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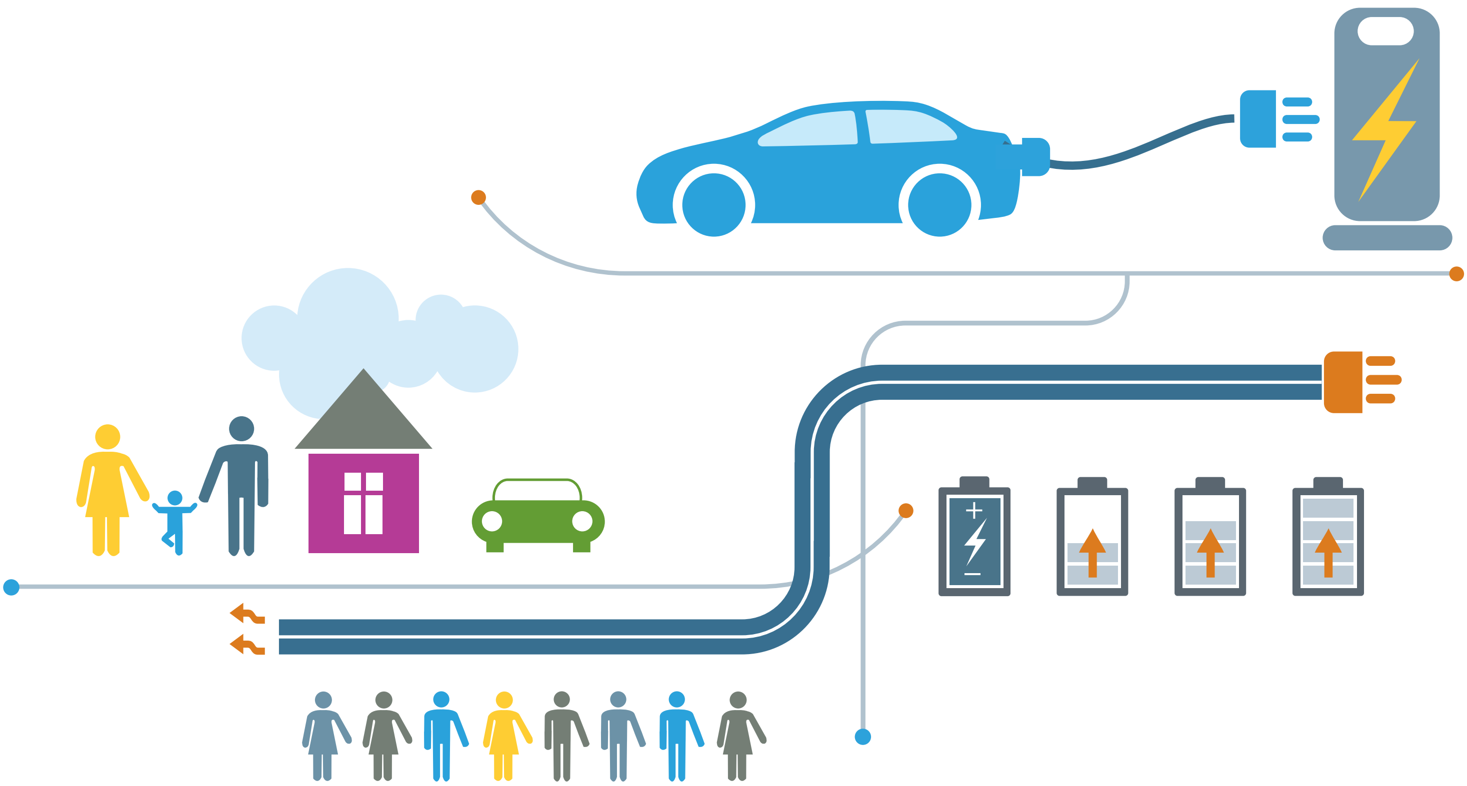
BEST PRACTICE FOR FUTURE PROOFING ELECTRIC VEHICLE INFRASTRUCTURE



March 2020

ACKNOWLEDGEMENTS

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FOREWORD

The UK is legally committed to reducing its greenhouse gas emissions to net zero by 2050, and many cities have ambitions ahead of national policy. This ambitious task will require significant changes, including the decarbonization of road transport. Replacing hydrocarbon fuels with electricity in cars and other vehicles will help to reduce greenhouse gas emissions and address the crisis of air quality in our cities. The large-scale, rapid electrification of road transport will require a significant investment in supporting infrastructure.

Britain is on the cusp of a rapid expansion of public electric vehicle (EV) charging infrastructure that will support the replacement of petrol and diesel cars with EVs, but the cost of this national infrastructure investment will be considerable. Stranded assets, inefficient or unnecessary installations, or poorly planned infrastructure development will add to costs, challenge consumer confidence and harm both profitability and the consumer experience. Those who invest in, own or operate public infrastructure will be accountable to the public and to shareholders. We hope the advice in this description of best practice to future proof EV infrastructure will help to deliver the long-term value of this vital upgrade to national infrastructure.

Jeremy Yapp
Head of Flexible Energy Systems, BEAMA

BACKGROUND

In June 2019 the London Mayor's EV Infrastructure Taskforce published its delivery plan.[1] The plan identifies eight 'enablers' to help facilitate charge point installation and overcome identified barriers. One of these is to publish guidance on future proofing public EV charging infrastructure to encourage investors. BEAMA has been tasked with providing this guidance in the form of a description of best practice.

In a 2016 EV consumer survey[2] consumers in China, Germany, and the US ranked insufficient access to efficient public charging stations as the third most serious barrier to purchasing a battery EV, behind price and driving range. Extrapolating to the UK market, as EV prices decline and vehicle battery range increases (currently the top two concerns for customers) then access to public EV charging could become the top barrier.

It is therefore imperative that the availability of charging infrastructure keeps pace with consumer need. Significant steps are being taken to facilitate private EV charging, whether in residences or workplaces, but public charging will remain important. Even as larger batteries and faster charging rates combine to make public charging – especially using rapid chargers – more convenient and popular, perceptions of the availability of charge points will be critical to public confidence in EVs.

Whether public charging infrastructure is provided by public entities, private companies or a mixture of the two, it is essential that the design, manufacture, placement, maintenance and operation of public EV charging infrastructure be efficient and cost-effective.

This document is intended to describe a **basis of best practice** and **guiding principles** for the planning, design, manufacture and procurement of public EV charging infrastructure. It is designed for use by manufacturers of public EV charging infrastructure, providers of services related to public EV charging, investors in EV infrastructure and planners at local, regional or national level.

THIS DOCUMENT IS ADVISORY ONLY AND IS NOT LEGALLY BINDING, A STANDARD OR A SPECIFICATION.

1 London electric vehicle infrastructure delivery plan, Transport for London, June 2019 http://lruc.content.tfl.gov.uk/london-electric-vehicle-infrastructure-taskforce-delivery-plan.pdf

2 https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/electrifying-insights-how-automakers-can-drive-electrified-vehicle-sales-and-profitability

PUBLIC EV CHARGING INFRASTRUCTURE

Not all EV charging infrastructure is covered by this document. A broad definition of electric vehicle infrastructure could include every physical part of the system starting at the plug or connector between a charge point and a vehicle, then the charge point itself and its housing, data and electrical connections, and control system, to the electricity network reinforcement necessary to support its public use.

This report considers only charge points and their immediate connections with surrounding infrastructure, but investors and providers of public charging will also need to take account of local electricity network constraints. More advice on managing the costs of street works and grid connections can be found in the report on this subject by the Energy Saving Trust.[3]

In scope are on-street and off-street publicly available charge points for cars and light goods vehicles, consisting of single or double roadside charge points, hubs for six or more charge points, or static posts connected to a lamp column.

Out of scope are charge points of any kind for heavy goods vehicles, buses or electric bicycles or scooters; emerging technologies (such as wireless or mobile charging) that are not currently viable at scale for light vehicles; and private charging infrastructure.

However, the notes on interoperability and cyber security are applicable to private infrastructure in many cases and the general points made herein about the need for design, placement, interoperability and planning may apply generally to most technologies and most types or forms of charging.

> This document follows the categories of public charging infrastructure set out in London's Electric Vehicle Charge Point Installation Guidance.[4] For an overview on the types of charge points available and more technical details on charging equipment see BEAMA's Guide to electric vehicle infrastructure.[5]

Public charging infrastructure may be either publicly or privately owned or operated. One key recommendation of the London EV infrastructure delivery plan was that public charge points should be open to all, with a few exceptions; notably for taxis in central London and other specific, priority groups that need extra support due to mandatory requirements and operational needs.

3 Minimising the costs of street works and gird connections for electric vehicle charging infrastructure: a report by the Energy Saving Trust August 2019 https://www.energysavingtrust.org.uk/sites/default/files/Local%20Authority%20Guidance%20-%20Minimizing%20the%20costs.pdf

4 London's electric charge point installation guidance, Transport for London, December 2019 http://lruc.content.tfl.gov.uk/london-electric-vehicle-charge-point-installation-guidance-december-2019.pdf

5 http://www.beama.org.uk/resourceLibrary/beama-guide-to-electric-vehicle-infrastructure.html

FUTURE PROOFING

'Future-proof' infrastructure is designed and manufactured for longevity and ongoing use, and to be of continuing high value to consumers. It can be procured, installed, maintained and operated with confidence that it is resilient to unforeseen technical, market, behaviour and regulatory changes. Technical and physical interoperability, interchangeability and adaptability supports the purchase and rollout of infrastructure in a way that allows providers or investors to gradually build their provisions without unreasonable risk of costly false starts or of needing to replace equipment before the end of its life.

Public infrastructure can be expensive. Future proofing means maximising the longevity and value over time of the infrastructure asset. Future-proof equipment is resilient to change and will continue to be used (and therefore to repay the investment) for the life of the asset. Future proofing means being ready for regulatory change as well as market and technological changes.

> **The need to remove, scrap and replace a working asset before the end of its intended life, and therefore before its use has provided the expected returns for the investment, can be avoided by making sure the charge point is:**
>
> - Interoperable with all electric vehicles and systems
> - Able to communicate securely, as required, with all legitimate third parties
> - Placed, installed and operated in such a way that it will continue to be used for the lifetime of the asset
> - Adaptable to expected and unexpected changes in use, technology and operation, ideally without a site visit.

Non-financial benefits of future proofing public EV charging infrastructure

As well as identifying financial savings by avoiding obsolete or stranded assets that need to be replaced before end-of-life, there are non-financial but similarly important benefits of future proofing infrastructure. Public confidence in the rollout of EV charging infrastructure is crucial to the switch to EVs. This confidence relies not only on the reliability of charge points, their ease of use and the accuracy of websites, signposts and other indicators of charge point location, but also on the perception that the infrastructure rollout is good value for money and appropriately targeted.

Removal of working public charge points before end-of-life because they do not interoperate with a new service provider (for example) or with newly bought equipment could damage providers' business cases and may also affect confidence and enthusiasm for road transport electrification. Where possible a charge point should be remotely upgradable and resettable, without the need for a site visit. This functionality (over the air upgrades, or OTA) will reduce associated costs and delays, and this remote ability will become increasingly important as emergency and essential services become more dependent on charging infrastructure.

In addition, infrastructure 'false starts' that lead to working assets being removed and scrapped have the potential to create a serious waste management problem. Future-proofing infrastructure also entails a full understanding of the life cycle of the product, including the safe recycling and disposal of the asset when it is no longer needed. The Health and Safety Executive holds more information on the UK requirements in relation to the Waste Electrical and Electronic Equipment Recycling (WEEE) Directive.[6]

6 https://www.hse.gov.uk/waste/waste-electrical.htm

RECOMMENDATIONS

As the rollout of publicly accessible EV charging infrastructure gathers pace, we expect to see greater levels of standardisation and accreditation available to installers, manufacturers and service providers, with associated benefits for consumer confidence in charging products and the consumer experience of using an EV.

As a minimum, parties should pay particular attention to:

BS 7671,[7] especially s722

Electrical Safety Regulations[8]

Electricity Safety, Quality and Continuity Regulations 2002[9]

BS EN 61851 on the EV conductive charging system[10]

EMC Regulations[11]

Plugs, socket types and wall boxes are covered in the standards. Parties should ensure compliance where appropriate with:

BS EN 60309-2
BS EN 60309-4
BS EN 62196-2

Interoperability and interchangeability

Interoperability means different things in different contexts. Public charge points should be able to operate at the minimum required or specified functionality:

- ✓ with all approved service providers, including compatibility with multiple software systems, back office services, energy suppliers or charge point operators
- ✓ with all vehicle types, makes and models
- ✓ with multiple payment systems or a universal payment system such as credit or debit cards, without the need for brand-specific payment or loyalty cards.

Interchangeability refers to the ability to switch one charge point for another of a different make and model and retain required functionality. Interchangeability, therefore, also involves future proofing the charging and operating system and the supporting physical infrastructure (wires, communications systems, connections) so it is resilient in the face of changes to the charge point itself.

Roaming and payment systems

As a point of fundamental principle, public charge points should be accessible to all public users using common payment systems in much the same way as Automatic Teller Machines are non-proprietary, and usable by any customer with a debit or credit card. The Open Charge Point Interface (OCPI) is one such UK industry standard roaming protocol[12] and the roaming variant of the Open Charge Point Protocol (OCPP) for communication between an EV charge point and a central back office system.

More complex payment systems may emerge, including a demand for public charge points of the future to be equipped with a communications system allowing some users to register or record the electricity they buy from a public charge point against their domestic use. It is likely that most of the technology enabling this will be situated within the vehicle itself.

Data security

Where a public charge point communicates data that is personal to the consumer, that communication must be secure. Where a public charge point is responsive to remote signals in a way that affects the operation of the charge point, those signals must be secure. The entire system, including the vehicle, electrical and communications connections, and the

7 https://www.hse.gov.uk/waste/waste-electrical.htm
8 https://electrical.theiet.org/bs-7671/
9 https://www.hse.gov.uk/electricity/
10 http://www.legislation.gov.uk/uksi/2002/2665/contents/made
11 https://landingpage.bsigroup.com/LandingPage/Series?UPI=BS%20EN%2061851
12 https://www.gov.uk/government/publications/electromagnetic-compatibility-regulations-2016

electricity grid itself, needs to be secure to protect the electricity grid, customer privacy and consumer data.

Attacks on any system will usually be enacted through an identified weakest point.

All responsible parties should treat consumer data as high-sensitivity information and provide appropriate security to protect both the charging operations and the data resulting from them. This will include anonymizing or pseudonymizing all sensitive data at the point of use.

The charge point, its communications connections and back-office operations should all follow anticipated industry-wide data sharing arrangements, including support for public charge point information applications and a framework for data access and data policy. This framework will be essential for grid resilience and flexibility, which will be critical as electricity demand grows.

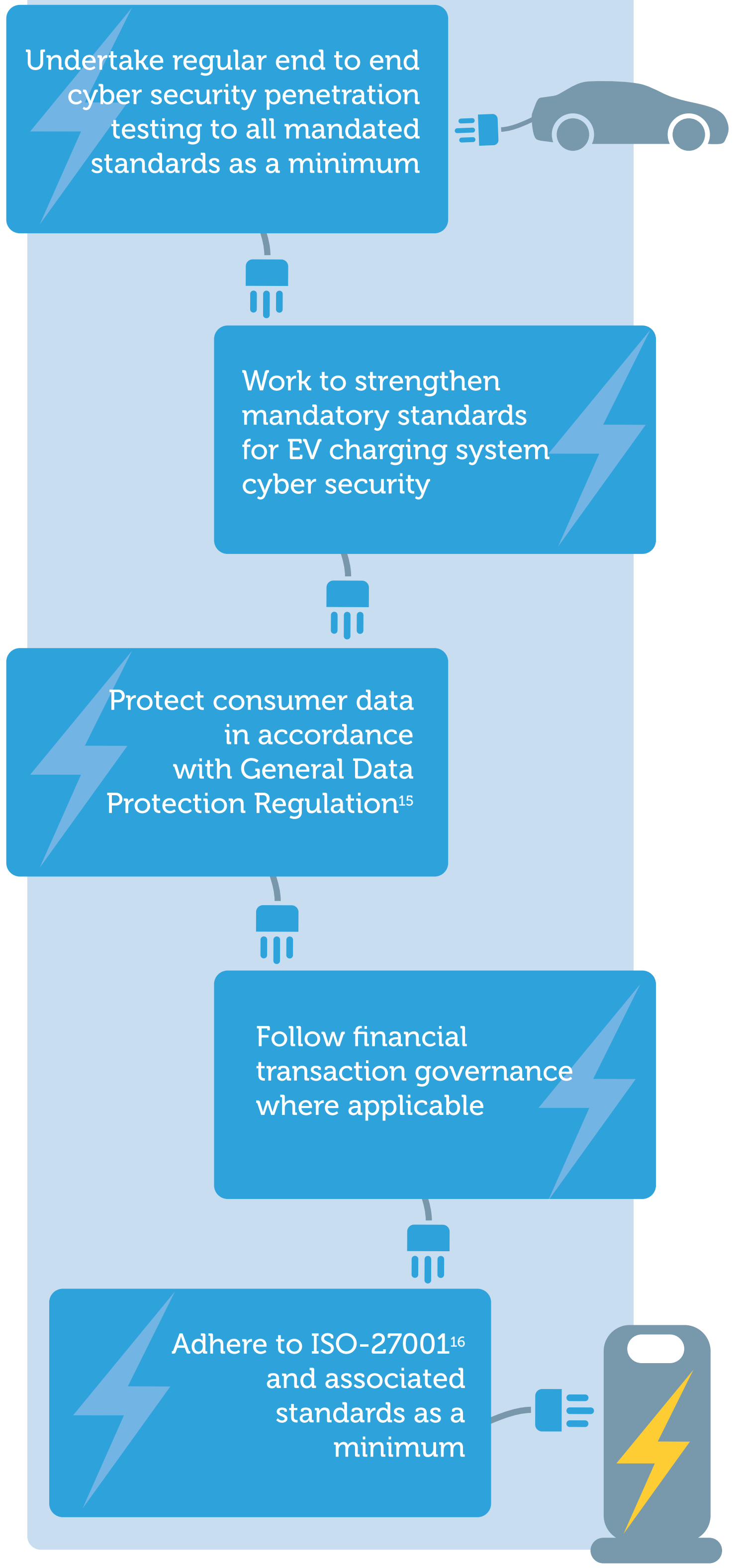
All parties should observe the findings and recommendations set out in the 2019 Report of the Energy Data Taskforce.[13]

Where communications or software systems are proprietary or specific to individual vehicles, the consumer experience of public charging may be compromised.

As the market grows and offerings to consumers become more complex, we may see more data being stored in the vehicle itself. This data could relate to energy contracts the consumer has with the home energy supplier or third parties, and the contracts may seek to entitle the consumer to charge the vehicle at public charge points at price points determined by the contract. It may not be necessary for public charge points to be installed now equipped with the functionality to manage these complex arrangements, but it may be prudent to keep these and other possible developments in mind when designing, procuring and installing charging infrastructure.

ISO-15118[14] may be an appropriate basis to prepare for interoperability with future payment, contractual and commercial models. Adoption of ISO-15118 may facilitate smarter charging and energy services. All parties should consider ways to future proof the connections and communications between vehicles and charge points.

Public charging will take place in a variety of ways, often when a consumer's time is limited and paying a premium for a rapid charge is an attractive payoff.



13 https://es.catapult.org.uk/news/energy-data-taskforce-report/
14 https://www.iso.org/standard/69113.html
15 https://gdpr-info.eu/
16 https://www.iso.org/standard/54534.html

Smart charging

Smart public charging will tend to take place when the charge can be slowed or paused according to network demands, to provide flexibility to the grid. The key smart charging scenarios are therefore 'duration' charging events. Duration charging occurs when the time the vehicle spends connected to the charge point is longer than the time required for charging; thus the rate of charge can be managed or the charge paused in response to price signals or network requirements. This is usually residential charging or destination charging, such as workplace or long- to medium-stay commercial parking.

This does not mean that other charging should not be smart, or smart-capable, but en-route charging, for example at short-stay parking bays or charging hubs, is not highly appropriate for demand modification because consumers generally do not want to extend these charging scenarios.

There are a variety of off-street charging business models able to provide flexibility, and some have particular implications for charge point design.

However, allowing drivers to connect wherever they park allows for greater system integration and potential for dynamic demand response. It may be helpful to think of an EV as an asset that can provide grid flexibility rather than a challenge to supply, but this approach is only possible with sufficient smart-capable infrastructure.

Retrofitting lampposts and other street furniture is one cost effective method of delivering urban EV charge points.[17]

These include:

- **Distribution System Operator (DSO) direct management**
- **Aggregators offering flexibility services to a DSO or Electricity System Operator (ESO)**
- **Suppliers offering time of use (ToU) tariffs reflecting variable network or energy charges**

This implies multiple possible routes for control signals and business-specific requirements. If a charge point is to be interoperable between systems, it may require functionality (or be able to be safely and cheaply modified) to support them all. But setting product requirements around providing support for all possible smart charging use cases would likely make the charge point very complex and expensive and may also introduce barriers to charging models that have not yet been identified.

This report, following the findings of the Electric Vehicle Energy Task Force,[18] recommends that rather than design a smart charge point that meets all possible needs, manufacturers should follow product requirements reduced to the minimum that meet the needs of all stakeholders. This is consistent with the Minimum Technical Standards[19] approach adopted by OLEV for current regulatory and fiscal policy for charge points.

Some principles for achieving resilient smart charge point design:

Charge points should follow technical requirements and specifications that allow it to be reliably operated in smart mode

Smart charge points must be interoperable with a range of systems and able to respond to signals from a charge point operator (reflecting local DSO constraints), aggregator, energy supplier or other intermediate party

Technical requirements and functionality should increase consumer acceptance and confidence in the product

Design should support the longer-term development of smart integrated operation of electrical assets

17 https://www.tsu.ox.ac.uk/pubs/2019-GULO-Phase-1-Final-Report.pdf
18 http://www.evenergytaskforce.com/
19 OLEV, Minimum technical specification – Electric Vehicle Homecharge Scheme (EVHS), (installations after 1 July 2019)

Placement, installation and operation

In all scenarios, parties responsible for the placement, installation and operation of charge points should ensure ongoing compliance with relevant law, in particular the Alternative Fuels Infrastructure Regulations 2017[20] and the Automated and Electric Vehicles Act 2018.[21] Public safety must be of the highest priority.

Public charge points need to be designed and installed so that they can be used by the public. The physical connections between the charge point and its housing, power provider, battery (if there is one), building or lamppost should not be proprietary or specific to individual makes and models, as this can have serious implications for the resilience and future proofing of the asset. This also applies to the physical connections with vehicles.

London's EV charge point installation guidance[22] provides design diagrams as examples of different types of charge points in on-street and off-street locations and outlines six design principles covering safety, comfort, inclusivity, coherence, attractiveness and reliability. These design principles can help identify potential sites for charge point provision and ensure the charge point type is site suitable.

For example, placement should consider facilitating access and use by people with physical disabilities. This might mean considering the space around disabled car parking spaces to allow for movement with a cable, having a dropped curb, ensuring the slant of the screen is appropriate for people with visual impairments, and other measures. Operators should also address the fact that on-street charging is particularly susceptible to vandalism or energy theft.

Charging bays should be wide, long and high enough to allow use by vans.

When located in public spaces, charge points need to be easy for users to find. This means, whether the charge point is located on the street, in a parking bay or in some other public area, it must be obvious to drivers and easily noticed by them (while they are also in control of their vehicles). This requirement includes clear signposting to public charge points located in underground car parks. However, both the charge point and the signposting must also meet local authority requirements for street furniture or public installations. This is a future-proofing issue because the streetscape around the charge point may change, so the device must be built with all these requirements in mind as well as the following:

- **Public safety, including adequate lighting for the personal safety of the charge point user**
- **Safety of wiring and other connections in light of potential new works or expansion of existing charge point to include additional connections**[23]
- **Security of the charge point and ability to withstand accidental damage or vandalism**
- **Balancing various and sometimes contradictory local needs for the charge point to be easy to locate but also match its surroundings.**

The industry should consider standards or a consumer code to ensure high-quality advice at point-of-sale or point of installation of public EV charging infrastructure.

Locational decisions should be driven primarily by consumer need and behaviour, not by what is easiest or least cost.

A combination of technology change and behaviour change will result in changing infrastructure needs, so all parties should plan and procure for future projected need, not for present need. This may mean leaving significant potential for a charging site to grow as demand increases; it also may mean guarding against over-procuring. Range will increase and charging times will fall as vehicle, charge point and battery technology all improve. Use patterns (consumer charging behaviour and range expectations) may change, and the optimum distance between public charge points may change also.

Charge point operators should ensure the latest version of firmware is implemented wherever possible, to maintain optimum functionality and security.

If a new electrical connection is required for the EV charge point, allowance should be considered for future expansion within the electrical substation. Charge points are sometimes added to existing sites in stages, and if this is not considered at the initial design stage then additional costs may result from upgrading the infrastructure a second or third time for each stage of the charge point upgrade.

20 http://www.legislation.gov.uk/uksi/2017/897/made
21 http://www.legislation.gov.uk/ukpga/2018/18/introduction/enacted
22 London's electric charge point installation guidance, Transport for London, December 2019
http://lruc.content.tfl.gov.uk/london-electric-vehicle-charge-point-installation-guidance-december-2019.pdf
23 https://electrical.theiet.org/bs-7671/

ENSURING ADEQUATE GRID REINFORCEMENT AND ELECTRICITY PROVISION IS ESSENTIAL.

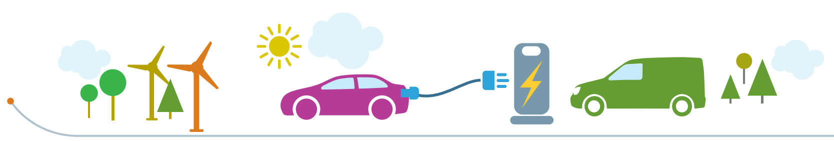
Installing a larger substation or electricity connection will assist with future expansion and demand. If a site has a restricted or costly upgrade route, it is possible to install higher capacity charge points to lower capacity connections and reduce the output of the larger charge points to match the maximum capacity of the electrical supply. The charge points can be connected with a communications system so that if only a few vehicles are charging, the charge points can ramp up to meet the total capacity allowed by the electrical supply connection, thus charging faster if only a few vehicles are connected.

Planning charge point deployment

Planning at local, regional and national levels is of prime importance and crucial to avoiding unneeded or obsolete installations of public infrastructure. Ideally, local authorities should have comprehensive plans for public infrastructure that have the support and cooperation of investors, infrastructure providers, other stakeholders and, just as importantly, the public users. These plans should take account of present and likely future needs and constraints, influenced or determined by present and changing patterns of use and by network management requirements.

Given projected levels of EV use, authorities should plan for sufficient charge points at local and street level and not rely solely on hubs to meet demand. This needs to be done within current and future constraints of electricity system capacity and the parking and road network. For this reason, adapting and repurposing existing infrastructure and promoting lower power capacities and longer charge times may be a more economic and scalable approach that will allow optimal use of the electricity grid and continued use of current parking locations with minimal interruption. This assumes that a majority of drivers will continue to prefer to 'top up' rather than 'fill up'.

As has been stated, patterns of public use and consumer behaviour are likely to change as battery and vehicle technology improves, as average range increases, and as recharging times fall. Along with these various, complex and sometimes contradictory pressures, the growth in EV use will also have profound implications for the amount and type of public charging required, and how charge points are distributed geographically.

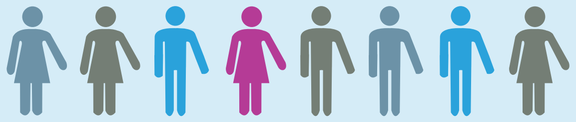


Some basic principles should apply to planning. These are most relevant at a local or municipal level, for either public or private procurement of publicly accessible charge points.

Current demand is not always the best indicator of future demand.
The need for infrastructure will grow. But as technologies improve, so will the range a vehicle can travel on a full battery. The most efficient geographical distribution of public charge points will be responsive to these changes.

Public charging areas should be flexible.
It is unclear which public charging technologies will emerge as the most appropriate. Public charging areas could be most useful if they offer a mix of rapid, fast or slow charging, or if there is a mix of such options available within a small local area. Designated areas should be designed with a view to expanding capacity or adapting to unexpected driver requirements.

Charging services should be appropriate.
Rapid charge points tend to be expensive: both hardware and network connection costs are greater than for slower forms of charging. There is little to be gained by providing rapid charge points in places where there is scant need or demand for them.

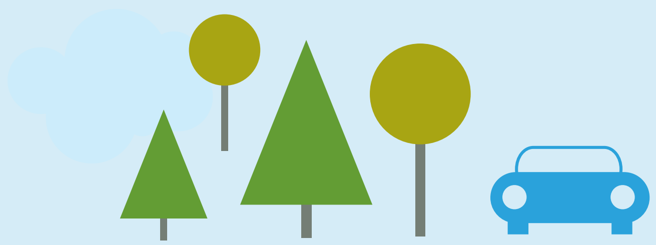


Engage with network operators and other stakeholders.
Conducting market research into consumer demand before installing charging infrastructure is not enough; engagement with network operators, network managers and DSR service providers is also essential.

Make the charge point easy to use and operate.
Drivers should find the charge points easy to use. On-street charge points should be easy to locate while also meeting local requirements for street furniture. Charge points should be easily connectable to vehicles, and the payment system should be simple, transparent and reliable.

Follow a suitable combination of placement criteria.
Placement of charge points solely on consideration of network costs may result in installations being in the wrong places for consumers. Installing charge points in the most convenient place for consumers may add unreasonable or unforeseen network costs.

Future proof the connections, not just the charge point
Network load management and passive provision are just as important as guarding against the obsolescence of the charge point itself.



Consider the future of network management.
Planners should investigate the benefits of installing smart public infrastructure and leave options open to replace or upgrade non-smart with smart charge points if required.

Ready access to maintenance services is essential
Contracts locking operators into specific providers of equipment, communications, maintenance or services may inhibit the growth or adaptability of a local charging system. Charge points should be interoperable in the sense that they can be operated by a new charge point network operator if need be.

Partnerships can be beneficial.
Partnerships between the owner or operator of the charge point and other stakeholders – the landowner, local businesses, private investors and neighbourhood groups – are increasingly common and allow a variety of approaches to funding and operating charging infrastructure and making installations more resilient to change.

Procurement

Publicly available charge points may be funded by central or local government budgets, by private companies, or through a variety of public-private partnerships. It is not the intention to list or analyse all these funding models, but some general points can be made.

The current procurement frameworks are not standard across local authorities. The Go Ultra Low City Scheme, the Switched-on Towns and Cities Challenge Fund and the On-street Residential Chargepoint Scheme do not stipulate a common framework, and individual local authorities or other public sector procurers are encouraged to develop their own methods.

A benefit of this may be that it allows local authorities to develop bespoke arrangements or collaborations to fund the capital investment in charging infrastructure. Local authorities and others may benefit from consulting the UK EVSE charge point procurement guidance.[23]

'To inform future-focused procurement, London Councils provide support with input from the TfL Commercial team to London boroughs participating in the Go Ultra Low City Scheme.

'Own and Operate' models are an increasingly common approach to public EV charging infrastructure, especially where the infrastructure is owned by a local authority. In this approach, the owner (or contracting party) funds the capital cost and receives all revenue while private companies bid to install the infrastructure and operate and maintain it for an agreed period and fee. A future-proof approach to this model would ensure that the physical infrastructure, including the charge points, will be able to function as intended if the charge point operation contract changes hands, or if the contractor changes its software or management system.

When procuring public charging infrastructure, therefore, parties should make sure they are buying equipment that will work across a range of operation and management scenarios.

Under **concession models** the charge point operator would be responsible for costs associated with the charge point, and there may be an arrangement to share some of the profits with the Local Authority. This is distinct from a services contract where costs are shared between parties.

Local Authorities should seek early engagement with the relevant procurement and commercial teams. In this scenario, the owner may have less say over the quantity and position of the charge points. This is because, depending on the agreement, the operator may have more rights with respect to developing or expanding the installation. The private operator is not guaranteed a fixed fee but sees its returns dependent on the viability of the investment. Concession arrangements should build KPIs into the agreement.

Depending on the contracted terms, therefore, the maintenance, updating and future proofing of the software, network and back-office systems may be the responsibility of the operator rather than the contracting owner. There are advantages to placing the responsibility for future proofing onto the party with the most immediate cost and profit pressure and risk exposure.

Adaptability

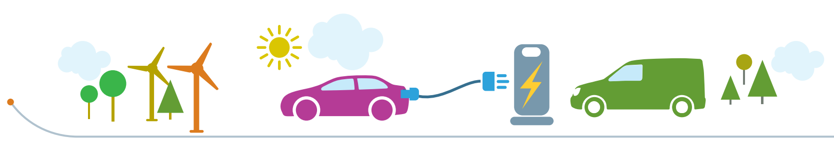
Assets must be designed, manufactured, installed, operated and recycled according to existing standards. Future proofing involves anticipating likely changes to these requirements or making the asset adaptable to unforeseeable changes.

Future-proof infrastructure is likely to be modular and designed to meet complex and variable customer needs that will change over time. It is necessary but not sufficient to identify customer 'segments' and design products to meet those different needs.

Charging infrastructure should be designed, manufactured, procured, installed and maintained in a way that allows providers or investors to gradually build their provisions without unreasonable risk of costly false starts or of needing to replace equipment before the end of its life.

A key principle of future proofing is adaptability and resilience to change. Individual companies will find their own approaches to this challenge, but some general principles apply and are likely to be common to most solutions. Adaptability is characterised by:

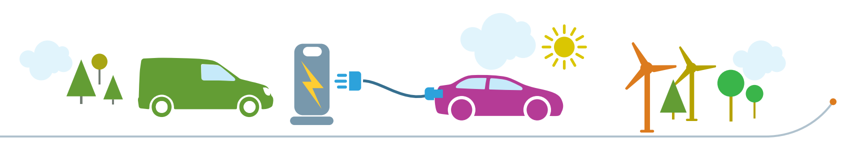
- **An ability to build on existing charging technology**
- **Public providers' ability to augment and retrofit rather than replace infrastructure as other technologies or consumer behaviours change**
- **Charging technology and infrastructure planning that are responsive to changes in vehicle technology, especially charging rates and battery capacity (vehicle range)**
- **An open architecture, not a closed or proprietary system.**



CONCLUSIONS

Future-proof infrastructure will be resilient by virtue of being adaptable to changing needs and being interoperable with other parts of the charging system. It will be planned, deployed, installed and operated in ways that enable it to serve multiple users effectively and efficiently. And, where necessary, it will be part of a smart system the contributes to the flexibility and resilience of the electricity grid and manages consumer data in a way that improves the customer experience of charging – and thus improves public confidence in the electrification of road transport.

This description of industry best practice to future proof EV charging infrastructure acknowledges the uncertainties and challenges to an optimal rollout. Successful management of these risks and challenges will lead to a virtuous circle of market, investor and consumer confidence. Future proofing demands avoiding stranded assets, which includes minimizing their underutilization. To achieve this, the interoperability, longevity and adaptability of infrastructure should be prioritized. Secure, reliable and safe connections, both electrical and for smart communications, are integral to this outcome. Standards and legal requirements for placement, installation and operation should be followed, but there remain many ways to roll out public infrastructure, and some trade-offs between imperatives will be inevitable in determining the optimal approach. The decarbonization of road transport is essential if the UK is to meet its carbon abatement commitments, and the provision of adequate charge points is critical. The need for resilience and efficiency should guide the design, manufacture, planning, procurement, installation and operation of this newly essential public infrastructure.



This paper is not a procedural guide or handbook of steps to follow. It is intended to be a description of best practice for all stakeholders so that EV infrastructure is designed, built, procured, installed, maintained and used appropriately for present and future needs. It is offered in the hope that the majority of public charge points are used for the full life of the asset in ways that contribute to public acceptance of and confidence in the electrification of road transport.

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