# ELECTRIC VEHICLES

## Innovation towards an excellent user experience

Insights and recommendations on user experiences, data ecosystem, digital technologies and standards within the Electric Vehicles Sector.

Recommendations report presented by Digital Catapult, and Connected Places Catapult, on behalf of Innovate UK, the UK's innovation agency.

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# EXECUTIVE SUMMARY

Innovate UK is leading the development of the "Plugin Vehicle 2025 Stakeholder Success Vision" to support the electrification of transport in the UK. It is doing so by fostering collaboration and uncovering user perspectives on current gaps and shortcomings in the electric vehicle offering, aimed at enhancing the user experience by 2025.

This report, a follow-up to our previous study, Electric Vehicles Towards an Excellent User Experience (2018), is intended as a key next step in this direction and aims to provide a nuanced gap analysis based on the current state of play in the UK's EV sector and future targets. More specifically, the report provides insights on emerging EV trends, maps a number of user profiles and the challenges associated with different user journeys and scenarios while also providing insights into the relevant uses, opportunities and effects of data, standards, ethics and technology. The following subsections discuss some of the key elements and takeaways of this report.

**EV trends relating to emerging or potential EV technologies and developments could provide opportunities to enhance EV user experience.**

*These trends, in summary, include:*

### Vehicle developments

- **Vehicle battery range increasing and costs decreasing:** Although the combination of range and affordability remains a challenge at present, the industry is working towards reducing vehicle costs. This also provides an opportunity for new business models that would aim to reduce the cost of ownership. When parity with internal combustion engine (ICE) vehicles is reached, the uptake of EVs is expected to increase significantly
- **EV options increasing:** Whilst the variety of EV models on the market is increasing, affordability remains an issue. There are still a relatively small number of vehicle options that offer the combination of range and affordability that customers are looking for
- **Better information to those considering EVs:** Potential EV buyers and users may benefit from information with regards to key purchase considerations such as the real costs of EV ownership, income avenues from EV ownership and charging infrastructure

### Charging infrastructure developments

- **Charge on my drive:** By 2025, it is possible that many homeowners will be renting out their driveways for both parking and charging EVs, which could be a useful source of passive income for the homeowner, and could provide a welcome source of additional charging options for users
- **Charging demand management and vehicle to grid(V2G):** EV managed, smart charging and V2G are expected to become common amongst homeowners and businesses. Managed charging can intelligently limit the rate of charging at individual charging points at certain times to enable the overall power requirements needed locally to be spread over time and avoid high peaks in demand
- **Charging superstations and multimodal hubs:** Businesses are starting to recognise the EV charging opportunity as a draw to pull in customers and install a large number of charging points at strategic locations across the UK
- **Better information on where to charge:** EV users would expect easy access to details of: the exact location of charging points, real-time availability of charging points, cost of charging at various locations. Much of the decision-making process could be automated based on the driver's preferences and charging stops are seamlessly integrated into the vehicles sat nav system
- **Workplace charging:** Enabling employees to go electric (for those that cannot practically use public transport, walk or cycle to get to work) will be seen as a socially responsible thing to do by employers. Employers would also be encouraged to install smart charging infrastructure and potentially V2G if affordable

- **Inductive charging:** The primary focus for EV inductive charging is for stationary vehicles, but there is potential for this to be embedded into the carriageway for dynamic vehicles to charge them as they drive, or to provide a charge boost as vehicles are stationary on approach to traffic signals
- **Mobile charging units:** For locations where there is still a lack of charging infrastructure mobile charging units can go to wherever vehicles are in need of charge. This is popular for users without charging points at home, employers who want to offer charging to employees without the infrastructure costs and for event parking such as at festivals
- **Charging speed increasing:** Vehicle charging points are getting more powerful, and as a result the time needed to charge vehicle batteries is decreasing. A challenge related to faster charging is avoiding excessive heat, and cooling systems are needed for both the batteries and the cables

### New and adapting business models

- **EV car clubs and mobility-as-a-service:** Car clubs are growing in popularity, especially in large cities around the world. However, car clubs have their challenges. Every town and city is unique with its own demographics, public transport provision, road capacity and other factors that have a potential impact on uptake. Once a suitable location is identified, convincing users to try a car club is a challenge
- **Fleet operators switching to EVs:** Interest in EVs from commercial organisations is growing. Fleet operators are seeking to embrace the environmental and running cost benefits of zero emission vehicles

**These trends are further looked at from user perspectives, mainly to understand what anxieties and user needs continue to be unmet with respect to their EV experiences.**

A number of fictional user types such as a self-employed business traveller, a taxi driver, a train commuter and a disabled home-maker, are explored. Although each of these user profiles highlights a range of 'priority' user needs and desires when considering and using EVs, some baseline, cross-cutting requirements are present across all users.

*Some of the* ***key learnings from the user journeys*** *studied are summarised as follows:*

- Sat navs need to integrate traffic updates with real-time availability of operational charging points on a route and present the information clearly to the driver
- Mobile charging units could be deployed during times of high congestion levels or extreme weather conditions to temporarily increase charging capacity and help allay user concerns
- V2G should be an attractive option with the potential benefits made clear to consumers; V2G could also be integrated with public charging points
- Mobile charging units could help with charging in remote locations where the cost of fixed cabling could be prohibitive
- Information should be easily accessible to EV users on how to charge safely, including on the use of extension leads
- Sophisticated energy accounts could split the bill by users rather than by household
- Travel apps could offer sophisticated multi-modal options, combining driving and charging an EV with public transport, bike hire, walking, etc. which could encourage modal shift

Building upon the EV trends and user needs, this report compiles what is considered to constitute **fantastic EV experiences**, separated into Individual User Experiences and Fleet Operator Experiences. Through illustrative diagrams, we highlight key areas to address to ensure positive user experiences. These include affordability, purchase / setup, resilience, ease of use and other benefits specific to EVs.

**The user scenarios presented in the report call forth visions of a fully connected, digitally-enabled future EV world, with rich communications between all stakeholders in a seamless, secure, and trusted manner.**

In this target future scenario, multi-source data is intelligently applied for the benefit of the user and the wider ecosystem, with an open-access model for exchange of energy, information, and value between all parties. To compare this future scenario with current state of play, a combination of desk research, online surveying, round tables, and structured interviews with key stakeholders were undertaken to capture a snapshot of the current data landscape in the UK's growing EV sector.

The emergence of these optimal user experiences are still some distance from becoming a reality, and largely hindered by a **lack of coordination and standardisation around data produced by various actors** within the EV ecosystem, despite the good intentions of many.

Under negative data experiences, we explore **four particularly important areas where data fragmentation is inhibiting the EV experience,** and identify the causes for each. These are the **UK's public charging infrastructure, its private charging infrastructure, and demand forecasting in the power grid, and interoperability and roaming**. The key takeaways and learning from these are captured in the recommendations section of this report.

There are, however, several recent positive changes which may redress this fragmentation and data hoarding and allow progress towards a better EV future. These include regulatory changes, publicly-funded demonstrators, and progressive local governance. Under progressive governance, we explore a number of case studies including that of Transport for Greater Manchester (TfGM), ChargePlace Scotland and Optimise Prime – the world's biggest trial of commercial EVs launched in January 2019.

**Advanced digital technologies will play a crucial role in improving the end-user experience and driving the uptake of EVs by 2025.**

While many of the data-related issues preventing a good EV experience appear to be amenable to improved standardisation and governance, ensuring complete interoperability and feature-rich experiences will benefit from the application of more advanced digital technologies to collect, distribute, collate, analyse, and present insights to the user.

In this report, we review the current state of a range of these technologies in the EV sector, including the internet of things (IoT), wireless communications, distributed ledger technologies, artificial intelligence, and immersive technologies, and then extrapolate their potential impacts by 2025.

1. **IoT:** Currently, IoT endpoints in the EV ecosystem include vehicles and charge points. Interviews with stakeholders have identified that most data from these sources is not open or readily available to consumers. There is also lack of standardisation over data formats and communication protocols in place.
2. **Wireless connectivity:** As EV adoption and automation increases, and vehicles themselves take on more responsibilities for driving tasks, vehicle communication systems must also improve their connectivity. Cellular V2X systems are currently being designed to cope with these future requirements, based on an extended LTE stack commonly known as LTE-V (or C-V2X).
3. **Distributed ledger technology (DLT):** DLT faces a unique set of challenges preventing widespread adoption. Not only are there deep technical issues regarding the general scaling of distributed systems and transaction volumes, its value proposition is largely unproven, and governance and business models for decentralised infrastructure are not yet mature.
4. **Artificial intelligence:** A large amount of effort is currently being expended by multiple companies attempting to create artificially intelligent, 'driverless' vehicles. Current range estimation for EVs is largely inaccurate due to a lack of data over environmental temperature, driving conditions and driving styles feeding into models of battery consumption. Accurate range prediction would alleviate anxiety associated with driving new or long routes with an EV.
5. **Immersive technologies:** Augmented reality (AR) can be used to overlay points of interest directly on top of the building or service, representing an improvement over a traditional screen-based GPS. As the data becomes more available, EV charging points could be displayed in a similar manner, showing their usage, cost and status as the driver approaches. With respect to VR, a driver wearing a headset that blocks their vision is clearly unsafe. However, VR can be a useful tool outside of a car for the marketing of EVs in 'virtual showrooms', as seen with Jaguar I-PACE.

Aside from assessing their current state of play, the report also explores the potential developments and EV applications of these technologies. **One key theme will be the convergence of these different layers, so that data captured by on-board IoT is transmitted via 5G-enabled V2X and made available to machine learning systems** via a shared DLT platform, before being presented to the driver in an immersive environment.

**This data and technology mapping exercise highlights the key opportunities within the advanced digital technologies startup and scaleup ecosystem, in terms of existing strengths and opportunities.**

Further, the data and technology mapping exercise is supported with a review of cybersecurity, standards and ethics considerations, surrounding data collection and use in the sector.

**With regards to standards, there are more than 1,000 organisations, alliances, associations and other groups internationally that are developing standards.** This provides a very difficult and confusing landscape to navigate. Therefore through the standards and policy landscape analysis, this report focuses on the most relevant standards and related policy interventions that will support the development of a coordinated and open innovation ecosystem for an enhanced EV user experience. As an overall principle, it is recommended that open standards should be adopted that are technology agnostic and not overly prescriptive in order to support innovation.

*Together, these different work streams have led us to identify two key themes as potential enablers for enhancing the user experience by 2025:*

### Theme – EV knowledge dissemination and market interventions

*The gaps to be addressed and opportunities for innovation include:*
- How to stimulate the market and encourage significant early uptake for EVs
- Lack of knowledge amongst both private and commercial potential EV users
- Creating an EV charging experience which is reliable and convenient

#### RECOMMENDATION 1
Fleet operators could have a large impact on early EV adoption. Fleet operators should be provided with tools, information and incentives required to switch their fleets to EVs.

#### RECOMMENDATION 2
Ensure consumers can easily get information regarding EVs and hands on experience using them.

#### RECOMMENDATION 3
Local and national governments need to take further steps towards a better EV charging and user experience.

### Theme – Data sharing and standardisation

*Under this theme the gaps to be addressed and opportunities for innovation include:*
- How to stimulate the market and highlight the benefits of knowledge transfer
- Lack of industry standardisation
- Promotion of open data and use of standard APIs

#### RECOMMENDATION 4
Promotion of more open data, data ethics and standard APIs relevant for EVs and charging infrastructure.

#### RECOMMENDATION 5
Government and other stakeholders should develop and adopt relevant EV standards.

#### RECOMMENDATION 6
Innovation challenges should address key battery issues (data access, end of life, technical standard adoption, etc.).

*Further potential solutions and actions related to each recommendation are described within the Recommendations section of the report.*

# INTRODUCTION

Electrification of passenger vehicles is ever more certain following the launch of many more EV offerings from vehicle manufacturers, legislation to curb Internal Combustion Engine (ICE) powered vehicles and municipal concerns over air quality. Policy makers, technologists, energy regulators, vehicle and EV infrastructure industries are increasingly concerning themselves with enhancing enablers and removing barriers to EV adoption.

This recognition and call to action is playing out to differing degrees worldwide and, by being proactive, the UK has the potential to build on its position as the third largest vehicle producer in Europe and expand its vehicles offering and supporting arrangements.

Against this background, in January 2018, a cross-Catapult working group drawn from Future Cities, Transport Systems, High Value Manufacturing and Energy Systems Catapult consulted with a broad range of stakeholders that were affected directly by, or could seize opportunities presented by, the mass adoption of EVs.

Its aim was to understand where stakeholders thought they were today and what would be needed to deliver an excellent user experience. From the stakeholder views expressed, it was clear that a large number of initiatives are underway to enhance understanding and develop road maps for future EV uptake. It was also apparent that many businesses are exploring the impact within their respective domains but with less focus on multi-domain implications and opportunities that could be exploited to enhance the EV user experience.

This report further builds on the findings published in 2018's **Electric Vehicles Towards an Excellent User Experience** report and focuses on those cross-domain activities that will benefit from a diverse set of perspectives and allow the different domains to co-operate in an effective way.

The mantra of "Towards an Excellent User experience" is retained: EV user experiences are developed further using thematic scenario based approaches to characterise how EV users' interactions with EVs and associated activities can be enhanced.

Stakeholders also frequently cited the importance of access to data and how it is used and controlled as key in delivering an excellent user experience. As a result, our research also considers the data landscape associated with EVs and how that might be managed in a secure and integrated manner in pursuit of an excellent user experience.

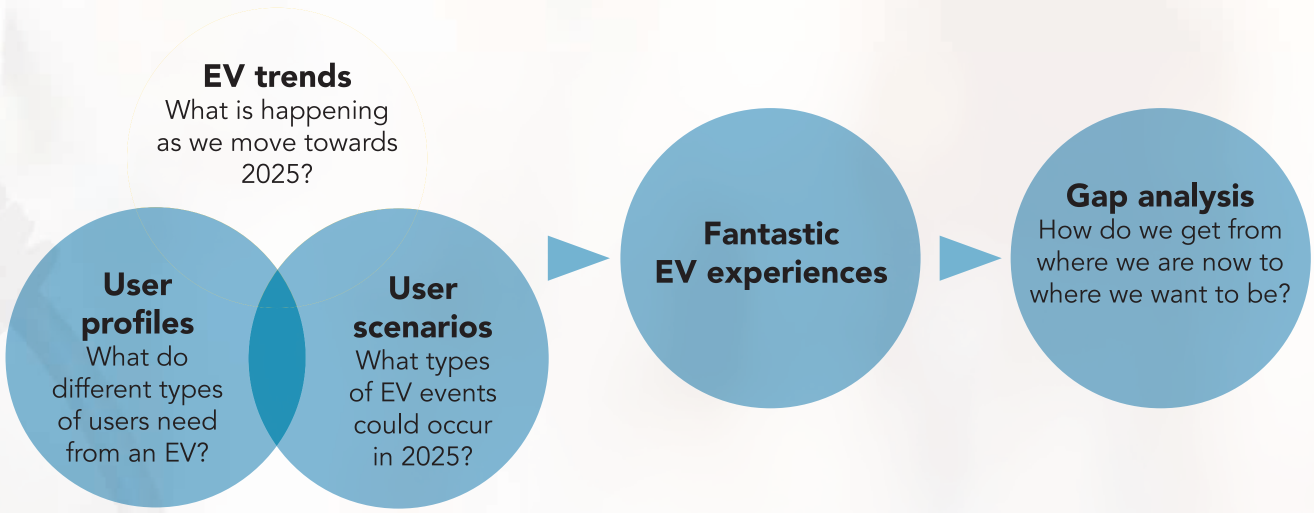
THE UK HAS THE POTENTIAL TO BUILD ON ITS POSITION AS THE THIRD LARGEST VEHICLE PRODUCER IN EUROPE AND EXPAND ITS VEHICLES OFFERING AND SUPPORTING ARRANGEMENTS.

## Our approach and assumptions

In our first report, we contrasted how an Internal Combustion Engine (ICE) powered vehicle might be used and the apparent differences from an EV. We explored what this meant for journey planning, refuelling /recharging, payment, driving and ownership.

For this report, to better understand how an excellent EV user experience can be enhanced by integrating multiple domains, we have created a range of traveller profiles and journeys to help explore the challenges they may encounter and opportunities that might arise to mitigate them, or simply to enhance the overall experience. The underlying assumption is that whilst an excellent user experience is a personal one, several elements that contribute to that experience can be common across many consumers.

This study assumes a target year of 2025 for investigating the type of EV experiences that may be possible. These experiences have been informed by considering three key areas: EV trends, user profiles and user scenarios.




**EV trends** relate to emerging or potential EV technologies and developments that could provide the backdrop to the 2025 assumed target. A range of **user profiles** are described to investigate the needs of different user types and to anticipate how they may be affected by EV trends. We then consider a number of **scenarios** or events that enable consideration of issues that users face and can be addressed through innovative interventions.

The purpose of this analysis is to understand what great EV experiences might look like and to consider the gaps from where we are now to the 2025 vision.

We make the assumption that access to, and use of, data across many stakeholders will be an essential part of an excellent user experience.

An important outcome of this assessment is therefore an **understanding of the data that needs to be generated and shared.**

Our approach to the data elements is first to understand the data landscape across the user experience enhancing domains and then to understand how data is accessed, controlled and used. We go on to explore how emerging technologies could be used to manage data in the future and what might hinder or enable developments. Supporting the data landscape will be a review into the policies and standards available to regulate the digital technology including what standards exist or that need to be developed or improved to help address the challenges identified.

Further, whilst the electrification of transport is far reaching and touches on public transport, commercial fleets and delivery vehicles, the predominant focus of this report is on the perspectives of private car users. We do however consider potential intercepts with public transport users, commercial vehicle users, 'sharing economy' users and fleet operators. We also assume that the main component technology elements required to deliver an excellent user experience exist today, however their integration with each other is relatively nascent and worthy of further consideration.

Similarly, it is recognised that the transition to EVs is taking place at the same time as the transition to autonomous vehicles (AVs). Whilst there could be some nearer-term use cases for AVs, such as self-parking vehicles or motorway-only operation, it is anticipated that fully autonomous vehicles that are capable of handling all different driving situations on all road types and in all weather conditions will not be widely available by our 2025 target year. Therefore, this study has kept the transition to AVs in mind with relation to how infrastructure can develop, but they do not form part of our scenarios and gap analysis.

Furthermore, the scope of this study is to investigate what can be done to facilitate the move to full battery power, without the need for an ICE for backup power. Therefore, this report predominantly discusses the move to battery electric vehicles (BEVs), rather than considering in significant detail the move to plug in hybrid electric vehicles (PHEVs) or range extended electric vehicles (REEVs). Both PHEVs and REEVs incorporate an ICE[1] and represent something of a compromise in terms of environmental ambitions for the technology.

# ELECTRIC VEHICLE TRENDS

This section identifies a number of emerging trends that could provide opportunities to enhance the EV experience. These trends, in summary, include:

*The overall list is as follows:*

### Vehicle developments

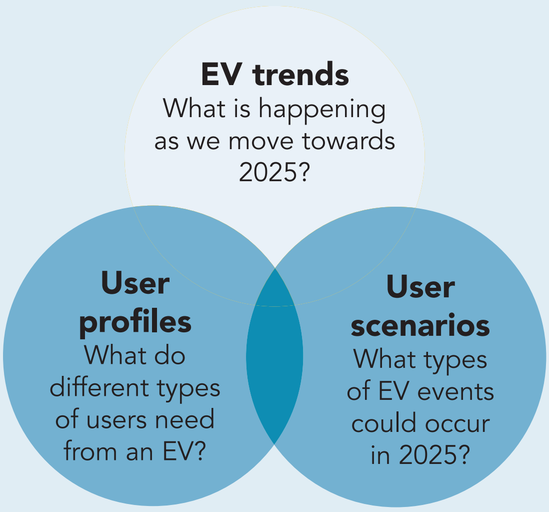
- Vehicle battery range increasing and costs decreasing
- EV options increasing
- Better information to those considering EVs

### Charging infrastructure developments

- Charge on my drive
- Charging demand management and vehicle to grid
- Charging superstations and multimodal hubs
- Better information on where to charge
- Workplace charging
- Wireless charging
- Mobile charging units
- Charging speed increased

### New and adapting business models

- EV car clubs and mobility as a service
- Fleet operators switching to EVs




[1] For a PHEV, the ICE can propel the vehicle, whereas for a REEV the ICE can recharge the vehicle battery.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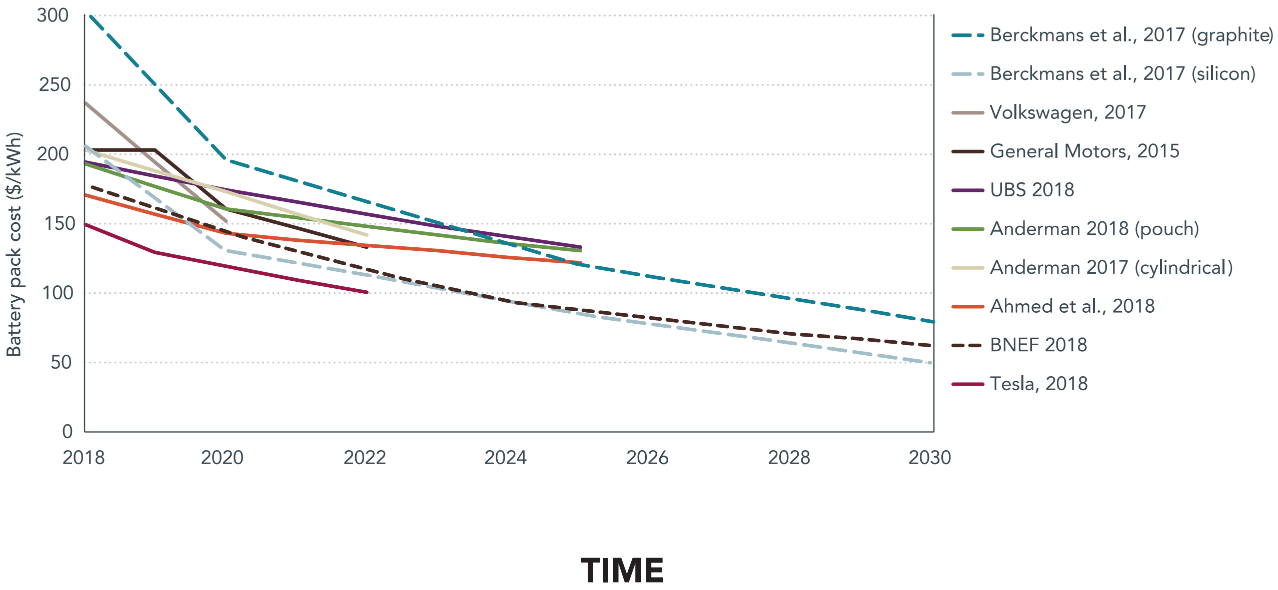
# VEHICLE DEVELOPMENTS

**EV TREND 1:** vehicle battery range increasing and costs decreasing




A key advantage that ICE vehicles have over EVs is the distance they can travel without needing to refuel. An ICE vehicle can cover many hundreds of miles on a full tank of fuel. In the early days of EVs, range might be limited to 70 miles or so during cold weather. However, this is changing. By 2025 EVs are expected to be capable of many hundreds of miles on a full charge. There are currently vehicles on the market with a range in excess of 250 miles, including the Tesla Model S, Tesla Model X, Nissan Leaf e+, Jaguar I-Pace, Kia e-Niro and the Hyundai Kona Electric 64kWh. In addition to increasing EV ranges, costs are starting to decrease, showing a trend towards more affordable higher-range vehicles.

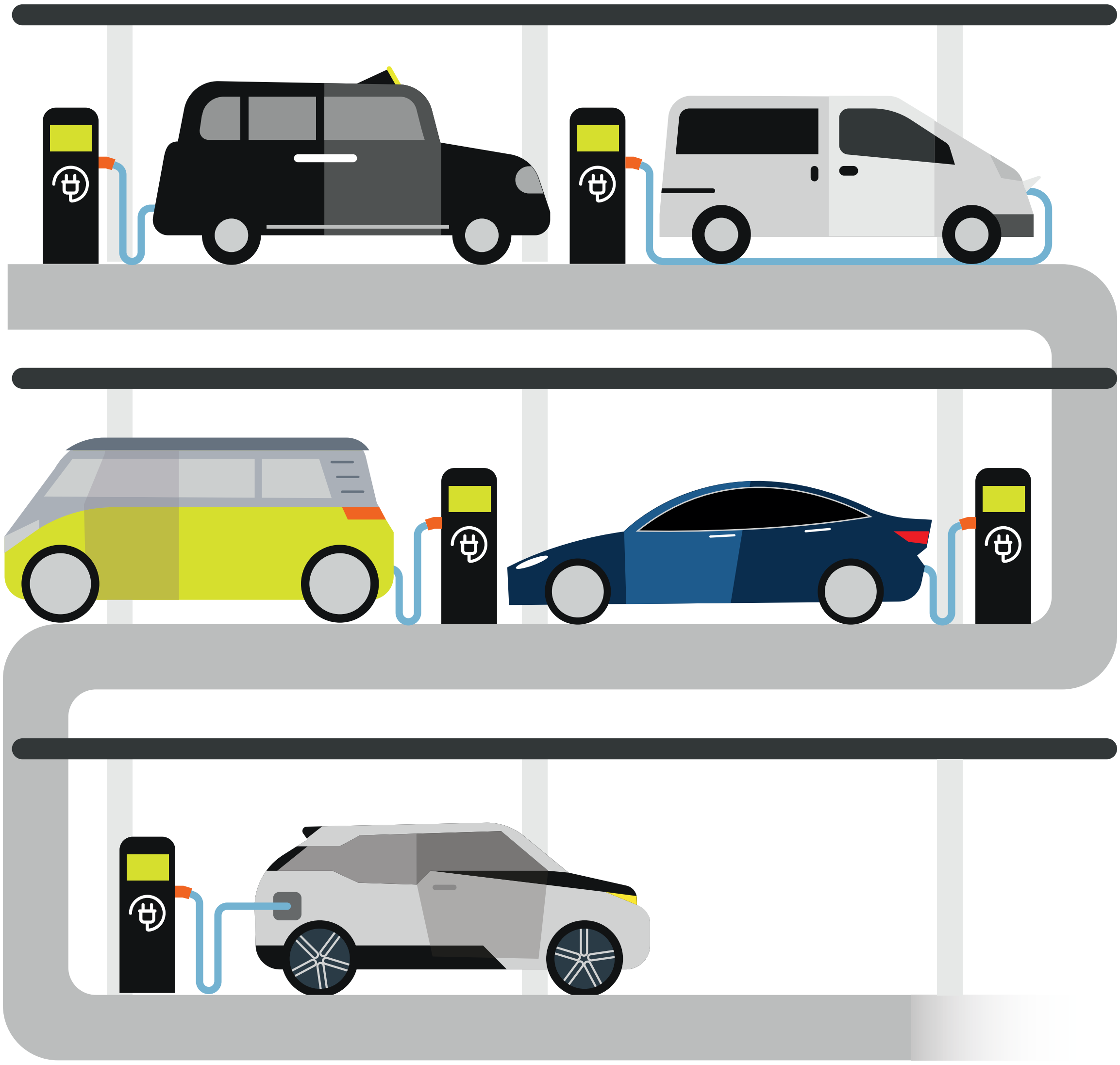
Even with higher range vehicles available, some users may continue to use lower-range vehicles for many years because they will be cheaper to buy either new or second-hand and may suit the typical journey patterns of the individual.

Although the combination of range and affordability remains a challenge at present, the industry is working towards reducing vehicle costs. This also provides an opportunity for new business models that would aim to reduce the cost of ownership. When parity with ICE vehicles is reached, the uptake of EVs is expected to increase significantly.

Fiscal incentives will remain key to reducing this cost differential through 2020 in most markets including UK. Additional complementary support policy will be important through 2025 or later to continue to address charging infrastructure and consumer awareness barriers. As EV technology costs are reduced over time, incentives can be lowered.

### **EV TREND 2:** EV options increasing

Several years ago the number of highway-capable EV options was limited, but the variety of makes and models on the market is now quickly increasing. There are currently in excess of 40 highway-capable fully-EV models on the market and many more due for release in the coming year. In addition to passenger cars, Hackney Carriages[2], vans and buses are now on the market too and in operation in several cities. Electric heavy goods vehicles are towards the latter stages of development and are starting to be offered for commercial release. By 2025 it is expected that most types of ICE vehicle will have an EV equivalent available.



*A wide variety of EV types are coming onto the market, to meet the needs of a wider spectrum of users.*

Whilst the variety of EV models on the market is increasing, affordability remains an issue. There are still a relatively small number of vehicle options that offer the combination of range and affordability that customers are looking for. Vehicles that are starting to offer this combination tend to have significant waiting lists. ICE vehicle buyers are accustomed to a wide range of choice and options. This needs to be replicated in the EV market.

[2] *Commonly known as 'Black Cabs'*

### **EV TREND 3:** better information for those considering EVs

*Potential EV buyers and users may benefit from information with regards to:*

- the real costs of EV ownership and how it compares to other options
- how to maximise income from their EV, including providing access to it via car clubs, ride sharing, etc
- how to maximise income from their charging infrastructure, including how to rent it to other users and how to generate revenue from vehicle 2 grid charging units
- a detailed 'lifestyle plan' on how an EV can accommodate their travel needs and how other options can help plug any gaps
- a detailed breakdown of the environmental impact of EV use and how it compares to other options, including using other modes of transport
- how to find and use public charging points, including for those who may need regular access when home or workplace charging is not an option
- information about energy tariffs for EVs

*Image courtesy of EV Experience Centre, Milton Keynes*

The EV Experience Centre[3] in Milton Keynes is the UK's first brand neutral centre dedicated to EVs. They offer visitors free education and advice, and the chance to test drive or borrow a range of EVs, which provides potential EV buyers with hands-on experience in driving and charging an EV. Vehicles are loaned to members of the public for either five or seven days at subsidised rates.

Within 18 months the EV Experience Centre has facilitated 3,000 EV test drives, approximately 400 long term loans and has received approximately 80,000 visitors.

The Go Ultra Low website[4] enables various cost comparisons, including fuel tax (basically comparing an EVs tax of zero against ICE models). It also provides a useful journey/cost comparison based on daily mileage and allows the user to input the amount they pay for electricity and the current petrol/diesel prices, as well as providing an indication of the tailpipe emissions that will be avoided through switching. The full environmental impact of EV use, which might include vehicle lifecycle, carbon footprint and human capital deployed for manufacture and operation remains difficult to ascertain.

[3] *https://evexperiencecentre.co.uk/*
[4] *https://www.goultralow.com/*

Making a switch to EVs is a complicated decision that relates not just to costs but also lifestyle. Some users will be put off by the uncertainty around aspects of charging, such as exactly how to find and use public charging points.

Vehicle cost is still a key deciding factor for most users, but the more challenging cost to consider is vehicle depreciation as it remains unclear how well EVs will hold their value. Financing arrangements such as personal contract purchase or personal contract hire enables the user to pay monthly based on the vendors' projections of depreciation. A more reliable evaluation of residual value would help not only users and second-hand buyers, but also the vehicle vendors and financiers as well.

Users that park on the street at home will need to rely on other charging options, such as the use of publicly available rapid chargers or charging at work or at typical destinations. For these users, charging point costs and availability will be crucial to the decision-making process.

The work of the EV Experience Centre in Milton Keynes is helping to provide bespoke information and hands-on experience on how to use and charge EVs. Government could consider cost effective ways of scaling up the EV Experience Centre model and expanding the information to include a fuller environmental breakdown of the impact. This might include working with vehicle manufacturers, charging point operators and other stakeholders to create a nationwide service.

*Suggestions for achieving this include:*

- Working with vehicle manufacturers and car dealers to investigate how more tailored advice and hands-on experience can be provided at the point of sale
- Incentivising car rental companies to replicate the EV Experience Centre model
- Ensuring the EV Experience Centre isn't limited to a physical space, but could adopt a more mobile approach through events, such as car shows. Such demonstrations are starting to take place[5], but could be scaled up

[5] *For example. 'Go Electric Ride & Drive' events: https://www.greencarguide.co.uk/features/manchester-go-electric-ride-drive-event-review/ and Octopus EV: https://www.octopusev.com/ourevents*

# CHARGING INFRASTRUCTURE DEVELOPMENTS

### **EV TREND 4:** charge on my drive

By 2025, it is possible that many homeowners will be renting out their driveways for both parking and charging EVs, which could be a useful source of passive income for the homeowner, and could provide a welcome source of additional charging options for users. It could work particularly well for homeowners near desirable locations such as town centres, railway stations, sports stadia, etc.

# BOOKING ACCESS TO AND PAYMENT FOR A CHARGING POINT LOCATED ON A PRIVATE DRIVEWAY COULD BE EASY FOR USERS, AND BE INTEGRATED INTO THE OVERALL SYSTEMS FOR FINDING AND PAYING FOR CHARGING.

Booking access to and payment for a charging point located on a private driveway could be easy for users, and could be integrated into the system for finding and paying for charging.

Companies such as "Park On My Drive"[6] already advertise spaces that enable EV charging. Within the Park on my Drive application such spaces are indicated with a green marker on the map compared to the normal red for regular spaces.

Another company, "Bookmycharge"[7] is dedicated to offering EV charge locations provided by homeowners. It claims to increase certainty by enabling users to reserve private charging locations from fellow EV owners.

Zap-Home[8] is part of Zap-Map the online directory of charging point information (which is discussed in more depth later in this report). The Zap-Home network shows the home charge-points of users that have decided to share them with other EV drivers. Charge-point details are visible only to registered Zap-Map users, and owners can offer their home charge-point under their own conditions. Access times and charging costs are set by the owner, with some owners choosing to offer charging for free, and others charging a small fee, making use of the PayPal.Me peer-to-peer payment mechanism.

Today, driveway owners could build the potential cost of electricity into the parking rate, but it may be preferable to more accurately charge users based on a combination of driveway space and electricity used. This would require private users to install charging points that can separate their own electricity costs from those of people renting the charging point.

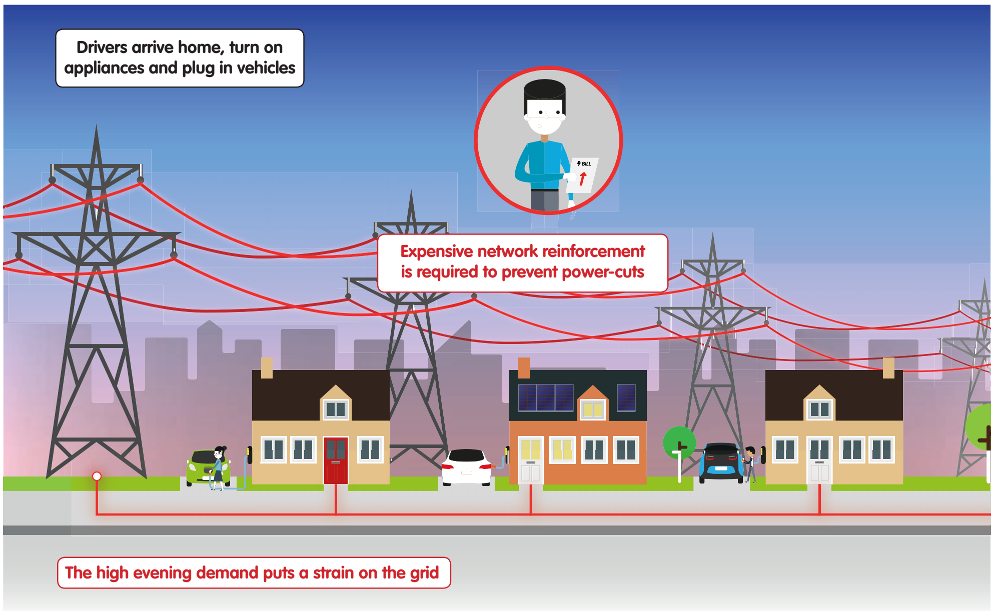
Those offering use of private charge points could help increase the supply of charging options and should be encouraged. These options could be presented alongside public charging infrastructure. More detailed information on how to use private charging points could be made more easily available in a standardised format. Furthermore, insurance companies could investigate potential offerings for protecting owners' charging infrastructure from damage.

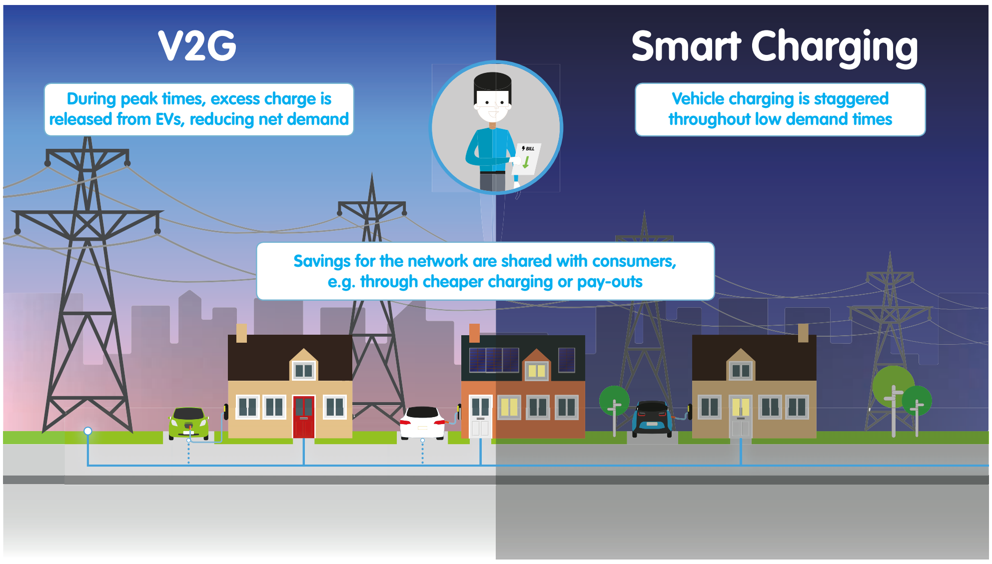
More detailed information on how to use private charging points could be made more easily available in a standardised format. Further, insurance companies should investigate potential offerings for protecting owner's charging infrastructure from damage from public use or even vandalism.

[6] *https://www.parkonmydrive.com/*
[7] *https://bookmycharge.com/*
[8] *https://www.zap-map.com/charge-points/public-charging-point-networks/zap-home-network/*

### **EV TREND 5:** demand management including vehicle to grid (V2G)

Managed EV charging, smart charging and V2G are expected to become common amongst homeowners and businesses. Managed charging can intelligently limit the rate of charging at individual charging points at certain times to enable the overall power requirements needed locally to be spread over time and avoid high peaks in demand. When managed charging is used for providing grid services and smart services to the user, smart charging is implemented. V2G takes this one step further and enables a bidirectional flow of electricity. This provides significant benefits to the overall power network and better facilitates the move to renewable energy sources. Utilising V2G to support the electricity network would reduce the energy demand from flexible sources, such as gas plants, and can potentially reduce the requirement for grid connected electricity storage. Providing grid services via V2G would bring additional revenue to the vehicle or fleet owner and the V2G supply chain.




During times of increased electricity demand (for example. early morning and evening) through smart charging and V2G, plugged-in electric vehicles will be able to release energy back to the grid to balance demand. This can be enabled via smart systems with no or minimal user input. As with managed charging, the user will have to specify their desired state-of-charge and desired plug-out time. Additionally they could specify the proportion of the battery capacity that could participate in V2G. Alternatively, and for services that do not require instantaneous response, the user could also be notified through an application, and incentivised by their energy provider to participate in V2G, if energy needs to either be absorbed or released to the electricity network. By also implementing managed charging, charging to full capacity would happen in the overnight time period when electricity demand is low.

The amount of charging that can be drawn from each vehicle could also depend on the number of vehicles participating in V2G at a given time. A higher number of connected vehicles would mean that the energy fed back to the grid per vehicle will be lower compared to cases when fewer vehicles are connected.

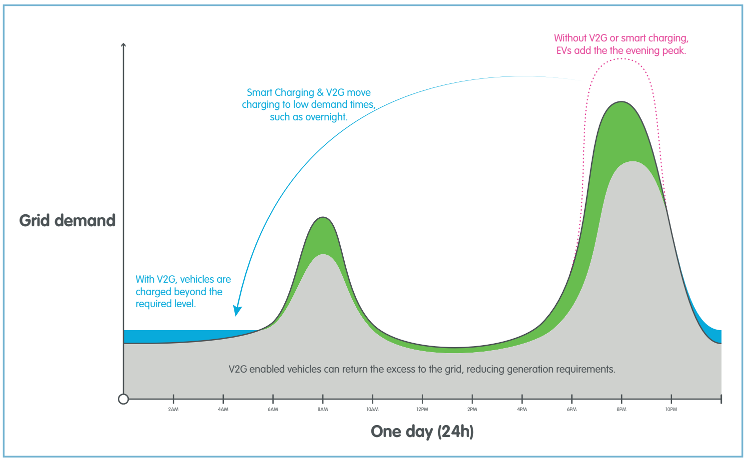
The user remains in control of the flow of energy from the battery. The user approves such use prior to it energy being taken from it.

Providing grid services can also be a revenue stream for fleet operators and public charging point operators. As seen in the above figure, electricity can be drawn from vehicles during daytime and not just in cases of peak demand. Vehicles parked during the day, for example at the workplace, train stations or large car parks can be aggregated via virtual platforms for V2G purposes.

For V2G to materialise a number of considerations should be made. Users will be willing to provide grid services if the right market arrangements are in place. Furthermore, the willingness to participate will be dependant on the reward system and generated revenue. As mentioned above, away from home charging has high potential for participating in V2G if charging incentives and appropriate business models are available.

As reported in Cenex V2G Market Study[9], the UK is one of the first markets to adopt V2G through technology demonstrations.

In the UK, Cenex led with a number of V2G studies and prototype demonstrators, supporting installation of the UK's first permanent V2G unit at Aston University (2016) and installing the first domestic V2G unit in Europe as part of the project 'Ebbs and Flows of Energy Systems (EFES)' in early 2017. A list of V2G projects are included at Appendix D of the report, including SEEV4-City[10].




The most critical barrier stated in the Cenex V2G Market Study is to develop a clear understanding of the economics for V2G and the various potential revenue streams and as such to develop robust business models that enable clear identification and targeting of appropriate customer groups. Business models would be able to account for risk and uncertainty in supply, for example short-term wind availability or available vehicle battery capacity. This will enable hardware to be developed in line with the needs of these customers, therefore reducing costs and increasing the value to the customer.

For both individuals and fleet operators, willingness to participate in V2G and charging behaviour should also be analysed to better understand user requirements and potential available capacity to assess the viability of relevant business models.

There could also be a need to understand the impact on the battery health from the V2G activity and the associated resale value of the vehicle.

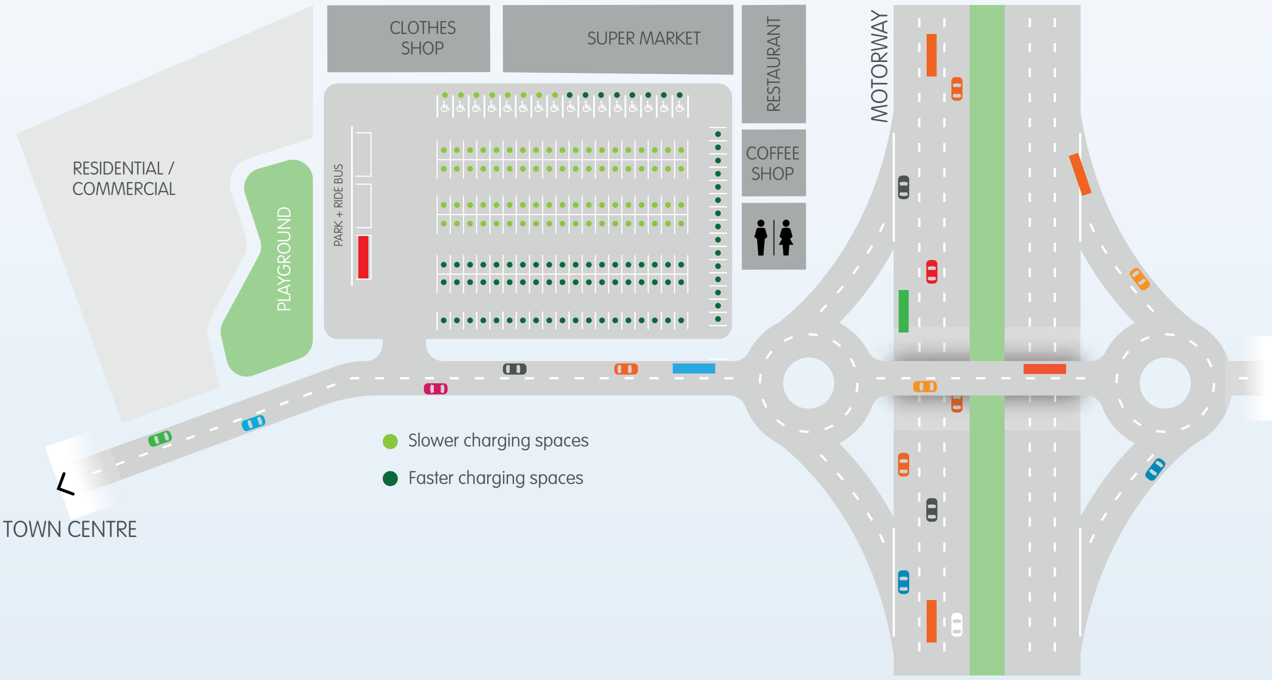
Finally, to better understand the economics and potential revenue from providing services to the grid, granular analysis is required to assess the effect that electrification of heat and increased generation from intermittent sources will have on the energy demand from V2G.

[9] https://www.cenex.co.uk/energy/vehicle-to-grid/
[10] https://www.seev4-city.eu/

### **EV TREND 6:** charging superstations and multi-modal hubs

Businesses are starting to recognise the EV charging opportunity as a draw to pull in customers and install a large number of charging points at strategic locations across the UK. These charging superstations could be marketed on the promise that there will always be a charger available, and customers can choose the charging speed they need. As such, they become attractive stopping points for many journeys.

The optimal locations for such charging superstations will be where they can attract many types of users. An example of such a location is indicated in the diagram below. This example shows a retail park which is located near a motorway, so it can attract those stopping for short breaks as well as longer-stay shoppers. Local businesses could make arrangements for employees to use charging points at certain times. Local residents that have no home charging available could benefit from leaving their vehicle charging overnight when the facility is otherwise empty.




The above example also shows a park-and-ride facility. Integrating charging superstations into key interchange points such as railway stations, coach stations and park-and-ride facilities could not only provide charging opportunities, but could also attract modal shift and ease congestion in city centres.

It may be beneficial to provide a range of chargers. Some users may be parked all day or night (for example local residents who would benefit from a lower cost slower option). Others may be parked for a couple of hours whilst shopping or visiting a restaurant or cinema, whilst some may need a quick charge whilst using the toilets and grabbing a coffee.

The needs of wheelchair users should also be considered. Charging points should also be incorporated into disabled parking bays.

It's worth noting that petrol station forecourts may not be the optimal location for charging infrastructure as there are generally limited things for people to do while waiting for a vehicle to charge, and charging is unlikely to become as quick as filling a tank with petrol within the analysed timeframe. The ideal place to charge is where people want to park anyway to do other activities.

There are currently approximately 19,125 public charging connectors located at 6,672 locations across the UK[11]. This equates to 2.86 connectors per location. Providing a higher number of connectors per locationwould provide more confidence to the user that a charger will be available (i.e.without someone already using it) when they arrive, which in turn could drive more users to that particular location. Steps could be taken to improve charge point reliability and measures to make charging areas highly visible as they can be difficult to find.

Green energy company Ecotricity has exclusive rights to install charging points at motorway service areas. Its website claims that there are more than 300 charging points across UK motorways. The Automated and Electric Vehicle act, passed in July 2018 as the primary legislation, will give the Government new powers to ensure motorway services are upgraded with more charging points, and allows mayors to request installations at large fuel retailers in their areas.

The issue of lack of home charging for users without private driveways is a problem at present, but may be less so in the future as vehicle range increases and new charging options become available such as workplace charging, supermarket charging, etc. This issue cannot necessarily be addressed by installing charging points along every street where on-street parking occurs. Some local authorities are investigating creative solutions which warrant further investigation, but even if shared charging points can be installed at the residential kerbside, disputes between neighbours could arise associated with the reservation of parking spaces for EV-only use.  It may be preferable to avoid allocating spaces, which may enable residential kerbside installation, or to think more strategically about how those without driveways can charge in other ways.

Significant investment has been put into public charging point networks, and this needs to continue as EV uptake continues to rise in the future. The business case relating to public charging point installation, and particularly how to secure further investment to increase the depth of the network in a manner that is in the public interest, is worthy of further investigation. Strategic sites that could become known as 'charging superstations', highly visible and convenient locations that attract multiple users, could be a priority for investment.

[11] *As reported by www.zap-map.com, 2nd January 2019*

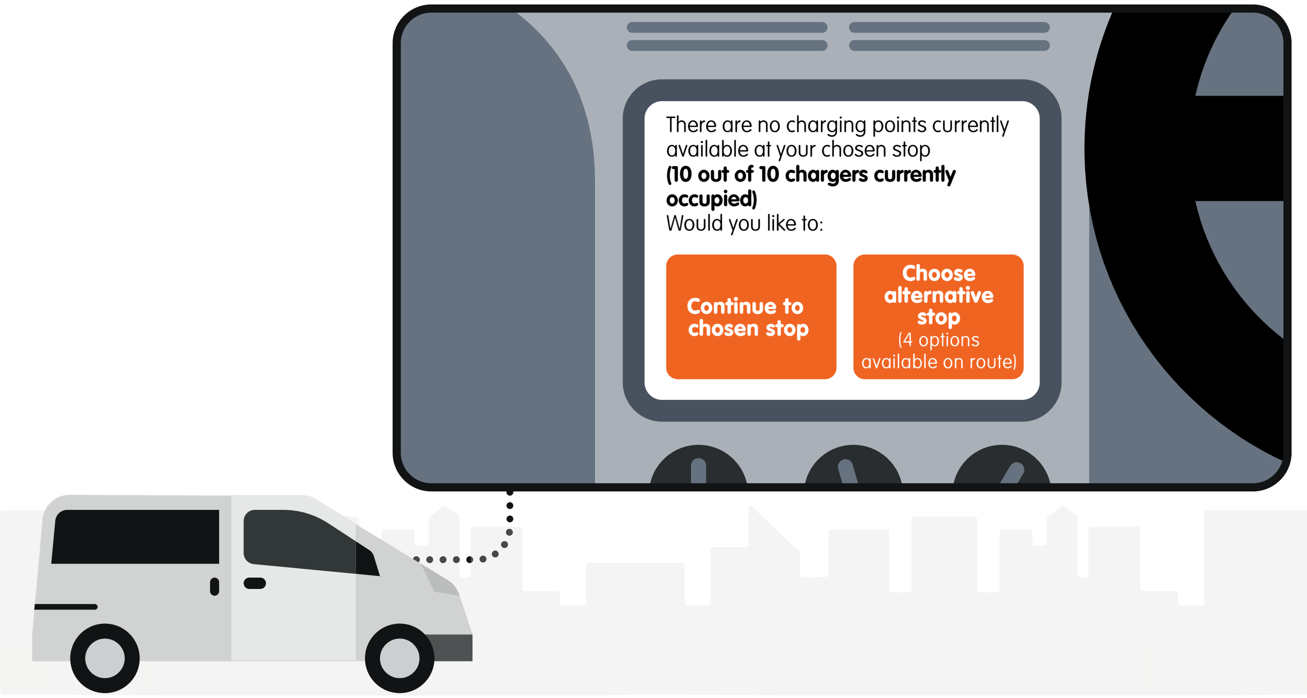
## **EV TREND 7:** better information on where to charge

*EV Users would expect easy access to details of:*

- The exact location of charging points
- Real-time availability of charging points
- Cost of charging at various locations (including those that include revenue stream or discounts on energy for V2G availability)

Much of the decision-making process could be automated based on the driver's preferences and charging stops could be seamlessly integrated into the vehicle's sat nav system.

Companies could manage demand for infrastructure by offering direct users to those chargers that are more likely to be available and to those that help balance demand on the National Grid. Standardised "Intelligent Charger Routing" could be incorporated into sat nav systems and EV apps.




The most commonly used platform for charging point information is Zap-Map, which is available on desktop and as an iOS and Android app. The app has a route-planning feature that allows the charging stops to be planned in advance.

Charging points can also be filtered by various criteria, including charging network, EV model, charging speed, location and type of provider. This tailors the information to the user.

Real-time status data on charging points, which is updated every five minutes, is available for over half of the connected public network.

*Other sources of information with respect to charging point location and availability include:*

- ChargePlace Scotland[12]
- National Chargepoint Registry UK[13]
- Charge Your Car[14]

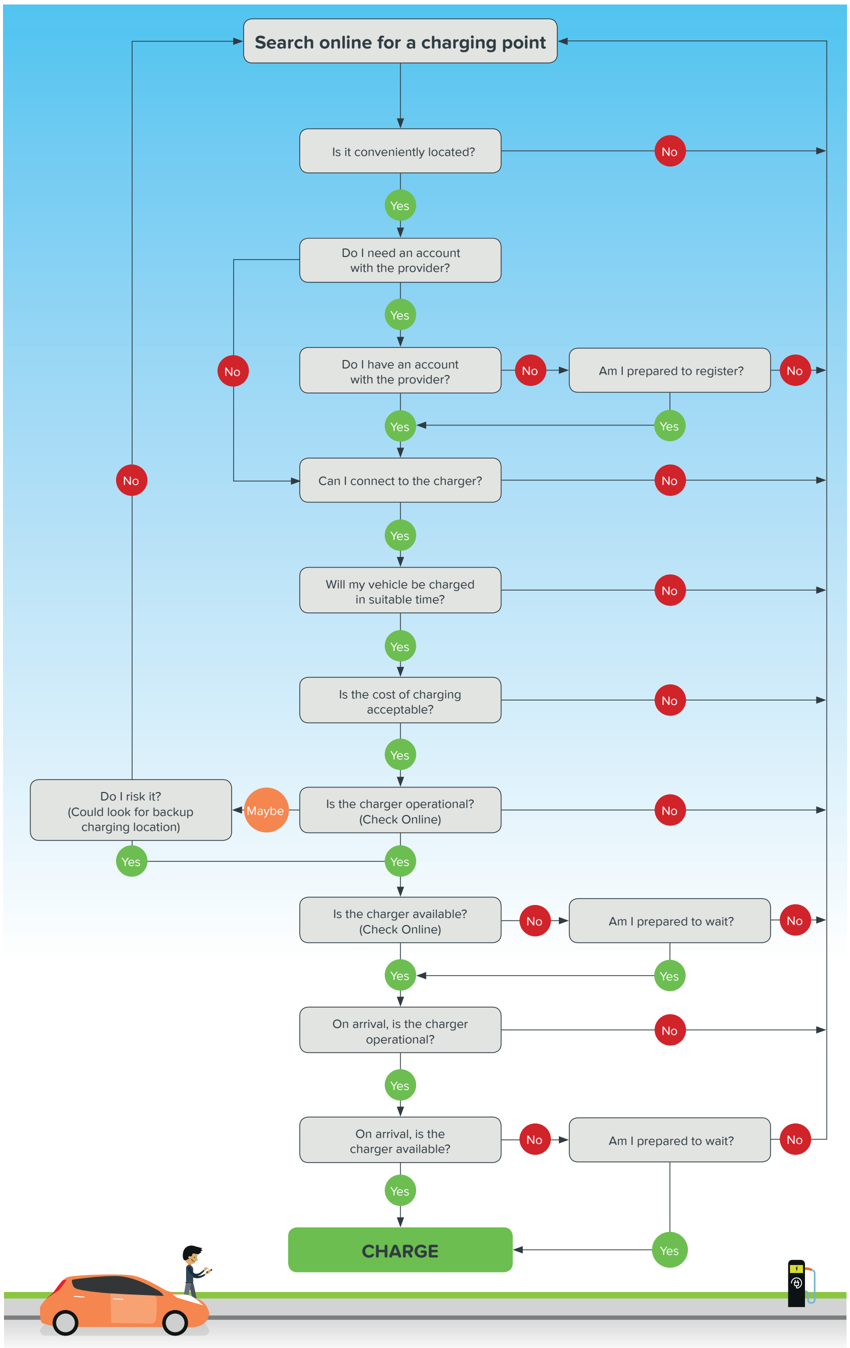
[12] https://chargeplacescotland.org/
[13] http://www.national-charge-point-registry.uk/
[14] https://www.chargeyourcar.org.uk/

To search for an EV charging point involves the following thought process as illustrated. Every petrol station provides two basic options, petrol or diesel, has a standard nozzle which fits every tank and payment can be made with either card or cash. *To search for an EV charging point involves the following thought process:*

Two key questions are whether the charging point is operational and available. For this, charging points need to be capable of transmitting their status (for example currently in use / available / out of action).

Most of the process is straightforward with a smartphone app, but for those unfamiliar with EVs it can be a daunting prospect, and this uncertainty creates a barrier to entry.

Built-in sat navs, which are incorporated into the centre console of vehicles, can provide some information that help with the above process but it is often not up-to-date or as sophisticated as smartphone apps. With many sat nav systems the user needs to pay for updates. As the number of EV charging points changes on a day-to-day basis people rely on their smartphone rather than the built-in sat nav. There could be a market for standalone sat nav devices to provide the functionality of smartphone apps with relation to charging point information.




## CHARGING STOPS ARE SEAMLESSLY INTEGRATED INTO THE VEHICLES SAT NAV SYSTEM.

Technology companies could explore how to best present detailed and timely information on public charging infrastructure to drivers.

### **EV TREND 8:** workplace charging

Employers are expected to provide workplace chargers for their employees. Some employers may choose to provide the electricity for free as an employee benefit, whilst others will have mechanisms in place for calculating the cost of electricity used and ensuring payment is made efficiently.

Enabling employees to go electric (for those that cannot practically use public transport, walk or cycle to get to work) will be seen as a socially responsible thing to do by employers. Employers would also be encouraged to install smart charging infrastructure and potentially V2G if affordable.

The Office for Low Emission Vehicles (OLEV) have a Workplace Charging Scheme[15] (WCS) in place to help organisations with the cost of providing workplace charging points:

*"WCS is a voucher-based scheme designed to provide eligible applicants with support towards the upfront costs of the purchase and installation of EV charge points. The contribution is limited to the 75% of purchase and installation costs, up to a maximum of £500 for each socket, up to a maximum of 20 across all sites for each applicant."*

Even with the WCS, the cost of including charging points can still be prohibitive for some organisations. A fully installed Type 2 7kW double-header would typically cost around £1500, after the WCS Grant – in this case worth £600 – has been applied. Likewise, a 22kW double-headed post unit costs £2,500-£5,000 (inc WCS Grant), while a fully installed rapid charge unit can cost up to £35,000.[16]

Some companies are starting to provide "Charging as a Service". In this model, the installation is provided and managed by a contractor, and the infrastructure is then leased to the site owner. This can make charging more affordable for some organisations and could be successful in the short term to move employers towards offering EV charging on-site.

For organisations that wish to place chargers in areas with public access, measures are also needed to prevent unwanted use. Most charge point manufacturers offer units that can be accessed with either a key or RFID card to prevent unwanted usage. However, there could also be an opportunity associated with this: organisations could consider allowing the wider public to make use of their charging infrastructure outside of working hours to generate revenue.

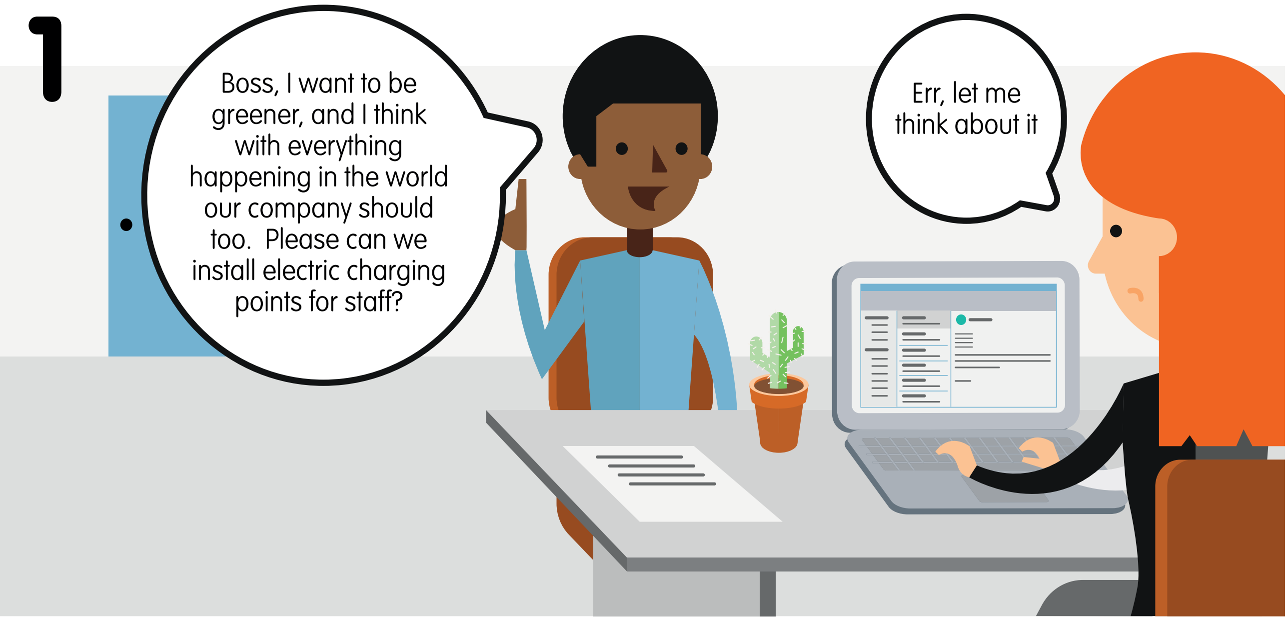
The overall load on the electricity infrastructure of the building (and perhaps the local area) would require assessment. There could be a need for upgrading cabling and substations if a significant number of charging points were planned, or local energy storage solutions and energy management systems could be put in place. Who pays for this is an open question.

As with home-charging and as described under EV Trend 2, there could be significant benefits in encouraging employers to adopt smart charging and V2G units.

Visitors may have different charging needs to employees and may need rapid chargers rather than fast chargers. There could be issues if demand exceeds supply and in deciding which employees/contractors/visitors get access to the EV charging bays. Managing this potential conflict might be an additional burden on the organisation.

## EMPLOYERS WILL INCREASINGLY PROVIDE WORKPLACE CHARGERS IN LARGE NUMBERS.

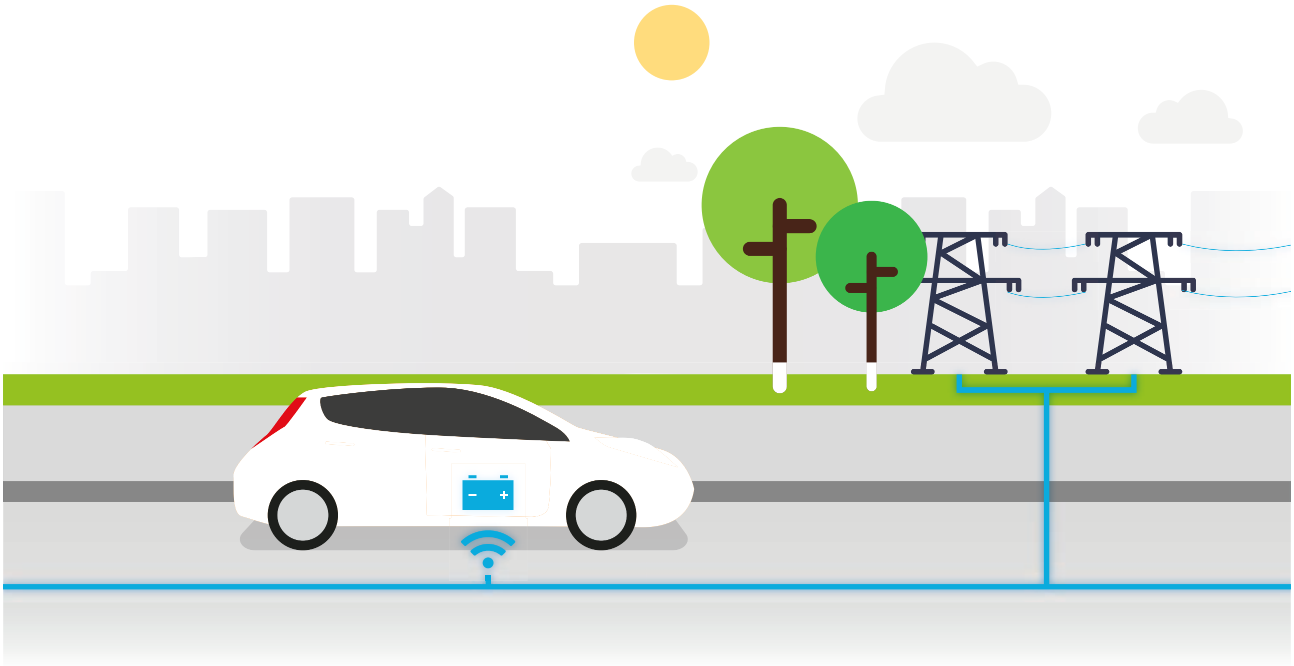
[15] *https://www.gov.uk/government/publications/workplace-charging-scheme-guidance-for-applicants-installers-and-manufacturers*
[16] *Costs from www.zap-map.com*





There are many considerations for employers and site owners relating to the installation of workplace charging. Targeted surveys of large employers could help illuminate the issues. Ultimately, it may come down to cost, but other factors could be significant. New business models are emerging, such as leasing of charging infrastructure, meaning businesses could also consider enabling out-of-hours access to their charging infrastructure to the wider public.

Workplace charging availability could help drive EV uptake and be particularly beneficial to those who cannot charge at home, but achieving this will require close collaboration between the Government, charging point installers and operators, energy companies and businesses.



### **EV TREND 9:** wireless charging

Inductive (or wireless) charging, is a method of charging batteries without the need for users to plug the vehicle/device into a charging point with a cable. It is commonly used for electric toothbrushes, mobile phones and is increasingly being proposed for vehicles.

An electromagnetic field transfers energy across a small gap between an EV and a charging pad. The charging pad is attached to a mains power supply, but the vehicle no longer needs to plug in with a cable.

*The advantages of inductive charging include:*

- It saves having to retrieve the charging cable, which may be in the boot of the car or attached to the charging point, and ensure it is correctly attached
- Avoids trip hazards associated with the cable
- More aesthetically pleasing than cables
- There is potential to offer a standardised platform across EVs, which has so far proved impossible for cable charging
- Could help facilitate the move to autonomous vehicles which could recharge themselves without human input

The primary focus for inductive charging is for stationary vehicles, but there is potential for this to be embedded into the carriageway for dynamic vehicles to charge them as they drive, or to provide a charge boost as vehicles are stationary on approach to traffic signals.

The concept of Wireless Power Transfer (WPT) through electromagnetic coupling has existed for more than a century thanks to the pioneering work of Nikola Tesla (1891). But the implementation of this technology for wirelessly charging EVs is still in its infancy.

*The two primary methods of inductive charging are:*

- **Inductive power transfer (IPT) –** magnetic field coupling is used between conducting coils to transfer energy. These systems require ferrite cores which makes them expensive and bulky. The operating frequencies of under 100kHz, result in large coils around the ferrite cores and low power densities
- **Capacitive wireless power transfer (CWPT) –** electric field coupling is used between conducting plates

[17] http://www.cbi.org.uk/insight-and-analysis/milton-keynes-wirelessly-charged-electric-buses/

to transfer energy. These systems do not need ferrite cores and can be operated at higher frequencies which allows them to be smaller and less expensive. However, due to very small capacitance between the transmitter and receiver plates, effective power can only occur at very high frequencies, which results in challenging design implications.

Other methods include magnetic gear wireless power transfer (MGWPT) and resonant inductive power transfer (RIPT).

There are many examples of inductive charging being commercially deployed for EVs. For example, Arriva has been using this technology for bus route 7 in Milton Keynes since 2014, and it has proved successful in terms of operation, battery life and cost savings. The bus charges inductively at each end of its route whilst waiting at the bus stand.[17]

*Although some systems have been deployed with certain vehicle types, there are real or perceived challenges associated with inductive charging, which include:*

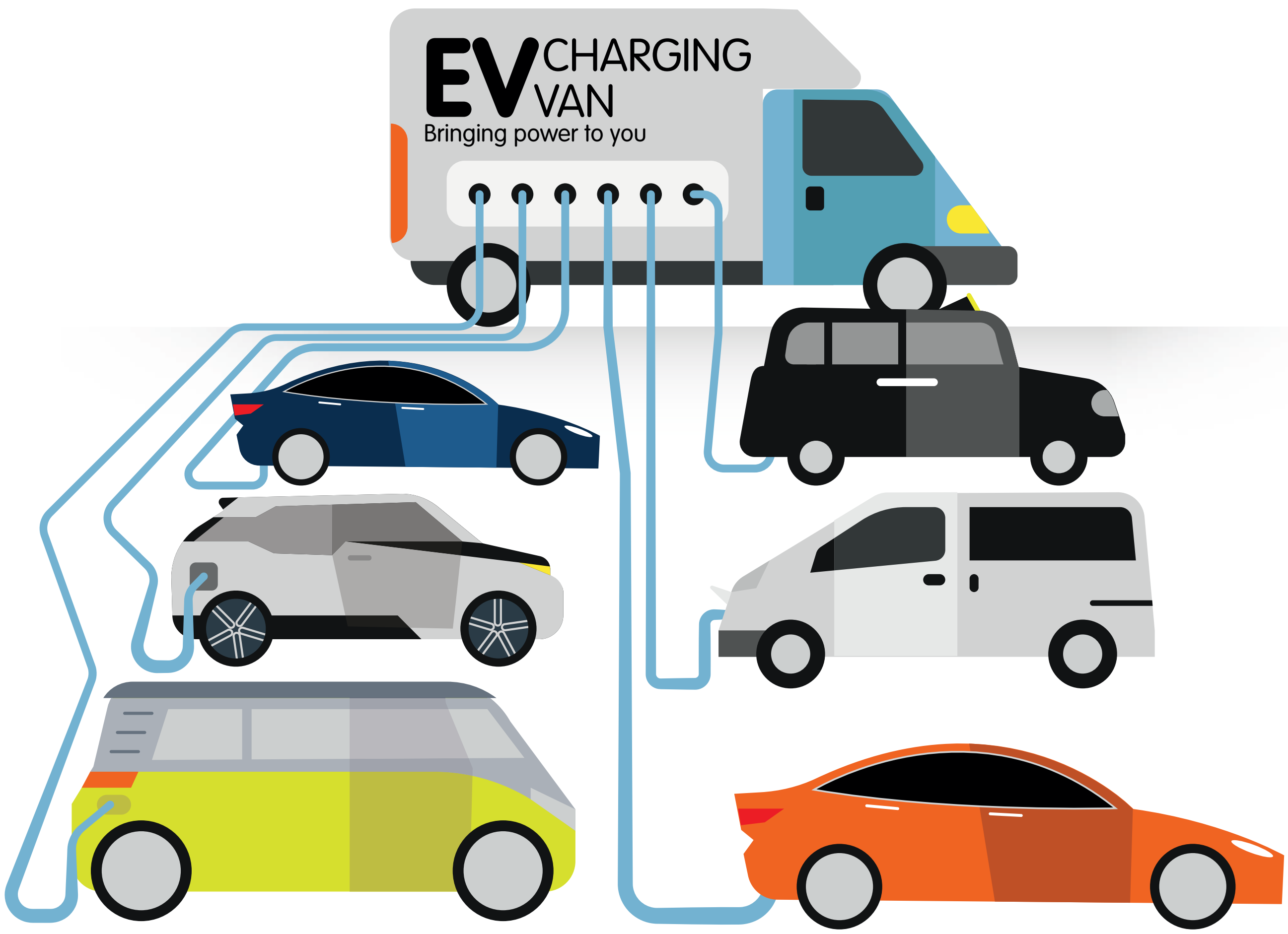
- Less efficient than cable charging, so takes longer to charge and uses more power
- There is a lack of universal standards, although this is being addressed as discussed later in this report
- The induction coils need to be close together, which is technically challenging given the ground clearances required for vehicles
- The vehicle needs good alignment with the charging plate for charging to commence
- Costly components will push up vehicle price
- The magnetic pad and induction coils are heavy and bulky in the case of inductive power transfer systems, adding weight to vehicles and taking up space within the chassis
- Hazards associated with electromagnetic radiation in close proximity or interference with other systems
- Slip hazard presented by the charging plate when not in use
- Excessive output from the primary to the secondary induction coil resulting in damage to the vehicle
- The potential for short circuits to cause fire
- Environmental conditions in which the charging plate operates and the presence of foreign matter can have a detrimental impact on its operation, for example extreme temperatures, snow, ice, rain, leaves, mud and litter. This has been overcome in recent implementations
- Potential damage to the charging plate from people walking on it, dropping objects onto it, etc. The pad could be embedded under the surface, reducing risk

Many of the above challenges have either been or are close to being solved. Therefore perhaps the challenge relates more to public education and acceptance of this technology, alongside efforts to make installation as seamless and affordable as possible.

Inductive charging represents a potentially transformational method for improving the EV operation and user experience. Investigations into where the UK could most effectively advance research efforts in this field could prove beneficial, alongside consideration into how installation can be as seamless and affordable as possible.

## **EV TREND 10:** mobile charging

For locations where there is still a lack of charging infrastructure mobile charging units can go to wherever vehicles are in need of charge. This is popular for users without charging points at home, employers who want to offer charging to employees without the infrastructure costs and for event parking such as at festivals. Companies are offering services to charge vehicles that are parked in particular locations.




Volkswagen has recently unveiled its mobile charging strategy.[18][19] The first systems will be set up in the first half of 2019 in Volkswagen's home town. Thomas Schmall, Chairman of the Board of Management of Volkswagen Group Components, was quoted:

*"The mobile charging stations are a decisive step toward an efficient network of charging points. They can be set up anywhere as required – with or without connection to the power supply. This flexibility enables a completely new approach for the rapid expansion of the charging infrastructure. Cities can, for example, find out the most suitable places for a permanent charging point before making major investments in developing the network. In addition, it will be possible to set up a large number of charging stations temporarily – exactly when and where they are needed."*

[18] *https://www.volkswagen-newsroom.com/en/press-releases/electrifying-world-premiere-volkswagen-offers-first-glimpse-of-mobile-charging-station-4544*
[19] *https://www.theverge.com/2019/1/2/18165265/volkswagen-ev-mobile-charging-station-battery*

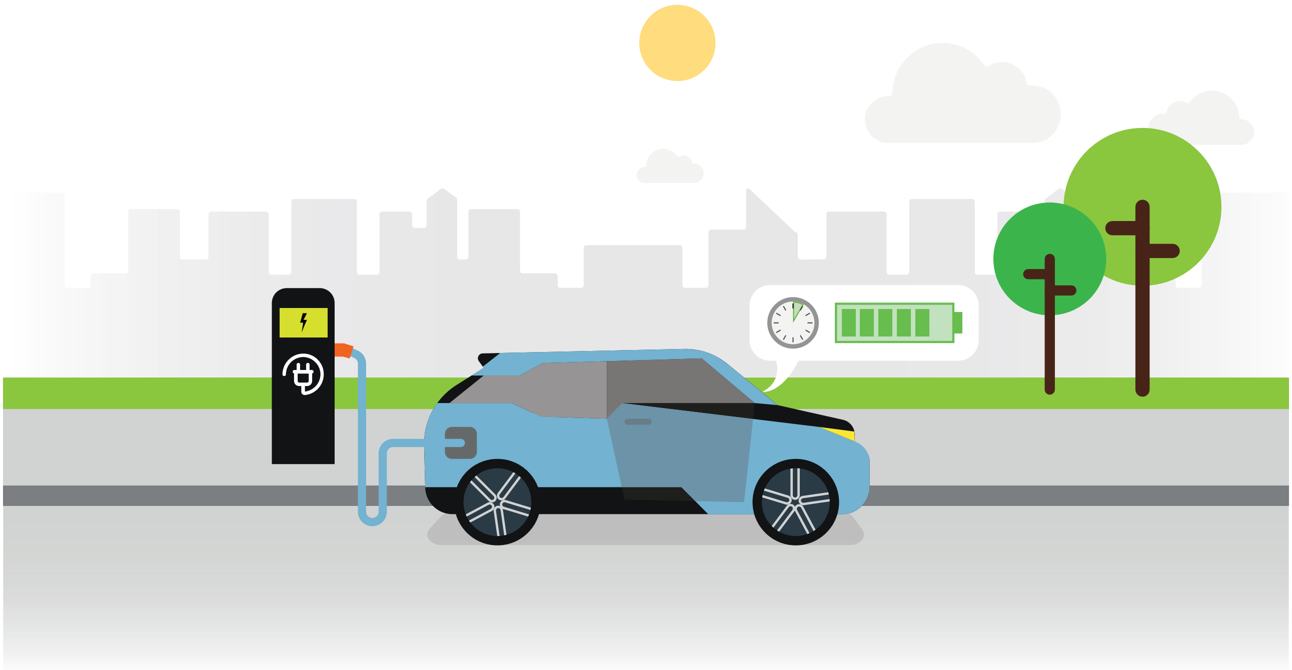
In the UK, ZAPINAMO has been using stored energy to 'Power Boost' its performance for Ultra-Fast charging of EVs. With its patented power electronics system, it can deliver high power to the EV at the maximum speed it can take from a limited grid feed. ZAPINAMO has been carrying out mobile charging at Heathrow airport since 2017 and is developing a range of products along this theme.


*Image source:* ***https://zapinamo.com/introducing-zapinamo/***

Freewire Technologies are a US based company that has developed a mobile charging solution in the form of a unit that can be deployed with no fixed infrastructure. It is operated with a joystick that allows for exact placement near the vehicle, and is supported by a software platform for intelligent energy and asset management. Freewire is working with Zipcar to develop a trial of this technology and is receiving funding from Innovate UK.

*Image source:* ***https://freewiretech.com/products/mobi-ev/***

Products and service models for mobile charging are in development but need to mature. The industry should continue developing and improving EV mobile charging products and services to help plug the gap in fixed charging infrastructure.



**EV TREND 11:** increasing charging speed

Vehicle charging points are getting more powerful, and as a result the time needed to charge vehicle batteries is decreasing. Charging points transfer electrical energy from the grid to the vehicle batteries[20]. At present, slower charging points of up to 3kW are best suited to overnight charging and usually take between six and 12 hours to charge an EV. 'Fast chargers' range from 7kW to 22kW. A typical electric car with a 60kWh battery takes just under 8 hours to charge from empty to full with a 7kW charging point.

Rapid chargers can operate on direct current (DC) or alternating current (AC), and typically operate at rates of 50kW for DC and 43kW for AC, although many companies are in the process of rolling out faster versions, which include AlfaPower (120kW), IONITY (350kW) and BP Chargemaster (150kW). Chargepoint are working alongside Gridserve to develop 500kW charging stations.

Tesla Superchargers operate on Rapid DC and charge at around 120kW, which can charge a Tesla Model S to 80% within 40 minutes. This provides in the order of 200 miles of range. Tesla is reportedly in the process of upgrading Superchargers to handle 250kW charging, which Tesla say could add 75 miles of range in five minutes.

Dutch Company FastNed are installing 175kW across Europe, including a site at Newcastle University. These charging points can be upgraded to 350kW in the future. In Denmark, Ionity has already installed 350kW charging points, although no vehicle currently on the market can accept such a charge. The upcoming Porsche Taycan is expected to be capable of charging at this rate.

A challenge related to faster charging is avoiding excessive heat, and cooling systems are needed for both the batteries and the cables.

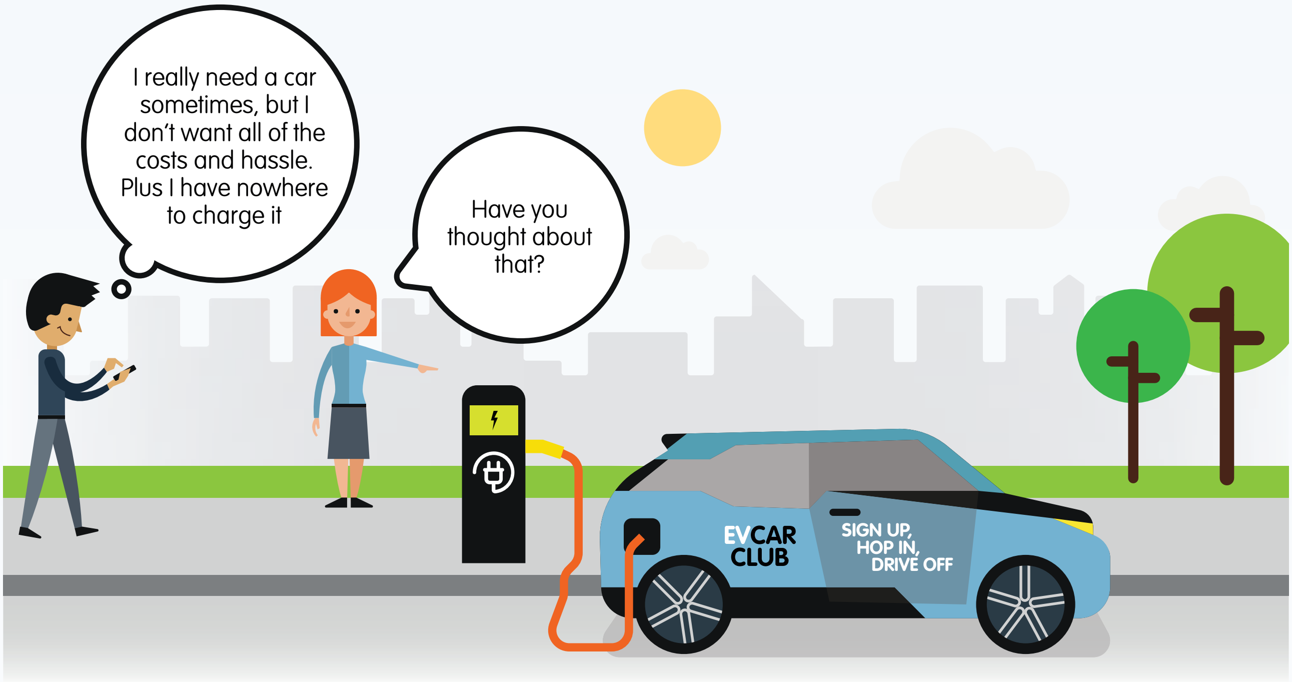
[20] *The power of the charging point refers to the rate at which it can transfer energy. It is measured in watts, which equates to the number of joules of energy transferred per second*

The result of faster charging will enable public charging stations to replicate the experience of petrol filling stations, where many hundreds of miles of range can be added in a short period of time. However challenges remain in terms of whether the grid can cope with such charging rates. The affordability of vehicles that can accept such high charging rates remains uncertain at present.

## NEW AND ADAPTING BUSINESS MODELS

### **EV TREND 12:** EV car clubs and mobility-as-a-service (MaaS)

Electric car clubs could grow in popularity in large towns and cities across the UK.




The service enables users to access an electric car without the cost, inconvenience and some of the other concerns associated with EV ownership.

Car clubs are growing in popularity, especially in large cities around the world. *There are various usage models, such as:*

- **Back-to-base:** cars are returned to their original starting point, for example Zipcar, Hertz 24/7, Enterprise Car Club, E-Car Club
- **Free-floating:** cars can be returned to any public parking bay within a predefined area, for example DriveNow, car2go, Zipcar Flex
- **Point-to-point:** cars are collected from and returned to stations or hubs, for example Bluecity
- **Delivery and collection:** cars are delivered to and collected from the user, for example Audi on Demand

However, car clubs have their challenges. Every town and city is unique with its own demographics, public transport provision, road capacity and other factors that have a potential impact on uptake. Once a suitable location is identified, convincing users to try a car club is a challenge. People often stick to their routine forms of behaviour and may require an incentive to make a significant change. The most effective incentive could be if a user's normal mode becomes unavailable, for example if their private car fails to start. During the London Underground strikes of 2017, Transport for London observed a 149% increase in bike hires.

EV car clubs could be marketed and promoted as the low-risk way to experience an EV, either as a stepping stone to owning one, or as a way to avoid the need for car ownership altogether.

EV car clubs could also help solve the 'chicken and egg' problem of EV charging infrastructure. One car club informed us that they have teams of people charging 40-50 vehicles every night in London using public charging points. This is helping to create the initial demand for charging that may facilitate further investment in charging infrastructure.

The fact that EV car clubs will require their own protected charging infrastructure and kerb space can be an infrastructure challenge. However some innovative EV charging solutions may avoid the need to reserve a parking space for charging.

A slightly different model is provided by companies such as Turo. This enables peer-to-peer lending of cars. Vehicle owners can offer their vehicle for others to rent to make money from it when they don't need it. Those wishing to rent can search for a local vehicle available at the time they need it.

For some, car sharing will not be as convenient as having exclusive use of a vehicle, but for those who use a vehicle occasionally it could offer a more cost-effective solution and for others it might provide a stepping stone to EV use.

Providing a car club is no small undertaking. Significant upfront investment is needed to reach the critical mass of vehicles to make the service convenient for the public. Zipcar, for example, has partnered with Volkswagen to share the upfront risk and investment costs.

From a consumer perspective, there is a barrier associated with behaviour change. Incentives could be provided to accelerate adoption.

Car clubs are in competition for kerbside parking and EV car clubs also are dependent on an extensive public charging network. Significant commitments are required from local authorities to make them work. A package of measures might be needed to facilitate EV car club uptake which could be a combination of 'carrot and stick' approaches, such as the roll-out of extensive charging infrastructure in the right locations, workplace parking levies, road pricing schemes, etc.

Another trend related to EV car clubs is the wider concept of 'mobility as a service' (MaaS). MaaS refers to the use of a digital interface to source and manage the provision of transport-related services to meet the mobility requirements of the customer. This could simplify ticketing and help present options across a range of public and private transport offerings. MaaS was explored in more depth in a report published by Transport Systems Catapult in 2016.[21]

EV car clubs could present a useful stepping stone for some users transitioning into EV use, whilst for others it could enable them to avoid vehicle ownership. They could also help create demand for charging infrastructure. Local authorities could consider packages of measures to encourage the roll out and uptake of EV car clubs. EV car clubs could be intelligently linked to wider Mobility-as-a-Service (MaaS) offerings.

[21] *https://ts.catapult.org.uk/wp-content/uploads/2016/07/Mobility-as-a-Service_Exploring-the-Opportunity-for-MaaS-in-the-UK-Web.pdf*

### EV TREND 13:
"fleet operators switch to EVs"

Fleet operators are expected to switch to EVs. *This includes public and private sector organisations, such as:*

- Taxi / private hire companies
- Car rental companies
- Government agencies (for example Highways England, Network Rail, local authorities, etc.)
- Public utility companies
- Couriers

Organisations may see switching to EVs as not just a socially responsible course of action, but also one that offers significant cost savings.

Interest in EVs from commercial organisations is growing. Fleet operators are seeking to embrace the environmental and running cost benefits associated with zero emission cars and vans. A poll[22] undertaken by telematics company Geotab in November 2018 found that 89% of 250 UK-based fleet managers surveyed expect EVs to play a dominant role in their company's fleet before 2028. According to the study, government incentives (48%), improvements in charging infrastructure (48%) and an improved selection of models from vehicle manufacturers (32%), are the leading motivators in the transition to a fully electric fleet.

## FLEET OPERATORS ARE SEEKING TO EMBRACE THE ENVIRONMENTAL AND RUNNING COST BENEFITS ASSOCIATED WITH ZERO EMISSION CARS AND VANS.

[22] https://www.geotab.com/press-release/uk-ev-fleet-survey/

The UK Government includes the following commitment within *'The Road to Zero – Next steps towards cleaner road transport and delivering our Industrial Strategy'* document, published in July 2018:

*"We will drive uptake of the cleanest new vehicles by leading the way by ensuring 25% of the central Government car fleet is ultra low emission by 2022 and that all new car purchases are ultra low emission by default. Committing to 100% of the central Government car fleet being ultra low emission by 2030."*

*The following sources of information are available to fleet operators at present:*

- The Go Ultra Low website includes a dedicated Fleet and Business section.[23]
- Energy Saving Trust in August 2017[24] and in
- 'Electric Vehicles Technical Briefing' published by the Institution of Engineering and Technology in 2016.[25]


89% of UK-based fleet managers surveyed expect them to play a dominant role in their company's fleet before 2028.

## COMMITTING TO 100% OF THE CENTRAL GOVERNMENT CAR FLEET BEING ULTRA LOW EMISSION BY 2030.

Fleet operators represent a demographic most ready for early adoption of EV. Organisations may be willing to switch if it would reduce business costs whilst at the same time improving their green credentials with limited negative (or positive) impact on operational performance. Government, EV manufacturers and charging infrastructure providers should work together to provide fleet operators with the tools, information and incentives required to switch their fleets.

*A strategy is needed which will:*

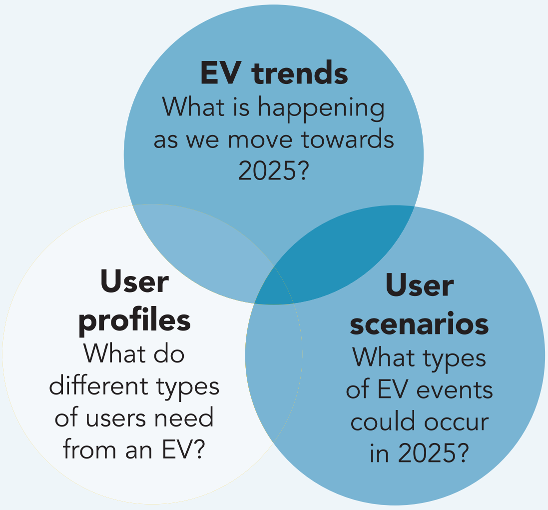
– better understand the needs of organisations, the infrastructure required to support EV adoption and barriers to implementation
– push the information to organisations
– offer bespoke advice to large fleet operators

Public sector fleets could form a key focus for government.

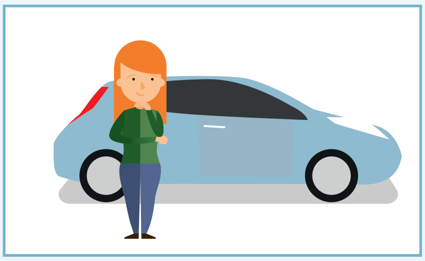
[23] https://www.goultralow.com/company-cars-and-fleet-vehicles/
[24] http://www.energysavingtrust.org.uk/sites/default/files/reports/6390%20EST%20A4%20Chargepoints%20guide_v10b.pdf
[25] https://www.theiet.org/publishing/iet-standards/transport/electric-vehicles-technical-briefing/

# USER PROFILES

In the preceding section, we highlighted and discussed some of the key trends currently emerging in the EV market. From user perspectives, it is crucial to understand how these trends relate to these experiences and also, to understand what anxieties and user needs continue to be unmet with respect to their EV experiences. We have therefore explored a number of fictional user types, summarised as follows:



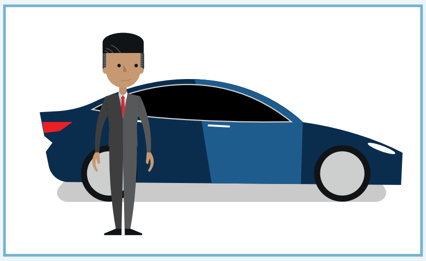

| SUSIE – COMPANY EMPLOYEE | | |
|---|---|---|
| AGE | OCCUPATION | REGULAR EV TRIP |
| 42 | IT trainer | Home to work |



Susie drives to work five days per week. She switched to an EV when her company started offering charging at work, and almost exclusively charges there. She has no driveway or charging facilities at home. She uses the car in evenings for shopping and occasional family trips with her children.

**Needs: Access to charger at work.**

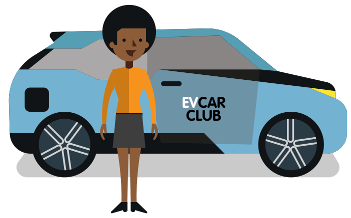
| LEON – SELF-EMPLOYED BUSINESS TRAVELLER | | |
|---|---|---|
| AGE | OCCUPATION | REGULAR EV TRIP |
| 54 | Self-employed business consultant | Business |



Leon enjoys driving. Being on the road makes him feel relaxed and he uses the time to plan for meetings, or listens to audio books. He was sceptical towards EVs but fell in love with them after trying one. He often drives around the country for business.

**Needs: Comfortable vehicle with high range. Easy access to public charging points.**

| SOPHIE – TRAIN COMMUTER | | |
|---|---|---|
| AGE | OCCUPATION | REGULAR EV TRIP |
| 31 | Policy advisor | Leisure |




Sophie lives in Manchester and works as a senior policy advisor in Liverpool. She commutes by train every day, which suits her well as she can read on the train. She doesn't feel she needs to own a car, but is a member of an EV car club. Sophie enjoys going to car boot sales to pick up bargains. For this, she prefers getting a car for the day so that she can be sure to get all of her treasures home safely afterwards.

**Needs: EV car club vehicles available when and where she needs them.**

| JOHN – RETIRED SALES EXECUTIVE | | |
|---|---|---|
| AGE | OCCUPATION | REGULAR EV TRIP |
| 72 | Retired sales executive | Leisure |

John lives in a small village with his wife Marnie. The couple have three adult children and two grandchildren. John and Marnie enjoy a fairly active life – they like going to visit historic houses all around the country and to the theatre. John and his wife often need to travel in excess of 200 miles to visit their adult grandchildren.

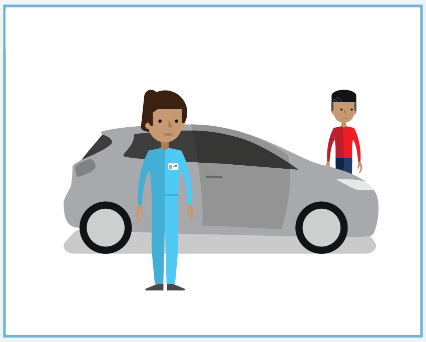
**Needs: Low cost vehicle capable of driving long distances. Charging superstations and better information on where to charge. They rent out their driveway to boost their income.**

| DAVE – TAXI DRIVER | | |
|---|---|---|
| AGE | OCCUPATION | REGULAR EV TRIP |
| 48 | Taxi driver | Work to work |

Dave has been driving his taxi for 20 years. He enjoys the social aspects of the job – small talk with different kinds of people, and helping people get to places – but would not say driving is his passion. In recent years, he has had problems with his back caused by the many hours he spends in the driver's seat each week. He mainly provides services from the train station to local area but sometimes ventures further.

**Needs: Comfortable and affordable taxi with sufficient range. Rapid charging infrastructure available when he needs a top up.**

| MONICA – SINGLE PARENT | | |
|---|---|---|
| AGE | OCCUPATION | REGULAR EV TRIP |
| 26 | Receptionist | Home to school to work |



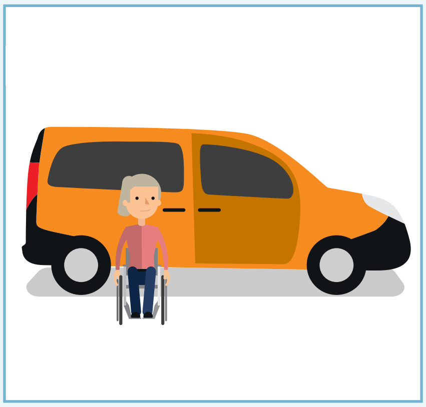
Monica has three young children and works part time as a receptionist. She struggles to make ends meet, and never seems to have enough time in the day to get to and from the places she needs to be. Monica lives close to her retired parents, and they help her in whatever way they can.

On weekday mornings, Monica walks over to her parents with her children. She leaves the youngest with her parents, and borrows their car to take the other two to school and then drives to work.

After work, she usually stops at a supermarket to collect essential groceries before collecting the children. She likes to charge the car at the supermarket if she can to help pay her parents back for lending her the car. She would charge at work if she could but there are no charging facilities.

**Needs: Low cost charging points available at supermarket or at work. Space in car for groceries and children.**

| CARMEN – DISABLED HOME-MAKER | | |
|---|---|---|
| AGE | OCCUPATION | REGULAR EV TRIP |
| 58 | Home-maker | Home to hospital |

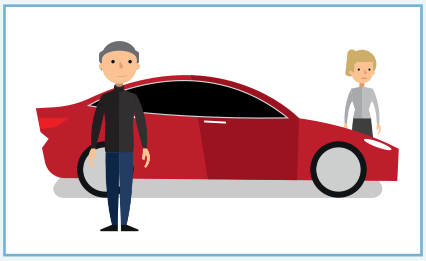


Carmen lives with her husband Manny in a suburb to Southampton. About ten years ago, Carmen was diagnosed with multiple sclerosis and she is now wheelchair bound. She can carry out most day-to-day chores on her own, but needs help to get outside the house, for instance to travel to hospital check-ups. For this reason, Manny works flexible hours, so that he can assist his wife when needed.

They regularly take the car from their house to the hospital, and also like to visit family and friends when they can.

**Needs: Vehicle with space for wheelchair. Wheelchair accessible charging spaces.**

| JACK – UNIVERSITY UNDERGRADUATE | | |
|---|---|---|
| AGE | OCCUPATION | REGULAR EV TRIP |
| 21 | Student | Leisure |



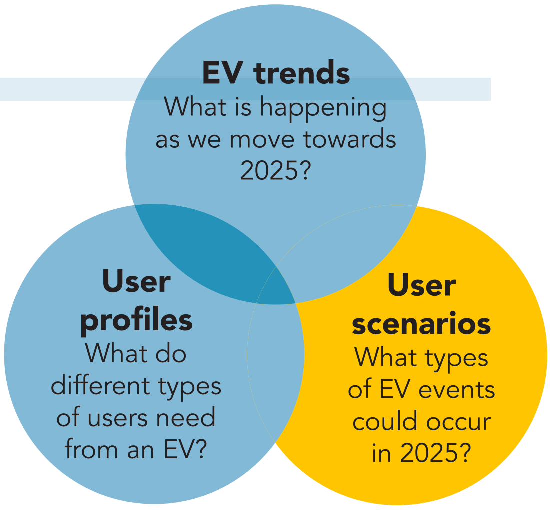
Jack is a computer science undergraduate at Cambridge who lives in his parent's basement to save money. He's very concerned about the environment, and is a member of several activist groups.

Jack often borrows his parents' EV to drive himself and others to activists meetings.

**Needs: Affordable charging and maintenance. Cheap, environmentally-friendly transport.**

The user needs analysis indicates that different users will have very different needs and desires when considering and using EVs. Usage model, vehicle type, range requirements, charging options and affordability will vary from user to user but there will be some cross-cutting requirements that would be needed or desired in all cases.

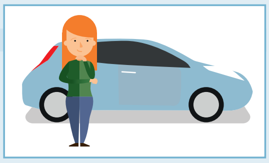
# USER SCENARIOS




For some of the above user profiles, we have imagined them in a particular scenario themed around a design year of 2025. The intention of this exercise is to promote thinking into more sophisticated EV experiences and identify further possible gaps in service provision. Needless to say, these scenarios are far from exhaustive and are only used as illustrative cases. Further, these scenarios are not necessarily alternative to each other.

## SCENARIO 1

### SUSIE TRAVELLING WITH HER FAMILY TO PLYMOUTH



*Themes explored:*
Issues with charging once EV uptake accelerates, mobile charging units deployed to areas of road disruption, integrating commercial offerings with charging, better information on where to charge and route planning.

It is a bank holiday weekend, and Susie and her family are going down to Plymouth to visit friends who have recently moved there. They've decided to drive. From their home outside of Birmingham it will be a round trip of around 400 miles.

Susie has a relatively old electric car and estimates that they will have to charge the vehicle about three times over the course of the weekend, but she decides she doesn't need to work out a journey charging plan. She knows that there are several charging superstations along the route, and she'll just pick one of them when it seems like the children need to stretch their legs.

The first part of the journey is uneventful. Coming past Bristol the children are getting restless when **her car sat nav tells her that the next charging superstation offers complimentary coffee for users of the slower charging points.** This sounds good to Susie, and even better when she discovers that there is a children's play area near to the coffee shop, so she can watch the kids get some exercise whilst sipping her cappuccino – everyone happy! She pulls into the charging area located just off the motorway where **there were clear signs to the charging points, and clear information on the costs.**

There were around 30 bays for slower charging and 15 bays for faster charging, with plenty of availability. Her car told her that 45 minutes of slow charging would be more than enough to get to Plymouth, so she chose that option.

Once they arrive at her friends' house in Plymouth, Susie plugs in the car for an overnight charge on the driveway. She insisted on paying for the electricity, which was easy through her **smart roaming payments app that links it to her own energy account.**

After a late breakfast on Monday morning, the family begins the journey home. It is a hot and sunny day, and Susie is keen to make a stop at Cheltenham to have lunch with a friend. She is keen to get to Cheltenham without charging so she's not late for her friend, so decides to attempt the journey on a single charge.

Shortly after they've driven past Bristol, they hit traffic. There's been an accident further north on the M5, and everyone travelling back from their weekends away are now stuck on the motorway.

The hot weather means it is impossible to turn the air conditioner off, which shortens the range of the vehicle and Susie starts to get concerned that she will need another charge soon. Susie's sat nav is telling her that she may not make it all the way to Cheltenham.

**Her car sat nav also integrates with real-time traffic updates from the highways authority, and knows the current availability of charging points on the route.** There is a charging point just two miles away, but the sat nav says it's very busy – probably because so many EV drivers have a similar problem.

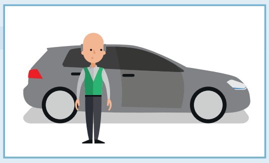
She hears a traffic update on the radio that **a large mobile charging unit is being despatched to the local area,** but it is not there yet. Her sat nav advises that there is a 60% chance of making it to Cheltenham, or a 100% chance of getting to another charging point before Cheltenham with good charging point availability, and which would only add 15 minutes to her overall journey time. She decides not to risk it and selects to top up the charge en route. Suddenly, she feels more relaxed.

After her quick top up, she heads into Cheltenham and her sat nav directs her to a space with a cheaper, slower charging point. She selects an option that provides more than enough charge to get her home, but decides not to completely recharge as its more expensive to charge here than at home.

**Key learnings:**

- Commercial offerings, such as free coffee at charge point stations, could encourage users to stop and charge
- Sat navs need to integrate traffic updates with real-time availability of operational charging points on the route and present the information clearly to the driver
- Mobile charging units could be deployed during times of high congestion levels or extreme weather conditions to temporarily increase charging capacity and help allay user concerns over charging needs

## SCENARIO 2 JOHN, MAKING USE OF V2G AND MOBILE CHARGING UNIT



*Themes explored:*
Information on purchasing EV, use of V2G, offering driveway charging to others, mobile charging units in remote areas.

John put a lot of thought into his decision to switch to an electric car. **He visited his local car dealership and borrowed a vehicle for a week to try it out.** He found the information provided by the staff extremely helpful in terms of how to plug in, what he needs to do to install equipment at home, how to find charging points, etc. He also got a tailored breakdown of the costs compared to using his previous internal combustion engine vehicle.

John has always believed in saving money and decided to also go for the 'vehicle to grid' home charging point. It allows him to charge at cheaper rates because it controls the time and rate of charge in the interests of the electrical system as a whole, and it also reverses the flow from the car to the grid, but John can control this and ensure the car is sufficiently charged for when he needs it. Occasionally, John receives a message asking him to plug in and give some power to the grid, for which he is rewarded. This sometimes happens during day time, but more frequently in the early evening hours.

## OCCASIONALLY, JOHN RECEIVES A MESSAGE ASKING HIM TO PLUG IN AND GIVE SOME POWER TO THE GRID, FOR WHICH HE IS REWARDED.


As John's car is often parked at home at that time, he usually responds to V2G requests in the hours of early evening when the demand on the network is high. He responds to incentives to charge his vehicle overnight as well. Through his mobile application he can set a limit on the battery capacity that will be used for the V2G service and he can also monitor the vehicle's state-of-charge. John noticed that he gets an increased amount of requests during cloudy days with low winds.

Late one evening there was a short, localised power outage in his neighbourhood. **Fortunately for John his V2G charging point also enabled his home to be powered by his car battery in case of emergencies.** Based on his current usage and the current battery level he could continue to run his home for 34 hours. John likes to help his neighbours in his rural community so he knocked on a few doors and asked whether anyone needed to borrow a plug for anything. It was lucky he did, as one of his neighbours really needed to charge her mobile phone before going out the next morning.

Being community-minded, **John has also made the spare part of his driveway available for others to charge their vehicles.** One individual sometimes works in the area and takes advantage of this, and John likes to say hello and has even made him a cup of tea in the past.

One of John's favourite activities is visiting historic houses, particularly those that he has not been to before. These are often located in rural areas and parking can be just on grass fields. In the past he would stop en route to charge, but recently he has noticed some of the properties have **started using large mobile charging units.**

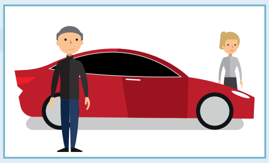
## BEING COMMUNITY MINDED, JOHN HAS ALSO MADE THE SPARE PART OF HIS DRIVEWAY AVAILABLE FOR OTHERS TO CHARGE THEIR VEHICLES.

**Key learnings:**

- Car dealerships need to ensure they can provide comprehensive information on all aspects of EV purchase and use
- V2G should be an attractive option with the potential benefits made clear to consumers
- Mobile charging units could help with charging in remote locations where the cost of fixed cabling could be prohibitive

# SCENARIO 3

## JACK VISITING HIS GRANDMOTHER ON THE WAY TO AN EVENT



*Themes explored:*
Knowledge around charging cables, payments between users of shared vehicles, mobile charging units deployed to events.

It's Saturday, and Jack's excited about a huge march against global warming that he's going to attend this afternoon. His dad has agreed Jack can take the car ("but don't make it a habit"), and suggests he makes a stop to visit Grandma, seeing as it's on the way. It's actually a great idea, as Jack could take the opportunity to top up the car in Gran's garage.

Jack takes the car to pick up his friend and then they're on their way to Bicester, where Gran will hopefully be welcoming them with lunch. They arrive at her house late morning, and Jack parks the EV in the garage where there is a 13-pin plug. The cable doesn't reach, so he asks gran for an extension cable, and she points him to a cardboard box that contains a birds nest of various cables. He knows there is at least one that will be safe, as his parents often charge here when they visit, but he has no idea which one it is. Gran is of little help. Jack contemplates chancing it, but decides he is not too keen on dealing with his dad's disappointment if something goes wrong.

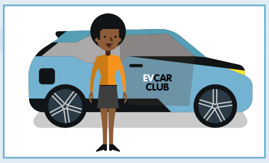
After lunch, the boys continue their journey to Oxford. The protest march is drawing a lot of visitors and traffic is very busy. They regret not using the park and ride, where they could have left the vehicle charging. They park the car on a big field that's been reserved for protesters and where the organisers have arranged mobile charging units for the many EV owners amongst the attendants. Jack does need to charge now and manages to secure a spot. It's a lot costlier than charging at home, but it's for a good cause.

When Jack arrives back home his dad awaits him with the breakdown of the energy bill for this month. There isn't much point in trying to negotiate, as it shows exactly how much Jack has been driving the vehicle and what his total EV energy consumption has been.

**Key learnings:**

- Information should be easily accessible to EV users on how to charge safely, including on the use of extension leads
- Sophisticated energy accounts could split the bill by user rather than by household
- Mobile charging units could be deployed at events where temporary parking is provided

## SCENARIO 4 SOPHIE'S COMMUTE



*Themes explored:*
V2G, mobility as a service, better information on where to charge.

To get to work Sophie normally drives her EV to the train station in Manchester where **she plugs it into the V2G public charging point.** It's convenient as she can adjust how much it charges depending on how much she'll need the car that week. She takes the train to Leeds and walks from the station to the office. However, on this particular morning when she gets to the station in Manchester she discovers the train services are disrupted. She decides she will need to drive all the way to Leeds.

Sophie grabs a coffee from a coffee shop and gets in her car. Luckily she has enough charge to get all the way to Leeds without charging en route. She would have liked to avoid driving during rush hour, but she can't work flexibly and needs to be in the office by 9am. As she reaches Leeds, the traffic is pretty much at a standstill, and Sophie worries she'll be late for work. **Through voice command, she opens up her travel app to see if it can suggest any alternative routes.**

The app estimates that the quickest way for Sophie to get to work would be to take a slight detour to a nearby public car park which has good charging point availability and then use a hire bicycle nearby and cycle in to the office. It's a beautiful morning, so Sophie wouldn't mind a bike ride. She proceeds to book the charging and the bike through the app, and also gets the option of choosing how to get back to her car again after she's finished work. It will be dark by then and she'll be tired, so taking the bus would be preferable. As she will pay for the charging directly through the app, it gives her several options to choose from. She doesn't need a full charge, but just enough to get her back to Manchester, so she selects that option.

**Her app directs her straight to her allocated parking space and then to her bike.** She arrives at work at 8:50, well in time to grab another coffee before her first meeting starts. She decides she would like to cycle more often!

**Key learnings:**

- V2G could integrate into public charging points
- Travel apps could offer sophisticated multi-modal options, combining driving and charging an EV with public transport, bike hire, walking, etc, which could encourage modal shift

# SUMMARY OF USER SCENARIOS ANALYSIS

The key learnings from the analysis above are summarised as follows. It's worth noting that the key learnings, while derived from separate, illustrative scenarios, cut across all users and cases and are desirable in all scenarios.

| SCENARIO | KEY LEARNINGS |
|---|---|
| **Scenario 1**<br>Susie travelling with her family to Plymouth | • Commercial offerings, such as free coffee at charge point stations, could encourage users to stop and charge<br>• Sat navs need to integrate traffic updates with real-time availability of operational charging points on the route and present the information clearly to the driver<br>• Mobile charging units could be deployed during times of high congestion levels or extreme weather conditions to temporarily increase charging capacity and help allay user concerns over charging need |
| **Scenario 2**<br>John making use of V2G and mobile charging unit | • Car dealerships need to ensure they can provide comprehensive information on all aspects of EV purchase and use<br>• V2G should be an attractive option with the potential benefits made clear to consumers<br>• Mobile charging units could help with charging in remote locations where the cost of fixed cabling could be prohibitive |
| **Scenario 3**<br>Jack visiting his grandmother on the way to an event | • Information should be easily accessible to EV users on how to charge safely, including on the use of extension leads<br>• Sophisticated energy accounts could split the bill by user rather than by household<br>• Mobile charging units could be deployed at events where temporary parking is provided |
| **Scenario 4**<br>Sophie's commute | • V2G could integrate into public charging points<br>• Travel apps could offer sophisticated multi-modal options, combining driving and charging an EV with public transport, bike hire, walking, etc. which could encourage modal shift |

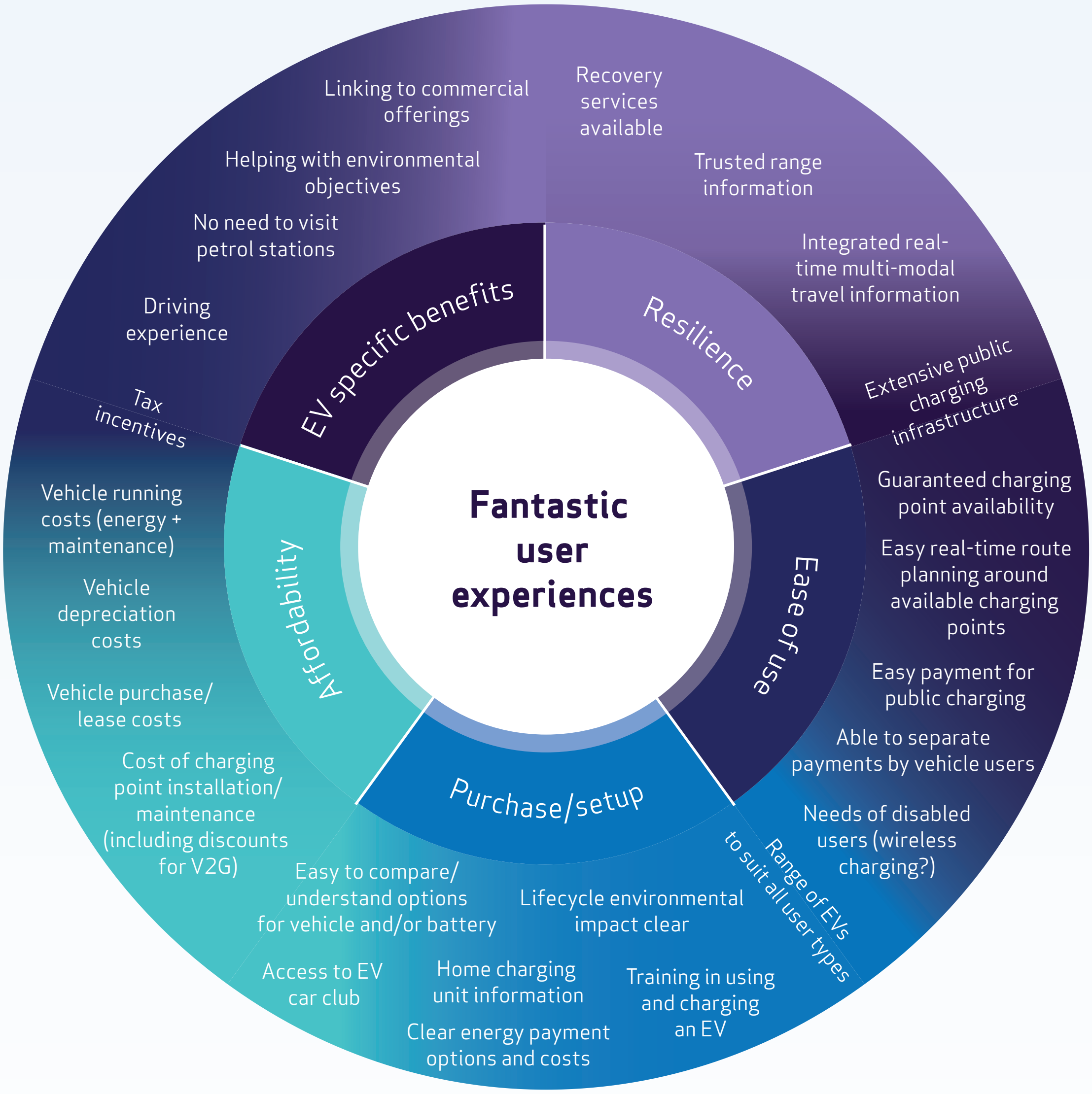
The above findings could act as innovation triggers to encourage technology companies, government and other stakeholders to work towards addressing some of the challenges presented.

# EV EXPERIENCES

Building upon the EV trends, user needs analysis and user scenarios, this section compiles what is considered to constitute fantastic EV experiences. Based on feedback from stakeholders, we consider the experience of the fleet operator to be an important consideration, therefore this section has been separated into individual user experiences and fleet operator experiences.

## Fantastic individual user experiences

*Areas to address to ensure positive user experiences are described as follows:*




The inner circle has been split into five areas and the outer circle describes aspects associated with those areas. Many of the topics overlap, and hence are shown linking across key themes.

*The key themes highlighted in the diagram are explored in more detail below:*

### Affordability

In Norway the purchase price of EVs is comparable to or cheaper than ICE vehicles. As a result of this, and the range of non-monetary benefits such as free parking in cities, use of carpooling and bus lanes, etc, uptake is high. This situation has arisen through a combination of far-reaching government incentives for EVs and the high cost of ICE vehicles in the country. Buying a new petrol or diesel car in Norway can cost considerably more than in the UK, which puts it on a more even footing with an EV. Once the low running cost is factored in, EVs become a natural choice for many people.

In the UK, for many people total cost of ownership is already lower in the UK for EVs compared to ICE vehicles. However, car buyers tend to think more about the initial purchase price when choosing a vehicle.

The depreciation of the vehicle and the degradation of the battery over time is also a consideration.

### Purchase / setup

For people to consider buying an EV there needs to be a good purchasing and setup experience. Customers are increasingly choosing to lease vehicles rather than buy outright, and the number of financing options can be confusing even for ICE vehicles. For EVs, the added complexity includes battery options (whether to buy with the vehicle or lease), whether to install a home charging point and then whether to register with various charging point operators.

For some drivers, driving lessons represent their first experience of driving. Government could look to encourage, through various incentives, driving instructors and schools to offer discounted driving lessons using EVs.

### EV specific benefits

EVs offer several 'new' advantages that are not available with ICE vehicles. For instance, the driving experience typically compares favourably, with smooth and often rapid acceleration and a quiet ride.

For some they provide the sense that they are positively contributing to being environmentally friendly, and EV users that charge at home or at work can avoid the need to stop at petrol stations to fill up. EVs may require less maintenance and could be more reliable due to the limited number of moving parts.

### Resilience

Resilience refers to the propensity of something associated with the EV to go wrong. This could include running out of charge mid-journey, or charging points that fail to function. Of course, things can, and often do, go wrong for ICE vehicles and recovery services are typically available, but in the future there could be a need for more extensive services and specialist mechanics focused on quick and efficient EV recovery.

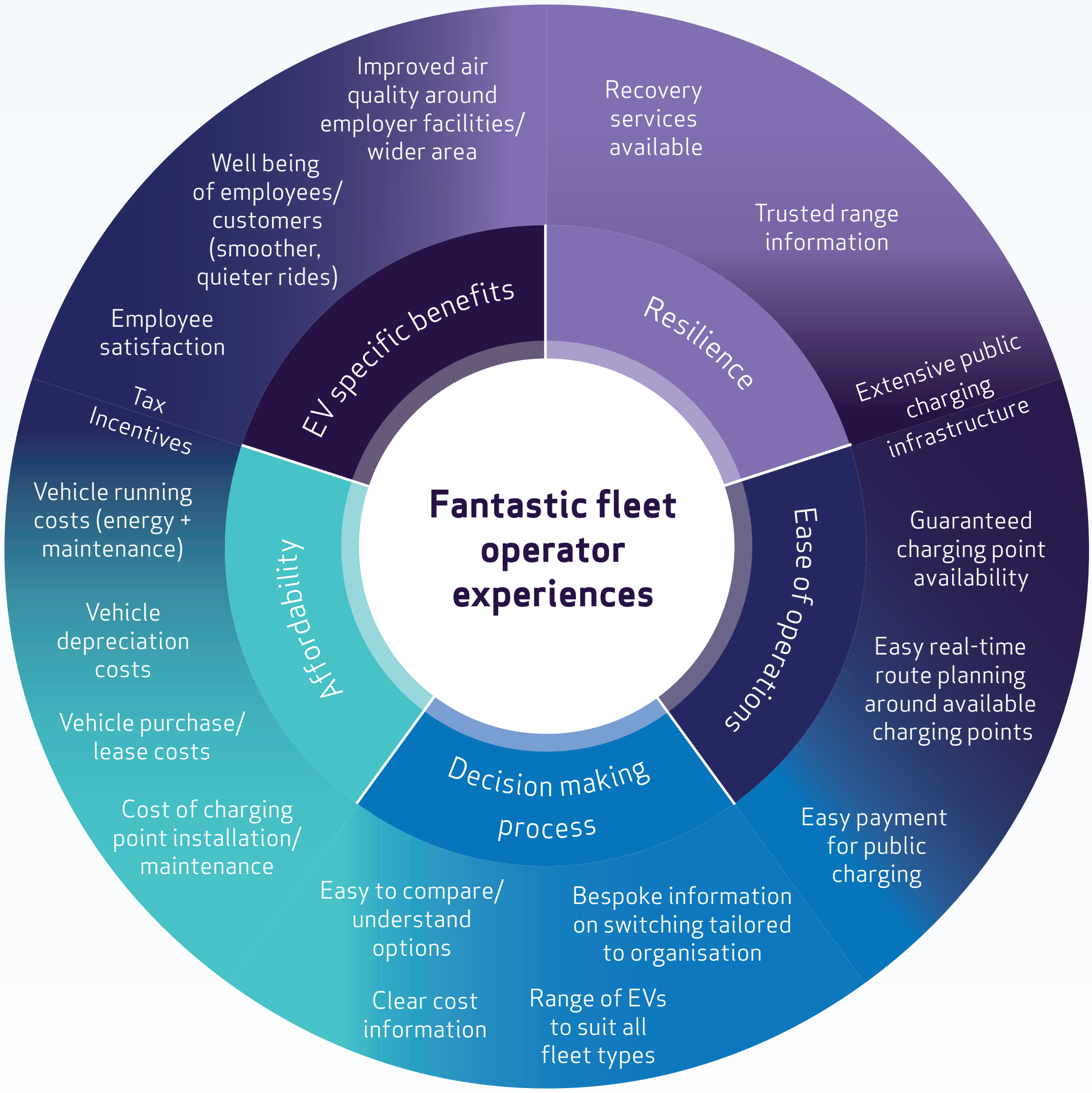
EV Roadside Assistance is commercially available from a number of providers, but given that range anxiety remains a concern amongst the general public, government could consider subsidising these services for a period of time so that they are included at no extra cost to the public. In addition, there will be growing need for specialist mechanics and repair garages for EVs - necessitating the introduction of accredited training courses and competency-based standards to ensure an adequate supply of qualified engineers and specialist mechanics.

### Ease of Use

Ease of use is vital to keep those that have adopted an EV from returning to an ICE. It is widely acknowledged that for those that can charge at home or work, and rarely need to or have an alternative vehicle for venturing further, EVs work very well. However, EV proponents will point to the quickly expanding network of public charging points, which is now enabling people to think beyond this. In addition, interoperability for charging points/operating companies or being able to charge at any charging point without signing up to different supplies will also make EVs more attractive in the future.

## Fantastic fleet operator experiences

*For fantastic fleet operator experiences, the following will need to be addressed:*




*Businesses might need to consider:*

- Matching vehicles and infrastructure to the needs of their business
- Whether they need to install EV charging facilities on site, and which options to go for, standard, fast, rapid, demand-managed, vehicle to grid?
- The back office systems that offers functions such as system monitoring, fee collection, remote monitoring, electricity metering, etc.
- The charging infrastructure service provider and the level of service provision
- The potential reliance of staff on public or home charging, and how this is managed

# DATA AND DIGITAL ENABLING TECHNOLOGIES

The user scenarios presented in previous sections call forth visions of a fully connected, digitally-enabled future EV world, with rich communications between all stakeholders in a seamless, secure, and trusted manner. In this target future scenario, multi-source data is intelligently applied for the benefit of the user and the wider ecosystem, with an open-access model for exchange of energy, information, and value between all parties.

To compare this future scenario with current state of play, a combination of desk research, online surveying, round tables, and structured interviews with key stakeholders were undertaken to capture a snapshot of the current data landscape in the UK's growing EV sector.

The emergence of these optimal user experiences are still some distance from becoming a reality, and largely hindered by **a lack of coordination and standardisation around data produced by various actors** within the EV ecosystem, despite the good intentions of many.

Given the recent emergence of the sector, these problems are not too surprising. They include the scarcity or lack of historical data for trend analysis, inconsistent data standards for reconciliation or communication between various hardware and software components of the ecosystem (a topic addressed later in the report), and companies operating business models which revolve around data capture and ownership. Each of these provides a unique challenge to innovation within the sector to achieve good user-centric outcomes.

Data is currently held by a broad range of disparate and independent organisations, often in a proprietary manner.

*These include:*

- EV manufacturers
- Charge point suppliers and operators
- Energy networks (including suppliers, distribution network operators, transmission network operators, system operators)
- Highways agencies (Highways England, Transport Scotland, local authorities)
- Service stations and retailers providing charge points
- Car park providers
- Car club operators

Vehicle owners themselves also unwittingly contribute to this data fragmentation, particularly those who charge at home. This is largely as a result of the wide variety of home charging solutions available on the market, and the shifting standards of 'smart' charging these have followed over time.

There also appears to be an imbalance between data supply and demand. There is presently little statutory or business requirement to openly share data, but several interviewees from various sections of the EV ecosystem identified particular data they would like to gain easier access to from others. For example, through our research it was noted that local authorities still have large data gaps around domestic charging. A charge point provider mentioned the lack of battery charge level data availability from car manufacturers when using standard AC charge points. A key industry player in the energy sector noted the lack of visibility across the energy ecosystem as to when EVs are being charged.

As more people recognise the need for data and the demand increases, often the "data sources" hold on to them as they recognise their intrinsic value. There is not, however, a practical outlet where data can currently be traded such as a marketplace with market arrangements

### Negative data experiences

We will explore four particularly important areas where data fragmentation is inhibiting the EV experience, and identify the causes for each. These are the UK's public charging infrastructure, its private charging infrastructure, demand forecasting in the power grid, and interoperability and roaming.

### Public charging infrastructure

An estimated 40% of future EV owners will be unable to install domestic charge points. While the UK may be numerically able to meet the anticipated demand

[26] http://www.emu-analytics.com/whitepapers/electric_vehicles
[27] https://www.cenex.co.uk/energy/vehicle-to-grid/innovate-uk-v2g-competition-projects-2018/#_ftn1

of 100,000 charge points for 1m EV owners by 2020[26] (growing to 9m by 2030[27]), EV uptake will be sectoral and not evenly spread across society as a whole due to limitation in cities. Data plays an important role in overcoming the problems with the existing charging infrastructure.

The National Chargepoint Registry[28] (NCR), established in 2011, is an open database containing information regarding the UK's public charge point network. The Office for Low Emission Vehicles transferred the management of this database to Cenex, an independent, not-for-profit consultancy and research organisation in mid-2017 in order to develop and upgrade the infrastructure. The NCR also provides developers with API access to the database. It currently has records for 7,077 charge point connectors across 36 owner-networks, and 366 separate types of installed device.

However, the NCR does not hold data on all of the UK's public charge points, as some network operators choose to withhold data from the public. In addition, where data is provided it may not be real-time, or may not show whether or not a charge point is functional. Charge point companies are also still producing, and local authorities are still installing, 'dumb' chargers - charge points that are not extensible, do not abide by any emerging data standards, and do not relay data to others.

The primary source of charge point information for many EV drivers looking for en-route vehicle charging in the UK is currently Zap-Map, with data on 20,051 charge point connectors compared to the NCR's 7,077. Based in Bristol, Zap-Map currently has over 50,000 cross-platform users per month. This single small business holds more critical data on the location of the UK's EV charging points and other information such as their plug type, charging type (rapid, AC, DC, etc.), and state of repair than the NCR. Over seven years they have managed to secure commercial deals with the majority of the UK's charging providers, allowing them to access real-time data for more than 50% of the UK's public charging infrastructure, including vehicle battery data from rapid chargers. However, the majority of the charger availability and status data available to app users is user contributed.

**Local authorities also find public charge point placement problematic.** This comes from a lack of open data regarding local EV charge point capabilities, EV ownership rates, EV user hotspots, and a lack of street-by-street capacity mapping for the local electricity network.

Better, richer, open data available direct from charge point owners, vehicle registries, and electricity networks all play a role in achieving a vision of sufficient installed charge points to meet the demands of 2025. Furthermore, making charge point locations and capacities available to EVs for range calculations and mapping algorithms will help overcome 'charge anxiety'.

### Key takeaways

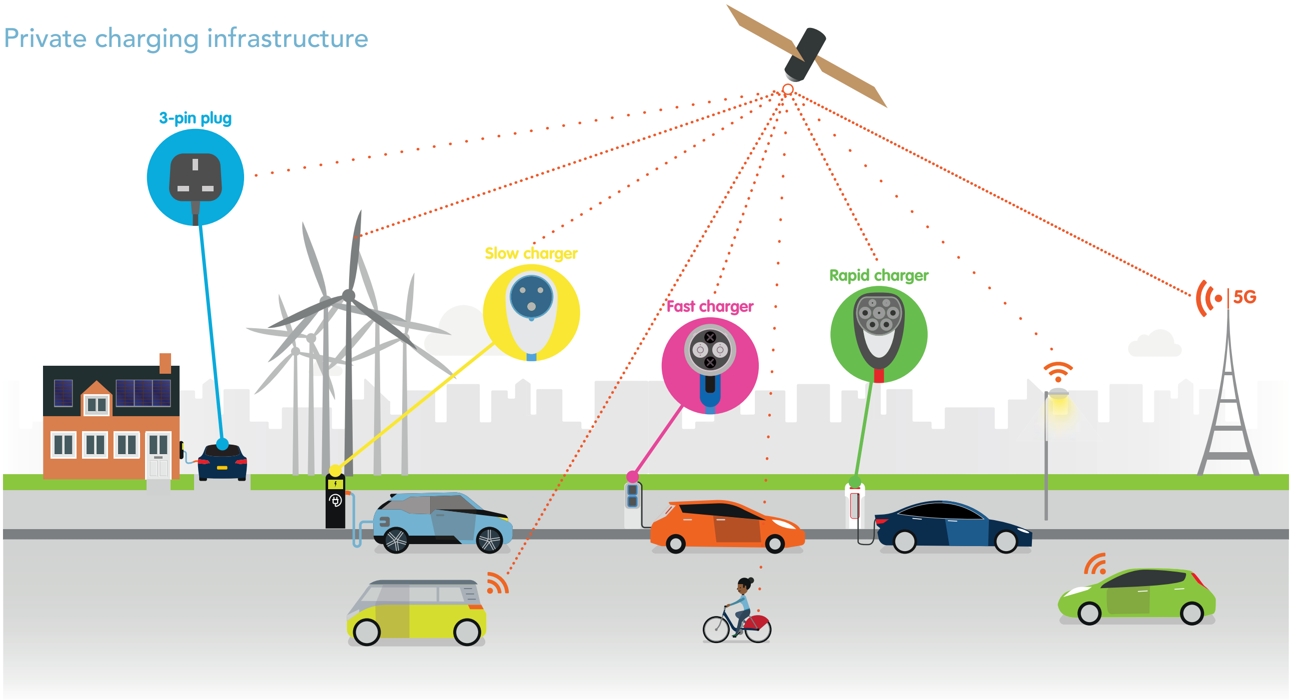
**Currently, the vast majority of UK charge point data (more than 50% of the UK's public charging infrastructure) is held by a single private company (Zap-Map), which has significantly more data than even the UK's national registry.** Measures should be undertaken to promote more open data and use of standard APIs to reduce barriers to entry for new players. There must be efforts to standardise and improve rich bi-directional communications between all levels of public charging infrastructure, including vehicle to charge point, charge point to grid, and grid to energy supplier.

**There is also a lack of data available to those responsible for installing public charge points** regarding local EV ownership rates, EV user hotspots, and a lack of street-by-street grid capacity mapping for the local electricity network, which makes placement of public charge points challenging. This has in several cases led to ill-informed placements and subsequently, low utilisation rates of installed charge points.

**There should be a concerted effort to make finding a public charge point as easy as finding a petrol station on a digital mapping tool,** with additional real-time data for slot availability, charge point plug type and charging speed, quality of service, and pricing. The power of commercial NDAs and exclusivity must be balanced against the greater public good of EV adoption.

[26] *http://www.emu-analytics.com/whitepapers/electric_vehicles*
[27] *https://www.cenex.co.uk/energy/vehicle-to-grid/innovate-uk-v2g-competition-projects-2018/#_ftn1*
[28] *http://www.national-charge-point-registry.uk/*

## Private charging infrastructure




The majority of EVs are charged at home. Data on the total number of private charge points, whether at home or at the workplace, is difficult to obtain. The International Energy Agency estimates a 1:1 ratio for private charging points to EVs[29]. Domestic charge points can range from a basic three pin plug connected to a mains socket in the garage, to an internet-enabled smart charger.

The Department for Transport produced an Electric Chargepoint Analysis into the usage of domestic EV charge points in the UK in 2017[30]. The data in this analysis does not include any charge points wholly funded by private companies or individuals, as The Office for Low Emission Vehicles (OLEV) can only collect data where it has provided grant funding. This highlights the lack of any clear picture of the private charge point landscape in the UK. This will make it difficult to establish smarter charging mechanisms for data aggregation, machine learning, and enabling smart electricity grids to manage local supply and demand. This could lead to sizeable load swings on local networks, and inhibit any vision of widespread smart charging, V2G or homeowners renting their driveway space for ad-hoc public charging.

The energy industry's leading trade association, EnergyUK, identified the need to balance the rights of the individual to take part in 'smart' charging with provision of market incentives to encourage uptake and avoid a future of DNO-operated managed charging solutions[31]. Examples included rewarding homeowners for reselling electricity or V2G capacity. They also recognised the need for charging standards which enable data-rich V2X scenarios.

[29] *https://www.nextgreencar.com/electric-cars/statistics/*
[30] *https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/764270/electric-chargepoint-analysis-2017-domestics.pdfs*
[31] *Developing standards for electric vehicle smart charging. EnergyUK, March 2018*

### Key takeaways

**There are large data gaps resulting from homes without smart chargers, or 'insufficiently smart' chargers.** Format, type, and content of data from these chargers is also unstandardised at present. There is a need for rich bidirectional communications between homes and electricity suppliers to enable EV user experiences such as smart charge scheduling through automated local grid balancing, and scenarios such as reselling of domestic solar electricity to the public while renting the driveway for EV charging or having the vehicle owner pay for the electricity supplier directly. This is a gap in current legislation, which only addresses smart connectivity requirements for public charge points.

**There is also a basic need for information regarding locations and types of current private installations, but balancing this against GDPR will likely prove problematic.** Lack of data on private charge points poses a significant challenge for future demand planning and planning interventions to encourage further charge point installations or regional electricity network upgrades.

### Energy forecasting

Considerable change is expected to when and how electricity is generated and used with increasing renewable generation, electrification of heat and opportunities for energy storage all changing rapidly. With the uptake of EVs set to rapidly increase, consideration needs to be given to the impact this will have on energy networks when considered in a wider context. Our electricity network operators – three TNOs and six DNOs – are responsible for ensuring continued network reliability under these changes.

*In the context of this report there are three aspects of energy forecasting that need to be considered:*

1. Long term changes in demand due to uptake of EVs and other new technologies
2. When, and at what scale, during the day these demand changes are likely to occur
3. Where on networks new demands will appear and when this is likely to happen

National EV uptake scenarios have limited value in helping this understanding as they do little to predict exactly where and when these vehicles will appear. This is of vital importance as the ability of individual network components to support EV deployment can be heavily influenced by the history of those components. For example, in some areas historic changes from electric to gas heating might mean that there is plenty of spare network capacity. In other areas new housing or changes in commercial or industrial demand might mean that networks are already heavily constrained. This means that some areas will be able to support a significant number of EV charge points whilst other areas will be unable to support any charge activity at certain times.

Furthermore, electricity network design has historically used typical domestic electricity use patterns and assumed diversity of demand between neighbouring households to estimate network capacity requirements. Individual households can have very high peak electricity demand. However, this generally occurs over comparatively short periods of time such that the average demand of a group of houses is generally quite low (an average value of 2kW per household is typically used for after diversity maximum demand when designing networks). In contrast EV charging is likely to occur over longer time periods such that the after diversity maximum demand of a group of houses could be considerably higher at times when several households are charging simultaneously.

This situation is exacerbated by a lack of monitoring on local electricity networks. Whilst network operators have good data at higher voltages and understand demand across the areas served by monitored assets there is very little network monitoring at lower voltages so that it is hard to establish the spare network capacity available at individual points on these networks.

Traditional energy forecasting methods are unlikely to be able to deal with these challenges as the uptake of EVs rapidly increases. It will be crucial that data collection improves, both through improved distribution network data and a push for the wider use of smart chargers.[32]

For example, there is often limited awareness within energy distribution networks of capacity being used for charging EVs. It is vital that EVs are not classed as 'second class citizens' given the significance of their power draw; suggestion has been made that there should be direct control to their charge, however this could be considered unfair as they should be treated the same as any other smart load.

A coordinated approach across the ecosystem will be required to balance demand and supply power flows as they become increasingly complex.

Smart charging and vehicle to grid technology will help smooth energy usage by EVs in the future. Already, a number of traditional and challenger energy suppliers have launched EV specific tariffs with pricing plans encouraging off-peak charging.

The National Grid has doubled its 2040 forecast due to the rapid rise in EVs. They estimate there will be 36m EVs on the road by 2040, double what they anticipated last year, according to the National Grid Future Energy Scenarios released last year.[33]

### Key takeaways

**To ensure network reliability, forecast of EV electricity demand is essential.** Rapid increase in the uptake of EVs will have an impact on energy networks. As the number of EVs grows, electricity demand will also grow. To better understand and be able to predict the energy usage of EVs, forecast models will have to predict the long term increase in electricity demand from EVs, where in the network, when and at what scale during the day these loads will occur. Information such as location of charge points, predicted EV uptake, charging profiles at on-street and off-street locations will be vital to be able to predict electricity demand at local level and low voltage networks.

**A coordinated approach across the ecosystem will be required to balance demand and supply power flows.** The ability to predict demand will enable a range of technologies and business models, such as smart charging and vehicle to grid, that will be able to shift demand to off-peak hours. Long term forecasting of where the loads are likely to appear could also support local councils in planning EV infrastructure.

## Interoperability and roaming

Interoperability and roaming are basic prerequisites for a ubiquitous, positive EV experience. One would not expect a Vauxhall or Ford to provide a different user experience when refuelling, whether in Cornwall or Scotland. Nationwide roaming is nearly possible but there are still some hurdles to a truly frictionless experience. For example the need to register with multiple charge point providers in case your usual provider is not available at your destination. This will only be improved through standardisation and opening of data flows and communication methods between vehicle, charger, grid, and end-user.

These require solutions in both the software and the hardware space – software for data formats, content, and protocols, and hardware for plug and charger types, wireless networking, and battery packs.

The current status of these various aspects will be discussed under **Application of digital enabling technologies.**

[32] *https://es.catapult.org.uk/wp-content/uploads/2018/07/Preparing-UK-Electricity-Networks-for-Electric-Vehicles-FINAL.pdf*
[33] *http://fes.nationalgrid.com/media/1363/fes-interactive-version-final.pdf*

### Positive changes

There are, however, several recent positive changes which may redress this fragmentation and data hoarding and allow progress towards a better EV future. These include regulatory changes, publicly-funded demonstrators, and progressive local governance.

### Regulatory changes

A broad range of regulations have recently (or will soon) come into force to encourage data openness and standardisation across the UK's EV marketplace. The Alternative Fuels Infrastructure Regulations 2017 were implemented as a statutory instrument in response to European Directive 2014/94/EU. This directive forms part of the EU's drive to increase smart grid penetration to reach 80% of European consumers by 2020, with the ambition to reach 100% by 2025. It standardises a number of references to aspects of charging infrastructure, including 'normal' and 'high power' charging points, and requires implementation of existing standards for these charging points for purposes of interoperability (e.g. EN 62192-2 for vehicle connectors). It further requires that charging infrastructure operators must make the location of their installations publicly available, and allow ad-hoc access to customers without pre-existing contracts. It also establishes powers for enforcement and civil penalties for those operators who fail to comply.

The Automated and Electric Vehicles Act 2018 outlines areas where regulations can be implemented to require operators of public charging infrastructure to standardise payment methods, EV plug sockets, user verification, information sharing, and interoperability. It also enumerates a number of data points that these operators will need to make available, all of which have strong user benefits.

The Electric Vehicle Homecharge Scheme (EVHS) will also continue in its current form with a grant of £500 per installation of domestic smart charger. 60,000 domestic smart chargers have so far been installed under these measures since 2014. The scheme will however change from July 2019 to enforce compliance with new technical specifications, ensuring all government-funded chargers installed at homes will be truly 'smart'. In practice this means implementing OCPP v 1.6 (Open Charge Point Protocol) and it also specifies the ability to adjust the rate of charging or discharge based on information received by the charge point including the ability to be accessed remotely through a data communication protocol, as well as some broad cyber-security backstops. This broadly aligns with the provision for smart charging set out in the Automated and Electric Vehicles Act 2018. The Department for Transport (DfT) believes the use of truly 'smart' chargers will reduce high peaks of electricity demands.

We explore the regulatory and standards environment in greater detail in the section on **Standards and policy landscape.**

### Electric vehicle energy taskforce

The Electric Vehicle Energy Taskforce[34] was launched in July 2018 as part of the government's 'Road to Zero'. It brings together diverse voices from the automotive and electricity industries, as well as the Office for Low Emission Vehicles, the Low Carbon Vehicle Partnership, and Energy Systems Catapult. Their remit is to plan and prepare for the energy system changes that will take place as a result of rising EV use, putting the EV user at the heart of these changes. It aims to ensure that EV costs and CO2 emissions are lowered as far as possible, and to capitalise upon opportunities for vehicles to provide grid services for the benefit of the grid, bill payers and EV owners.

[34] *https://www.lowcvp.org.uk/projects/electric-vehicle-energy-taskforce.htm*

### Publicly-funded demonstrators

There are a variety of such demonstrators covering a broad range of the EV ecosystem. Optimise Prime[35] is an industry-led consortium focused on the electrification of commercial vehicles. Innovate UK has funded 20 V2G projects developing hardware and software solutions, business models and customers propositions, and trialing technologies in real world, with the outlook to get to commercial V2G implementations. There are also positive leading examples of forward-planning and technological awareness at authorities such as Transport for Greater Manchester (TfGM) and ChargePlace Scotland.

The Department for Business, Energy and Industrial Strategy (BEIS) is currently reviewing consortium tenders for its recently-closed load control functionality of smart meters infrastructure call, administered under the Small Business Research Initiative (SBRI). The goal of these trials is to advance demand-response capabilities and learn what architecture and grid data infrastructure is required to respond to, and manage, demand from local public or private EV charging infrastructure. The trials are intended to draw in multiple EV stakeholders (electricity suppliers, charge point manufacturers and operators) and will ultimately involve homeowners.

In 2018, Milton Keynes launched the 'Electric Vehicle Experience Centre', a public-private venture between the council, several EV manufacturers, and charging infrastructure providers. The centre is designed to help members of the public access EVs, overcome misconceptions, and demonstrate the advanced nature of current technology. They provide independent advice on all aspects of the EV experience, and one-week vehicle loans for potential customers.

## PROGRESSIVE LOCAL GOVERNANCE

### **CASE STUDY:** Transport for Greater Manchester (TfGM)

Local authorities have final control over the selection and installation of EV charging infrastructure, and are therefore critical for ensuring any such projects are implemented in a coherent and future-proof manner. For EV infrastructure, each public sector organisation faces an initial decision point – should it get actively involved and own/operate charging infrastructure or should charging products be left entirely to the market? TfGM recognised the scale of this challenge following low utilisation rates in its first round of EV charge point installation, and has now adopted a coordinated approach to address it. Recognising that much of their existing infrastructure dates back five-six years, and that new standards and suppliers continue to emerge, TfGM has elected to adopt what they are terming a 'hybrid' approach to ensure private sector input alongside best-practice adoption by the public sector.

TfGM has already secured funding from the Early Measures Intervention Funding from the Department for Transport's Joint Air Quality Unit and further funding from Office for Low Emission Vehicles (OLEV) (ULEV Taxi Infrastructure Fund and ULEV Bus Fund) and are expecting the appointed supplier to also bring private investment. TfGM will also be working alongside the Energy Saving Trust to collect fleet vehicle data and create a costed business case to enable switching to EVs.

TfGM's current procurement for the Greater Manchester Electric Vehicle (GMEV) network began by developing an in-house geographic information system (GIS) based location model to collect and identify charging demand from public sector partners plus a number of private landowners during an extensive period of market engagement. TfGM purposely designed the £58m GMEV procurement contract to ensure cohesion across their entire region, rather than fragmenting into the 10 smaller domains representing each local authority, and managed by separate competing suppliers. The contract requires, and funds, the selected infrastructure

[35] *https://www.ofgem.gov.uk/system/files/docs/2018/11/op_fsp_final_public_v1-clean.pdf*

supplier to undertake a refresh of existing old charging infrastructure which TfGM will continue to own, while allowing the supplier to install and operate an expanded publicly-owned network under the purview of TfGM. Pricing for the public network will be set and controlled by TfGM. The supplier is also able to install their own infrastructure alongside the public network, and set their own prices for charging on this infrastructure.

TfGM has recognised that EV technology iterates rapidly, and has therefore elected to undertake a period of technical review and specification prior to commencement of work, as well as regularly reviewing the technical requirements for GMEV's charging infrastructure throughout the contract period. While the contract accommodates all current charging types, it will focus more on fast, rapid, and ultra-rapid charging at strategic locations. TfGM have also outlined pathways to innovation that charging infrastructure, energy, and customer products could take to win the contract, and anticipate awarding the contract to a supplier in mid-2019.

### **CASE STUDY:** ChargePlace Scotland

ChargePlace Scotland is a national network of EV charge points available across Scotland. The ChargePlace Scotland network has been developed by the Scottish Government through grant funding of local authorities and other organisations to install publicly available charge points. Recipients of the funding are known as 'hosts'. A host is the designated owner of the charge points they have installed and is also responsible for maintenance and general upkeep of their charge points. The ChargePlace Scotland network is operated on behalf of the Scottish Government by Charge Your Car Ltd.

All the data collected from the charge points is held by the Scottish Government, which has a rich and ever-growing pool of data offering opportunity for innovation. This data is augmented by some domestic charging data also held by the Scottish Government, however this is extremely patchy as during the past few years that the Scottish Government has been collecting data, people have been installing so-called "dumb" chargers.

This is being tackled as moving forward Energy Saving Trust (EST) will install charge points for people buying new EVs in Scotland, and these will be smart charge points. The collected data is not currently being shared.

Transport Scotland's large volumes of data could be a key resource for the exploration and implementation of advanced digital technologies in the coming years.

### **CASE STUDY:** Optimise Prime

Optimise Prime, the world's biggest trial of commercial EVs launched in January 2019. The three-year innovation project seeks to understand and test the end-to-end impacts of the rollout of commercial EVs, and develop innovative solutions to accelerate the EV transition. It is led by technology solutions provider Hitachi Vantara and electricity distributor UK Power Networks, and will see up to 3,000 EVs from Uber, Centrica and Royal Mail take to the road, supported by distributor Scottish and Southern Electricity Networks, Hitachi Europe and Hitachi Capital Vehicle Solutions.

With businesses buying 58% of all new vehicles in the UK, the programme will operate as a commercial testbed. The tools and data sets developed by Hitachi as part of the project will be designed in such a way that, once the project is complete, they can be replicated and/or used on public cloud platforms or third party container systems.

The core system components will be a "data ingestion layer" and a "data innovation lab". The former is responsible for loading and storing all data needed to support analytical capabilities. The data ingestion layer allows for simple seamless connectivity to other systems. For example, subject to the appropriate security policies, the data stored in the system will be accessible to the DNO's existing analytics platform allowing for integration with the DNO's existing workflows. The latter provides an experimental environment for data discovery and advanced analytics to be performed.

## **CASE STUDY:** V2G

The UK Government has allocated nearly £30 million towards research into vehicle to grid technologies. The funding has been awarded by Innovate UK to 20 V2G projects, to pay for research, design and development, with the aim of exploring and trialling both the technology itself and the commercial opportunities.

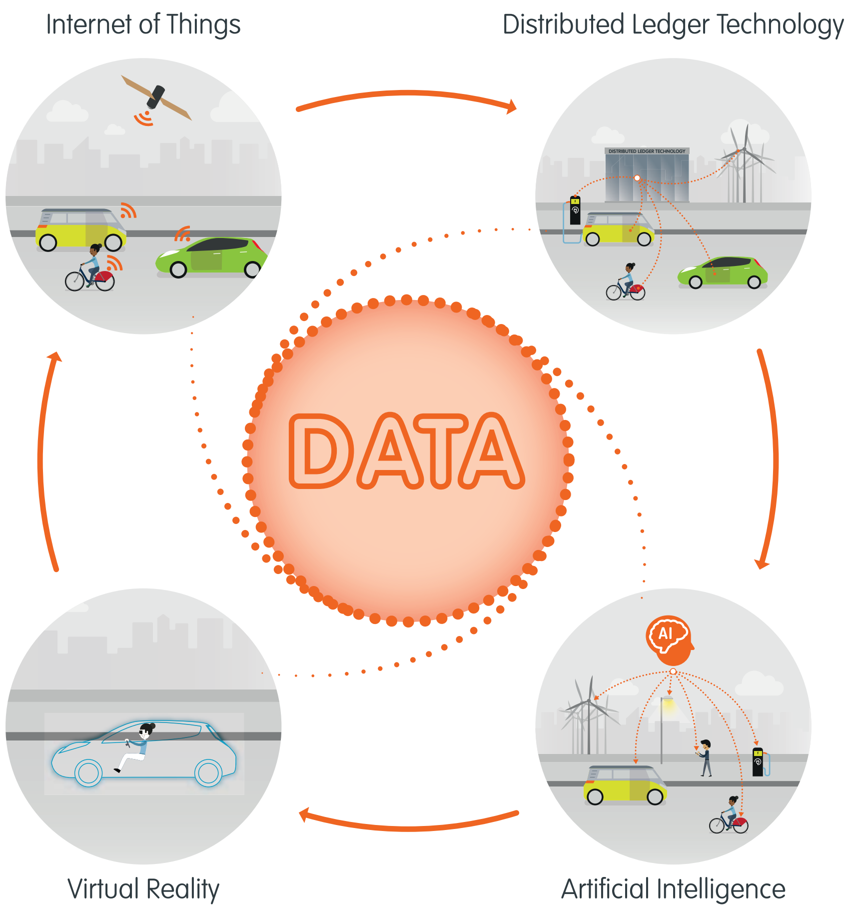
These schemes, including EDF Energy's V2GO scheme, will demonstrate how energy stored in EV batteries could be borrowed by the electricity system during peak hours, before being recharged during the off-peak in time for their drivers to set off on their next journey.

Through this funding, OVO Energy last year installed the world's first V2G charge point in collaboration with Nissan, Indra and Cenex.

OVO customers with a Nissan Leaf are able to sell energy back to the grid, making use of the company's VCharge software, which remotely connects flexible electrical devices – such as certain EVs – and aggregates them into a virtual power plant. The system then reacts as a whole to changes in demand and supply.

### Application of digital enabling technologies

Advanced digital technologies will play a crucial role in improving the end-user experience and driving the uptake of EVs by 2025. While many of the data-related issues preventing a good EV experience appear to be amenable to improved standardisation and governance, ensuring complete interoperability and feature-rich experiences will benefit from the application of more advanced digital technologies to collect, distribute, collate, analyse and present insights to the user. Here we review the current state of a range of these technologies in the EV sector, including the internet of things, wireless communications, distributed ledger technologies, artificial intelligence and immersive technologies, and then extrapolate their potential impacts by 2025.



### The Internet of Things (IoT)

The internet of things (IoT) is a network of physical objects that contain embedded technology to communicate and sense or interact with their internal states or the external environment (Gartner ). A typical IoT system architecture includes: IoT devices, IoT gateways, and an IoT cloud platform. The IoT devices have sensing/actuation capabilities, can perform basic processing, and can communicate with the IoT gateways via one or more wireless communication technologies (for example Bluetooth, WiFi, IEEE 802.15.4, LPWAN, cellular networks). The IoT gateways can run local storage services and edge analytics, and stream data back to the IoT platform via the internet. The IoT platform mainly provides data storage services, advanced analytics, and visualisation services.

Today, IoT platforms (e.g., Microsoft Azure IoT[37], AWS IoT[38], IBM Bluemix[39]) have reached a good level of maturity allowing energy suppliers to collect and process data from smart meters however data currently stays with the energy supplier companies who must comply with GDPR (for example render data anonymous or pseudonymous, ensure the right of deletion).

**Currently, IoT endpoints in the EV ecosystem include vehicles and charge points (both domestic and public). Interviews with stakeholders have identified that most data from these sources is not open or readily available to consumers. There is also lack of standardisation over data formats and communication protocols in place (for example: some public charge points are connected with low-bandwidth 2G, some with 3G, others via ethernet).**

Without interoperable access to this base level in the EV data stack, there will be no possibility of creating analytics services to enable EV experiences based upon forecasting the local load on the grid, balance it by regulating and optimising the pricing at a granular level, and directing customers towards charging points that have the highest electricity available. A chargepoint could use dynamic pricing to influence demand at different points in time, resulting in different prices over time.

### Future IoT applications

With the number of connected devices (cellular and non-cellular) expected to reach 25 billion by 2025 (GSMA, 2018[40]), IoT will reshape our societal environment and open up new opportunities. The total economic impact of IoT is estimated to be in the range of $3.9-11.1 trillion per year in 2025 (McKinsey, 2015[41]). More recently, IoT has become the next big contender to deliver on the technology breakthroughs needed to develop urban areas into more sustainable, efficient, and liveable cities. Combined with data analytics, learning and decision techniques, IoT technologies offer to transform urban environments by turning vast amounts of data into actionable information that helps running the processes in a much more efficient and predictive way. For instance, they can enable data-driven policy-making and provide impartial evidence to identify issues and problems in an urban environment (for example air pollution, space and transport system utilisation).

IoT will play a crucial role in the development of smart grids which allow adjustments to be made in the distribution of energy according to actual consumer demand, opportunely monitored by IoT-enabled smart meters connected to communication infrastructure. IoT-enabled smart grids in turn are the drivers for the development and widespread adoption of EVs in the next few years. In fact, EV charging depends on the efficient distribution of energy and the capacity of the grid to perform more complex EV loading management (such as load management, smart charging and V2G).

[36] https://www.gartner.com/it-glossary/internet-of-things/
[37] https://azure.microsoft.com/en-us/overview/iot/
[38] https://aws.amazon.com/iot/
[39] https://www.ibm.com/cloud-computing/bluemix/node/4471
[40] https://www.gsmaintelligence.com/research/?file=061ad2d2417d6ed1ab002da0dbc9ce22&download
[41] https://www.mckinsey.com/~/media/McKinsey/Business%20Functions/McKinsey%20Digital/Our%20Insights/The%20Internet%20of%20Things%20The%20value%20of%20digitizing%20the%20physical%20world/Unlocking_the_potential_of_the_Internet_of_Things_Executive_summary.ashx

*By 2025 we anticipate that IoT-connected vehicles will enable a new range of applications including:*

- **Predictive maintenance.** Sensors in the vehicles will be constantly reporting data as to the status of components in real-time that will be analysed in the backend by manufacturers that can predict component failure and suggest an inspection. Also, if a component needs to be replaced, the vehicles themselves can place an order at the dealership to resolve the issue
- **Enhancing transport efficiency.** The vehicles will have access to road traffic sensors and public transport timetables so that a journey planner app can suggest a path to a destination based on the preferences set by the drivers (for example avoid polluted areas or congested areas) or inform the drivers of exceptional events happening in the city (for example strike, sports event), which might cause delays. On the other side, knowing the location of the vehicles in real-time, the municipalities will increase the level of control they have over traffic and reduce road congestion as well as the time vehicles spend idling.
- **Improving driver safety.** Vehicles could connect to driver smart wearables to monitor vital functions such as pulse, and use on-board cameras to monitor for fatigue symptoms. Both the driver and emergency services could be alerted if any anomalies are detected.

In general, these new features will greatly enhance the functionality of EVs/connected vehicles in the future, transforming the way we drive and maintain vehicles, and how manufacturers will sell them and manage the after-sale process. Laying the groundwork now will ensure positive user experiences through IoT by 2025.

## Wireless connectivity

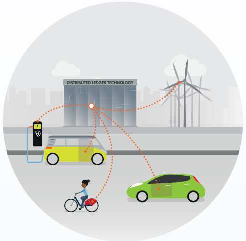
Vehicle communications can be divided into 'on-board' and 'off-board', with wireless connectivity primarily concerned with off-board communications, and are distinguished according to whether the vehicle is communicating locally (for example to neighbouring vehicles, or pedestrians) or remotely (for example to 'the network' or V2N). Another term for these off-board communications is 'vehicle-to-everything', or V2X.

In recent years, two candidates for off-board vehicular communications have evolved for the support of road safety and traceability applications. The first of these is dedicated short-range communication (DSRC) networking, which operates in the 5.9GHz band specifically for ad-hoc vehicle-to-vehicle and vehicle-to-infrastructure communications. This is a standard dating back to 1999, and designed for low-latency, highly secure communications between fast moving vehicles even in extreme weather conditions. The applications of DSRC are primarily safety-oriented, such as advanced driver assistance systems which share status information (for example rapid deceleration) to increase the awareness of nearby drivers.

The second are the existing cellular networks. Most of the current connectivity services designed for EVs are similar to those of connected traditional vehicles. These are typically (i) mapping services and (ii) telematics. Mapping has become near-ubiquitous in modern vehicles, and it is unlikely that any future EVs will lack mapping capabilities. With respect to telematics, many fleet vehicles, for example, are currently equipped with aftermarket telematics modules that connect to the vehicle's controller area network (CAN) bus through an on-board diagnostics (OBD-II) port and either have an integrated 2G/3G cellular module or are tethered with the driver's mobile phone through bluetooth.

## Future wireless connectivity

As EV adoption and automation increases and vehicles themselves take on more responsibilities for driving tasks, vehicle communication systems must improve their connectivity. Cellular V2X systems are currently being designed to cope with these future requirements, based on an extended LTE stack commonly known as LTE-V (or C-V2X). **For future vehicles that are likely to be increasingly dependent upon off-board communications, failure to grow network capacity may inhibit the range of services on offer to EV users and end-user safety.**



## Distributed ledger technology

Distributed ledger technology (DLT) is primarily concerned with the safe and trusted distribution of data from its producers to its consumers. It combines many of the features found in traditional, centralised databases, but with additional guarantees around availability, irrevocability, and auditability of the data within the ledger, now shared between multiple equal stakeholders.

Traditional methods of managing access to data rely upon contractual relationships formed between the data provider and data consumer, with one or more intermediaries managing these exchanges and extracting value from one or both sides of the marketplace. DLT is instead envisaged to provide a neutral platform for brokering data relationships between multiple independent stakeholders within an ecosystem, creating a fair marketplace for all participants. Data exchanges can be automated from the ledger by so-called 'smart contracts' to replace traditional bureaucracy (code-as-law), and financial values can be attached to individual transactions to track and enforce payments.

There are a number of teams currently exploring a variety of use cases for this technology within the electricity marketplace, and by extension, EV charging. A few core concepts have emerged in this marketplace, including 'transactive grids' to allow peer-to-peer tracking and trading of electricity consumption and production, the formation of agile microgrids and energy service providers from local energy producers (solar, wind), and using intelligence to hedge costs and shift consumption times or producers. Following its foundation in the USA, LO3 Energy[42] is currently one of the UK's market leaders with its Exergy 'transactive grid' blockchain being piloted with 200 residential and business customers in Cornwall as part of Centrica's 'Local Energy Market' programme. This 'transactive grid' concept is also being piloted by others including London-based Verv who announced a trial with Centrica to combine its home-based IoT and AI consumption-analysing device with a blockchain platform for peer-to-peer (P2P) trading of solar energy within a small community in Hackney. Around the same time, Electron also reported a successful trade of capacity market obligations (CMO) between EDF Energy and UK Power Reserve using their blockchain platform. Manchester-based Energimine is focused on trading electricity for the EV charging market. Bringing their years of experience of sourcing and trading electricity for commercial organisations, they are now working with Electra Commercial Vehicles to use a blockchain-based platform to incentivise companies who convert their heavy goods fleets into zero emissions EVs.

## Future applications of distributed ledger technology

One of the key challenges facing V2X communications is data privacy. Future EVs may need to hold highly sensitive user profile and payment data that is used for access to charging and bidirectional payments in V2G applications. Some DLT companies, such as the IOTA Foundation, are already experimenting with these potential use cases, providing EVs with autonomy over charging payments.

Some of the open challenges related to V2X data connectivity are how to keep a vehicle's identity and location information untraceable, especially if that could be linked to the passenger's identity, while also enabling the benefits of large-scale machine learning or data mining for common good. Singapore-based Ocean Protocol are developing a ledger for encrypted data exchange and encrypted machine learning, ensuring the auditability of data usage through the guarantees of DLT, with payments routed back to the original data provider.

[42] *https://lo3energy.com/lo3-energy-secures-major-support-exergy-blockchain-platform-two-new-projects-launch-uk-usa/*


## Artificial intelligence

A large amount of effort is currently being expended by multiple companies attempting to create artificially intelligent, 'driverless' vehicles. We will focus instead on the less well known developments of AI in the EV sector.

Current range estimation for EVs is largely inaccurate due to a lack of data over environmental temperature, driving conditions and driving styles feeding into models of battery consumption. Accurate range prediction would alleviate anxiety associated with driving new or long routes with an EV.

Improving this situation first requires a number of independent data sources to be standardised and made available from multiple providers, including onboard EV batteries, weather forecast, regional traffic forecast data (perhaps from V2V sources), as well as real-time data from the vehicle. This real-time data detailing local environmental conditions (temperature, rain estimates from level of windscreen wiper usage, road surface quality and driving style, etc.) needs to be collected and fed into an onboard predictive analytics model. That would then combine this information in order to produce a more accurate range estimate.

To a certain degree, some of this information can already be obtained from vehicles from an on-board diagnostics (OBD) telematics device. Synaptiv is one company working with on-board telematics in order to extract meaningful data from vehicles. However, this data feed is often not standardised even across different vehicle types from the same manufacturer, and differing telematics OEMs operate different protocols for extracting/decrypting their onboard data.

Spark EV[43] is another startup that is actively collecting data for range analytics. The company is currently targeting fleet vehicles to circumvent issues with interpretability due to the level of uniformity within a fleet.

Beyond range analytics, AI will also provide an important element of local grid forecasting, monitoring and control for charge point operators and domestic or commercial V2G applications. At present there are no companies capable of connecting all the moving parts necessary to create such a holistic integrated system.

## Future role of artificial intelligence

With an established network of connected vehicles using standardised data formats and communication protocols for providing V2V and V2G information, certain 'smart' features will be taken for granted. This includes the ability for local or regional electricity suppliers to forecast grid usage and balance grid load taking into account local domestic and commercial electricity demands, as well as drivers experiencing on-board traffic systems to better forecast charge and traffic to a destination.

It is possible to imagine a scenario slightly beyond 2025 where an EV AI recognises upcoming sunny weather conditions in the user's weekend calendar, and draws down sat-nav information from a number of vehicles to plan around likely high vehicle traffic to coastal tourist regions. The combination of temperature forecasts combined with traffic forecasts could give an accurate estimation of vehicle range under these conditions (for example, high temperatures could reduce range since extra power is being used to run the air conditioning). Integrating information about live charging points could aid informed decisions as to when to leave for holiday in order to beat traffic, or get to charging points first, or where to take a small detour in order to use an en route charging point on a route that is forecast to have less traffic, or which route to take in order to use wireless charging.

By 2025, the first applications of smart connectivity are likely to be seen in fleet vehicles, helping companies boost the efficiency of their fleet and improving the conversion to electric in order to achieve compliance with increasingly stringent air quality regulations. It is possible that these fleet EVs will use smaller batteries than at present, if range estimation coupled with knowledge of charging stations reaches high enough accuracy to allay fears of being unable to recharge en route.

[43] *https://www.businessgreen.com/bg/news/3021622/uk-tech-firm-unveils-software-and-phone-app-to-combat-ev-range-anxiety*

Additional economic benefit to fleet operators would result from a reduced number of vehicles on the road as optimisation between the number of vehicles and the number of deliveries that need to be fulfilled becomes more accurate. There would be knock-on benefits from the analytics that could inform local authorities regarding the installation of charging points at optimal locations, and reduced congestion from fewer vehicles on the road. There would be the potential for fleet operators to complete more journeys between charges, add extra journeys/drop-offs to EV routes based on remaining capacity, and overall reduced emissions and charging demand.

The data collected by fleets, and predictive models developed with them, could then inform or be sold to the domestic market. This could either act as a source of revenue or common national resource.

Collection and curation of data to enable this future will require a significant amount of manual effort and in order to create models representative of the population and to account for seasonality effects. Some investment is needed to support the 'cold start' problem of sufficient data for a satisfactory model. Data sharing across different stakeholders may also be an issue, where individual companies may not wish to share data to the benefit of the whole.

### Immersive technologies

Immersive technologies cover a range of visualisation methods that take advantage of our immense visual processing capabilities to relay key data to vehicle operators. These include fully-immersive virtual reality experiences as well as augmented reality.

The simplest form of driver immersion has existed for decades as a head-up display (HUD) – a form of augmented reality. This displays the same data usually available on a dashboard (for example speed, speed limits, distance to the vehicle in front) via projection onto the windscreen or with a transparent combiner display. HUDs exist as both integrated and after-market products that connect to the on-board diagnostics (OBD). They have the advantage of providing a driver with important information without having them change focus from the task of driving. The most advanced HUDs available (such as WayRay's Navion[44]) currently incorporate elements of spatial awareness using simultaneous localisation and mapping to understand where the vehicle is in relation to its local environment. This allows the device to show context-aware information, such as map directions placed as lines on the road, or highlighting hazards. Augmented reality can also be used to overlay points of interest directly on top of the building or service, representing an improvement over a traditional screen-based GPS, which leads a driver to a section of road. As the data becomes more available, EV charging points could be displayed in a similar manner, showing their usage, cost and status as the driver approaches.

With respect to virtual reality, a driver wearing a headset that blocks their vision is clearly unsafe. However, VR can be a useful tool outside of a car for the marketing of EVs in 'virtual showrooms', as seen with Jaguar I-PACE[45]. Potential buyers can learn how EVs differ from IC vehicles using 'x-ray' vision to view the internals of a vehicle from various angles and distances that are not possible to achieve in person. Models and configurations suited to the customer's taste can also be shown, without needing a physical asset, and then the customer can experience sitting in and driving the bespoke vehicle. Complex vehicle infotainment systems can be easier to explain via a headset than a traditional manual. At the moment virtual showrooms exist mainly in dealerships since only a small number of British homes (6% in Q1 2017) have some kind of VR headset. A challenging aspect of VR/AR marketing is creating the high quality application to match the customer's final expectations of the product and brand, where a negative experience could push a customer away from purchasing.

[44] *https://wayray.com/navion*
[45] *https://www.jaguar.com/jaguar-range/i-pace/index.html*

### Future immersive experiences for EVs

As display technology improves along its current trajectory, it is quite likely that the entirety of a vehicle's windscreen will be able to function as a head-up display. This would make it possible to show large scale augmented content to all passengers in the vehicle, rather than directed to the driver as exists today. Volkswagen's concept EV I.D. VIZZION[46] incorporates head mounted augmented reality (AR) to display a virtual ring interface that passengers interact with via gesture and voice control. Niantic[47] are developing a planet-scale AR platform based on their work with Pokémon GO, which handles the scale and complexity required for multi-vehicle applications. Thus by 2025, there could be a connected geospatial AR world that can handle millions of users. 5G will help move rendering for VR and AR to edge-based servers, making it possible to aggregate data from multiple sources, and display computationally intensive applications without requiring excessive in-vehicle processing. This could open potential avenues for retrofitting heads-up display (HUDs) to fleet vehicles to keep drivers in visual contact with each other, and optimise routes even further with rich mapping data.

## Anticipated developments by 2025

### Implications of the upcoming 5G roll-out

By 2025 all new vehicles will provide some type of connectivity and about 30% of them should have at least Level Three of autonomy[48], which is primarily driven by regulations related to improving safety and traffic efficiency.

In 2018, advanced connected vehicles transmitted on average 30Gb of data each to the cloud per month. Gartner, the global research and advisory firm believes this will rise 30-fold to over 1Tb of status and sensor data per connected vehicle by 2025. All of this data is likely to feed into AI platforms to develop predictive solutions for planning, autonomous driving, or alerts.

Deployment of 5G will likely improve driver safety with V2V communications and sub-millisecond response times from 5G-enabled edge processing at the roadside, local traffic can be monitored and accidents avoided more quickly than natural human reflexes would allow[49].

### Cyber security considerations

When considering the cyber security of EVs, it important to recognise that they do not operate in isolation but form an integral part of the rapidly evolving UK transport ecosystem. The cyber security of each EV is to a large extent dependent on its interfaces and interactions with that ecosystem and vice versa. Vehicles can even be compromised by cyber security flaws in seemingly isolated components such as car alarms[50]. From the perspective of the EV user, cyber security is important in order to protect their privacy, their safety, and the reliability of their EV transport experience.

As discussed under **Implications of 5G roll-out**, EVs are rapidly evolving in terms of their level of connectivity and autonomy, which means that the cyber security risks are also growing over time as the size of the associated threat surface explodes. This is recognised by the Department of Transport and the Centre for the Protection of National Infrastructure (CPNI) who have published a set of key principles of vehicle cyber security for connected and automated vehicles[51].

We highlight here a small sample of the cyber risks associated with just the charging systems of EVs.

[46] *https://www.volkswagen.co.uk/electric-hybrid/id/vizzion*
[47] *https://nianticlabs.com/blog/nrwp-update/*
[48] *Transport Systems Catapult - Market Forecast for Connected and Autonomous Vehicles - 2017*
[49] *http://www.ieeevtc.org/conf-admin/vtc2016fall/36.pdf*
[50] *https://www.bbc.co.uk/news/technology-47485731*
[51] *https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/661135/cyber-security-connected-automated-vehicles-key-principles.pdf*

### Battery management system (BMS)

Safety of the BMS can be compromised through vulnerabilities in the EV communication system. The BMS will be controlled using software, running on an embedded processor or microcontroller designed from a hazard / safety perspective as distinct to a cyber security perspective. The attack here is on the BMS control systems that are used to ensure that there are no thermal runaway events between the anode and cathode of Lithium Ion cell of the EV batteries. An uncontrolled thermal runaway event could cause the battery to release gas, catch fire, and/or explode.

This impact of this cyber risk will grow over time as battery manufacturers aim to pack more energy into smaller batteries.

### Personal data privacy

The EU has ruled that data generated in a vehicle is the property of the driver and no one else. This clarification of ownership is going to add a significant compliance burden to car manufacturers, rental car companies and fleet operators. EV data privacy can be compromised in many ways not least by compromised V2X communication. However, the example we highlight here is specific to the electrical nature of the EV connected autonomous vehicle (CAV) and involves an attacker exploiting the G2V/V2G connectivity.

An EV will charge its batteries at charge points (CPs) operated by charge point operators (CPOs), and all data transactions between EV and the grid (in either direction) will be recorded on the servers of the CPO.

### Grid integrity

Given that the UK road transport system and the UK energy grid are two of the UK's 13 Critical National Infrastructures, they will be natural targets for potentially hostile nation state actors and others.

We highlighted earlier the ability for a threat actor to compromise the battery management system (BMS) of an EV CAV to create a potential fire/explosion. In this example, however, we use a different attack vector, i.e. the EV supply chain to implant a backdoor into the motherboard of the BMS of a number a major EV manufacturers.

Then at a specific time (determined by geopolitical tensions) the threat actor launches a synchronised attack by setting a timer on the BMS malware it has installed. This could cause all plugged-in EVs to synchronise their charging to create a peak load, or synchronise a V2G energy dump to cause a power surge that would take down the grid.

Alternatively the threat actor could cause all EV batteries to simultaneously cease functioning, grinding traffic to a halt for a prolonged period of time.

### Response time

Current detection and response times against cyber attacks are on the scale of days or weeks. This is unacceptable when talking about the potential of millions of vehicles being remotely commandeered or disabled. Serious consideration must be given to instilling cyber-secure practices throughout all EV infrastructure, and avoiding 'security through obscurity' which results from keeping software design and code closed-source.

### Summary

A key point to emphasise in our brief consideration of EV cyber security is its dynamic nature. As the EV ecosystem evolves, so too do the economic benefits associated with reduced pollution, running costs, and smart energy. However, the threat level associated with cyber risks also grows, but not necessarily at the same rate.

During the evolution of the EV ecosystem, focus should be given to those periods where the rate of growth of the threat surface/threat level is faster than the rate of growth of the benefits. Digital Catapult would recommend our Benefit Harm Index (BHI) approach to cyber risk management in complex ecosystems to address this.

User devices should be regularly tested by charge point manufacturers or operators for cyber security concerns. There should be clarity from government over who is responsible for carrying out this testing, by what means, and to what standard.

# DATA ETHICS CONSIDERATIONS

The level of personalised service that is expected by future EV consumers will naturally require the collection of personal data. It is crucial that careful consideration is given far in advance to the ethical responsibilities of data holders and consumers to enable a positive EV user experience while guaranteeing the rights of the citizen from corporate or government intrusion. Particular consideration should be given to how companies utilise data to target the marketing of their products or tailor insurance premiums.

As discussed under the section on cyber security, as more vehicles become connected to live communication networks, the attack surface for intrusion, subverting control, and data theft will rise. These must be combatted not only as a security consideration but as an ethical proposition to ensure user safety and peace-of-mind.

There are also concerns around the unforeseen or unforeseeable consequences when shared data is erroneously believed to be sufficiently anonymised. Such scenarios have already been played out to some extent in the ridesharing industry, where weaknesses in the anonymisation methods for taxicab data officially released by New York City allowed the identification of individual passenger data[52]. Such concerns have spawned research efforts in advanced cryptographic methods, such as homomorphic encryption, to be applied to this data. Here, the data that is to be analysed is encrypted, and queries run on the encrypted data, with the answer delivered without ever revealing unencrypted data. In principle, such techniques could allow full interrogation of datasets without revealing private information. In practice, this technique is still under intense research, and whilst one company does claim to be able to apply this to ridesharing, it remains to be seen if their tool will be widely adopted[53].

In addition to this, there is the ongoing ethical conversation regarding data ownership. Currently, data is often *de facto* owned by the data gatherer, with companies only releasing data when it suits their interests[54]. This is seen with the case of Scotland, who are not currently planning on releasing their data for public consumption, and Zap-Map, who have had to engage multiple charge point providers in business agreements in order to access their data.

This data hoarding behaviour naturally leads to data silos and monopolies built upon end-user data. Monopolies are known to prevent new entrants from being able to build more compelling products, risking technological and economic stagnation. We must therefore be careful to balance the competing forces of exploiting multi-user data in the EV marketplace as a communal, public good (data socialism) and allowing individual companies to grow and dominate where they have taken risks to be the first mover, and have demonstrated leadership (data capitalism).

In light of the lack of consensus as to how data should be ethically treated, a number of organisations have formed data ethics committees and published best practices. The Open Data Institute has published a Data Ethics Canvas[55] alongside a set of tools designed to help identify potential ethical issues within a project, they also offer a half-day course using the tool. The Alan Turing Institute publishes a number of research findings regarding data ethics in a wide variety of research domains. TechUK has appointed a board for the newly established Centre for Data Ethics and Innovation. The UK Government has itself formed the Centre for Data Ethics and Innovation Consultation and published a Data Ethics Framework containing data ethics principles with additional guidance and a workbook to record ethical decisions made within a project.

All these efforts signal the rapidly emerging area of data ethics and the steps that organisations need to take in order to maintain the trust of their users. Whilst some steps have been taken to apply technology to these concerns, the main way in which it is addressed relies on process and consideration when embarking on and carrying out projects.

[52] *https://gawker.com/the-public-nyc-taxicab-database-that-accidentally-track-1646724546*
[53] *https://www.wired.com/story/oride-encrypted-rideshare*
[54] *https://www.theguardian.com/technology/2017/apr/03/the-customer-is-always-wrong-tesla-lets-out-self-driving-car-data-when-it-suits*
[55] *https://theodi.org/article/data-ethics-canvas/*

# STANDARDS AND POLICY LANDSCAPE

The UK Government has introduced a series of policy measures to promote the development of the EV market. Specifically, it set an ambition in 2015 to "ensure almost every car and van is a zero emission vehicle by 2050", which has been more recently accompanied by sales targets for 2040, and a goal for the UK to be a world leader in the development and manufacture of both zero emission vehicles and the batteries used to power them.

More recently in March 2019, Department for Transport published the Future of Mobility Urban Strategy, which sets a principles-based approach for the future of mobility including new mobility services needing to lead the transition to zero emissions. *This further prioritises electric vehicles with plans including:*

- Launching a £400 million charging Infrastructure Investment Fund
- Investing up to £80 million for the 'Driving the Electric Revolution' challenge to support innovation in power electronics, machines and drives
- A £40 million programme to develop innovative, low-cost charging solutions for electric vehicle owners and users without off street parking, and supporting wireless charging for commercial vehicles
- A consultation on green number plates, smart requirements for electric car charging, and changing building regulations so every new home has a charge point

In addition to these high level policy targets, there is a need for additional ancillary policies that support the establishment of future EV trends such as workplace charging or charge on my drive. Therefore, technical implementation of these policies also requires a supporting set of standards adopted to ensure solutions are interoperable and meet internationally agreed best practice, for example for cyber security.

With regards to standards, there are more than 1,000 organisations, alliances, associations and other groups internationally that are developing standards. This provides a very difficult and confusing landscape to navigate, therefore this report helps to focus on the most relevant standards for EVs that will support creating an excellent user experience. For the purposes of this report, we have largely focused on de jure standards (those adopted by formal standards bodies) being developed by European and international standards organisations and identified more than 60 standards relevant to EVs.

Specifically, the International Standardisation Organisation (ISO) and the International Electrotechnical Committee (IEC) who joined together to form the "ISO/IEC JTC 1" technical committee for development of electrotechnical standards, have been active in EV standardisation. The British Standards Institution (BSI), the UK's national standards body supports the formal adoption of these standards in the UK as British standards. However, we have also recognised other emerging standards and protocols which are influencing the EV market as emerging 'de facto' standards (those that are first to market and have received public acceptance).

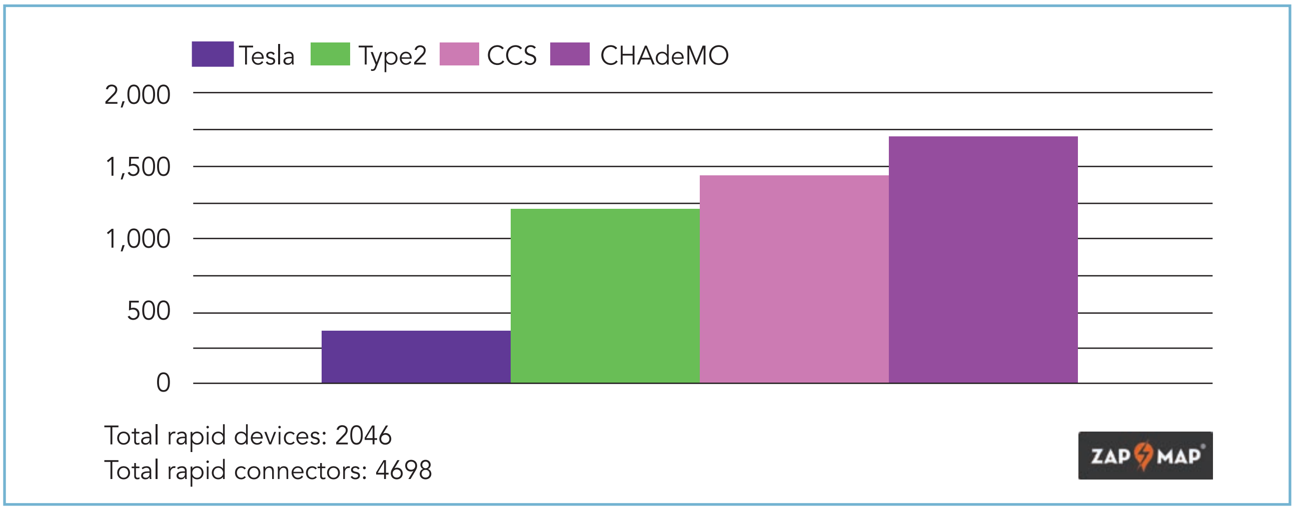
The following subsections explore the range of standards and policy interventions that would support the development of a coordinated and open innovation ecosystem to support future EV trends and enabling technologies identified in this report. As an overall principle, it is recommended that open standards should be adopted that are technology agnostic and not overly prescriptive in order to support innovation.

## Infrastructure

As highlighted in the **EV trends section**, to support user experience, it is expected that a much wider range of charging facilities will be provided in the future including at the workplace, interchange points (for example stations), ad-hoc destination charging, commercial charging 'superstations' and shared economy offerings such as 'charge on my drive'. To enable this, the adoption of the most appropriate relevant standards and policies should improve the user experience.

Whilst the Alternative Fuels Infrastructure Regulations 2017 set out to provide consistent EV infrastructure specifying at least a Type 2 charger or for rapid charge a minimum of a Combo (CCS), vehicle manufacturers, have still not converged on charger types and are unlikely to. There are currently four dominant standards

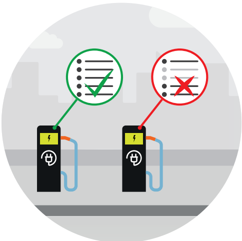
Profile of rapid devices: Zap-Map, March 2019




including, in order of prevalence in the UK, the CHAdeMO, CCS, Type 2 and Tesla. Data from ZapMap shows that CHAdeMO is still the most widely available rapid charge device in the UK as a result of the popularity of japanese electric vehicles in the UK. The fact that CHAdeMO is not mentioned in the regulation does not well reflect user requirements, especially given that convergence of these standards is unlikely and that CHAdeMO is maintaining popularity amongst both Chinese and Japanese car manufacturers. It therefore is recommended that this regulation is reconsidered.

A new standard that would help users to navigate compatibility of charging infrastructure is a clear labelling scheme. CEN, who are one of three european standards agencies recognised by the European Commission recently approved *EN 17186:2019 'Identification of vehicles and infrastructures compatibility – Graphical expression for consumer information on EV power supply'.* This specifies the informational needs of users regarding the compatibility between the EV charging stations, the cable assemblies and the vehicles that are placed on the market, similar to the labelling scheme adopted for diesel and petrol vehicles. The UK Government should also consider adoption of such a labelling scheme.

Another issue raised, which is only anecdotal, was that not all home charging operator equipment is fully compliant with the standards that are being specified through OLEV's (The Office for Low Emission Vehicles) technical specifications that apply to grants home charging. This including IEC 61851 (the supply between the chargepoint and EV) and the OCPP (Open Charge Point Protocol) v1.6 (for the communication between the CPO back office and chargepoint), with anecdotal evidence that some are being selective about the requirements they meet. It is therefore recommended to look at the reasons for this in more detail as part of an EV standards implementation review, potentially in collaboration with the BSI. This should be used to help government to provide direction as to what standards need to be supported (as a minimum spec) and if there is a need for enforcement such as through type approval by an accredited test house.



## Planning policy

Linked to issues with infrastructure is the need to improve specified requirements for EV charging infrastructure within local planning policies, to ensure that a range of charging infrastructure being provided meets user needs.

The National Planning Policy Framework (NPPF), published by the Ministry of Housing, Communities and Local Government (MHCLG) states that 'applications for development should be designed to enable charging of plug-in and other ultra-low emission vehicles in safe, accessible and convenient locations."

The framework however doesn't reference any specific standards that should be used and we have not found evidence as part of this work of any other detailed national guidance. It is ultimately up to local authorities to define their own local plan requirements. There are 418 local authorities in the UK and the concern is that if each local planning policy specifies a different set of requirements there will not be consistency in provision or the quality of provision which could lead to a lack of consistency both for EV charging operators and EV owners.

A review of 12 existing local planning policies (London, Leeds, Lewes/Eastbourne, Dartmouth, Lancaster etc.) that specify EV charging for new development, a summary of this is provided in Appendix A, shows local planning policy is not consistent. At present it lacks clarity and has loopholes that means it may not be fit for the future. Examples include the ability to specify 'charge enabled bays', which are loosely defined and may not meet future requirements or reflect local context (for example rural vs. city centre locations), and often do not reference standards. The issues with passive charging infrastructure (i.e. charge enabled bays) is that the capacity for this has to be secured with the grid and currently will only be reserved by the grid for up to three years.

Consideration should be given to developing central guidance for specifying EV charging infrastructure in new developments with input from a broad range of stakeholders to ensure consistency and appropriate requirements are being specified for EV charging in new developments. Modelling tools for assessing need and local capacity for EV charging would also be beneficial to support planning of EV infrastructure requirements. An example of this is Growthplanner[56] a tool used to identify infrastructure capacity for new housing in Belfast.

### Standards to support V2G, demand management and smart charging

The ISO 15118 series of standards is the most comprehensive and future proofed set of standards for V2G. It enables both charging from the grid and discharging back to the grid. The first version ISO 15118:2013 is currently undergoing review and new editions of the series have been added recently such as ISO 15118-8:2018 which defines protocols for Wi-Fi communication between the vehicle and charge point for wireless communication. It is imperative that the government and related institutions and agencies including BSI and Innovate UK support EV operators with using this key new set of standards so that consumers can benefit from potential V2G opportunities such as trials or training academies. Vehicle manufacturers also need to be part of this to ensure they are designing vehicle communication controllers to support the ISO 15118 communication protocol. Also, it is imperative to learn from standards that are being used as part of the current Innovate UK V2G trials to feed into work to agree on appropriate standards.

Open Charge Point Alliance has developed a protocol called **Open Smart Charge Protocol (OSCP)**[57] which is the interface between the Network Operator and the charge point management system. OSCP essentially manages the congestion of the grid by communication forecasts of its available capacity. EV users can indicate their vehicle's charging needs to a central system and the network operator will ensure that the grid's limited capacity is maintained. The EV can be charged when it needs to but on the other hand, if the EV does not need charging, equally power can be discharged back to the grid. However, this protocol has only recently been published. Currently, OLEV's technical specification for home charging[58] defines OCPP v 1.6 (Open Charge Point Protocol) under smart charging, in addition to other requirements.

For example, it sets out the ability to adjust the rate of charging or discharge based on information received by the charge point including the ability to be accessed remotely through a data communication protocol, as well as some broad cyber security backstops. This broadly aligns with the provision for smart charging set out in the Automated and Electric Vehicles Act 2018. However, this is in the absence of an agreed standard for smart charging and there seems to be some confusion currently in the market about what a smart charger is.

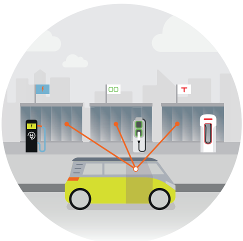
In March 2018, Energy UK undertook a consultation on developing standards for smart charging and has since formed the EV charging forum to take forward these discussions. However, a standard to define what smart charging is is still yet to be confirmed.

[56] *http://growthplanner.net/*
[57] *https://www.openchargealliance.org/protocols/*
[58] *https://www.gov.uk/government/collections/government-grants-for-low-emission-vehicles*

### Wireless charging

Wireless charging is an emerging area but is likely to be significant due to the convenience it provides for different users (for example. taxi drivers, disabled users, buses etc). SAE International published J2954, which is the Wireless Power Transfer for Light-Duty Plug-In/Electric Vehicles and Alignment Methodology. This is a recommended practice establishing an industry-wide specification defining acceptable criteria for interoperability, electromagnetic compatibility, EMF, minimum performance, safety and testing for wireless charging of light duty electric and plug-in electric vehicles[59].

There are a number of standards in development that are being informed by field trials such as the IES TC 61980-3, published in February 2019. It is recommended that the UK should engage with this standards development activity so that UK companies can benefit from learning from this development to enable future product development, trials and roll out of wireless charging technology in the UK.



### Data

This is a key enabler. There is currently inconsistency between the data provided by charge point operators with some only providing static data (for example location, type of charger and operating hours) whilst others also providing dynamic data (for example real-time availability and working status). For example, Pod Point [60] and Chargemaster[61] provide static data but do not provide dynamic data. In our interviews it was reported that this data is not currently being shared potentially due to commercial reasons. The Automated and Electric Vehicles Act 2018 makes provision for regulations to be put in place to ensure information is provided by charge point operators including how and to whom this information should be provided. *This information may include:*

- the location of the point and its operating hours
- available charging or refuelling options
- the cost of obtaining access to the use of the point
- the method of payment or other way by which access to the use of the point may be obtained
- means of connection to the point
- whether the point is in working order and
- whether the point is in use

However, there is currently no specified data standard for charge point operators to define the required attributes. There are also no mechanisms in place to ensure all publicly accessible charge points are providing this data to aid discovery of the charge point. OLEV has provided guidance for local authorities for roadside charging (relating to the available grants[62]) which requires that charge points should allow remote data collection compatible with OLEV Charge Point Use Data Requirements. These data requirements cover charge point ID, plug in and unplug date and time, charging start and end date and time and total kWh. This, however, is not consistent with the data specified by the Automated and Electric Vehicles Act 2018 and is only applicable to on-street charging that is applying for the grant, so additional mechanisms are needed.

It is recommended that a minimum data standard should be agreed with data users and consumers (for example static vs. dynamic data) and made a requirement for future installations and potentially, for existing installations.

It has also been reported that the National Chargepoint Registry (NCR) is not fit for purpose and needs improvement as detailed in a recent discovery commissioned by DfT[63]. There is also a risk that there are only a handful of mapping tools available to support EV users and therefore it is recommended that the

[59] *https://www.sae.org/standards/content/j2954_201711/*
[60] *http://pod-point.com/*
[61] *https://bpchargemaster.com/*
[62] *https://www.gov.uk/government/publications/grants-for-local-authorities-to-provide-residential-on-street-chargepoints*
[63] *https://www.digitalmarketplace.service.gov.uk/digital-outcomes-and-specialists/opportunities/6633*

redevelopment of the NCR, currently being led by CENEX[64] the Low Carbon and Fuel Cells Centre of Excellence, should be expedited and better mechanisms to upload and download the data in real-time be adopted, for example standard APIs. This will not only help increase the number of tools available for users to find charge points but also improve the quality of information available.

### Providing flexible payment options for EV users

The Alternative Fuels Infrastructure Regulation sets requirements for all charge point operators to offer 'ad-hoc access' as of November 2018. Whilst this has removed some barriers, for example contracts, it does still typically require users to have an app to use the service, leading to multiple apps provided by multiple EV operators in the UK.

The alternative is through the use of EV roaming services, which are being widely adopted in Europe and utilise the Open Charge Point Interface (OCPI). The International Electrotechnical Committee (IEC) is also producing standards that include EV roaming under IEC 63110 and IEC 63119 to provide a unified global standard for roaming service protocols. This allows users to roam between multiple EV operators across borders. For example, with its EV roaming service 'New Motion', offers access to 100,000 charge points in 28 countries across Europe, as a result of agreements it has with other operators. IEC is developing a new international standard to align international protocols for inter-network roaming under IEC 63119, which defines requirements and information exchange for the establishment of an e-mobility ecosystem. Part 1 – general requirements was published in 2017 for general comment and is forecast to be published in September 2019 with the full suite of supporting standards due by 2022. This standard should potentially provide a more coordinated global EV charging market, enabling service providers to operate across international borders, thus, opening up a wider market for UK charging operators and other related companies.

It is therefore recommended that trials to look at EV roaming are held in the UK to learn from the approaches being developed in Europe and more widely so that the UK can benefit from these.


### Maintenance

The Institute of the Motor Industry has raised the need to have minimum competency based standards in place for vehicle technicians and also for EV apprentices. The use of a standard equivalent to BS10125 (for vehicle damage repair garages) has been suggested to support this. This would potentially address concerns from EV owners and potential safety issues for technicians as well as creating possible opportunities for new service providers that specialise in EV maintenance to support the market.

It is therefore recommended that a set of competency based standards should be developed for engineers and repair garages, drawing on the requirements of BS10125.

The RAC Foundation highlighted in 2017 that, as of June 2017, 13% – one in eight – of charge points were out of action at any one time. **Public trust in the availability of existing charging infrastructure, beyond concerns of range anxiety and 'space blocking', is a key factor in realising ultra low emission vehicle (ULEV) uptake.** The RAC Foundation proposes a time-limit for repairs to address this problem. The Automated and Electric Vehicles Act 2018 states that regulations may impose requirements on operators of public charging or refuelling points in connection with 'performance, maintenance and availability'.

It is recommended that consideration is given to ensuring maintenance requirements are put in place for EV operators, particularly for charge point performance and availability and to ensure a maximum time limit to repairs.

[64] *https://www.cenex.co.uk/about-us/*

### Improved range and batteries

Range anxiety is a significant barrier to EV users and this anxiety is further compounded by a lack of trust in manufacturers' quoted ranges. For example, in November 2018, based on their own tests, 'WhatCar' reported that the Tesla Model S 75D was 100 miles short of its claimed 304 miles range quoted online[65]. Now while it is acknowledged that this type of test is not a fair comparison, due to the different driving conditions compared to the lab, it does highlight a key concern from users.

Another issue is the different test procedures for measurement of the range of vehicles. Historically different test procedures have been used based on varying standards and test scenarios undertaken in the lab and thus, produce different results. These tests may be based on the World Harmonized Light Vehicle Test Procedure (WLTP), the New European Driving Cycle, or the US Environmental Protection Agency (EPA), all of which provide a different result. For example, the Jaguar I-Pace has a quoted range of 336 miles, 298 miles, or 234 miles respectively, depending upon how the range is measured66. The WLTP however has now become mandatory for new cars as it is the most up to date and has a more dynamic drive cycle to try and match more closely with how people will drive in the real world and at the same time NEDC is also phasing out.

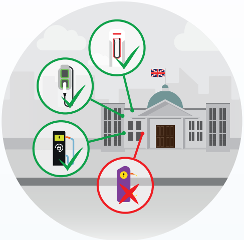
However, as accurate and dynamic as these tests aim to be, they will only ever have a certain level of accuracy as can be expected. What would help all of these standards is the possibility of collecting aggregated real driving data from vehicles on the road, which could be fed back to manufacturers to calibrate range data and also to feed into testing methodologies to provide a more realistic range estimate.

It is, therefore, recommended that mechanisms be developed for capturing aggregate vehicle driving data in order to provide users with vehicle range data that more closely relates to real-world data.

Another anxiety of EV owners is whether the battery will degrade over the life of the vehicle. These batteries undergo discharge (when the car is being driven) and charge (when the car is plugged in) and over time this energy throughput take a toll in terms of how much charge the battery can hold – and therefore, how far the EV can travel before it needs to be recharged. This is why many manufacturers are providing warranties for, say up to 60,000 or 100,000 miles. At the end of the battery's life, arises the problem of what to do with the battery. Currently there is a lack of guidance on suitable options for EV battery re-use and how they can be used as part of a circular economy. This provides additional innovation opportunities for new products and business models. However, the European Commission has been undertaking research on development of eco-design standards[67] for batteries as well as guidance relating to the circular economy[68].

Whilst providing warranties is part of the solution, consideration should be provided to battery durability standards to provide further assurance and to ensure battery durability meets certain performance standards. Solutions and business models related to circular economy also need to be developed to support re-use of batteries such as through the Faraday battery challenge, a £246M fund set by the Industrial Strategy Challenge Fund on battery development for the automotive electrification market.

[65] *https://www.whatcar.com/tesla/model-s/hatchback/review/n150/on-the-road*
[66] *This is because each method accounts for different ambient temperatures (batteries perform worse in colder conditions), different speeds, gradients and accounting for different user behaviours (e.g. may or may not account for use of air conditioning or heating) as well as how they factor in any battery degradation over time.*
[67] *http://publications.jrc.ec.europa.eu/repository/bitstream/JRC113420/kjna29371enn.pdf*
[68] *https://circular-impacts.eu/sites/default/files/D4.4_Case-Study-EV-batteries_FINAL.pdf*

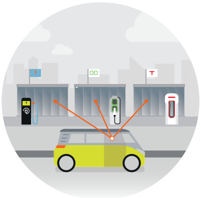


## Governance

Gemserve is consulting on the development of an overall Governance Framework[69] that helps provide a single source of the different actors in the market and the standards being used, along with looking at consumer standards that are needed. From the issues identified above, it would make sense for there to be an overall defined set of good practice requirements and standards that are agreed for each actor in the market, ensuring that the guiding principles of standards as introduced earlier on in this section are followed. This could be brought into an overall 'Code Of Practice' which simplifies and makes it easy for vehicle manufacturers, EV charging operators and manufacturers to know what is expected including the data exchange standard, installation standards, safety standards, maintenance standards and requirements for data privacy and cyber security, similar to the technical specifications that OLEV is using as part of its grant scheme that bring the different requirements together. Alongside this, general consideration is needed to ensure the market has access to the knowledge, appropriate training and support so they can benefit from these and other emerging standards such as for vehicle to grid, roaming services and wireless charging. Currently there is a lack of awareness of these emerging standards in the UK compared to the rest of Europe, which will ultimately impact on the UK market's ability to innovate and grow to support the EV user experience.

[69] *https://www.gemserv.com/our-thoughts/electric-vehicle-governance-framework-evgf/*

*The following illustration provides a summary of the standards that are recommended as part of this report and their status i.e. whether they currently exist, are being adopted or are under development.*



Agreed data standard for charge point operators defining minimum static and dynamic data improving information to EV users

Agreed standard API for exchange of information from national charge point register to user Apps/satnav

National Planning Policy Guidance to provide more consistent local planning requirements


Competency based maintenance standards agreed

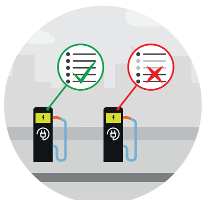
Agreed standards based governance framework to provide consistent market and consumer protection

IEC 63119: standardised flow of information between charge point operators allowing users to 'roam' between different service providers

IES TC 61980-3: agreed standard tested and adopted for wireless charging

IEC 63110: a standardised flow of information from EC charge point to charge point operators

ISO 55118: enabling vehicle to grid with EV's able to charge and discharge in response to the grid



EN 62196-2 EN 62196: agreed standards for fast and rapid charging infrastructure

IET Code of Practice for Electric Vehicle Charging Equipment Installation

**Not currently available**

**In development**

**Partially adopted**

# RECOMMENDATIONS

By uncovering the gaps and emerging trends across the EV ecosystem from data, technologies, standards, security and ethics in previous chapters, two key themes have emerged from our research as potential enablers for enhancing the user experience by 2025: EV knowledge dissemination and market interventions and achieving open data and standardisation.

Specific recommendations under each of these themes are discussed below. In addition, for ease of reference, the recommendations are summarised and laid out on a time scale in the Executive Summary section.

## EV knowledge dissemination and market interventions

### Gap to be addressed / innovation opportunity

- How to stimulate the market and encourage significant early uptake for EVs
- Lack of knowledge amongst both private and commercial potential EV users
- Creating an EV charging experience which is reliable and convenient

### RECOMMENDATION 1

Fleet operators could have a large impact on early EV adoption. Fleet operators should be provided with tools, information and incentives required to switch their fleets to EVs.

#### Potential solutions / actions:

*Government, EV manufacturers and charging infrastructure providers could work together to:*

1. better understand the needs of organisations, the infrastructure required to support EV adoption and barriers to implementation. This could include data collection which could be made available to innovators and researchers
2. push information to organisations
3. offer bespoke advice to large fleet operators
4. create public or private sector logistics EV testbeds to build on the work of current testbeds such as Optimise Prime, for example by targeting major hubs such as ports, other future industrial EV fleet environments, or last mile delivery.

### RECOMMENDATION 2

Ensure consumers can easily get information regarding EVs and hands on experience using them.

#### Potential solutions / actions:

The work of the EV Experience Centre in Milton Keynes is helping to provide bespoke information and hands-on experience on how to use and charge EVs. Government could consider cost effective ways of scaling up the EV Experience Centre model and expanding the information available at the point of purchase to include a fuller environmental breakdown of the impact of switching to each particular EV.

This might include working with vehicle manufacturers, charging point operators and other stakeholders to create a nationwide service and knowledge base. *Suggestions for achieving this include:*

- Car dealerships could start to offer more tailored advice and hands-on experience
- Car rental companies could be incentivised to replicate the EV Experience Centre model
- The EV Experience Centre could target events, such as car shows, around the country. Such demonstrations are starting to take place, but could be scaled up.

**EV car clubs could present a useful stepping stone for some users transitioning to EV use,** whilst for others it could enable them to avoid vehicle ownership. They could also help propel demand for charging infrastructure. Local authorities could consider measures to encourage the roll-out and uptake of EV car clubs. EV car clubs could be intelligently linked to wider Mobility-as-a-Service (MaaS) offerings.

For some drivers, driving lessons represent their first experience of driving. Government could look to **encourage, through various incentives, driving instructors and schools to offer discounted driving lessons** using EVs.

Businesses providing corporate tax incentives along the lines of 'cycle to work' schemes could encourage employees to switch to EVs.

Public dashboards, such as the ones installed on **street furniture, could be used to display data on environmental impact vis-à-vis usage of EV vs. ICE vehicles,** compared between different areas with varying EV vs. ICE vehicles usage. This will help to better disseminate the environmental benefits of EV adoption.

Explore mechanisms relating to **how and where innovators can gain access to data currently not available for public consumption.** This could, for example, take the form of a data sandbox. Domestic charge point owners could be encouraged to share data into the sandbox environment, and comprehensive regional datasets such as the Scottish charge point network could potentially be included. This could be opened up as a national resource to maximise the potential for innovators utilising advanced digital technologies like AI. This sandbox could also be augmented by a smart local grid demonstrator, showcasing a smart charging/V2G neighbourhood in action. (30)

The **redevelopment of the NCR, currently being led by CENEX, should be expedited and better mechanisms to upload and download the data in real-time adopted** for example standard APIs. This will not only help increase the number of tools available for users to find charge points but also improve the quality of information available (16)

Launch **trials to explore EV roaming in the UK** and learn from approaches being developed in Europe and globally. This could include the creation of a UK-EU taskforce.

### RECOMMENDATION 3

Local and national governments need to take further steps towards a better EV charging and user experience.

#### Potential solutions / actions:

With reference to the EV trend looking at charging superstations, the **focus of new, expanded and enhanced public charging infrastructure should be on highly visible strategic locations to create large clusters of charging points** that provide redundancy and guaranteed availability for the user. Places of work, town centres, retail hubs, railway station car parks, park and ride facilities and motorway service areas offer good candidate locations for charging hubs, with different charging speeds and costs available for different types of users. The Government needs to be aware of exclusivity arrangements between charging point operators and strategic charging hubs and ensure that they are operating in the public interest.

UK government should consider **adopting a labelling scheme for EV charging infrastructure** to make it clearer for consumers how to charge their vehicles which should align with EN 17186:2019 which specifies the informational needs of users regarding the compatibility between the EV charging stations, the cable assemblies and the vehicles that are placed on the market, similar to the labelling adopted for diesel and petrol vehicles.

Consideration needs to be given to ensuring **maintenance requirements are put in place for charge point operators,** to ensure minimum standards for performance, availability and repair time.

**Investigate cost effective models for replacing legacy standard (non-smart) chargers with smart chargers,** including incentivising upgrades of existing domestic smart chargers to 'smart' functionality.

**Improve public access to in-drive charging** by devising the rights and mechanisms by which homeowners or tenants can portion and resell their charging infrastructure and electricity supplies to others.

**Ensure that smart charging solutions are designed to save consumers money.** They should not leave the consumer out of pocket for energy usage compared to standard charging.

In order to provide a **more realistic range estimate to users,** mechanisms should be developed for capturing aggregate vehicle driving data from vehicles on the road, which could be fed back to manufacturers to calibrate range data and also to feed into testing methodologies.

**Improving the availability of workplace charging** could help drive EV uptake and reduce pressure on home charge point installation. Large employers could be targeted to understand barriers to workplace charging installation. New business models are emerging, such as leasing of charging infrastructure which can make it more affordable. Businesses could also consider enabling access to their charging infrastructure to the wider public outside of working hours to generate revenue.

EV roadside assistance is commercially available from a number of providers, but given that range anxiety remains a concern amongst businesses and the general public, the **Government could consider subsidising roadside assistance for a period of time** so that they are included at no extra cost for businesses and the public.

**Mobile charging units could help fill current gaps in charging infrastructure in rural settings,** and should be investigated further. This could include permanent solutions in remote locations, charging units at temporary parking sites associated with events, or emergency situations where demand for charging is expected to exceed supply. Further investment into the development of mobile charging solutions could accelerate commercialisation.

To facilitate better user experiences, explore **mechanisms for smart, automated payment methods for use of public charge points,** potentially based on *Automatic Number Plate Recognition* (ANPR).

Inductive charging represents a potentially transformational method for improving the EV operation and user experience. **Investigations into where the UK could most effectively advance research efforts** in this field could prove beneficial, alongside consideration into how installation can be as seamless and affordable as possible.

Develop **robust business models for V2G applications** to better understand the potential revenue streams.

## Data sharing and standardisation

Gap to be addressed / innovation opportunity

- How to stimulate the market and highlight the benefits of knowledge transfer
- Lack of industry standardisation
- Promotion of open data and use of standard APIs

**RECOMMENDATION 4**

Promotion of more open data, data ethics and standard APIs relevant for EVs and charging infrastructure.

Potential solutions / actions:

There should be **increased UK engagement and knowledge transfer activity with international standards development** relating to wireless charging, V2G and roaming services so UK companies can actively participate and stay abreast with the developments for future product development, trials and roll out of infrastructure.

The **reasons for non-compliance of some charging operator equipment with the standards** specified through OLEV's technical specifications should be investigated in more detail as part of an EV standards implementation review, potentially in collaboration with the BSI. This should inform if standards need to be revised or additional training or support is needed or whether, in fact, tighter enforcement should be considered.

As the uptake of data-rich EVs grow, and the private domestic smart-charging network expands, the Government should consider exploring ethical implications of collecting and sharing data. This could be within the remit of the Centre for Data Ethics and Innovation, for example.

**RECOMMENDATION 5**

Government and other stakeholders should develop and adopt relevant EV standards.

Potential solutions / actions:

A set of **competency-based standards should be developed for EV engineers and repair garages,** equivalent to BS10125 (specification for vehicle damage repair processes). This will address concerns from EV owners and potential safety issues for technicians as well as creating possible opportunities for new service providers to specialise in EV maintenance.

The government should **clarify the requirements for dynamic/real-time data provision, and types of network connectivity, under the Automated and Electric Vehicles Act 2018.** Any inconsistencies between minimum data requirements specified by the Automated and Electric Vehicles Act 2018 and other bodies, such as the OLEV, should be standardised to avoid conflicts.

**Supporting EV operators with using a key new set of standards such as the ISO 15118 is imperative** so that consumers can benefit from potential V2G opportunities. Vehicle manufacturers also need to be part of this to ensure they are designing vehicle communication controllers to support the ISO 15118 communication protocol. Also, it is imperative to learn from standards that are being used as part of the current Innovate UK V2G trials to feed into work to agree on appropriate standards.

Standards for smart charging and definitive guidelines on what constitutes 'smart chargers' need to be developed as soon as possible.

**RECOMMENDATION 6**

Innovation challenges should address key battery issues (data access, end of life, technical standard adoption, etc.).

Potential solutions / actions:

Consideration should be made regarding the **adoption of battery durability requirements in the UK** (for example ISO 12405-4 and IEC 62660-1:2010) **as well as eco-design criteria for batteries** to encourage their end of life uses.

**Extend Faraday Challenge to include end of life of batteries and total cost of ownership** to help batteries retain their value over time even post-vehicular usage.

Extend **existing legislation (and standards) to open up data from battery packs,** which is currently held by EV manufacturers with no obligation to share it.

# CONCLUSION

To successfully deliver an excellent user experience for EV users, the **Plugin Vehicle 2025 Stakeholder Success Vision** recognises that by fostering an ecosystem on the topic of EV adoption can provide a platform for inspiring the UK market to respond by providing innovation solutions and services which can contribute to enhancing the EV user experience.

Despite some of the key challenges with user experiences expressed today, early adopters frequently report that they would not want to go back to driving an ICE vehicle and the last four years have seen a remarkable surge in demand for EVs in the UK with new registrations of plug-in cars increasing from 3,500 in 2013 to more than 195,000 by the end of January 2019.

Although the uptake is increasing and predicted to continue doing so, the user journey experience could be enhanced. Our research conducted to date is intended to shed light on some of the key barriers and highlight enablers that might contribute towards enhancing the EV user experience and foster ongoing collaboration with various actors within the EV ecosystem.

The Catapult centres are overseen by Innovate UK and are places where the best of the UK's innovative businesses and researchers work together to bring new products and services more quickly to commercialisation. Focusing on areas with great market potential, Catapults open up global opportunities for the UK, generate economic growth and ready to help address the challenges and realise the opportunities associated with the electrification of transport.

If you would like to find out more about our research or contribute to future initiatives, you can get in contact with us at info-LDN@cp.catapult.org.uk

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Gemserv
HERE
Hitatchi Vantara
IOTA Foundation
IOTA Foundation
LO3 Energy
London Business School
Measurable Ltd
Metiscube Limited
Nissan Technical Centre Europe
Northumbria University
Oxfordshire County Council
Pod Point
Poyry
RAC Foundation
The Optimise Prime Project
Transport for Greater Manchester
Transport Scotland
University of Hertfordshire
Zap-Map
Zipcar

# APPENDIX

## Summary of planning policy requirements for EVs

The following table provides a cross section of what is currently being specified within local planning policy. As can be seen below, there is a significant variance on the required allocation of charge points along with the type required, which does not match with the recommendations of this report. Standards are not commonly referenced and there are generally no requirements relating to smart charging, appropriate layout, data requirements and installation. In many cases developments may get away with providing just a three pin plug or cabling within the ground for future installation or in other cases 100% of parking spaces need to be provided with charge points. Leeds and Dartford were found to have the most comprehensive guidance but there is a lack of consistency and clarity provided in planning policy, with each council developing their own guidance and their own assessment of local need rather than referencing any central best practice or infrastructure capacity data in order to tailor policies towards local needs.

| Planning Policy | Charging Requirements | Charging standard | Smart req. | Layout req. | Data req. for public charging | Installation require-ments |
|---|---|---|---|---|---|---|
| Leeds Parking Supplementary Planning Document (SPD) | 1:1 for EV spaces allocated parking and 1:10 EV spaces for non-allocated parking | Type 2 | No | Spatial require-ments | No | Yes: IET Code of Practice |
| Westminster City Plan | 50% active and 50% passive EV parking for all spaces | No | No | No | No | No |
| Lewes / Eastbourne Technical Guidance Note | 1:1 standard charger for homes with a garage or drive.<br>1 'fast charging unit' for flats with 11 or more spaces/bays.<br>2% allocation for commercial property with 100+ parking spaces | No (localised specification to define standard, fast and rapid charge) | No | No | No | No |
| Milton Keynes Parking Standard | 21-50 spaces = one EV space<br>51-100 spaces = two EV – one per 100 thereafter 10% passive provision | No | No | No | No | No |
| Dartford Borough Council Development Management Advice Note | 100% provision for residential. Double charge point per 10 spaces for commercial | Type 2 outlet, standard for allocated, fast for unallocated | No | Limited | Communica-tion protocol: OCPP for commercial unallocated. No minimum data specified | Yes: IET Code of Practice |
| Lancaster: Provision of Electric Vehicle Charging Points for new developments | One per house with a garage or driveway. Flats: 10% provision, all others with passive wiring.<br>Other developments: at least two spaces and 4% where more than 50 parking spaces | Specification of 3.7-7.4kW for residential, 7.4kW for commercial and 43kW for supermarkets, no standards specified | No | No (need to be free stand-ing and 'weather-proof') | No | No |
| Surrey County Council: Parking Guidance for Development | 1 Fast charge socket per house.<br>Flats: 20% fitted with fast charge socket.<br>Commercial: 10% of spaces with fast charge socket.<br>Short stay high demand uses: 20% of spaces with 'Fast charge' | Type 2 connector (7kW) | No | No | No | No |
| London Plan | 20% passive and 20% active for all new development | Unspecified | No | No | No | No |
| Brighton & Hove Parking SPD | All schemes of 1000m$^2$ or more 10% of provision active EV and 10% with passive | Unspecified | No | No | No | No |
| South Northants Parking SPD | All new homes with private drive or garage external wall mounted charge point; homes with more than three bedrooms, two charge points. 20% provision for flats. Commercial should have 'fast' DC or equivalent | Unspecified | No | No | No | No |
| Warrington Standards for Parking in New Development | 5% of spaces with EV charging or enabled for future retrofit | Unspecified | No | No | No | No |
| Basingstoke Parking SPD | All new homes with suitable electric circuit to enable fitting of a charging point at a later date | Unspecified | No | No | No | Basic guidance provided e.g. protect from vehicle collision |


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