charging and therefore support the installation of larger volumes of charging than would otherwise be achievable. Typically, DNOs will allow up to 25% greater capacity to be installed using a load management system than without. It is worth noting that the deployment of smart charging or V2G systems benefit greatly from long dwell time, it's likely that customers would not see any benefit in derating their charger or discharging the battery when their only objective whilst away from the vehicle is to charge. It is therefore not advised to implement smart charging systems or V2G in short dwell locations.

Smart Charging and V2G technologies are discussed in more detail below.

5.1 Smart Charging

The mechanism for Smart Charging is like that of standard charging where electricity flows in one direction, via the charger to the EV battery. However, smart chargers can be controlled so that power transfer to the vehicle can be managed both in terms of when charging occurs (scheduling) but also by controlling the power transfer rate at which charging takes place. Smart charging enables demand shifting which can then be utilised to provide energy services including:

- Time of use (TOU) tariff optimisation,
- Peak demand shaving,
- Network constraint management,
- Simple renewable optimisation.

Smart charging remains unidirectional (charging only) and does not support export of power from the EV to the grid. As discussed above, V1G can be used to provide a range of services. The definition of V1G charging is currently inconsistent in the market, resulting in products being labelled as 'Smart' while offering anything from simple scheduling of charging based on user inputs, to fully dynamic systems which monitor and respond to market signals.

Smart charging counts as a form of 'Export Limitation Scheme' (ELS) under the distribution code, and therefore can be utilised to enable large numbers of EVSE to be installed at a site while maintaining a set capacity limit. Key applications for this are public and workplace car parks, where the local distribution network may not be sufficient for large numbers of concurrently connected standard chargers without resulting in significant upgrade costs.

Smart charging is already in the process of introduction to the market by electric vehicle supply equipment suppliers, these early applications typically are aimed at small scale, localised load management services. An example of this is Circontrol's Dynamic Load Balancing Server, this offers real time control of the power requests from clusters of chargepoints. The server tunes down the power provided to each chargepoint when a local system limit is reached. The price for the increased functionality included with smart charging is typically an additional £200-£300.

The UK Government has mandated that all domestic chargers are required to be smart by July 2019, meaning that dumb charging units will no longer qualify for the EVHS. The likelihood is that this will be expanded to cover public charging systems in the future to reduce the impact of publicly charging EVs on the network.

5.2 Vehicle to Grid (V2G)

The main concept behind V2G is to utilise the large battery packs on board electric vehicles as energy storage, allowing electrical energy to be charged into the vehicles at one time (often when electricity prices are low or when there is excess local generation) and stored, with the option of selling the energy back to the grid when prices are higher (e. g. during early evening peaks in electricity demand). Further value can be found by participation in ancillary services such as the Frequency response market in the UK.

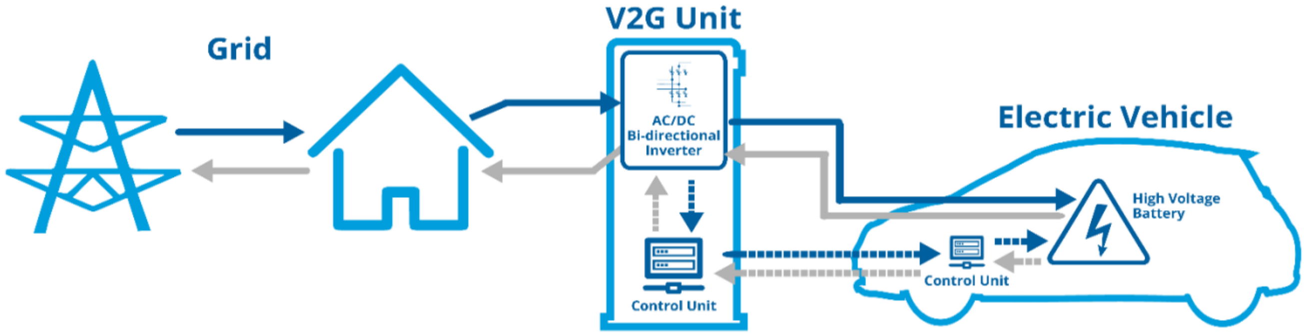


Figure 16 Vehicle to Grid System Diagram

Thanks to the added capability of bidirectionality, V2G can be used to provide a range of services at different levels in the energy system through demand shifting, generating (discharging) or a combination of the two. These can be broken down into the following areas:

- **Behind the Meter (BTM):** These are benefits such as peak charge avoidance or increasing utilisation of renewable generation which can be monetised directly by the customer.
- **Transmission System Services:** These are services such as capacity markets and balancing services which can be contracted through the Transmission System Operator (TSO).
- **Distribution System Services:** Similar to TSO services, these are contracted through the Distribution System Operator (DSO) for provision of services at the distribution network level. These services are usually geographically specific and relate to the needs of the network in that location. Unlike TSO services, the provision of these services from DSR assets is in its infancy in most countries, although some small-scale services are in commercial operation, most notably in Sweden.
- **Wholesale Energy Market:** Energy is traded ahead of time, meaning that traders must predict the demand and generation requirement for any time period. Within this period, the trader must control their assets/contracts to manage any variance or 'imbalance'. Traders gain financially through trades but are financially penalised for any imbalance. DSR gives traders increased flexibility in their portfolio, which enables these imbalance costs to be reduced. Wholesale energy trading is limited to energy suppliers in many countries, although some utilise 'balance responsible partners' (BRPs) which enables non-energy suppliers who manage an energy portfolio, such as aggregators, to access this market.
- **Peer-to-Peer Services:** This is a relatively new concept. Where customers have a direct connection or sit under a single network node such as in a micro-grid, it may be possible to 'trade' energy locally at a better rate than could be achieved externally or to enable a non-financial benefit such as reduced dependence on the grid.

From the service areas discussed above it is clear that the potential for V2G market participation is promising; however, there are a number of barriers to participation that require resolving to allow V2G to become a larger part of the energy mix in the UK. At present most of the TSO markets are not easily accessed. This, coupled with the fact that these markets were not designed with intermittent storage such as V2G in mind, results in entrance into the market often being prohibitive due to technical requirements. However, National Grid are currently implementing changes to the balancing services to provide improved market access from V2G.

5.2.1 *V2G Hardware and Vehicle Compatibility*

Figure 16 shows that there are two different flows for each direction of travel, the solid arrows indicate energy flow and the dashed lines indicate communication or control flows. In export mode, the EV operates as a small-scale source of distributed generation. EV battery storage capacity typically ranges between 15 to 60 kWh with only a few vehicles (Tesla EVs, Jaguar I-PACE, Hyundai Kona) having a higher battery capacity, although there is an expectation that this will become more typical. The level of export depends on the power electronics within the V2G charger as well as the EV. Units deployed to-date are capable of exporting between 3 and 10 kW of power. At present V2G activities have been limited to using the CHAdeMo DC connection standard and protocol, the result is that vehicle compatibility has historically been limited to vehicles that make use of the standard such as the Nissan leaf and Mitsubishi outlander. However, CharIN e.V. has released the roadmap for grid integration (V2H, V2G) of charging systems based on the Combined Charging System (CCS), this will open the door for vehicles that do not conform to CHAdeMo, but instead use the CCS connection, typically associated with European OEMs.

Figure 17 Prototype V2G Units - Commercial Building (left) and Domestic Building (right)

Currently, V2G units have primarily been used in innovation project and as such were built as one offs or as low volume demonstration units. The result is that the cost of the units were very high typically in the range of £6,000 - £15,000 (£700-1000/kW). However, the market for both V2G chargers and V2G compatible vehicles is increasing in size, this means that there will be cost down in the technology as the adoption rate increases.

5.2.2 *UK V2G Government Support*

The UK government has continued to show support for the development of V2G technologies, in total, £30m of funding has been awarded to 20 V2G projects in 2018 to pay for research and design and development, with the aim of exploring and trialling both the technology itself and commercial opportunities[18].

Further information on the current status of V2G can be found in the Innovate UK commissioned V2G Market Study, available via the following link: [https://www.cenex.co.uk/energy/vehicle-to-grid/.](https://www.cenex.co.uk/energy/vehicle-to-grid/)

[18] https://www.gov.uk/government/news/30-million-investment-in-revolutionary-v2g-technologies

5.3 Load Management Operational Strategies

The use dynamic load management enabled EVSE within car parks offers the potential for the car park operator to diversify their income opportunities through the provision of EV charging and external energy market participation.

The provision of V2G chargers may be more financially intensive at the beginning of the project but once the regulatory barriers of V2G participation in energy markets has been resolved then there is a clear revenue opportunity for both the car park operator and the end user. Some operational strategies have been proposed in Table 8 that make use of smart chargers and V2G chargers:

Table 8 Load Management Operational Models

Model Name	Description	Load management solution	System Requirements
Integrated park and charge	This would be viewed as the base scenario, the vehicles parking and charging requirements are billed for in an integrated platform. There is no intelligent balancing of demand from the EVSE	No Load management	• Vehicle to receive full power charge for duration of dwell or until battery is at capacity.
Park and Smart charge	As above with the added ability for the customer to opt into dynamic reduction of charging power availability at site. The customer may receive a reduced overall bill as incentivisation to participate. Premium payments could also be implemented that ensure the vehicle is not receiving de-rated charging.	Smart charging system	• If opting in the customer should receive the charge required by the time they return.
Park and V2G	The customer will choose to opt in or out of participation in bidirectional charging, V2G fits with long dwell charging such as airport car parks. The approach could be that the vehicle does not get charged for parking on the condition that V2G activities are opted into. Opting in could allow the vehicle to take part in grid services or peer to peer charging within the car park.	V2G	• Vehicle to be fully charged upon customer return. • Agreements on acceptable discharge limits to be put in place.

Key Points:

Section 5: Load Management

- Dynamic load management is likely to become common across car parks where large numbers of charge points are being installed, as it enables peak electricity demand limitations to be overcome by controlling the power delivered to each unit, ensuring that total demand stays within a set limit. This enables greater numbers of chargepoints to be installed than would otherwise be acceptable within the DNO network connection agreement.
- Smart charging can provide some degree of control, by controlling the power delivery to the vehicle the unit can provide active demand load management thus facilitating the placement of a larger number of chargers on-site.
- V2G provides an opportunity to enable the carpark to provide additional, revenue generating services utilizing parked vehicles. There is future opportunity for V2G enabled markets in the UK to be accessed, this is particularly relevant for car parks that experience long dwell, such as airport parking.

6 Localised Generation and Storage

Renewable energy is seen as a potential solution to meet the extra added demand of EVs and could support installation of higher volume of chargepoints at singe sites. The challenge at present is that the generation of renewable energy does not always coincide with demand. A further solution to tackle this could include V2G charging and/or the deployment of onsite energy storage.

Possible solutions for generation and storage of energy are discussed below:

6.1 Solar PV Integration

Solar PV can be intelligently deployed in the form of solar charging canopies or on-roof solar for multi-storey car parks. This could provide a portion of the charging requirements from a local renewable source, reducing the strain on the distribution network. The case for solar charging could be furthered by the incorporation of battery storage at site, storing energy from the solar PV during times of low demand and releasing it when an EV begins charging. Furthermore, using smart charging or V2G would allow load shifting of EV charging demand to be employed to increase self-consumption of PV power and move the EV charging into off-peak periods[19].

The main components of a solar charging station are shown in Figure 18 as follows:

- Solar PV system, including DC/AC inverters,
- EV chargers,
- Control Centre to coordinate the power flow according to the EMS strategy,
- Interconnection with the grid or other demand sources in order to consume the surplus energy.

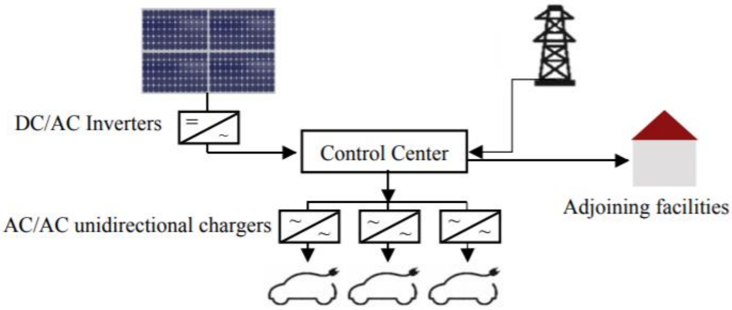


Figure 18 Solar Charging Station

The solar arrays provide the additional benefit of shade and shelter from the sun and rain. Typical applications of solar charging are shown in Figure 19. Configurations range from simple solar PV car ports shown in the left image to more complex systems which employ solar tracking. Solar tracking can be used to move the panels, ensuring that they are always perpendicular with the sun's rays and thus maximising generation.

Figure 19 Solar PV Canopy Configurations[20]

[19] Van Der Kam, M. and van Sark, W., 2015. Smart charging of electric vehicles with photovoltaic power and vehicle-to-grid technology in a microgrid; a case study. Applied Energy, 152, pp.20-30.

[20] Nunes, P., Figueiredo, R. and Brito, M. (2016). The use of parking lots to solar-charge electric vehicles. Renewable and Sustainable Energy Reviews, 66, pp.679-693.

Both roof-mounted and ground-mounted solar installations use either polycrystalline or monocrystalline silicon PV panels, typically mounted into aluminium frames. These panels are also commonly used in domestic and commercial PV installations, due mainly to their low cost and wide availability. The limitation of solar PV is that the panels have limited achievable efficiencies, with high performance panels reaching efficiencies of 22.5% commercially[21]. However, the installation of tracking systems can allow to production from the solar panels to become more efficient.

Tracking can be deployed on a single axis basis or the more advanced dual axis tracking. Both will follow the sun's trajectory based on the optimum tilt angle of the solar panel. Evidence suggests that that the use of tracking can increase the output of the solar panels by up to 39%. However, tracking systems considerably increase the cost of a solar installation.

The average cost of installing small scale rooftop solar PV is shown in Table 9:

	4kW	10kW	50kW
Averaged 2017/18 Installation Costs	£7,359.84	£15,094.61	£57,645.17

Table 9 2017/18 Averaged cost of install by power capacity[22]

Solar Car ports can vary greatly in cost, driven mainly by the number of PV modules included, rather than on the number of car parking spaces. Indicative costs of two different size systems are shown in Table 10:

Number of PV modules	Car Parking Spaces	Power (kWp)	Cost, including installation and connection.
25	3	6.6	£31,000
44	3	7.04	£42,000

Table 10 Solar Car Port Costs

21 https://news.energysage.com/what-are-the-most-efficient-solar-panels-on-the-market/

22 https://www.gov.uk/government/statistics/solar-pv-cost-data

6.2 Wind Turbines

Wind energy provides another option for local generation in car parks, provided that there is adequate space for installation and maintenance to take place safely. Historically wind energy has been captured via 2 conventional methods, the first being the horizontal axis wind turbine (HAWT) which is the format by which large wind turbines are typically laid out, the second is less common vertical axis wind turbine (VAWT) both of which will be discussed in the coming sections.

6.2.1 *Horizontal Axis Wind Turbines (HAWT)*

The deployment of HAWT has increased in recent years as the financial burden of energy generation via wind reduces, currently the cost per MWh for onshore wind generation is £94/MWh for large scale wind farms[23]. This figure whilst useful in proving that the cost of wind generation is not prohibitive, does not tell the story of smaller generating sets. The power curve and image of a 10kW HAWT are shown in Figure 20, the cost of this unit delivered to site is roughly £15,000 based on the provision of a 12m mounting pole. The cost of this will rise due to the provision of installation, including civils, electrical and commissioning.

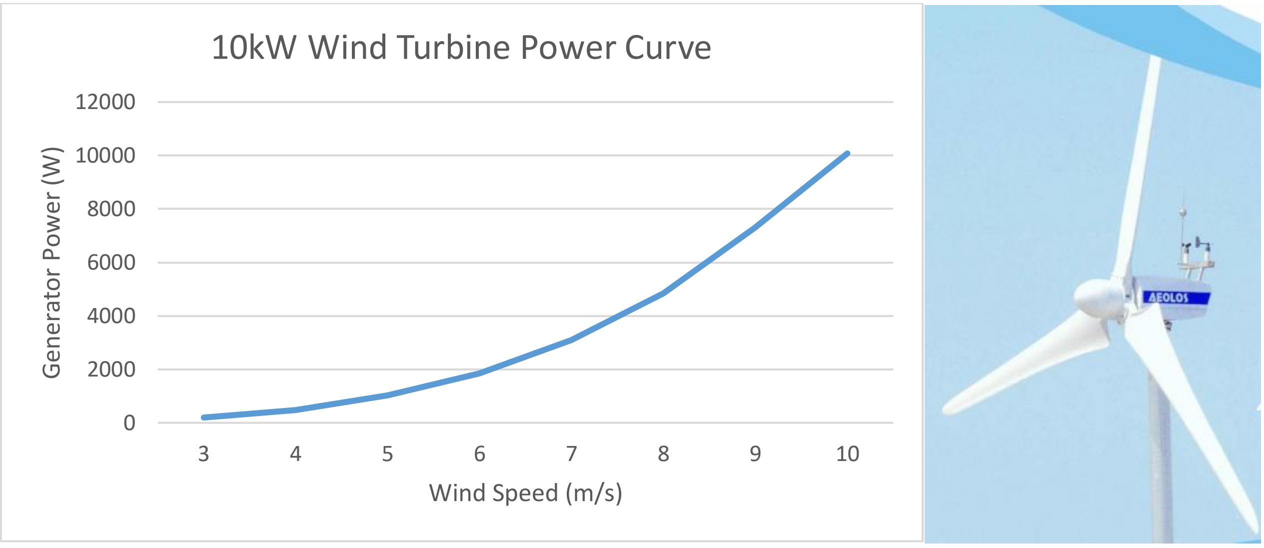


Figure 20 Aeolos 10 kW HAWT Power Curve

In terms of practicalities of installing a HAWT, there is a requirement for the turbine to be placed in a suitable location, the use of a HAWT in inner city scenarios will likely reduce the generation ability of the turbine. This is due to the HAWT's poor conversion of turbulent air; these turbines are therefore better suited to deployment in surface car parks that have adequate space for installation.

[23] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/65716/71-uk-electricity-generation-costs-update-.pdf

6.2.2 *Vertical Axis Wind Turbines (VAWT)*

The VAWT provides a less space intensive approach to wind energy generation, there are several benefits to the use of VAWT over traditional HAWT the first of which being that there are less components required, this is due to the main motor shaft being orientated vertically, as opposed to horizontally in the nacelle of a HAWT. Furthermore, as the blades are mounted vertically there is no requirement for the blades to be positioned perpendicular to the direction of wind, the result being that the VAWT is capable of capturing wind in any direction. VAWT have seen increases in popularity within towns and cities, partially due to the aforementioned reduced operating footprint and partially due to the ability to make use of turbulent wind conditions.

There are drawbacks to the deployment of VAWTs over the more conventional HAWT, these come in the form of reliability concerns and reduced efficiency. The reliability concerns come from the

One example of a VAWT is the Aelos 10kW, Figure 21 shows the power curve and an image of the turbine. From the graph it can be seen that the cut in power is shown to be 2.5m/s a cut out speed of 12m/s is stated by the manufacturers data sheet. The cost of this unit alone was found to be ~£15,000, which would increase as the cost of installation and commissioning of the unit is factored in.

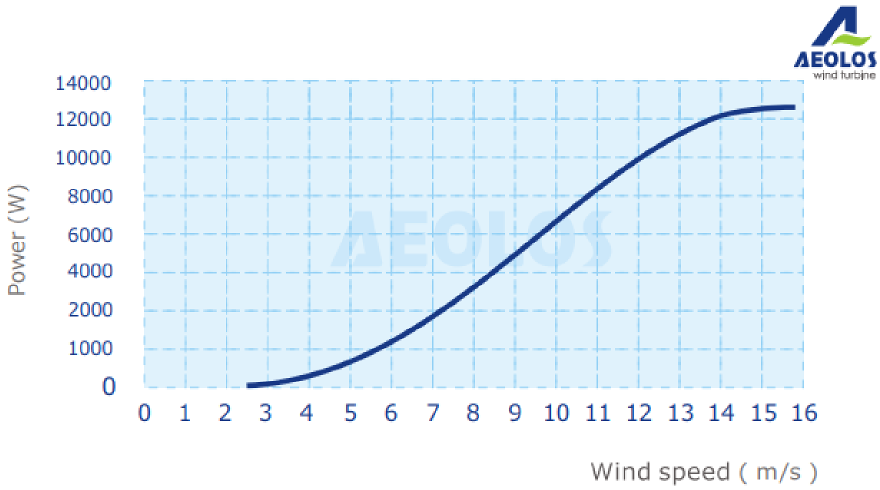


Figure 21 Aeolos 10 kW VAWT Power curve and design[24]

[24] http://energodyn.sk/wp-content/uploads/2015/09/Aeolos-V-10kw-Brochure-H-Model.pdf

6.3 Local Energy Storage

The application of energy storage solutions in carparks represents an area with great innovation potential. However, the specific application would need to be evaluated on a case-by-case basis to ensure that a system can be tailored with the needs of the specific site in mind.

The installation of local energy storage provides value to the car park operator from a range of sources:

- **Load Management:** Similar to V1G and V2G, batteries can be used to provide load management services by charging when electricity demand is low and discharging to offset demand from other assets as demand gets close to the agreed limit.
- **Increased self-sufficiency:** The car park would be less reliant on the grid, ensuring that even during times of grid instability the charging service can continue for the life of the batteries.
- **Flexibility markets:** Similar to EV batteries in V2G, stationary batteries can be used to provide flexibility services for third parties – charging and discharging to meet the requirements of and aggregator of flexibility market. This would enable spare capacity in the battery to be used to earn additional revenue for the site. Restrictions are currently in place surrounding minimum power requirements for participation in these markets, meaning that site operators would typically sign up to a flexibility 'aggregator' who would combine the battery with a range of other assets to meet the minimum requirements of the markets.

One of the limiting factors of batteries has historically been cost. Current forecasts suggest that the cost of batteries will reduce between 2019 and 2030, meaning that these could become realistic options for a wider number of customers. Figure 22 shows future cost projections produced by multiple companies, the overall consensus is that the cost of stationary battery systems is on a downward trend, at its lowest the cost of batteries is predicted by BNEF to be ~$100/kWh.

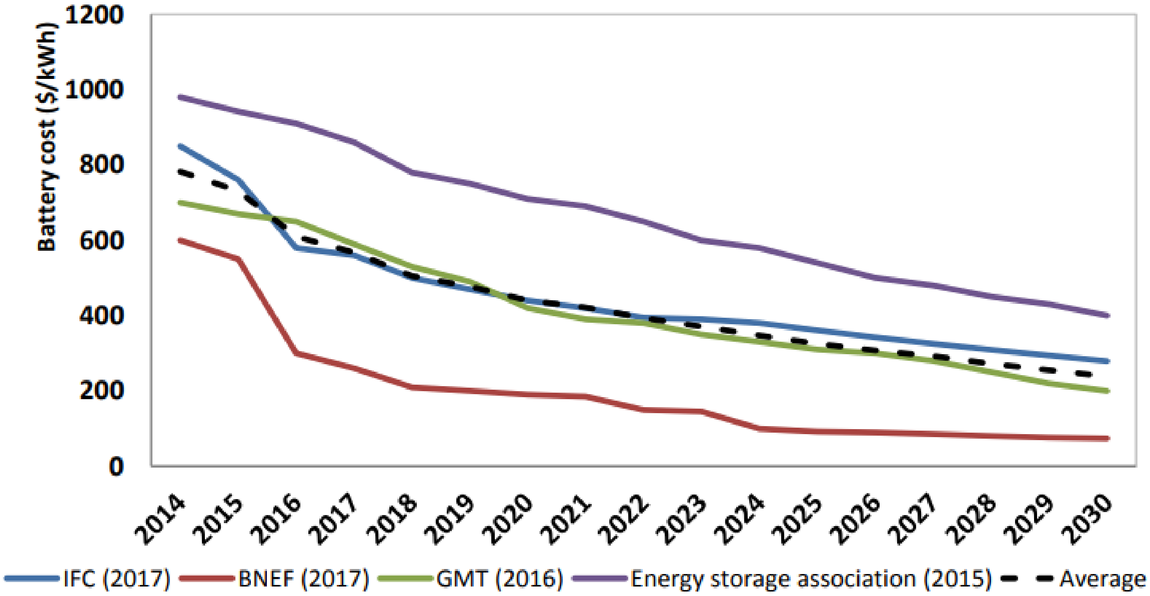


Figure 22 Forecasted cost of stationary battery systems to 2030[25]

[25] http://www.ee.co.za/wp-content/uploads/2018/10/Beth-OConnor-Cilliers-Silindokuhle-Nyoka-Eskom-paper.pdf

In addition to the applications described above, some chargepoint manufacturers have been investigating opportunities for integrating batteries into the chargepoints. This could enable higher power charge points to be installed, but supplied by a small direct power connection, supplemented by a 'top up' from the battery. The battery can then be charged when the chargepoint is not in use, creating a more consistent and lower power demand profile.

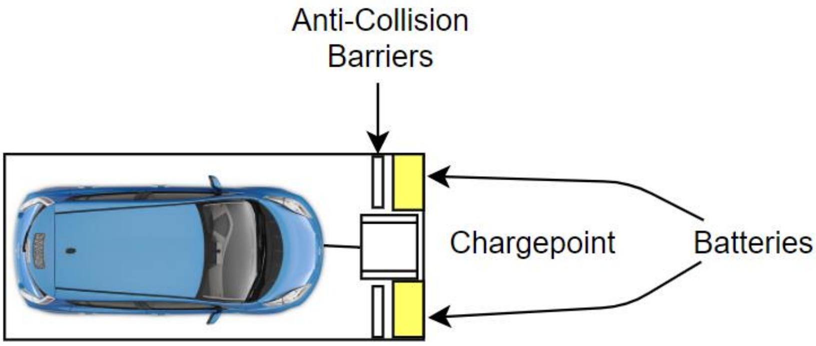


Figure 23 EV Charging with Energy storage

Key Points:

Section 6: Localised Generation and Storage

- Solar PV integration is possible and already being implemented in some car parks. Solar tracking offers significant increases in system efficiency but is currently prohibitively expensive. The economic viability of solar tracking is a potential area for investigation to try to reduce costs, making this a more viable option.
- Wind energy provides another option for local generation at car parks, typically VAWT are suitable for inner city applications but suffer from reduced generation efficiency, HAWT on the other hand are better suited to areas where the wind is less turbulent, such as surface level car parks.
- Battery storage systems are becoming more economically viable, offering the opportunity to increase a sites self-consumption of renewable energy.
- By employing solar PV and energy storage systems car park operators can reduce the impact of EV charging on the overall sites demand. However, PV generation may not align with demand from EV charging. Therefore, load management is required to maximize the value of these systems.

7 Supporting Innovations for EV Charging in Car Parks

To support the integration of electric vehicle charging systems in car parks, the existing services and infrastructure may also have to adapt. This includes:

- Integration of smart parking systems,
- Integrated charging and payment systems.

Whilst autonomous vehicles may be a longer-term consideration, implementing systems such as smart and monitored parking systems will help car parks become more future proof, making the inevitable integration of autonomous vehicles (AVs) more seamless and while providing benefits for current customers as well.

7.1 Smart Parking systems

Smart Parking systems are deployed with the aim of making the parking experience as user friendly as possible. Technology plays a big part in the delivery of these systems by utilising the following:

- Parking bay monitoring systems,
- Wayfinding, navigation systems and 'Smart Signage',
- Vehicle movement control for Autonomous EVs.

7.1.1 *Parking Bay monitoring*

Parking bay monitoring is an area which has seen significant technological development in recent years. The technology could be relatively simple to integrate with charging systems and could allow updates on the status of a charger's availability based on whether the bay is occupied or not. This would alleviate the concerns surrounding ICE vehicles parking in charging bays and it would allow notifications to be sent to drivers if they are parked within a charging bay but not drawing charge, such as in the case where a customer has incorrectly connected the vehicle. The integration of these systems with chargepoints is technically possible, however it would require additional capital to complete as there is no off the shelf solution as of yet that bundles charging and bay monitoring with notifications.

7.1.2 *Wayfinding Technologies*

Wayfinding is a key feature of the parking and traffic management sector. The main aim of wayfinding technology is to ensure drivers and pedestrians have the most up-to-date information to ensure that the route they take in and out of, as well as within car parks, can be as efficient and user-friendly as possible. For this to be possible clear and updated information must be available and made visible to drivers.

When utilising a car park for the purpose of EV charging, the user has more considerations to make than the typical ICE driver does. These include:

- Location and availability of charging units,
- Availability of compatible connectors,
- Rated power level of the chargers,
- Means of access and payment.

Up to date information on these concerns could be effectively communicated through the use of smart signage, as shown in Figure 24. These systems could easily be adapted to include the availability of chargers, where they are in the structure, and the power rating of the chargers. However, these signals would be dependent on the availability of accurate information from the chargepoint and any bay monitoring systems.

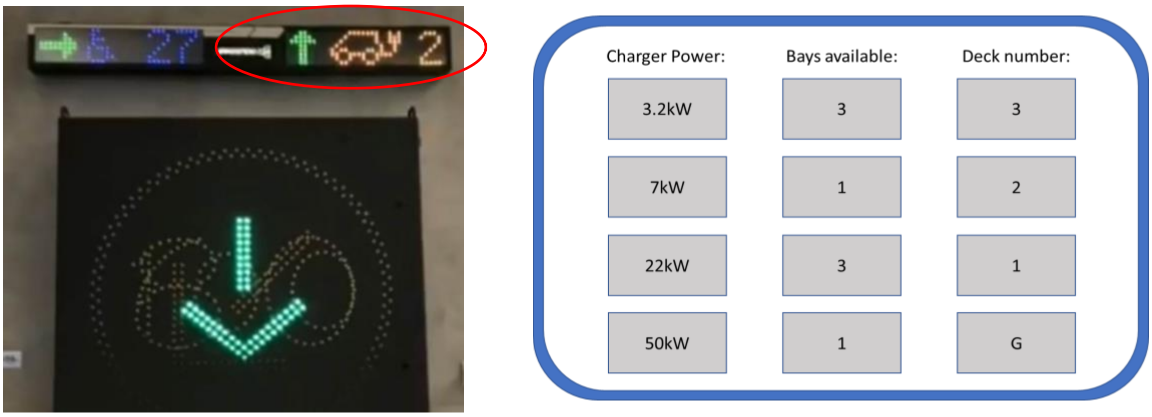


Figure 24 Signs displaying the location of EV Charging Bay

7.1.3 *Vehicle Movement Control for Autonomous EVs*

Moving forward to a future transport system that relies heavily on EVs as the main mode of personal transport, the use of multi-storey car parks as bases for charging vehicles can be expected to increase rapidly. By recognising the motor industry trend towards ACES (Autonomous Connected Electric and Shared Vehicles) it is likely that charging will also be required for autonomous EVs used for taxi and car club operations. Multi-storey car parks offer a potential hosting location from which to base the operation of autonomous vehicles, with these vehicles self-parking and self-charging when they are not in use.

VW's 'V-Charge' system is an example of this technology being applied to a demonstrator site[26]:

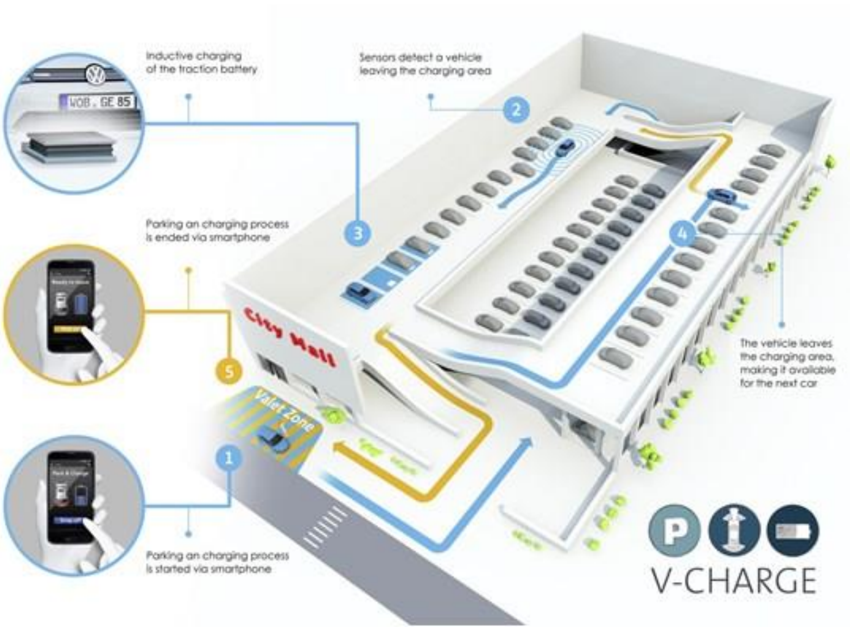


Figure 25 VW's V-charge system

This project seeks to employ autonomous electric vehicles with inductive charging. One of the beneficial features of this approach is that an autonomous vehicle can be programmed to vacate a charging bay when it is either fully-charged or is required for a journey which can be completed on its current state of charge. Charging priority can be assigned based on the battery state of charge, or on the urgency of making a specific vehicle available for use.

26https://www.fleetnews.co.uk/news/manufacturer-news/2015/07/15/volkswagen-showcases-automated-park-and-charge-system

While charging for autonomous vehicles is likely to be important in the future, the development of autonomous vehicles is still in early stages and far from commercialisation. As a result, while it should be considered when designing an EV charging system, it is important that the system also meets the immediate needs of EV drivers.

7.2 Integrated Payment Methods

Historically many car parks have employed third parties to install and operate their EV charging infrastructure, however as EV charging becomes more 'normal' it is expected that EVSE will become more integrated with other car park facilities including payment mechanisms. This is an area of innovation for the development of combined charging and payment terminals that can be used in car parks. Examples of this are shown in Figure 26:

Figure 26 Integrated Charge and Park payment methods

Traditionally car parks employ two modes of payment, these are:

- Ticketing
- Automatic number plate recognition (ANPR)

The benefit of ANPR is that it is paperless. However, the simpler ticket system means that upon entry to the car park a ticket is issued. Ideally, in order to provide a good customer experience, it will be increasingly important to integrate payment systems for both parking and EV charging, however there is not yet a consistent method available for doing this. In the UK there is regulated requirement for public charging systems to provide Ad-hoc payment which is currently being implemented using contactless payment systems or application-based payment platforms.

7.2.1 *Other Innovations in Payment for Charging*

Prioritisation of charging can be a key challenge for EV infrastructure, especially where demand exceeds availability. 'Transactive control' has been proposed as a key tool for tackling this challenge. The transactive control concept is best described with an example below:

An EV driver enters the parking garage and is low on battery. They need to charge their car as soon as possible for a scheduled departure in a few hours. However, on arrival, all the EV charging spots are occupied. The EV driver finds a current user of the EV charging spots (directly or through an app) who is willing to delay the charging of his own car and receives a financial compensation.

Current parked users can then submit 'bid' prices to disconnect and allow the new user to charge, or the new user can submit 'offer' prices which can then be accepted or rejected by existing users.

A transaction-based framework therefore allows market-based coordination to overcome limitations in charging facilities. Whilst this system does not yet exist commercially there is a potential for innovative applications within the EV charging applications. However, this system is based on limited EV charging being common. Ideally however, sufficient charging infrastructure should be installed to meet the needs of all potential customers.

Key Points:

Section 7: Supporting Innovations for EV Charging in Car Parks

- Many of the current 'Smart Parking' systems which are beneficial for EV charging would also be beneficial for autonomous vehicles. Therefore, by considering the requirements of autonomous vehicles during current site upgrades, car park operators could reduce the requirement for further future upgrades.
- Integration of payment systems for parking and EV charging will become increasingly important but is not currently widely available.

8 Conclusions

This report set out to investigate the challenges that are present when integrating electric vehicles into car parks, in addition to identifying areas of innovation that would support this integration.

EV charging within car parks has become an area of increased focus among the car parking sector. The industry is becoming more aware of the requirements for charging facilities and new business cases are being developed to incorporate charging within parking facilities.

The installation of charging infrastructure requires considerations to ensure the proposed site is suitable and to identify the type and number of charging points required. In particular, this includes evaluating the local demand for EV charging. Furthermore, behaviour and dwell times of current customers plays a critical part in correct selection of charge points. For example, long stay car parks may choose to employ slow charging systems which can be deployed at low cost and high volumes; whereas short stay car parks with a high turnover may be better served by fast or rapid charging.

Existing electrical infrastructure at site will need to be able to support the additional demand from the implementation of charging infrastructure. This includes the local distribution network, as well as on-site electrical systems. Should the electrical infrastructure not be sufficient then there may be a requirement for an increase in supply to the site. Alternatively load management could be implemented with smart charging systems. This would allow charging of EVs to be optimised to allow more vehicles to connect, albeit at a lower charging power. V2G and local battery systems offer further innovation for load management; and should the site experience dwell times of days at a time (Long stay airport parking), there is potential for the vehicle to participate in flexibility markets, adding a diverse revenue stream to the car park operator.

Local renewable generation and storage systems provide the opportunity to make use of free locally generated energy with the option to store it for times of high demand.

The installation of charging infrastructure will inevitably require civil works. These will include the installation of signage systems to promote the presence of the chargepoints. Furthermore, the chargepoints will require impact protection to reduce the potential for damage to the hardware. Impact protection can in the form of barriers or wheel stops.

The integration of EV charging and parking into a streamlined single payment method will become an increasingly important area for innovation. However, current systems typically remain separate, requiring car park operators to consider methods for reconciling usage of EV charging on top of existing payment systems.

Supporting innovations for the deployment of charging equipment have been identified, including utilising sensor based smart parking and wayfinding, the aim of which is to streamline the process of finding a charging bay. This would allow for greater monitoring of chargepoint use to identify times where a charging bay is occupied but charging is not taking place, such as when an ICE has parked in the bay or a charging session has been interrupted due to not being connected properly. As well as supporting current EV drivers, these systems are also critical for future autonomous vehicle parking, enabling car park operators to ‘future proof’ and potentially avoid further site upgrades in the future.

Overall, the key challenge facing EV charging at car parks is not the technology, but the cost of accessing sufficient electrical supply. Therefore, car park operators considering implementing EV charging should begin their journey by investigating what supply is available to them from the local distribution network.

Cenex (the centre of excellence for low carbon and fuel cell technologies) is an independent, not-for-profit consultancy with a mission to reduce the environmental impact of transport and its associated systems. Cenex has been active in the field of transport and electrification for 14 years, working with both public and private sectors to help organisations transition to lower carbon solutions. For further advice or guidance around anything raised in this report, please contact one of our team at info@cenex.co.uk.

Appendices

Appendix A: Number of Parking Spaces in Selected European Countries

	EPA Off-street	EPA On-street	EPA Total	Q-Park (2013) Total	Q-Park Market share
Netherlands	1,085,257	431,773	1,517,030	96,974	8.94%
Germany	4,935,623	2,638,385	7,574,008	88,214	1.79%
Belgium	664,331	343,480	1,007,811	45,928	6.91%
Great Britain	2,700,000	1,600,000	4,300,000	52,237	1.93%
France	1,676,318	1,028,250	2,704,568	105,690	6.30%
Ireland	268,897	84,259	353,156	23,474	8.73%
Denmark	292,693	123,911	416,604	57,158	19.53%
Sweden	933,211	227,577	1,160,788	248,518	26.63%
Norway	382,185	103,571	485,756	58,499	15.31%
Finland	445,276	129,222	574,498	28,628	6.43%
Total	**13,383,791**	**6,710,428**	**20,094,219**	**805,320**	**6.02%**

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