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Development of the UK Public Chargepoint Network

Harold Dermott

December 2018

The Royal Automobile Club Foundation for Motoring Ltd is a transport policy and research organisation which explores the economic, mobility, safety and environmental issues relating to roads and their users. The Foundation publishes independent and authoritative research with which it promotes informed debate and advocates policy in the interest of the responsible motorist.

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About the Author

Harold Dermott has spent over 35 years in the motor manufacturing industry, including 15 years running his own company.

He has project managed a major vehicle programme as well as creating and running the Business Development and Customer Care Departments for McLaren Automotive Ltd. Since launching HD&A Consultancy in 2011, he has worked exclusively in the EV charging infrastructure business.

His extensive involvement in every aspect of the installation and operation of all types of EV chargepoint for many years has enabled a clear understanding of both the commercial and customer requirements necessary for an effective chargepoint network.

Harold has a BEV and regularly uses public chargepoints.

Acknowledgements

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Disclaimer

Contents

Figures list

Tables list

Foreword

In my foreword to Harold Dermott's previous report for us, just over a year ago, I wrote that the then "fragile state of the UK electric car market" was a sign that we were still at the very start of the journey towards a zero-emissions future for motoring.

What's changed?

On the positive side it is now practically impossible to pick up a copy of any of the regular motoring publications without finding reference to another new electric model either being tested on the road or being promised for sale in the relatively near future.

The Government has secured Royal Assent to its Automated and Electric Vehicles Act, which means the powers now exist to tackle some of the factors blocking the take-up of electric cars, and has convened an Electric Vehicle Energy Task Force to advise on how best to ensure that our energy system is ready for and able to facilitate and exploit the mass take up of electric vehicles. London's mayor, Sadiq Khan, has also convened an Electric Vehicle Infrastructure Taskforce to advise on the roll-out of public chargepoints in the capital.

But challenges remain. Demand for new electric models is now outstripping the supply in showrooms, with lengthy waiting lists building up for popular models and prices rebounding for used cars.

And confusion still reigns when it comes to the task of recharging, which, in turn, risks undermining the effectiveness of public initiatives to secure the right publicly available charging options: the pace at which a vehicle can accept the charge is as important as the rate at which a chargepoint can deliver it. A chargepoint will only ever be as 'rapid' as the car that it plugs into.

For those of us with access to off-street parking where a dedicated charger can be installed, at home or at the workplace, public charging is likely to be less of an issue. Even so, certainty of being able to recharge on occasional longer journeys is still key to giving individual motorists peace of mind, and that in turn matters for the fleet buyers, who will focus not just on the bottom line of running costs but also on the general attractiveness of the vehicles they buy for their customers.

The more we understand about the costs, benefits and practicalities of the electrically powered world, the better for making it a reality.

Steve Gooding

Director, RAC Foundation

List of abbreviations

AC	alternating current
AEVA	Automated and Electric Vehicles Act 2018
BEV	battery electric vehicle
CCS	Combined Charging System
CPN	public chargepoint network
DC	direct current
DNO	Distribution Network Operator
EV	electric vehicle
EVCH	electric vehicle charging hub
EVHS	Electric Vehicle Homecharge Scheme
EVSE	electric vehicle supply equipment
GWh	gigawatt-hours
HDA	Harold Dermott & Associates
HPR	Hornsdale Power Reserve
ICE	internal combustion engine
IRENA	International Renewable Energy Agency
kW	kilowatts
kWh	kilowatt-hours
LEVC	London Electric Vehicle Company
LFR	large fuel retailer
MSA	motorway service area
MW	megawatts
MWh	megawatt-hours
NDA	non-disclosure agreement
OEM	original equipment manufacturer
OLEV	Office for Low Emission Vehicles
PHEV	plug-in hybrid electric vehicle
QMS	quality management system
RCN	Rapid Charge Network
RtZ	Road to Zero (report)
SMMT	Society of Motor Manufacturers & Traders
SOC	state of charge
SRN	Strategic Road Network
V2G	vehicle-to-grid
V2X	vehicle-to-everything
WCS	Workplace Charging Scheme
WLTP	Worldwide harmonized Light vehicles Test Procedure

Executive Summary

The developed world is about to undergo the biggest revolution in personal mobility for over a century. The main aspects of this will be automated (driverless) vehicles, changes in how mobility is accessed, and the widespread adoption of electric propulsion for vehicles. As with all disruptive change, this has promoted fear, uncertainty and doubt in the minds of those facing it, which over the next twenty years or so will be everybody who currently drives a motor vehicle.

This report reviews the status and performance of the current public chargepoint network (CPN) and the changes to it that may be necessary over the next few years to meet advances in technology and growing demand.

This year, the UK Government clarified its own intentions in this area by means of the Automated and Electric Vehicles Act 2018 (AEVA) and *The Road to Zero: Next steps towards cleaner road transport and delivering our Industrial Strategy.* Most important of all, the Government plans to ban the sales of all new internal combustion engine (ICE) vehicles in the UK from 2040, and this assumption is critical to all future projections used in this report.

Electric vehicles (EVs) need to have their batteries charged in order to operate. Whilst most of this charging will take place at home or at the workplace, there is an additional requirement to be able to charge away from these locations, and the UK already has an extensive CPN. The term EV includes battery electric vehicles (BEVs) together with ICE vehicles which have additional battery assistance, known as plug-in hybrid electric vehicles (PHEVs) but excludes simple hybrids with no ability to connect to a power source. The difference between BEVs and PHEVs is not in general understood by the public.

The report notes the perceptions of the CPN held by potential EV private purchasers, which indicates that negative information about EVs and the CPN in wide circulation. It is to the benefit not only of the government, but all involved in the industry to ensure that accurate information is more readily available to all potential EV purchasers, whether private or fleet.

Two types of charging on the CPN are identified: 'Journey' charging, where the primary reason for being at the location is to charge the vehicle; and 'Grazing' charging, in which the driver is at the location primarily for another purpose. Grazing chargepoints suit the driver's existing routine and 'dwell times'; examples of locations include car parks for shopping, gyms and hotels. Journey chargepoints are exclusively Rapid chargepoints, whereas Grazing chargepoints are almost exclusively Fast AC (alternating current).[1]

One of the most common misunderstandings at all levels of the debate is the false belief that any EV on the road can accept any charge rate available from a roadside AC chargepoint. This is absolutely not the case, as the chargepoint by the roadside and the charger in the car are in series, and therefore the actual charge rate will be the lower charge rate of

1 Rapid charging is defined as a charge rate greater than 22 kW; fast charging is defined as a charge rate of between 7 kW and 22 kW.

the two chargers. This point is probably the single most important piece of information in this report and cannot be emphasised strongly enough: it is the source of a great deal of misinformation and confusion. It follows that OEMs must fit their vehicles with on-board chargers and charging systems appropriate to their intended use.

The report identifies five fundamental requirements for a successful CPN:

1. matching supply to demand;
2. ensuring that the chargepoints are attractive to use, and have the necessary facilities
3. ensuring that the chargepoints are reliable;
4. ensuring that the installations are commercially viable; and
5. ensuring that the demand on the grid can be managed.

Matching supply to demand

Long-term projections of EV sales require so many assumptions as to render them almost meaningless, owing to the rapidly changing EV market place and almost continuous changes in technology. This paper therefore concentrates on detailed projections to the end of 2020.

An extensive analysis of the number of EVs on the road by type, battery capacity and charging ability together with the available charging infrastructure by output and outlet type shows that by any realistic metric, the CPN is meeting demand. Projections of this data to the end of 2020 show that to continue to meet demand, the chargepoint networks must increase the impressive chargepoint installation rate they achieved in 2018 (about 1,000 Journey chargepoints and 2,500 Grazing chargepoints) by 50% in 2019 and 30% in 2020. EV Original Equipment Manufacturers (OEM) must also improve their advanced communication with network suppliers on vehicle battery size and charge rates to ensure the relevant roadside chargepoints are available in the right quantities.

The paper provides evidence that since no PHEV currently on sale in the UK can realistically use electric power outside urban environments, no provision should be made for charging these vehicles at Journey locations.

Ensuring that chargepoints are attractive to use

Whilst the number of chargepoints of all types is meeting demand, the experience of using these chargepoints is not always attractive, especially for drivers used to the ICE refuelling experience. There has been little or no improvement in this area in the last year, as both government and the chargepoint industry remain focussed only on how many chargepoints there are on the map, not their effectiveness.

The report investigates typical user experiences and suggests basic requirements for all chargepoints, whether Journey or Grazing.

However, the concept of the electric vehicle charging hub (EVCH), where multiple chargepoints are gathered under one roof, will provide all the facilities that a BEV driver requires for a Journey charge. It is in effect the BEV equivalent of a modern petrol filling station, and the standard that all modern drivers of ICE vehicles have become used to. The report proposes that the installation of a trial number of EVCHs across the UK should begin in 2019.

Ensuring that chargepoints are reliable

There has been an improvement in reliability of chargepoints on the CPN over the last year. The like-for-like improvement between July 2017 and May to August 2018 is a reduction of out of service chargepoints on the CPN from 14.8% to 8.3%. Whilst any improvement is welcome, it nevertheless means that about one in twelve chargepoints is not working, which is still unacceptable. This compares with the 99% availability expected by the Dutch CPN.

Arriving at a lone chargepoint to find it is not working is still a significant concern to BEV drivers, and the AEVA regulations need to set requirements for chargepoint availability and repair times.

Ensuring that the installations are commercially viable

The Government states that it wants to:

> "encourage and leverage private sector investment to build and operate a thriving, self-sustaining public network… With the right policy framework for investors and consumers, as EV uptake increases and utilisation rates improve, we expect the market to be able to deliver the public infrastructure needed in the long term. It is essential that viable commercial models are in place to ensure continued maintenance and improvements to the network."

It is therefore absolutely clear that the CPN must be commercially viable, but the time frame for achieving this is not clear.

The report analyses published data on the profitability of Rapid chargepoints at Journey locations and finds that the projected usage required for profitability depended on an aggressive sales price for electricity sold (3.3 times cost) and an 18% year-on-year increase in use *at each and every chargepoint*. This in turn relies entirely on a similar or greater growth in BEV sales and effectively no competition for customers.

The average usage in this 2017 report was between two and three charges per chargepoint per 24 hour day. Extrapolated to today's network, this indicates a usage per chargepoint of three to four charges per chargepoint per 24 hour day.

Not only does this not paint a picture of a CPN which is struggling to meet demand, it also indicates that making the CPN commercially viable will be difficult until there are enough BEVs on UK roads to create sufficient demand.

The report also points out that meeting profitability requirements (more BEVs per chargepoint) is inconsistent with the perceived demand for more chargepoints on the CPN (less BEVs per chargepoint), and this might require government support in the transition phase.

Ensuring that demand on the grid can be managed

Demand side management, which encourages EVs to charge when other demand is low and which is particularly suitable to Home charging, which accounts for about 80% of all EV charging.

Energy storage inserts a time-disconnect between the time of demand and supply. Thus energy stored at night can be made available during the day and energy stored when the wind is blowing or the sun shining can be made available at any time. This paper suggests that the potential benefits for energy storage as an inherent part of the CPN are substantial, and may provide an additional source of income to network operators.

Using the energy stored in the EV fleet itself to help balance the grid also has potential. V2G (vehicle to grid) and V2X (vehicle to anything) are both being currently investigated by UK Power Networks amongst others, When conclusions are reached, the AEVA has the powers to create regulations which would make the EV fleet part of the solution, not the problem.

The report also notes that it is also essential to ensure that V2G takes full account of the needs of the EV owner and the vehicle battery, *and not just the grid, electricity supplier and aggregator*.

There is an opportunity for the AEVA to be used not only to ensure that the rapidly expanding demand for electrical power for EVs can be met by the UK's twentieth century grid, but also to encourage emergence of the new technologies that the grid will require in the twenty-first century. This would appear compatible with Ofgem's current view of "taking a more holistic view regarding what regulatory arrangements are appropriate for the future energy system"

Key conclusions

The report also suggests how the legislation in the AEVA could be used to draft regulations to address many of the issues identified in the report.

One of the conclusions of the report is that the CPN only represents a small part of the EV refuelling requirement: it is also essential that local councils and developers ensure that all new houses are built with provision for 7 kW EV charging in every home. In addition, new industrial and commercial units being built now should have a minimum of 25% of their parking spaces fitted with a 7 kW charger.

For those EV owners, mainly in large cities, without access to off-street charging, there have been developments in the last year, including a government grant to help local authorities provide on-street charging. Various on-street charging schemes are being trialled, of which lamp post charging currently looks the most promising.

Noting these requirements for new domestic, commercial and industrial property emphasises how different the EV ‘refuelling’ process is, and how wide-ranging the changes required Home and workplace charging are as important as the CPN in ensuring a smooth transition to EVs.

At the end of July 2018, there were **111,890 PHEVs** and **53,727 BEVs** registered in the UK

One of the most common misunderstandings is the **false belief** that any EV on the road can accept any charge rate available from a roadside AC chargepoint

For all EVs **when AC charging**, the overall charge rate will be whichever is the **lower** of the charge rate of the **roadside chargepoint** and the charge rate of the vehicle's **on-board charger**

Irrespective of what charge rate a roadside **AC chargepoint** is capable of delivering, all current PHEVs will be limited by the capacity of their **on-board chargers to 3.6 kW**

The public **chargepont network (CPN)** should not make any provision on motorways and trunk roads for charging PHEVs until these vehicles have an **electric range that is relevant** for use on motorways and trunk roads and **a 50 kW Rapid charging capability**

Between **May to August 2018**, the average percentage of chargepoints **out of service** on the CPN was **8.3%**

The CPN provides two types of charging:

'Journey' charging is where the primary reason for being at the location is to charge the vehicle. This applies almost exclusively to **Rapid DC charging**

'Grazing' charging is where the driver is at the location primarily for another purpose. This means using chargepoints which **suit the driver's existing routine and 'dwell times';** locations include car parks for shopping, gyms and hotels. A typical chargepoint for these locations would be a **7 kW AC Fast charger**

There is currently no good business case for the installation of **more** Rapid chargepoints to meet current (low) demand for **BEV Journey charging**

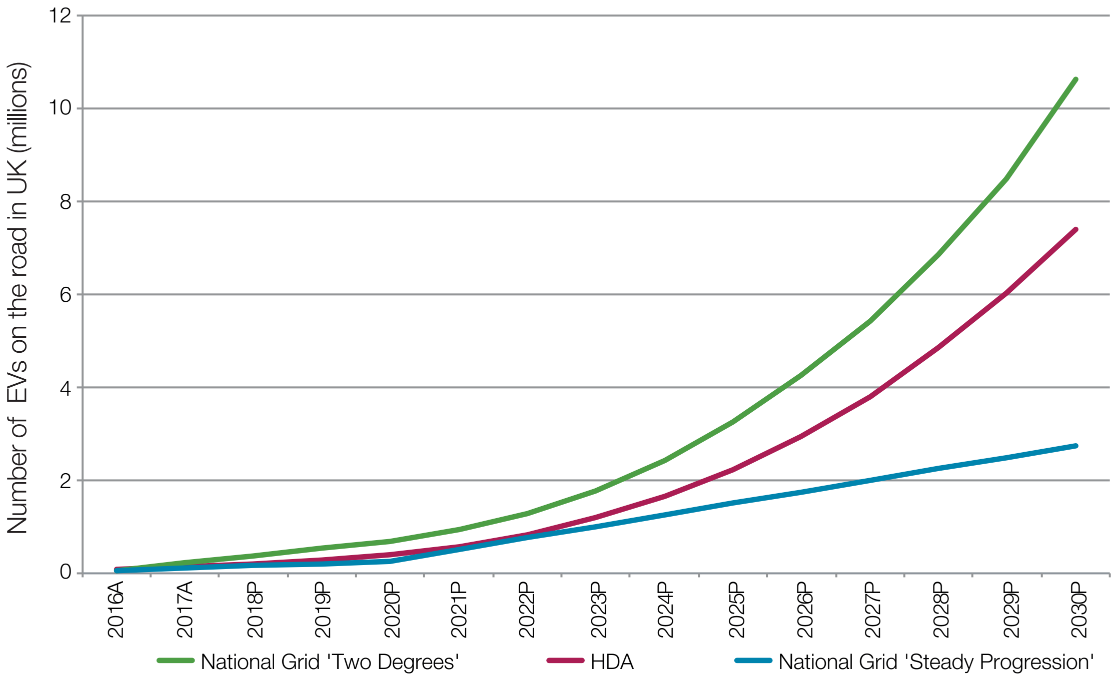
Home and Workplace charging are **as important** as the CPN in ensuring **a smooth transition** to EVs

1. Introduction

The developed world is coming to terms with the greatest change in personal mobility for over a century: not only will there be a change in the way mobility is accessed, but before the end of the second quarter of the twenty-first century, new vehicles in the UK will no longer be powered by the internal combustion engine (ICE).

Graphs, such as Figure 1.1, projecting the rate and profile of this change are issued regularly by almost every organisation on which it might impinge (National Grid, 2018). In the UK, they are based on the Government's intention to effectively ban new ICE vehicles from 2040 (Defra & DfT, 2017). The main interest in such projections is to note the wide variation in predicted volumes of electric vehicles (EVs) by 2030, which can often vary by over 100% from the same organisation.

Figure 1.1: Actual and projected number of EVs on the road in the UK 2016 to 2035



Source: National Grid 2018, HDA projections based on SMMT data
Note: Assumes all new car sales will be EV by 2040
HDA = Harold Dermott & Associates, A = actual, P = projected

In reality, detailed projections beyond 2020 are almost impossible, owing to the rapidly changing EV market place and almost continuous changes in technology. The inevitable transition to electric propulsion is only just beginning, most of the changes are still to come, and nobody knows what they will involve or how technology – or even the very concept of car ownership – will change. Long-term projections of EV sales require so many assumptions as to render them almost meaningless. Figure 1.1 indicates what the general trend beyond 2020 might look like, as it is important for some aspects of the discussion.

This document will instead look in detail at the changes between now and the end of 2020, using the more specific data available for this period. It will also focus on EVs, which are defined as battery electric vehicles (BEVs) and ICE vehicles with additional battery assistance, the plug-in hybrid electric vehicle (PHEV). It is important to understand that this does not include standard hybrid vehicles with no ability to charge by plugging in to a power source. **Therefore in this report, EV = BEV + PHEV.**

This report is an update to the 2017 RAC Foundation report (Dermott, 2017), which is referenced where it provides more detail or to avoid repetition. The objective of this report remains the same as that of the 2017 report: to review the current effectiveness of the UK public chargepoint network (CPN), noting what must happen to ensure that the constant changes in EV technology and customer usage patterns are reflected by equivalent changes in the CPN that supports them. It will also consider how the legislation in the Automated and Electric Vehicles Act 2018 (AEVA) can be used to assist in achieving this goal. The *Road to Zero* (RtZ), a document which explains the Government's plans to achieve its goals of "cleaner air, a better environment, zero-emission vehicles, [and] a strong clean economy" (DfT, 2018a: 1) will also be referred to regularly.

2. Background

With the uptake of EVs in the UK continuing to rise, and the number on the road expected to double between 2017 and 2019, and double again between 2019 and 2021,[2] it is obviously essential that the 'refuelling' system for such vehicles is able to meet the demand and the changing technology that this form of propulsion is bringing to the market.

A good starting point for assessing how well this if going might be the existing EV owners' views on how well they are being provided for. Almost more interesting is the perceived view of the growing numbers of people who are considering an EV as their next vehicle.

Two recent surveys – from the AA (2018) and OVO Energy (2017) – have shown that existing ICE drivers say that a shortage of public charging points for EVs is the main reason why they are not considering an EV as their next vehicle.

This very interesting statement raises the following questions/concerns:

1. How have they come to the conclusion that there are insufficient public chargepoints if they have never used an EV?
2. How many public chargepoints would they consider adequate to encourage them to change to an EV?
3. There appears to be no understanding of the differences between PHEV and BEV.

2 Harold Dermott & Associates (HDA) projections based on SMMT registration data

Whilst such surveys may prompt defensive reactions from those surveyed, these are important issues.

To take the first point, the alleged undersupply of public chargepoints: this perception can exist only if there is information biased against the shift towards EVs being circulated. The CPN is an easy target in this context, because at the end of 2017 only 0.4% of the driving public[3] were users of EVs and therefore had the opportunity to use it. Therefore at least 99% of people involved in the CPN debate have no experience of using it. If drivers considering a change to an EV are being led to believe that EVs will struggle to drive 50 miles on a charge (McGrath, 2018), and also do not understand that they will normally leave home with a full battery, the ability to charge on a journey will appear very important.

Car dealers are the only face-to-face contact that is available to potential private buyers who wish to discuss the purchase of an EV. Failure by these dealers to provide their potential customers with accurate information must inevitably result in lost EV sales. Some car salesmen are still financially incentivised to sell ICE cars rather than EVs, and in the author's experience, many of these customer-facing staff are themselves poorly trained and have poor understanding of any public charging issues. If vehicle manufacturers (original equipment manufacturers (OEMs) want to sell EVs, they need to urgently address dealer performance on the issues of both selling EVs and briefing buyers on how to use their new EV.

Every EV dealer must provide a comprehensive briefing about Home and public charging as part of the handover process. This will require dealer staff to receive new training on these subjects. The handover must be more than just explaining the controls: the refuelling of an EV is as major a change as the move from horse fodder to petroleum spirit was for new motor car owners in the early twentieth century.

Apart from removing sources of negative information, providing more positive information to potential EV buyers is also necessary. This should not be the role of government alone (which should probably create a more effective educational campaign than the Go Ultra Low campaign), as it also affords an opportunity for everyone involved in the industry to promote the transfer to EVs and engage with the full spectrum of the media.

Points 2. and 3. raise fundamental issues for all parties involved in the growth of EVs in the UK.

This will include not only government, but in particular the EV OEMs, CPN operators and the electricity generation and supply industry.

2.1 Types of EVs

At the end of July 2018, there were 111,890 PHEVs (7.6% of all EVs) and 53,727 BEVs (32.4% of all EVs) registered in the UK.[3]

In Q2 2018, there were 11,655 new PHEVs registered and 3,547 new BEVs registered, which means that PHEVs were outselling BEVs in the UK by a ratio of over 3:1. If PHEV

3 SMMT and DfT data (which includes both private and fleet registrations) analysed by HDA

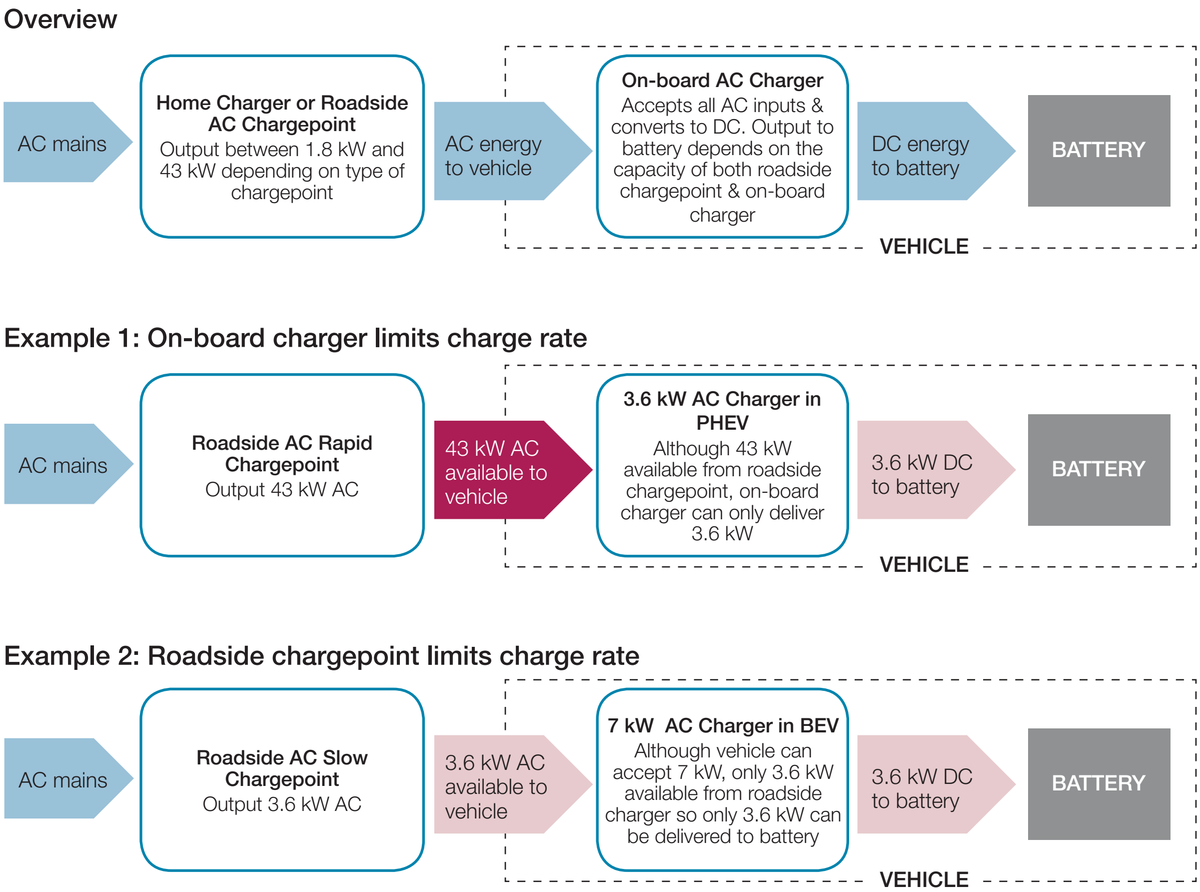
sales continue to expand at this rate, the cumulative number of PHEVs will rise from 67.6% of all EVs in the UK at the end of July 2018, to 69% by the end of 2018, and 72% by the end of 2019.

2.2 Types of EV charging

There are two types of EV charging process: AC and DC. AC charging is carried out via an on-board device on the car, usually called ‘the charger’. This on-board charger controls the entire charging process and also – just as importantly– might put a limit on the rate of charge, which maximum rate will vary from car to car. Figure 2.1 shows details of the AC charging process.

For all EVs when AC charging, *the overall charge rate will be whichever is the lower of the charge rate of the roadside chargepoint and the charge rate of the vehicle’s on-board charger*. Although this is clearly shown in Figure 2.1, it is surprisingly still not understood by many decision-makers, who assume that installing a 22 kW chargepoint means that any BEV or PHEV that connects to it will charge at 22 kW. It does not.

Figure 2.1: AC charging procedure for all BEVs and PHEVs (simplified)



Source: Dermott (2017), Figure 2.1

The other type of EV charging process is DC charging, which bypasses the on-board AC charger to charge the battery directly. The charge is controlled by the roadside chargepoint, via the battery electronic management unit on the vehicle. DC charging is used exclusively for Rapid charging; nearly all BEVs can accept DC Rapid charging.

2.3 PHEV usage and charging issues

Information from fleet use of PHEVs suggests that many PHEVs are never charged (TMC, 2017) – i.e. they run on their ICEs only. This raises the question of how the manufacturers of PHEVs expect their vehicles to be used, if their cars are being made with *an on-board charger that limits their charge rate to a level that is suitable only for Home charging*.

At this charge rate of 3.6 kW, the average UK PHEV battery capacity of 9.1 kilowatt-hours (kWh) will take about two hours to charge from 20% to 100% state of charge (SOC). This cannot be considered as a realistic time to charge on a journey to gain a real-world driving range of (for most PHEVs) of less than 25 miles.

Furthermore, some PHEV owners charge at the 43 kW AC Rapid chargepoints connectors available on the CPN. Figure 2.1 and Table 2.1 make it clear that, *irrespective of what charge rate a roadside AC chargepoint is capable of delivering*, all current PHEVs will be limited by the capacity of their on-board chargers to 3.6 kW. In the two hours that it takes the PHEV to gain about 7 kWh of energy and 25 miles of range, the same chargepoint could have delivered a 30-minute charge to four BEVs, each potentially gaining about 22 kWh of energy and 80 miles of range. *Nearly all UK Rapid chargepoints will charge only one vehicle at a time irrespective of how many individual sockets they offer*. From the perspective of commercial viability, this is the loss of a potential sale of 81 kWh of electricity.

This blocking of Rapid chargepoints by PHEVs must be ended. If it becomes widespread, the CPN network of Rapid chargepoints would fail for two reasons: Rapid chargepoints would never be available for their essential purpose of charging BEVs, and the network operator's income would collapse.

Table 2.1: Public charging capability of the most popular BEVs and PHEVs in the UK

Make	Model	Type	On-board		Public charging	
			Charge sockets	Charger standard/option	1st choice	2nd choice
Audi	A3 e-tron	PHEV	Type 2	3.6 kW	3.6 kW AC	N/A
BMW	i3 BEV	BEV	CCS, Type 2	11 kW	50 kW CCS DC	7 kW AC
BMW	i3 REX	EREV	CCS, Type 2	11 kW	50 kW CCS DC	7 kW AC
BMW	330e	PHEV	Type 2	3.6 kW	3.6 kW AC	N/A
BMW	225xe	PHEV	Type 2	3.6 kW	3.6 kW AC	N/A
BMW	530e	PHEV	Type 2	3.6 kW	3.6 kW AC	N/A
Hyundai	Ioniq PHEV	PHEV	Type 2	3.6 kW	3.6 kW AC	N/A
Kia	Nero PHEV	PHEV	Type 2	3.6 kW	3.6 kW AC	N/A
Mercedes	C350e	PHEV	Type 2	3.6 kW	3.6 kW AC	N/A
Mini	Countryman PHEV	PHEV	Type 2	3.6 kW	3.6 kW AC	N/A
Mitsubishi	Outlander PHEV	PHEV	CHAdeMO, Type 1	3.6 kW	CHAdeMO 22 kW DC	3.6 kW AC
Nissan	e-NV200	BEV	CHAdeMO, Type 1	3.6 kW/(6.6 kW)	CHAdeMO 50 kW DC	7 kW AC
Nissan	LEAF	BEV	CHAdeMO, Type 1	3.6 kW/(6.6 kW)	CHAdeMO 50 kW DC	7 kW AC
Porsche	Panamera S E-Hybrid	PHEV	Type 2	3.6 kW	3.6 kW AC	N/A
Renault	ZOE R(Q)	BEV	Type 2	22 kW/(43 kW)	22 kW/(43 kW) AC	7 kW/(22 kW) AC
Tesla	Model S	BEV	Special Type 2	11 kW/22 kW	Supercharger 135 kW	50 kW CHAdeMO
Tesla	Model X	BEV	Special Type 2	11 kW/22 kW	Supercharger 135 kW	50 kW CHAdeMO
Toyota	Prius plug-In	PHEV	Type 1	3.6 kW	3.6 kW AC	N/A
Volvo	XC90 T8 Twin Engine	PHEV	Type 2	3.6 kW	3.6 kW AC	N/A
VW	e-Golf	BEV	CCS, Type 2	7.2 kW	50 kW CCS DC	7 kW AC
VW	Golf GTE	PHEV	Type 2	3.6 kW	3.6 kW AC	N/A
VW	Passat GTE	PHEV	Type 2	3.6 kW	3.6 kW AC	N/A

No shading indicates BEV

Blue shading indicates PHEV

Orange shading indicates E-REV

Source: Author's own
Note: N/A: not applicable

Now consider a responsible PHEV driver who needs to drive from, say, Birmingham to London for a business meeting, and wants to use electric power in London to reduce pollution. Their only practical option is to make sure that they have fully charged their PHEV at home overnight, and then avoid using any electrical power on the journey, before finally deploying their electrical power once they have reached London.

Whilst this is good for London, on the journey from Birmingham their PHEV will just be a rather heavy petrol vehicle, producing *at least* the same climate change and air quality pollutants as any other petrol vehicle. It should be borne in mind that currently a PHEV is eligible for a 100% exemption from the London congestion charge irrespective of its electric-only range, and that this exemption applies even if its battery is not charged and it is therefore being driven by its petrol engine like any other vehicle (changes to the Ultra Low Emission Discount were consulted on in September 2018 (TfL, 2018)).

In general, manufacturers do not design their PHEVs to accept Rapid charging, although one manufacturer does: the Mitsubishi Outlander is one of the largest PHEVs currently on sale in the UK, and has the largest battery (increased from 12.0 to 13.8 kWh for the 2019 model year) to give a Worldwide harmonized Light vehicles Test Procedure electric-only range of 28 miles. However, this vehicle has a maximum DC charge rate of 22 kW, half the 44 kW minimum charge rate available at UK Rapid DC chargepoints. The Outlander will therefore take about 30 minutes to charge to deliver about 18 to 20 miles range at motorway speed, which is rarely enough even to reach the next motorway service area (MSA).

2.4 The PHEV conundrum

Even with Rapid charging, it is impractical to use the electric motor/battery combination to propel any currently available PHEV at motorway speeds for any significant distance. Therefore the ICE will continue to be the motive power for PHEVs on motorways and trunk roads for the immediate future, bringing into question the long-term benefit of these vehicles in reducing climate change and air quality pollutants.

It is important to realise that even a PHEV fitted with Rapid charging will be blocking Rapid chargepoints at MSAs, large fuel retailers (LFRs) and other ‘Journey’ locations (where the primary reason for being at the location is to charge the vehicle – see Chapter 3). Those plugging in to the 43 kW AC Rapid connector and drawing only 3.6 kW are an even bigger problem. This blocking of Rapid chargepoints by PHEVs must be ended. If it becomes widespread, the CPN Journey network of Rapid chargepoints will collapse.

The CPN should therefore not make any provision on motorways and trunk roads for charging PHEVs until these vehicles have an electric range that is relevant for use on motorways and trunk roads (for example, 50 miles at 70 mph) and a 50 kW Rapid charging capability.

Note that the Belgian Government has already announced that it will abolish corporate tax breaks for what it calls ‘fake’ low-emission vehicles such as hybrid cars with limited zero-emissions potential. From 2020, plug-in cars in Belgium will be granted tax relief on a sliding scale linked to their battery's storage capacity in relation to the total weight of the vehicle (TMC, 2017). China, the world's largest market for EVs, also scales grants according to a range of requirements, all intended to drive technology forward. These include electric-only range, mass energy density of the battery, and power consumption. There are no grants for BEVs with a range of less than 150 km (93 miles) or for PHEVs with an electric-only range of less than 50 km (31 miles) (Lambert, 2018). By pursuing a range-based policy, China is supporting those EVs which remove the most pollution from the roads, and is therefore deriving the best value from public money spent. The policy is driving domestic manufacturers to improve battery technology, which is a target in the UK as well (DfT, 2018a, Part 2d).

With other countries setting intelligent precedents, the Government has a reference to a proven strategy to incentivise development of the least-polluting vehicles. An urgent review of the grants shown on page 43 of the RtZ is required to keep the UK competitive. Aligning EV grants to the new benefit-in-kind bands to be introduced in 2020 (Middleton, 2016) would appear obvious, with the less-than-30-mile range band receiving no grant.

It should be noted that when this report was in the final stages of production, the government announced a change in plug-in car grant that effectively removed grant for new PHEVs (RAC Foundation, 2018).

3. Requirements for the UK public Chargepoint Network

There are five fundamental requirements for a successful CPN:

1. matching supply to demand;
2. ensuring that the chargepoints are attractive to use, and that BEV owners have the necessary facilities for a 20- to 40-minute stay at Rapid chargepoints;
3. ensuring that the chargepoints are reliable;
4. ensuring that the installations are commercially viable; and
5. ensuring that the demand on the grid can be managed.

The CPN provides two types of charging:

'Journey' charging, where the primary reason for being at the location is to charge the vehicle. This applies almost exclusively to Rapid DC charging, not only at an MSA or LFR, but many other locations as well.

'Grazing' charging, in which the driver is at the location primarily for another purpose. This means using chargepoints which suit the driver's existing routine and 'dwell times'; examples of locations include car parks for shopping, gyms and hotels. A typical chargepoint for these locations would be a 7 kW AC Fast charger.

3.1 Matching supply to demand

3.1.1 Journey charging

As has been shown, for Journey charging the CPN needs only to make provision for BEV owners.

To match supply to demand properly would require CPN operators to have access to OEMs' highly sensitive data on model introduction dates, battery capacity, Rapid connector type and expected annual production volume for the next five years. Whilst this is unlikely to happen, some less sensitive information could beneficially be supplied by OEMs under a non-disclosure agreement, preferably a year before the vehicle launch date. This might include type of charging connector, maximum DC charge rate and capacity of on-board charger. Until this happens, OEMs should not be surprised if the CPN operators cannot exactly match supply to demand.

At the moment there are three types of Rapid connector on the general CPN: CHAdeMO, Combined Charging System (CCS) and Type 2 AC. (Tesla use a fourth type, but this is specific to Tesla and used on their Supercharger network.)

The 50 kW CHAdeMO (DC charging) connector is of Japanese origin and is fitted to cars such as the Nissan LEAF and Mitsubishi Outlander. A separate connector for AC charging (Grazing, Home and Workplace charging) is required on these vehicles.

The 50 kW CCS (DC charging) connector is of European origin and is used by all European designed vehicles which have Rapid charging capability. The CCS connector incorporates a Type 2 AC connector, so only a single charging port is required on the vehicle for both DC (Journey) and AC charging (Grazing, Home and Workplace charging).

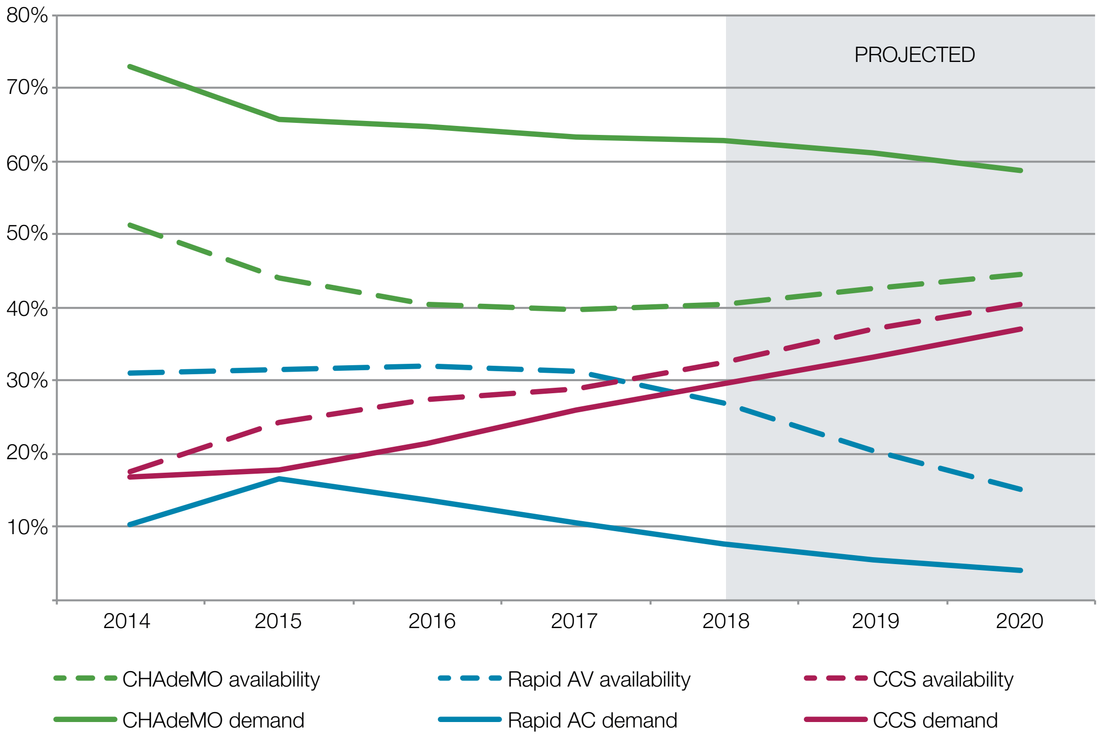
The 43 kW Type 2 (AC charging) connector can only be used at full capacity by one car – those Renault ZOEs equipped with an on-board 43 kW charger. Since the 43 kW on-board charger on the ZOE has changed from a standard fitment to a £750 option since mid-2015, the 43 kW AC requirement is now heavily over-provided (Figure 3.1). The ZOE is expected to have a CCS connector for Rapid charging as early as 2019 (Quartier, 2016).

It is therefore important to stop installing 43 kW Rapid AC connectors immediately. This will:

- increase the availability of the two (CHAdeMO & CCS) Rapid DC connectors (only one connector at a time can be used on most Rapid chargepoints);
- prevent blocking by the current early-version PHEVs which cannot Rapid charge, but can connect to the 43 kW AC connector; and
- reduce the average cost of Rapid chargepoint installation, as several have 'triple' connectors: CHAdeMO, CCS and 43 kW AC.

By examining the quantity, battery capacity and real-life ranges of BEVs currently available, and how these metrics are projected to change by the end of 2020, it is possible to obtain a clearer picture of the demands on the CPN for the next two years. Beyond that horizon, without robust dialogue between the OEMs and the chargepoint industry, there are too many variables (and therefore too many assumptions to be made) to realistically predict requirements.

Figure 3.1: UK CPN – matching supply to demand, Rapid chargepoints



Source: Availability: Zap-Map, Demand: DfT, Projections: HDA

In Figure 3.1 the solid lines show the demand–the number of BEVs with each type of Rapid charging connector as a percentage of the total number of BEVs.[4] The dashed lines show the availability–the number of Rapid chargepoint connectors of each type as a percentage of the total number of connectors (Zap-Map, 2018).

The demand for 43 kW AC can be seen to be falling, and by the end of 2020 will be generated only by a fixed number (of about 5,000) of 43 kW-capable Renault ZOEs. Currently installed 43 kW AC capacity more than satisfies this demand, and therefore no more capacity should be installed.

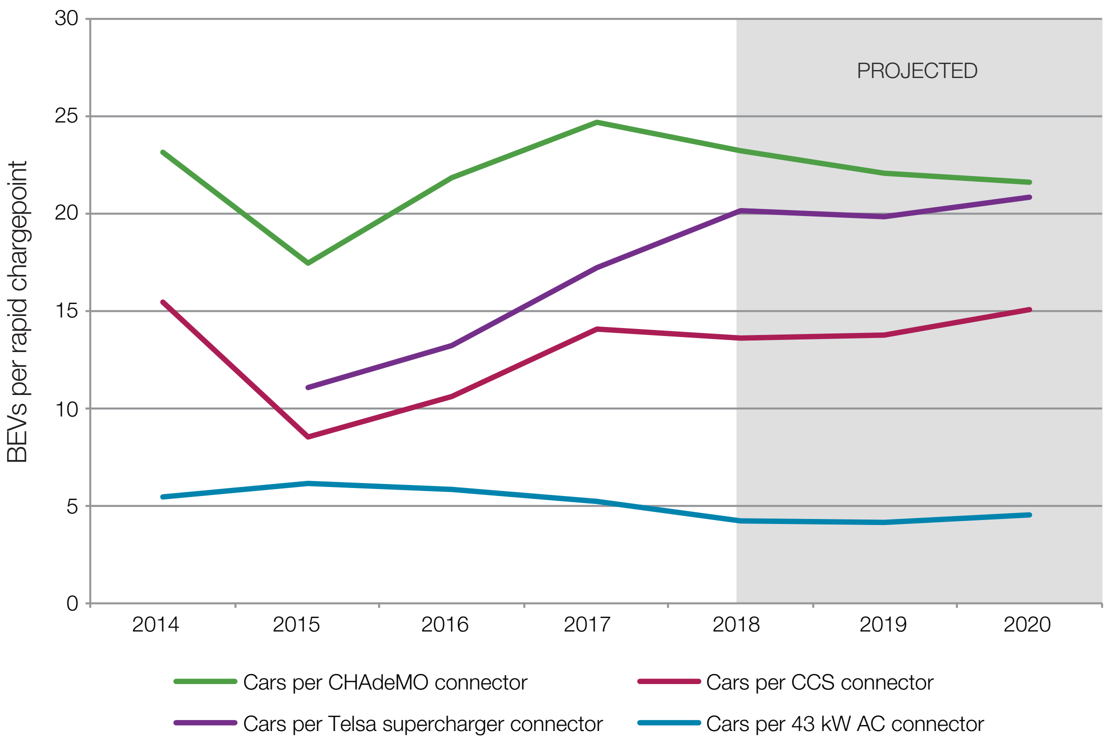
50 kW CCS availability can be seen to closely match CCS demand: it should be noted that CCS demand will continue to rise, as nearly all new BEVs being introduced into the UK over the next two years (and beyond) will be fitted with the CCS charge connector.

CHAdeMO availability as a percentage of demand is not as good as for CCS, as a result of the dominant position of the CHAdeMO-equipped Nissan LEAF in the UK and the resulting demand. However, as a wider range of CCS-equipped vehicles become available, the percentage demand for CHAdeMO will fall, and provided CHAdeMO chargepoint installations continue at the required rate, this gap will close.

4 HDA analysis of SMMT and DfT data

Figure 3.2 presents an alternative way of showing the status of the Journey CPN, which is by using the ratio of the total number of BEVs on the road to the total number of Rapid chargepoint connectors available. There is no 'acceptable' number for cars per connector, but experience of using the network for many years indicates that the current norm of 15 to 20 cars per connector does not generally result in queuing. In every CPN network there are a few sites which are exceptionally busy, and these are addressed by installing additional chargepoints.

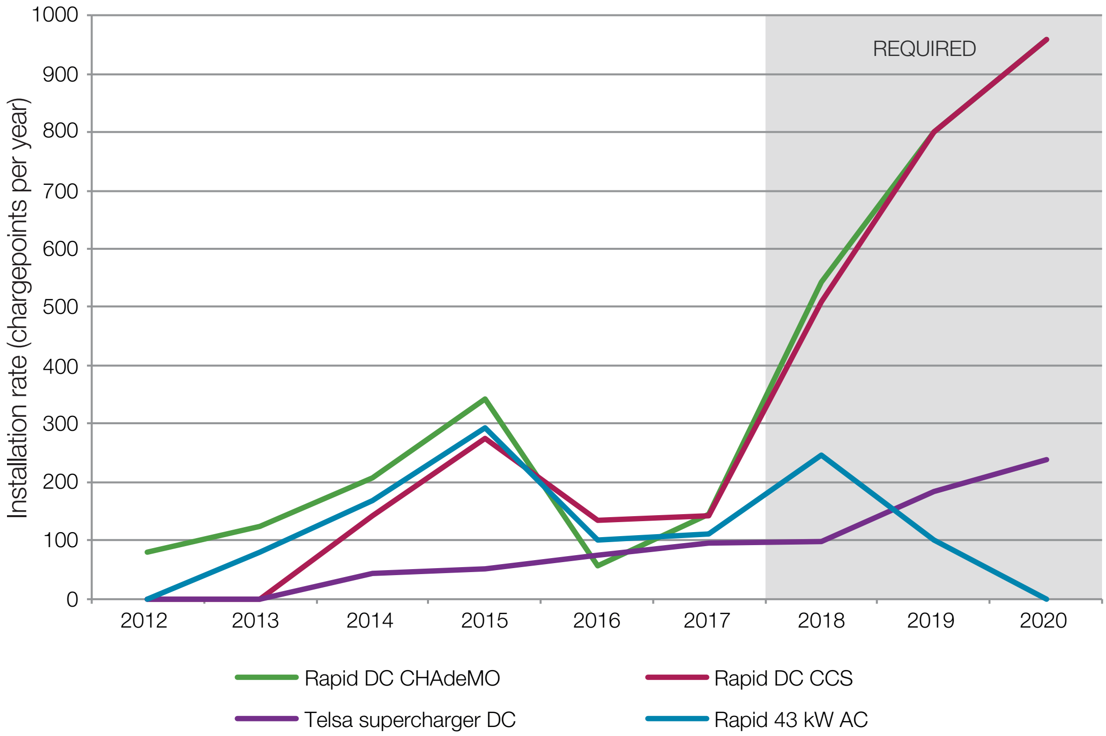
Figure 3.2: UK CPN – matching supply to demand, number of cars per Rapid connector



Source: Availability: Zap-Map Demand: DfT Projections: HDA

To achieve the projections in Figure 3.2, the CPN must install Rapid chargepoints at the rate shown in Figure 3.3.

Figure 3.3: UK CPN – Installation rate of UK public Rapid chargepoint connectors by type



Source: Availability: Zap-Map, Demand: DfT, Projections: HDA

The large increase in 2018 installation rate shown is conservative, as it is based on actual installations to the end of August 2018, when over 90% of the required installations had already taken place. Since in practice nearly all CPN DC Rapid chargepoints will be installed as 'double DC', which is a single chargepoint but with one CHAdeMO tethered connector and one CCS tethered connector, the installation rate of CHAdeMO and CCS connectors will be identical. The 2019 requirement is for 800 'double DC' chargepoints to be installed (compared with about 600 in 2018). In 2020, a further 1,000 such chargepoints are required. As already shown, the network needs to stop installing 43 kW AC chargepoints. This is shown as occurring by 2020, when existing stocks are exhausted. Tesla Superchargers have been added to this graph because Tesla charging demand might impinge on CPN availability from 2020.

Tesla have been installing their 135 kW Supercharger network since 2015, having designed their cars from the outset to accept a charge rate of 120 kW, and it has served the Tesla Model S and Model X well. However, Tesla has announced that the European Model 3 will be equipped with CCS as standard, and that the European Supercharger network "will be retrofitted with dual charge cables" (Tesla and CCS). It is possible that the expected high volumes of the Model 3 may result in Supercharger demand rising above 20 cars per connector (Figure 3.2), which would be double the demand in 2016. Tesla sells a CHAdeMO converter for the Model S and Model X, which owners use to access 50 kW chargepoints on the CPN. It is possible that more Tesla owners may be charging on the CPN from 2019/20, when the roll-out of 150 kW chargepoints is expected to start. These will be very attractive to the CCS equipped Model 3 and Model S and X owners with a CHAdeMO converter.

There is considerable debate about the effect of the increasing battery capacity of BEVs on CPN Rapid chargepoint usage and installation intervals. The argument is that since 80% of BEV charging is carried out at home (Zap-Map, 2016), the majority of BEVs will leave home with 100% SOC. (Several more recent surveys imply that charging locations are used in a mutually exclusive way – so, if an EV is charged at home, it is not charged on the CPN as well. The 2016 Zap-Map survey referenced here shows a more complete picture.)

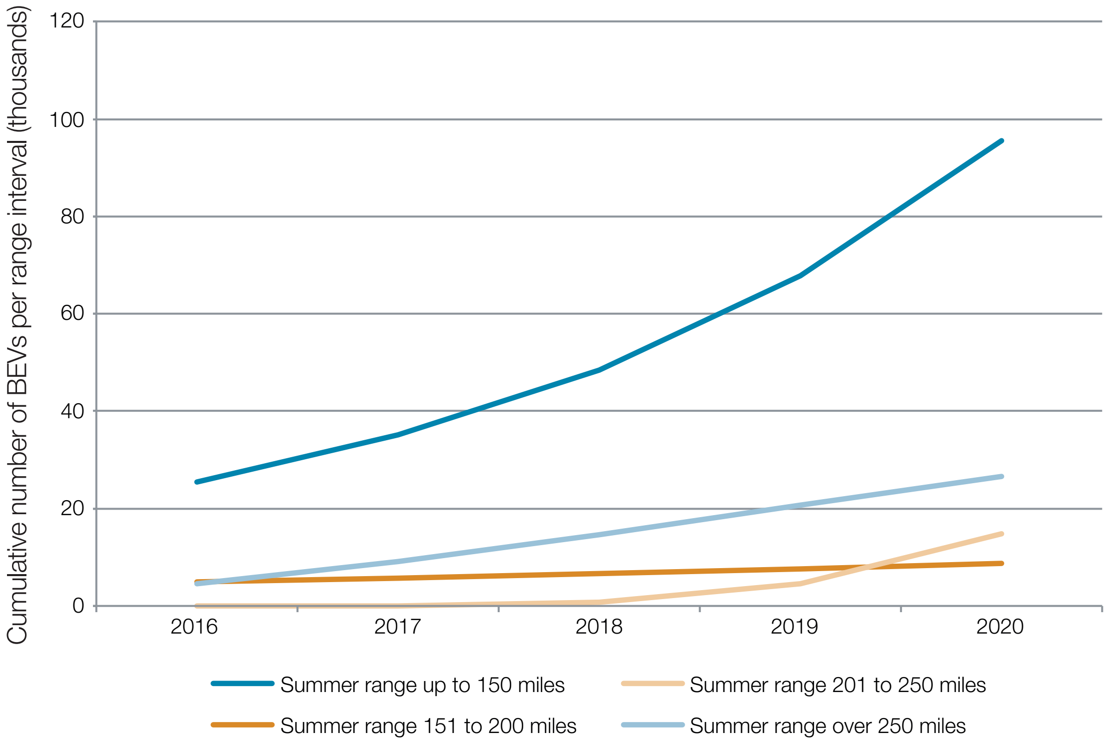
As battery capacity increases, this means that the return journey capability (where the destination is less than half the real-world range away) increases as well, reducing the likelihood of Journey charging. In order to know if this is a valid prediction, it is necessary to understand the real-life ranges of the BEVs available in the UK. Since BEVs have significantly shorter range in the cooler months than in the warmer months, this needs to be taken into account as well.

The summer and winter range profiles of existing BEVs and those known to be coming to market up to the end of 2020 are summarised in Figures 3.4 and 3.5 for summer and winter respectively. It should be noted that these ranges are not the total range of the vehicle, but rather 80% of the total real-world range of the vehicle, on the assumption that the vehicle starts with a full charge (100% SOC) and will be charged once the SOC has reduced to 20%.

It will be seen that the greatest Journey charge demand on the CPN is from vehicles which have a real-life range of up to 150 miles in summer and of between 100 and 150 miles in winter; this has been so since before 2016, and will continue until at least 2020. This suggests that the CPN should have a Journey chargepoint installation interval of approximately one every 50 to 70 miles.

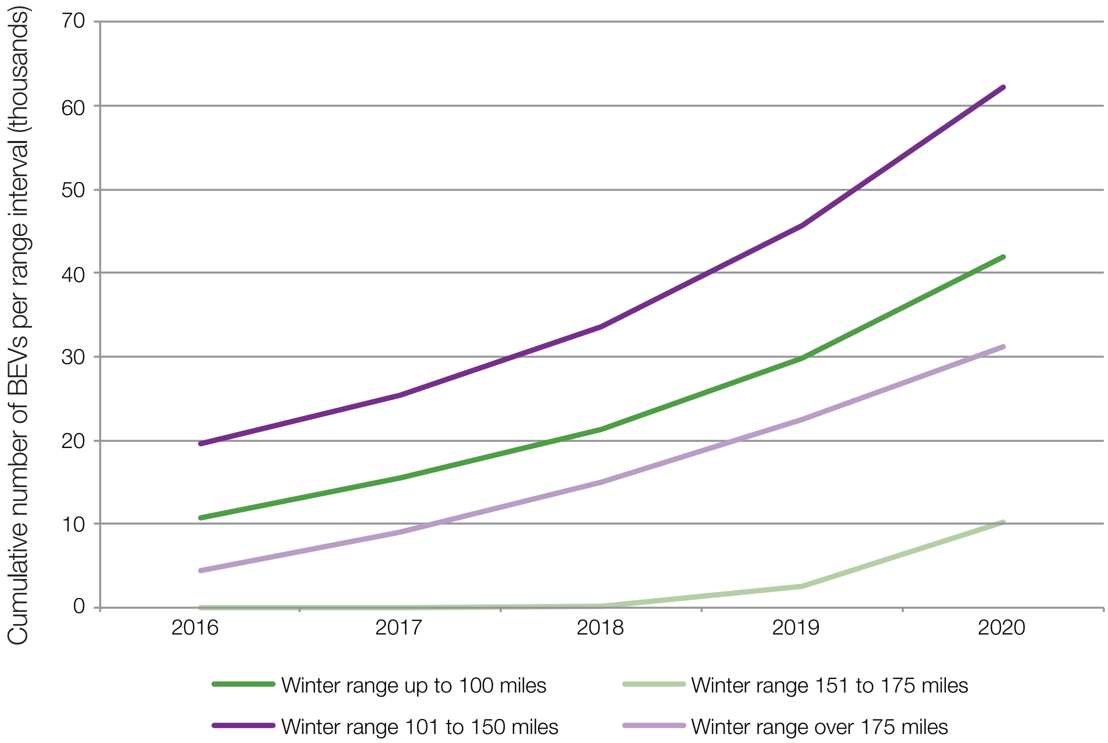
Interestingly, the proposed 350 kW Ionity CPN intends 'one Ionity charging station every 100 to 120 kilometres' (IONITY, 2018). It is not clear why a 350 kW CPN, which is intended to add 60 miles' range in about four minutes, would require installation of chargepoints at intervals of only four minutes' charge time. To put this in perspective, the equivalent for a 50 kW chargepoint would be installation intervals of about ten miles. It may indicate that Ionity has appreciated that drivers' perception of refuelling ability is more important than actual range, although its response is rather extreme. Thus, whilst a logical analysis of summer and winter driving range indicates an installation interval of 50 to 70 miles, the perception of BEV drivers may require intervals of 40 to 50 miles.

Figure 3.4: Real-life range between chargepoints (recharge at 20% SOC) for BEV by range intervals – summer



Source: DfT and EV Database.uk (2018)

Figure 3.5: Real-life range between chargepoints (recharge at 20% SOC) for BEV by range intervals – winter



Source: DfT and EV Database.uk (2018)

Since in the UK these BEV statistics are dominated by the Nissan LEAF, the availability, date and price of the expected e-Plus LEAF is relevant. With a battery capacity approximately 50% greater than the current new LEAF's 40 kWh, and an expected launch date in 2019/20, it will have a pronounced effect on this data, and therefore an allowance for this has been made in these projections. However, since the volumes in Figures 3.4 and 3.5 are cumulative, it will take some years before the majority of vehicles are capable of longer ranges between chargepoints.

Government data (DfT, 2018b, Table NTS0308) indicates that only 0.8% of trips by private car drivers are over 100 miles in length, which means that nearly all BEVs currently on sale in the UK can accomplish 99.2% of all trips without using the CPN. But irrespective of these statistics, drivers of BEVs want to know that they can refuel their vehicle at a wide choice of locations when they are on a journey. The concept of driving from one carefully planned charging location to another, which is the current requirement, is not the future of electric motoring. But oversupply creates its own problems. One possible result of this 'just in case' demand from BEV drivers for Rapid chargepoints on the CPN is that the network operators might find that there are insufficient charges per chargepoint to justify their investment.

Whilst there are some areas of poor coverage in the Journey CPN which must be addressed, much of the expansion in Rapid charging will consist of installing additional chargepoints at existing locations. As with a petrol station, this will allow both network and site operators to provide better facilities for BEV drivers as patronage increases. These facilities are similar to, but at the same time significantly different from, those required at a petrol station. Therefore if chargepoints are installed at small or large fuel retailers, facilities (such as described in section 3.2) must also be installed to take account of the 20- to 40-minute dwell times of BEV drivers, which contrasts with those of approximately five minutes for ICE drivers.

Another use of Rapid charging is in cities, where there is a higher likelihood of BEV owners not being able to charge at home (Dermott, 2017). In this case BEV owners would charge on a Rapid charger for about 20 minutes (depending on SOC) instead of charging overnight at home: this charging is likely to take place during the morning and evening commute during weekdays. Workplace charging might also replace Home charging for this group of BEV owners, and is a superior solution.

Rapid charging is also important for electric taxis in large cities: whilst many provincial electric taxi companies have their own Rapid chargers, in London there has been an increase not only of CPN Rapid chargepoints, but also 'taxi only' Rapid chargepoints (TfL, undated), coinciding with the introduction of the LEVC[5] electric taxi.

3.1.2 Grazing charging

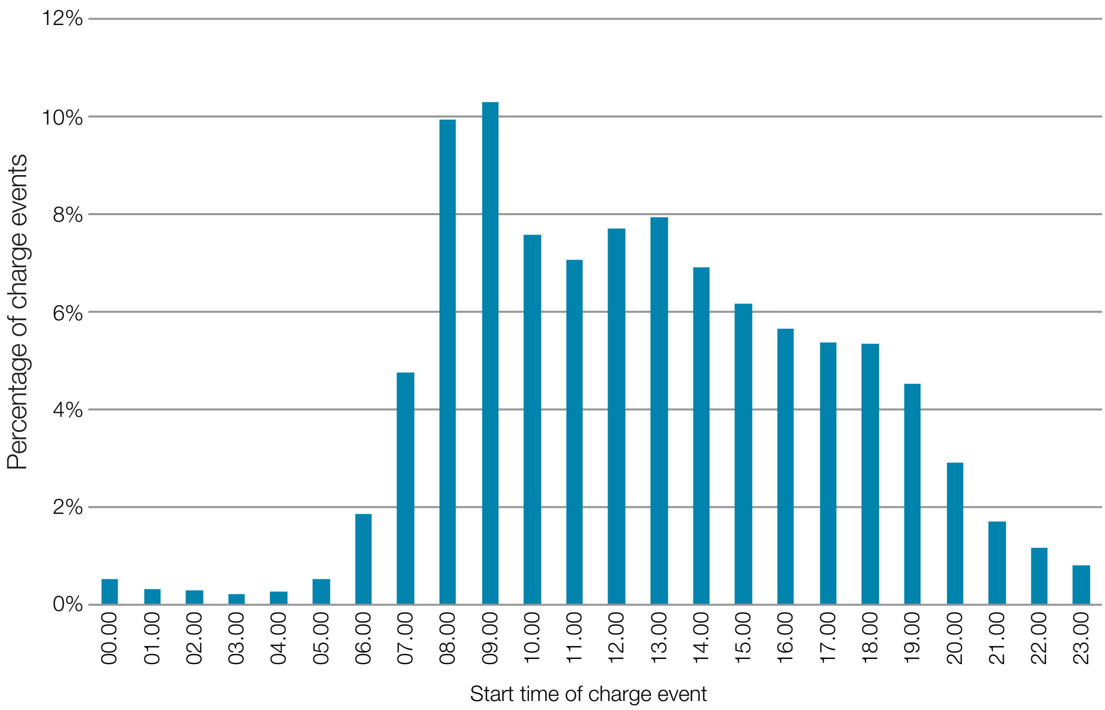
In addition to the Rapid DC Journey charging, the greatest demand for EV charging now and into the future will be Grazing charging. Grazing charging is defined as charging whilst being at a location primarily for a purpose other than charging. It means using chargepoints which suit the driver's existing routine and dwell times – for example using car parks for shopping, going to a gym, and staying at a hotel.

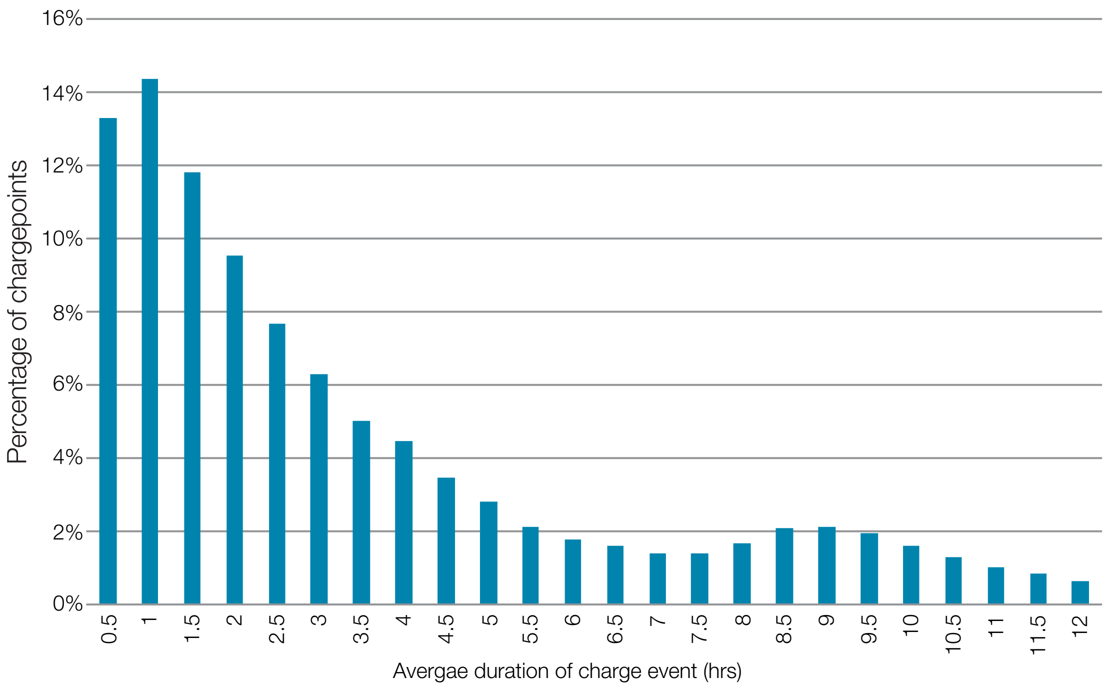
5 LEVC: London Electric Vehicle Company, a subsidiary of the Chinese carmaker Geely

A typical chargepoint for these locations would be a 7 kW AC Fast charger. There is more demand for Grazing charging than any other type of CPN charging (see Table 3.1). This type of charging is almost exclusively Fast AC charging, defined as between 7 kW and 22 kW.

The usage profiles (start time and average duration) for Grazing charging are shown in Figure 3.6.

Figure 3.6: Grazing AC charging usage profiles on the UK CPN





Note: UK CPN Grazing usage, 31 March 2017 to 31 March 2018
Source : Zap-Map data

The peaks in start time between 8 a.m. and 10 a.m. are not unexpected, as they would coincide with arrival at work (and parking in a public car park with EV charging) or arrival at a Grazing location for shopping, using a gym, and the like. The small but noticeable increase in charging events of between eight and ten hours is interesting. These are most likely to be due to EV owners without Home charging using a local CPN chargepoint for overnight charging.

Because Grazing charging is almost exclusively Fast AC charging, it is essential to revisit the most important issue involving this kind of charging. **One of the most common misunderstandings at all levels of the debate is the false belief that any EV on the road can accept any charge rate available from a roadside AC chargepoint.** This is absolutely not the case, and is the source of great deal of misinformation. Figure 2.1 clearly shows that the chargepoint by the roadside and the charger in the car are in series, and therefore the actual charge rate will be the lower charge rate of the two chargers. ***This point is probably the single most important piece of information in this report and cannot be emphasised strongly enough.***

For example, it is still being suggested that 22 kW AC chargepoints would be a useful addition to the CPN to bridge the perceived gap between 7 kW and 50 kW charge rates (Anderson et al., 2018: 17, Figure 2). At the end of Q1 2018, less than 8% of the UK EV fleet could charge on an AC chargepoint at 22 kW.[6] Indeed, it is unlikely that any new vehicles after 2020 will be fitted with such chargers (UK EVSE, 2018). This means that 22 kW chargepoints are already not relevant to 92% of the EV fleet, and these vehicles will charge just as quickly on a 7 kW chargepoint.

To put this in perspective, the Nissan LEAF, the biggest selling BEV in the UK, has a 3.6 kW on-board charger as standard, with a 6.6 kW charger as an optional extra since 2014 (Nissan Retail, 2018) The Mitsubishi Outlander, the biggest selling PHEV in the UK, also has a 3.6 kW on-board charger as standard. Between them, these two vehicles accounted for about 38% of all EVs currently on the road at the end of 2017[8] Assuming that 50% of LEAFs have the 6.6 kW charger option, then when Grazing on an AC chargepoint, *approximately one third of the current EV fleet can charge only at 3.6 kW whether they are plugged in to a 3.6 kW, 7 kW, 22 kW or 43 kW AC chargepoint*.

On-board chargers are likely to trend towards 7 kW or 11 kW, which correspond to the realistically available electrical capacities at domestic and office locations in the UK and Europe respectively. Therefore in the UK, the existing and extensive 7 kW network provides an excellent basis for expansion to meet the Grazing requirement – Table 3.1 indicates the demand and indicative dwell times at Grazing locations.

One essential part of Grazing charging which is often overlooked is that there is no requirement to charge the battery to 100% SOC. Grazing is exactly that: taking on board an amount of energy that is defined by the dwell time of the main purpose of the visit.

Thus a two-hour shopping expedition would result in an approximate 14 kWh energy transfer to a vehicle with a 7 kW on-board charger at a 7 kW chargepoint. This would add a

6 HDA calculations based on DfT registration data and manufacturer on-board charger data

useful 68 miles to a Renault ZOE in summer and 35 miles to a Jaguar I-PACE in winter. Both vehicles are likely to return home with a higher SOC than when they left (indicative mileages based on real-life miles/kWh from EV Database (2018)).

Table 3.1: Public charging usage and dwell times by location

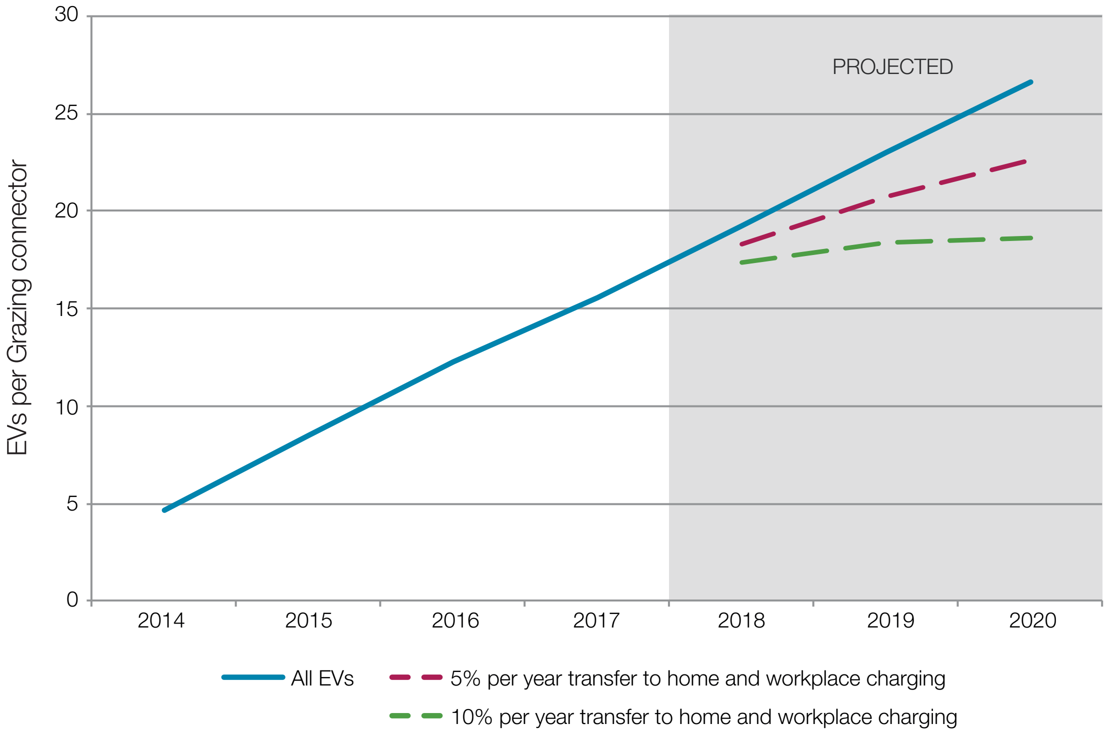
Location	Type	Usage		Typical energy transfer		
		AC (%)	Overall public (%)	Typical output (kW)	Typical dwell time (h)	Max energy transfer (kWh)
Home[a] (for reference only)	AC			7	10	70
Work[b] (for reference only)	AC			7	8	56
Public chargepoints - DC						
Motorway service area	DC		27%	50	0.5	25
Trunk road service station	DC			50	0.5	25
Other location	DC			50	0.5	25
Public chargepoints - AC						
Public car park	AC	20%	73%	7	1	7
Retail car park	AC	19%		7	2	14
Local authority car park	AC	17%		7	1	7
Dealership forecourt	AC	11%		7	1	7
On-street	AC	10%		7	2	14
Park-and-ride	AC	7%		7	3	21
EV charging hub	AC	6%		7	2	14
Hotel / other accommodation	AC	6%		7	10	70
Leisure centre	AC	2%		7	1	7
Other	AC	3%		7	1	7

Source: ZapMap (2016) and author's work
Note: (a) 81% of EV users have access to a home charger.
(b) Only 25% of EV users can charge at work.

AC chargepoint usage shown will reflect available chargepoint locations as much as desired locations to charge

It is these Grazing locations, rather than the higher-profile Rapid chargepoints at Journey locations, which will bear the brunt of charging demand for both BEVs and PHEVs until battery technology changes significantly. Figure 3.7 shows the relationship between supply and demand for Grazing locations. This demand can be almost exclusively satisfied by 7 kW AC chargepoints. (The lack of relevance of 22 kW AC chargepoints has already been explained.)

Figure 3.7: UK CPN – matching supply to demand, Cars per Grazing AC connector



Source: Availability: Zap-Map, Demand: DfT, Projections: HDA

It is important to realise that the demand for Fast AC Grazing charging is more likely than Journey charging to be affected by changes in Home and Workplace charging. The increasing availability of Workplace charging might result in Home and Workplace charging meeting all the charging needs of EV drivers, at least during the working week. The red and green lines on the graph show the potential effect on CPN Grazing demand of a transfer away from Grazing charging to Home and Workplace charging of 5% per year and 10% per year respectively.

Such a change in demand for Grazing CPN chargepoints may not affect all locations equally: hotel locations (which in effect replace Home charging when staying away) would logically be less affected than gym or shopping locations.

Therefore the Grazing CPN requirement is for a high quantity of 7 kW chargepoints, made in volume to keep the unit price down. There is no reason in this case for not using the best quality management systems (QMS) to ensure that low price and high quality go together, as the motor industry has been demonstrating for decades.

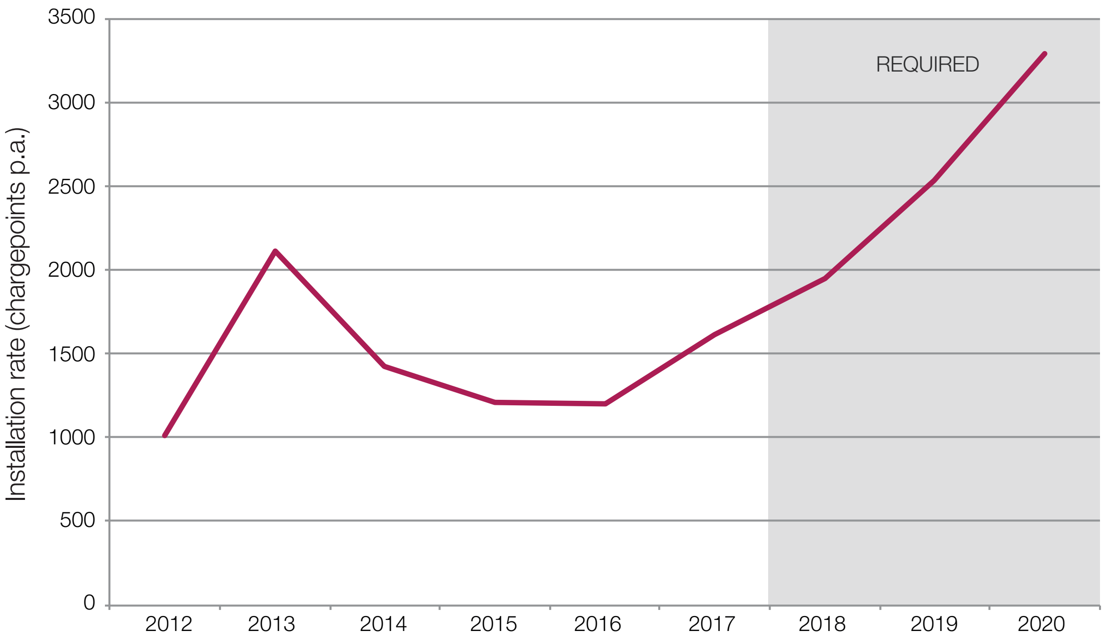
The biggest opportunity for CPN operators would appear to be hotels. The author found on a recent holiday that it was impossible in most areas to find a hotel which offered overnight charging. This meant unnecessary daytime stops at a Journey chargepoint, thereby wasting holiday time and incurring an unnecessary use of a Journey chargepoint. The only network offering a significant number of 7 kW Grazing chargepoints at hotel locations is Tesla.

Whilst at the end of 2017 EVs represented just 0.4% of the vehicles on UK roads, the rates of growth shown in Figure 1.1 mean that this figure will rise to about 1.2% by 2020, 6% by 2025 and 20% by 2030.

By 2030 therefore, every hotel in the country can expect approximately one fifth of their clients that arrive by car to require the ability to charge. To meet this demand, these hotels need to provide overnight charging facilities, which would mean allocating one fifth of their parking spaces to EVs by the end of 2030, each with a 7 kW chargepoint. They may also wish to consider allocating 1.2% of their parking spaces for this purpose by 2020, and 6% by 2025.

With a relatively low-cost multiple 7 kW installation, and up to 70 kWh (with perhaps an average of 20 kWh) energy transfer from each chargepoint per night, this would appear to be a good investment for the network operators. This charging would almost always take place at night, making it ideal for demand-side management V2G (vehicle-to-grid) or V2X (vehicle-to-everything) (see section 3.5.3).

Figure 3.8: UK Chargepoint network – installation rate of UK public Fast chargepoint connectors



Source: Zap-Map, Projections: HDA

The Fast chargepoint installation rate needed to support the demand shown in Figure 3.7 is shown in Figure 3.8.

Whilst the proposed installation rate in 2019 and 2020 appears to be inadequate to meet demand, this demand is highly dependent on the installation rate and usage of Home charging, and, more particularly, Workplace charging (see Figure 3.7). Both are currently supported by OLEV grants. Workplace charging is a much newer concept than Home charging, and a successful take-up rate is likely to reduce Grazing charging. CPN operators will need more information about user behaviour before investing in even higher installation rates of Grazing chargepoints.

In addition to Grazing charging, it is important to mention the two forms of charging that dominate EV charging, but which are not available to the public on the CPN. These are Home charging and Workplace charging.

3.1.3 Home charging

The objective of Home charging is to allow EV owners to recharge their vehicles overnight at the most practical time and the lowest possible cost. The average UK day and night rates for electricity are 15.5p/kWh and 8.6p/kWh respectively. Adding in the standing charge element increases these to a total electricity cost of 17.6p/kWh and 10.8p/kWh respectively (BEIS, 2018a, Table 2.2.4). Assuming that a 7 kW home charger is fitted, in a 10-hour overnight charge (8 p.m. to 6 a.m.), a car with a 3.6 kW on-board charger will take on approximately 36 kWh at a cost of £3.89, and a car with a 7 kW on-board charger will take approximately 70 kWh at a cost of £7.59. A 12-hour charge (7 p.m. to 7 a.m.) would increase the energy transfer to approximately 43 kWh and 84 kWh respectively. Assuming a typical 20% SOC at the start of charging, it will be seen that a 7 kW home charger is capable of fully charging any battery capacity up to 100 kWh overnight, provided the car has an on-board charger of at least 7 kW.

The important move to smart Home charging, which the AEVA will introduce, must be dealt with in a more effective way than the equivalent roll-out of smart electricity meters. The programme to fit smart meters to every home in the UK, an equally important step on the path to twenty-first century energy management, is behind schedule and has lost the confidence of the public. Similar setbacks in the roll-out of smart home chargers could be disastrous to an embryo industry trying to encourage the sale of EVs. To potential EV purchasers, the concept of a 'fuel station' at home will be new, and the installation and grant process must be straightforward and effective.

The EV OEMs must accept that they have a significant part to play in how their vehicles are charged in use. This has the following implications:

- They must stop providing charge cables with a domestic 13A plug and, within the price of the vehicle, provide the Type 2-to-Type 2 charge cables that can be used on all AC public chargepoints as well as on home and workplace chargers. (These charge cables are typically sold by OEMs as a £250+ optional extra.)
- In conjunction with this, OEMs should either provide and install an approved home charger within the price of the car (as Renault do with the ZOE), or facilitate the installation of an additional-cost home charger as part of the sale process (as Nissan, BMW and others do). No customer with the ability to charge at home

should ever collect a new EV and take it back to a charger-free home (all such home chargers are fitted with the same connector as public AC chargepoints: there is complete standardisation on this issue).

- They must ensure that *all* EVs that they manufacture have an on-board AC charger of at least 7 kW.

These changes would greatly enhance the buying experience of new EV owners, and remove their initial concerns about how the car will be charged, as well as ensuring that 7 kW roadside chargepoints can be used to capacity.

The OLEV Electric Vehicle Homecharge Scheme (EVHS) grant currently supports the installation of home chargepoints, which satisfy up to 80% of UK charging demand. However, the Government commits to this grant only “until March 2019, or until 30,000 installations in 2018/19 have been supported, whichever is sooner” (DfT, 2018a: 84), which is disappointing. This grant should be continued until it can be replaced by an equivalent grant which ensures that all future home chargers are smart technology enabled and capable of reverse charging to support V2X capability, as empowered by the AEVA.

For those EV owners, mainly in large cities, without access to off-street charging, there have been developments in the last year. The government now offers The On-street Residential Chargepoint Scheme, which is aimed at increasing the availability of plug-in vehicle charging infrastructure for those who do not have access to off-street parking. There are also various on-street charging schemes being trialled, of which lamp post charging currently looks the most promising as it requires virtually no change to the existing infrastructure.

3.1.4 Workplace charging

Workplace charging falls into two categories: employee charging and visitor charging.

For employee charging, with a typical dwell time of seven to nine hours and assuming an average commuting drive to work of 9.1 miles (DfT, 2018c, Table NTS0403), 7 kW chargepoints would be ideal. Whilst accepting that some employees may be able to charge at only 3.6 kW owing to the on-board chargers fitted to their cars, many will still be able to charge at 7 kW, and the future trend is likely to be towards 7 kW on-board chargers.

The main issues for installation of chargepoints at a workplace are (a) how many chargepoints to provide and (b) the availability (or lack of availability) of an adequate electrical supply. Whilst at the end of 2017 EVs represented just 0.4% of the vehicles on UK roads, the rates of growth shown in Figure 1.1 mean that this figure will rise to about 1.2% by 2020, 6% by 2025 and 20% by 2030. Therefore an initial installation might make provision to install 7 kW chargepoints at, say, 5% of the company’s parking spaces, to be reviewed in three or four years. This represents 12 or 13 chargepoints at a 250-person site and 125 at a 2,500-person site. Some government departments may therefore need to install over a thousand chargepoints on this basis.

With about 50% of all UK employment taking place in companies with a workforce of over 250 people (ONS, 2017, Table AH172), this represents a large investment in charging capacity. Without demand-side management, this daytime charging will add to the load on the national grid. The required electrical supply is 7 kW for each chargepoint, so 120 chargepoints require an electrical supply capable of providing 840 kW. In any case, and particularly to allow for future expansion, this may require an additional grid connection, energy storage, or both.

Visitor charging represents a quite different kind of demand. In this case, visitors arriving in BEVs are looking for a Rapid charge for the return journey, as they might well be on the site for no more than an hour. An average business journey is the UK is about 20 miles (DfT, 2018c, Table NTS0403), although some are obviously much longer. The most practical solution might be a 50 kW Rapid DC chargepoint in the visitor parking spaces which down-rates to 2 × 25 kW if two vehicles are charging.

Workplace charging installations which comply with the scheme requirements have been supported since November 2016 by grants under the OLEV Workplace Charging Scheme (WCS). The same principle that was stated for Home charging applies: the grants that OLEV provide should be continued until they can be replaced by an equivalent grant which ensures that all future workplace chargers are smart technology enabled and capable of reverse charging to support V2X capability, as empowered by the AEVA.

3.2 Ensuring that the CPN is attractive to use

The author identified last year (Dermott, 2017) that the UK CPN is not attractive to use. Apart from poor reliability, resulting in reduced availability (see section 3.3), the current CPN consists of:

- chargepoints that are completely unprotected from the weather (nearly all);
- chargepoints that are poorly lit (nearly all);
- Rapid chargepoints incorporating poor cable management, resulting in dirty charge cables (and therefore dirty clothes) and connectors lying on the ground or in puddles (further reducing availability) (many).

There are further issues:

- All non-Rapid chargepoints require a loose charging cable to be carried in the car. Poorly installed and badly located chargers result in dirty cables needing to be put back into the car.
- It is quite common for EV charging bays to be used as parking by ICE vehicles, resulting in EV owners being unable to charge because they cannot access the chargepoint.
- Some locations, even in town car parks, are quite remote, which could give rise to safety problems, particularly for the lone driver seeking to use them at night. Unlike most petrol filling stations, there is no attendant.

If this is the refuelling network intended to encourage new car buyers to choose an EV rather than another petrol or diesel car, then the user experience must be improved. These are the real consumer experience issues of using the current CPN. The items listed under the heading 'The consumer experience of EV charging infrastructure' on pages 100–101 of the RtZ seem out of date, and in general no longer exist. They are therefore largely irrelevant to making the CPN more attractive to use. There is no mention of the real issues of weather protection, lighting, and facilities for EV drivers whilst charging.

Unfortunately there have been negligible improvements to the user experience in the last year. All the major networks continue to install standalone chargepoints with no weather protection, no lighting and – in many cases – limited or no facilities for BEV drivers whilst charging. It remains a process designed to provide quantity not quality.

EV charging is as different from fuelling an ICE vehicle as fuelling an ICE vehicle is from fuelling the horse that preceded it. *Trying to make the refuelling process identical to that of an ICE vehicle by ever-shorter charging times is only a small part of the story.*

As has been shown, the vast majority of energy transfer to EVs takes place in the home, at work or in locations where EV drivers already go. In all these situations, the length of the charge time is irrelevant because the dwell times are long or very long, and are not set by the charging requirement but by the purpose of the visit. However, those chargepoints in this category that are part of the CPN – Grazing chargepoints – should as a minimum provision have weather protection and lighting.

The only situation where charge time is relevant is where the BEV owner is at the site specifically for the purpose of charging – Rapid DC chargepoints at Journey locations. These chargepoints need to make provision for providing an acceptable charging experience for their customers, and this will require, as a minimum:

- adequate weather protection at the chargepoint;
- adequate lighting at the chargepoint;
- good cable management;
- somewhere to sit in the warm and dry other than the vehicle;
- toilet facilities;
- food and drink facilities;
- a good-quality Wi-Fi connection; and
- well-marked bays to reduce ICE blocking.

Many current chargepoint installations can be likened to the petrol pumps of 60 years ago, which stood in the open with no facilities available. The main difference was that these petrol pumps were manned, whereas it is now the EV driver getting cold and wet to refuel their own vehicle. Why would anyone familiar with a modern petrol filling station want to go back to a 60-year-old concept if they change to an EV?

Figure 3.9: A typical CPN chargepoint

Source: Author

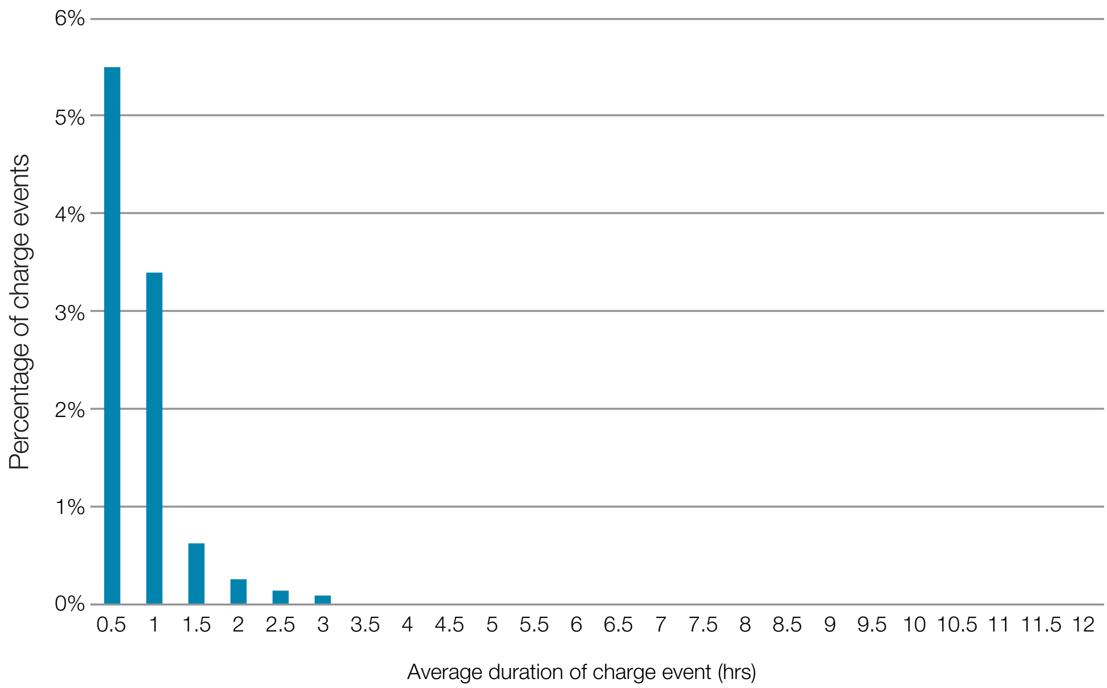
Figure 3.9 shows a typical CPN chargepoint. On this wet day, the two EV owners had to put up with:

- no weather protection at the chargepoint;
- no lighting at the chargepoint;
- charge cables lying on the floor, chargepoint surrounded by muddy earth;
- no Wi-Fi connection; and
- charging bays completely unmarked and regularly blocked by ICE.

This counts as a chargepoint in the government statistics, and is one of thousands like it. Compared with the electric vehicle charging hub (EVCH) in Figure 3.11, it is not in the same league. The concept of the EVCH, where multiple chargepoints are gathered under one roof, is to provide all the facilities that a BEV driver requires for a Journey charge. It is in effect the BEV equivalent of a modern petrol filling station, and the standard that all modern drivers of ICE vehicles have become used to.

Figure 3.10 shows that the majority of current Rapid chargepoint dwell times are no more than 30 minutes. It will be seen that charging an overstay charge after one hour to minimise blocking is entirely reasonable.

Figure 3.10: Average duration of Journey charge events on UK CPN, 31 March 2017 to 31 March 2018



Source: Zap-Map data

To investigate whether these dwell times are likely to change significantly, it is necessary to consider, as a minimum, charge rate and battery capacity.

3.2.1 High charge rate charging (100 kW or more)

At the moment in the UK there are only four cars capable of charging at 100 kW: the Tesla Model S and Model X, the Hyundai IONIQ EV and the Jaguar I-PACE. Of those, only the Hyundai and Jaguar would normally use the CPN to charge at this charge rate as Tesla drivers would normally use the Tesla Supercharger network. All have high-capacity batteries. By 2020, perhaps another ten vehicle models will be able to charge at this rate, but it is likely to be the early 2020s before such vehicles are available in sufficient volume to make 100/150 kW chargepoints economically viable.

A 50 kW chargepoint charging a 30 kWh battery is likely to have a similar charge time to a 150 kW chargepoint charging a 90 kWh battery with 150 kW charging capability (this is indicative only: DC charge rates depend on many variables including SOC, battery temperature and battery cooling efficiency). For Journey charging, even with 150 kW chargepoints *and vehicles capable of accepting this charge rate*, dwell times will remain in the 20- to 40-minute bracket.

From 2019 onwards, the CPN will need to install its first 150 kW chargepoints. Whilst the demand will be small in 2019/20, valuable experience will be gained. It will also be important for the networks to establish systems to prevent those BEVs which can charge at only 50 kW (currently about 80% of BEVs on the road) from blocking (by using) a CHAdeMO or CCS connector capable of delivering 150 kW, whilst a 100/150 kW-capable BEV waits.

A good case can be made for a 150 kW chargepoint fitted with two CHAdeMO and two CCS tethered cables which can deliver either a 150 kW charge to any single CHAdeMO or CCS vehicle, or two simultaneous 75 kW charges to any combination of two CHAdeMO and CCS vehicles. Such a chargepoint would maximise the available electrical supply and minimise the site space required, whilst *doubling the number of available* ***usable*** *connectors per chargepoint*. This principle has been used very effectively by Tesla Superchargers for many years.

There are even higher charge rates – 350 kW and beyond – on the horizon. Even at 350 kW, a 100 kWh battery with excellent temperature control is likely to take at least ten minutes to charge from 20% to 80% SOC, assuming a linear charge rate – and at present, no battery can deliver this at high charge rates. Above 80% SOC the charge rate in any case reduces, owing to battery chemistry and battery temperature limitations. One of the fundamental changes needed in order to achieve this 350 kW charge rate is to have batteries and chargepoints operating at a minimum of 800V rather than today's 400V (Reber, 2016). Such 800V architecture might be cost-effective only for premium cars with battery capacities of around 100 kWh, and consequently lower production volumes. It is expected that vehicles and chargepoints with this architecture will begin to be seen in 2019/20.

Therefore the future CPN may well include a range of Journey charging options, which may well incorporate the existing 50 kW chargepoints to charge the majority of EVs with battery capacities in the 40 kWh to 60 kWh range. The cost of charging at these chargepoints is likely to remain significantly less than at higher-capacity chargepoints because of the lower installation costs. Dwell times for these lower-capacity chargepoints would be as today (20 to 40 minutes), so the facilities required remain the same.

Even 150 kW units (which are at the limit of 400V capacity and will need liquid-cooled connectors) (ABB, 2018; Reber, 2016) are about twice the price of a 50 kW unit installed (Anderson et al., 2018), and might reasonably demand a price premium for charging. *It must be remembered that these chargepoints will only reduce charging times on those BEVs that can accept charge rates in excess of 50 kW.*

Dwell times for premium vehicles with large battery capacities and the ability to accept a 350 kW charge rate might shift from 20–40 minutes to 10–20 minutes over the next five to eight years, but not to 3–4 minutes. However, the bulk of BEVs with smaller-capacity batteries will continue to experience 20- to 40-minute dwell times unless they can accept 100 kW or 150 kW charge rates and the drivers are prepared to pay a premium to do so.

Therefore the introduction of EVCHs remains essential for mass acceptance of the CPN. An EVCH would offer a range of charging equipment (including, in time, a range of Rapid chargepoints rated at between 50 kW and 350 kW) to match the location. All units would be under cover and well lit: an attendant would be in place to assist with charger selection, advise on services available, and provide security. The key feature of any EVCH would be to offer services to match the charge dwell time. This would be achieved on-site with a café, perhaps some franchised shops, an ATM and free Wi-Fi. Signal boosters would ensure good telephone communications on all networks for customers. For business customers, who would want to choose EVCHs as meeting places, there would be meeting rooms for hire. (Dermott, 2017: 23).

Clearly, the investment needed for an EVCH is greater than for the installation of an equivalent number of individual chargepoints in the open: whilst government support and customer demand remain unclear, and despite the potential for additional income from the services provided, it appears not to be a step that the privately funded UK CPNs are prepared to make.

In July 2018, Dundee Council, with support from OLEV and the Scottish Government (AirQualityNews.com, 2018) opened an early-concept EVCH in Dundee. This EV-only facility has weather protection, lighting and good cable management. It also includes solar panels and an energy storage system, which uses second-life batteries from Renault. (The batteries will be used to improve the business case and manage the peak load while maximising the solar energy generated on-site to charge EVs) (Pratt, 2018). However it does not provide on-site facilities for BEV owners whilst they charge.

Using this installation as a pioneering example, OLEV should support the introduction of a small number of EVCHs (fewer than ten) in the rest of the UK. These should be distributed around the country, each with a slightly different execution/interpretation of the EVCH concept, and each operated by a different CPN operator. This would enable potential customers, car dealers and existing BEV drivers to understand what the future of EV charging looks like, and network operators to evaluate the feedback and refine the concept. The Government position on EVCHs is not clear, mentioning the Go Ultra Low Cities scheme in this context, but not being forthcoming elsewhere (DfT, 2018a: 98).

Figure 3.11: Dundee EVCH during 'chat & charge' meeting, August Bank Holiday 2018

Photo: supplied and with the permission of John P van Dieken

3.3 Ensuring that CPN chargepoints are reliable

Dermott (2017: 12) stated: "In reply to a query for this report, Zap-Map stated 'At the device level (rather than connector or location level), the percentage out of service is 13% – as of June 2017.'" As the number of devices shown at the time was 6,913, this represented about 900 chargepoints out of service. In 2018, Zap-Map, in a similar request for this report, supplied data showing that the average percentage out of service was 8.3% for the period from May to August 2018 inclusive.

Using the same revised method of analysis as for the 2018 data, Zap-Map revisited the data for July 2017, which by the same metric showed 1,090 out of 7,356 (14.8%) out of service. Therefore the like-for-like improvement between July 2017 and May to August 2018 is a reduction of out of service chargepoints on the CPN from 14.8% to 8.3%. However, as the number of chargepoints has increased over the last year, this still represents about 900 chargepoints not working. Whilst any improvement is welcome, it nevertheless means that about one in twelve chargepoints is not working, which is still unacceptable. This compares with the 99% availability expected by the Dutch CPN (NKL Nederland, 2017).

The AEVA (section 10.3) allows the government to take immediate action not only to reduce repair times, but also to set standards for chargepoint manufacture and testing, such as are already set in many industries, particularly the motor industry. One would hope that setting maximum permissible repair times will stimulate the CPNs to install more reliable chargers, rather than creating ever-larger maintenance departments.

In addition to mechanical and software failures in the chargepoints themselves, the author's experience of using the CPN is that lack of adequate data signal connectivity has caused the most problems on some networks. A reliable data signal is essential to the operation of the chargepoint: it allows the chargepoint to send data to the network operator (live map data, confirmation of user authorisation to allow a charge to start, charge data and error codes amongst others) and for the network operator to send data to the chargepoint (initiate a remote start or stop and carry out a reboot amongst others). Significantly, the ability to communicate reliably with the chargepoint is a fundamental requirement of enacting the AEVA legislation.

There are various types of failure that a chargepoint can either fail to detect or fail to transmit. Failure of the data connection obviously falls into this category, although it can be detected eventually by the failure of the chargepoint to send a 'heartbeat'. Thus a chargepoint can be shown as operational on a live map, only to inconvenience a customer who, despite checking in advance of their journey that the chargepoint was working, is unable to obtain a charge. The real failure rate is therefore almost certainly higher than the 8.3% rate relating to mechanical/software problems that is reported.

In 2018, an unreliable data connection is not really an acceptable reason for a chargepoint being unable to deliver a charge: it will certainly be necessary for the AEVA regulations to specify data communication standards, as to achieve its objectives, it relies entirely on a reliable transfer of data.

Making chargepoints more reliable is part of defining a technical specification for chargepoints to ensure that they comply with all the requirements of the AEVA, and thus it is critically important that this specification is itself 'SMART '– **S**pecific, **M**easurable, **A**chievable, **R**esults-focused, and **T**ime-defined.

3.4 Ensuring that CPN installations are commercially viable

The Government states (DfT, 2018a: 90) that it wants to:

> "encourage and leverage private sector investment to build and operate a thriving, self-sustaining public network… With the right policy framework for investors and consumers, as EV uptake increases and utilisation rates improve, we expect the market to be able to deliver the public infrastructure needed in the long term. It is essential that viable commercial models are in place to ensure continued maintenance and improvements to the network."

It is therefore absolutely clear that the CPN must be commercially viable, but the time frame for achieving this is not clear.

3.4.1 Journey CPN

A report on the UK part of the European Rapid Charge Network (RCN) studied the business model for operating a network of Rapid chargepoints in the UK in 2014/15 (Serradilla et al., 2017).

This showed that the average capital expenditure (capex) per Rapid chargepoint in 2014/15 was £36,500, rising to £42,000 if a new Distribution Network Operator (DNO) electrical connection was required. Across all sites, the charger costs averaged about 55% of capex, with installation/commissioning and new power connection costs accounting for the balance of 45%.

For the future, particularly when adding a second or third chargepoint at existing locations, or when installing 150 kW (or higher) capacity chargepoints, the DNO connection costs are likely to form a much larger proportion of the capex. It would be desirable for the Government's intention "to continue the work of future-proofing the Strategic Road Network, we will run a pilot working closely with Highways England to increase electrical capacity at a MSA in the RIS 1 period[7] " (DfT, 2018a: 97) to be extended to *all* Rapid sites on the SRN following the pilot study.

The relatively high capex for the Rapid chargepoints reflects the low manufacturing volumes compared with, say, those pertaining to motor vehicles or washing machines. This means that each chargepoint must absorb a higher percentage of development costs. However, it is essential that chargepoints become more reliable and less expensive: to achieve this simultaneously requires stable QMS-controlled production of higher volumes. This in turn

7 RIS 1: the first Road Investment Strategy period (2015/16 to 2019/20)

means a firm specification which can be supplied in the same form to as many countries as possible. This must be considered when applying the powers available in the AEVA: enforcing a specification which is UK-specific will only increase costs to UK EV drivers.

Apart from capex there are operating costs (opex), amongst which are electricity, site rental, back-office support, planned maintenance, emergency maintenance, 24-hour customer support and insurance.

The only income sources are from the use of the chargepoint, which would be profit from the sale of electricity and possibly a fixed connection fee for each charge. With a constant comparison to the cost of Home charging being made by users, there are practical limits to the fees that can be charged. Charging at home can be carried out at a UK average total electricity cost of 17.6p/kWh at the standard rate and 10.8p/kWh at the Economy 7 rate (BEIS, 2018a, Table 2.2.4).

Serradilla et al., (2017) noted that at a mark-up of 3.3 (3.3 times the cost price) on electricity costs (a retail price of approximately 30 to 35p/kWh), it would be possible to break even on their capex and opex assumptions within ten years, provided the amount of electric energy delivered per chargepoint increased at a compound average growth rate of 18%. The report associated this growth rate solely with the growth rate of EVs, whereas in reality not only are BEVs the sole relevant users of Journey chargepoints, but there are other variables such as competing networks, the battery capacity of vehicles being charged, realistic charger downtime, and the fact that electricity was being supplied free when the baseline electric energy delivered per chargepoint was calculated. A better way to understand the electric energy demand growth per chargepoint would be by considering the number of BEVs available per chargepoint.

With regard to retail pricing, the cost to charge on the CPN varies between the network operators, and there are wide variations between instant access prices and membership schemes. To provide an indication of viability, a price around 30p/kWh is common, sometimes with a per-charge connection fee. (It is worth noting in passing that these prices make charging on the CPN about twice as expensive as charging at home on standard rate, and about three times as expensive as the night-time Economy 7 rate.)

With regard to demand for charging, Figure 3.2 shows CHAdeMO demand per chargepoint gently falling between 2017 and 2020, with CCS demand virtually static in the same period. This indicates that, providing the chargepoint installation rates detailed in Figure 3.3 take place, the numbers of charges per chargepoint will not increase between now and 2020, which will provide operators with a static, rather than an increasing, income per chargepoint over that period.

With regard to the number of charges per chargepoint, Serradilla et al., (2017) also noted that the average energy delivered per chargepoint per month between July 2014 and September 2015 was 625 kWh per month, or about 20 kWh per 24-hour day, indicating an average across all the chargepoints in their network of between two and three charges per chargepoint per 24-hour day. This indicates that during the survey most Rapid chargepoints were little used, despite at that time being supplied with free electricity. If this rate is factored up by the growth in BEVs since 2015, at the same time allowing for the increase in Rapid chargepoints in the same period, it implies an average present-day usage of three to four charges per 24-hour day. The move from free to chargeable electricity in the same period can only reduce these numbers.

This does not paint a picture of a CPN which is struggling to meet demand.

If three to four charges per day is the average, what is the maximum and minimum chargepoint usage? Most networks would be pleased to be delivering eight to ten charges per Rapid chargepoint per day as an average across their network. On the other hand, a significant proportion of chargepoints on the CPN are delivering fewer than two charges per day, providing a service to the users and an almost certain loss to the operators.

It is against this background of limited demand, and what is in effect a price cap, that the Government expects the CPNs to find private investment for new, higher-capacity (more expensive) chargepoints (DfT, 2018a: 90). Also needing to be taken into account are the costs of a possible retrofit campaign which would fit all existing chargepoints with additional functionality to meet the requirements of the AEVA, and the possibility of energy storage costs with future installations (although this latter should also provide an additional income stream).

The obvious commercial conclusion is that whilst three to four charges per chargepoint per 24-hour day is unlikely to result in either profit or queuing, the only way to maximise financial return is to install only sufficient chargepoints to ensure that every one of them is in almost continuous use, ideally 24 hours per day, which will imply queuing.

Major companies (for instance BP and Shell) are starting to acquire the existing CPN operators, which may provide the investment needed to expand the network and to invest in other associated profit opportunities such as energy storage (surely an ideal opportunity for companies already involved in the energy business). However, it may also result in higher prices for charging (Shell is already testing pricing at 49p/kWh) and more ruthless culling of chargepoints that have limited use.

Since the viability of investment in the Journey CPN is critically dependent on demand (which is a direct function of the size of the BEV fleet), it is very disappointing that the H2 2018 European sales of BEVs might turn out to be limited by production capacity rather than any shortfall in consumer demand.

In their H1 report of the European market, EV Volumes.com (2018) put a caveat on their projections for H2:

> "Our tracking of plug-in vehicle inventory shows an average of only four days of supply on stock and 2 months of order back-log. Models with more than 10 000 unfulfilled orders, each, are Hyundai KONA, VW e-Golf, Jaguar i-PACE and Nissan Leaf and obviously the Tesla Model 3, all of them BEVs."

In summary, the Government's intention that the CPN should be privately funded and profitable in the long term might result in a model which is incompatible with their intentions for the CPN in the short term. The Government might therefore need to consider how to future-proof the investments currently being made by CPN operators.

3.4.2 Grazing CPN

The main debate about the commercial viability of the CPN is about the Rapid chargepoints at Journey locations. This is because the Journey requirements of EVs are perceived as a problem. However, the demand for Grazing chargepoints is approximately three times the demand for Journey charging (Table 3.1), and the corresponding installation rate should therefore be commensurately faster. There must be a clear business case for CPN operators to make this investment, remembering that their only income will be from the sale of electricity.

Grazing chargepoints are simpler and cheaper both to make and to install, and are in general much more reliable than Rapid chargepoints, which means lower capex and maintenance costs. However, a 7 kW Fast chargepoint delivers only about one seventh of the electrical energy that a 50 kW Rapid chargepoint does (this is indicative only – charge rates will depend on many variables), and therefore generates about one seventh of the income in any given period. This also assumes that all cars have an on-board 7 kW charger, whereas it has been demonstrated that all PHEVs (about 70% of the fleet) and many early EVs, including many of the best-selling Nissan LEAFs, are restricted to 3.6 kW charging by their on-board chargers.

Comparing Figure 3.6 with Figure 3.10 shows that the median charge time on a Grazing Fast chargepoint is approximately four times longer than for a Rapid chargepoint. There were approximately five times as many Fast chargepoints as DC Rapid chargepoints installed on the CPN as at the end of 2017 (Zap-Map, 2018).

These approximate figures demonstrate that Grazing charging has the potential to provide at least as much if not more income as Rapid charging, provided the network operator has a large enough number of Fast chargepoints – and provided they are in the right locations. Since only about 25% of the vehicles currently charging can accept the full 7 kW available, the average amount of electricity sold per charge will be about 40% less than the scenario in which all vehicles charge at 7 kW. It should also be remembered that *all* EVs can charge at AC Grazing locations, which triples the number of potential customers compared with (BEV-only) Rapid chargepoints. As previously noted, Grazing chargepoints require less investment in customer facilities (as the customer will be leaving the site to do something else), but weather protection and lighting should nevertheless become the norm.

Although the installation rate of Grazing chargers is impressive, it may need to rise even higher. To ensure the relevance of these installations, there needs to be clarity about the requirements of the AEVA for Grazing chargepoints. This would include not only the chargepoint's mechanical, electrical and durability specifications, but also data requirements and details concerning smart charging (including whether reverse charging will be required), since Grazing charging would appear suitable for local V2X networks. All of this will add cost and incur delay, as chargepoints need to be designed and tested to the new specification.

To avoid an even larger estate of legacy chargepoints, OLEV needs to act quickly.

3.5 Ensuring that the demand on the grid can be managed

The author provided an overview of this topic last year. (Dermott, (2017) section 2.7). Just two aspects of this complex and substantial subject will be considered in the context of this report: demand-side management and energy storage.

3.5.1 Demand-side management

Demand-side management remains one of the most powerful tools for matching available grid capacity to demand, and Ofgem's Future Insights Paper 5, published in July 2018, and provides some relevant proposals (Ofgem, 2018: 4):

> "The transport and electricity sectors are becoming increasingly connected. Much of the 'fuel' for EVs will come from our national electricity grid – changing how, where and when electricity flows across the network. EV owners will not just be passive consumers of energy, but could also play an important role in the future, balancing the electricity network. New bundled offerings that combine energy and transport services will cut across traditionally distinct sectoral boundaries, and therefore regulatory jurisdictions".

Their research established that (Ofgem, 2018: 26):

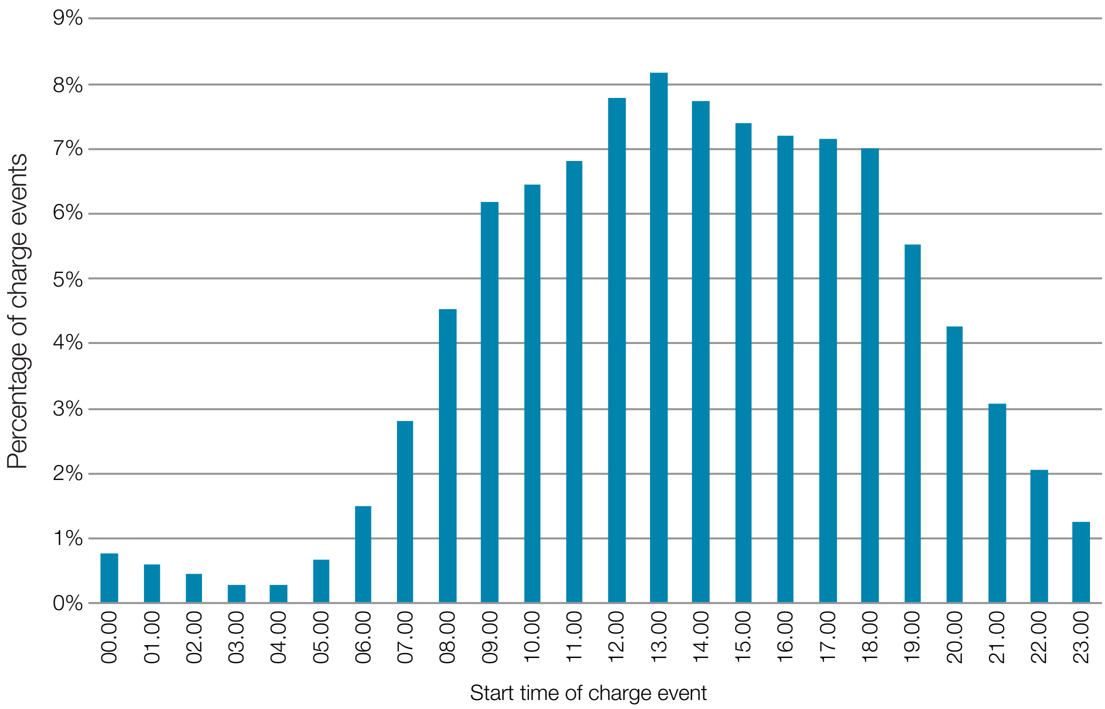
> "…smart, flexible solutions allow at least 60% more EVs to connect to our existing network, before reinforcement need be considered. If 'fast' charging is adopted, flexible solutions may allow up to six times more EVs to connect."

The paper goes on to suggest various ways of managing the EV home charging demand, which will take place mainly during the increasingly important overnight transfer of energy to EVs. All these proposals will require a smart electricity meter, and some will also require a smart home charger. Legislation to require the latter for all Home charging is provided for in section 15 of the AEVA.

Since the enabling legislation now appears to be in place, supported by an increasing amount of encouraging data from the electricity supply industry, it must be hoped that demand-side management for EVs can be put in place during 2019. At least one UK energy supplier is already offering tariffs for EV owners which involve a smart charger charging the vehicle at specific times during the night in exchange for very low tariffs at those times (Myenergi, 2018).

However, this demand-side management is almost exclusively aimed at overnight charging, when other demand is low and EV charging demand on home chargers is expected to be high. Unfortunately, Journey charging at Rapid chargepoints has a different demand profile (Figure 3.12), and a different solution to managing the load on the grid is required: energy storage.

Figure 3.12: Start time of Journey charge events on the UK CPN 31 March 2017 to 31 March 2018



Source: Zap-Map data

3.5.2 Energy storage

There is hardly any aspect of balancing the effect on the grid of EV charging that could not be improved by energy storage. All the mechanisms of demand-side management require managing load peaks over a relatively short time interval. The huge advantage of energy storage is that it inserts a time-disconnect in this process. Thus energy stored at night can be made available during the day, and energy stored when the wind is blowing or the sun shining can be made available at any time.

As their prices fall, batteries are becoming increasingly popular for energy storage. These can be small domestic units, typically 5 to 12 kWh, to vast DNO-level units, the largest to date being the Tesla 100 MW (megawatts) / 129 MWh (megawatt-hours) battery in South Australia.

The International Renewable Energy Agency (IRENA) 2017 investigation found that total electricity storage capacity appears set to triple in energy terms by 2030 (IRENA, 2017: 14), which is an increase by a factor of 17 compared to today's estimate of the level needed to meet the requirements for doubling renewables in the global energy mix. This boom in storage will be driven by the rapid growth of utility-scale and behind-the-meter applications.

This report also observed that it is not just grid balancing that energy storage can provide. Ancillary grid services, such as primary (fast) frequency regulation, secondary frequency regulation, voltage support, and capacity reserve, will all grow in significance as the amount of variable renewable energy increases. It should be noted that the provision of these ancillary grid services would add value to energy storage on the CPN.

An example of this is the Tesla 100 MW / 129 MWh battery, known as the Hornsdale Power Reserve (HPR) in South Australia, mentioned above. The official initial report from the Australian Energy Management Operator states “the regulation [Frequency Control Ancillary Services] provided by the HPR is both rapid and precise, compared to the service typically provided by a conventional synchronous generation unit”, noting that “this market has seen high prices for this service” (AEMO, 2018: 5).

IRENA also acknowledges the important role that BEVs, with their significant storage capacities, can play in supporting grid operation (IRENA, 2017: 73). They support Ofgem’s comments (Ofgem, 2018: 4) by noting that BEV batteries can provide flexibility to the electricity supply by helping to integrate the variable production of renewables into the grid. However they also note that this will mean a major change in attitude for both the transport and energy sectors, if they are to achieve greater decarbonisation of the two sectors by coupling them.

The Dundee EVCH (see section 3.2.1) is just one example which shows that the concept of using second-life BEV batteries is not a future theoretical concept, but a current reality. Using second-life BEV batteries for energy storage has other benefits: by providing a demand for first-life batteries, it should allow OEMs the opportunity to reduce the cost of new BEVs, and by approximately doubling the useful life of BEV batteries (Groupe Renault, 2017), it significantly reduces both the lifetime cost per kWh delivered and any environmental costs of battery manufacture (Renault-Nissan, 2018).

3.5.3 V2G and V2X

IRENA summarises the V2G concept as “allow[ing] a controllable, bidirectional electrical flow between the vehicle and the grid (IRENA, 2017: 73)”. However, it emphasises that “the potential for demand-side management and for ancillary service provision to the electricity market from electrical vehicles is heavily dependent on the specific energy market context, and regulations that would facilitate and enable this future are not standardised globally (IRENA, 2017: 73).”

It should be noted that the powers granted under the AEVA in sections 14 and 15 appear to address only some of these issues in the UK, the rest appearing to be dependent on the wholesale electricity market.

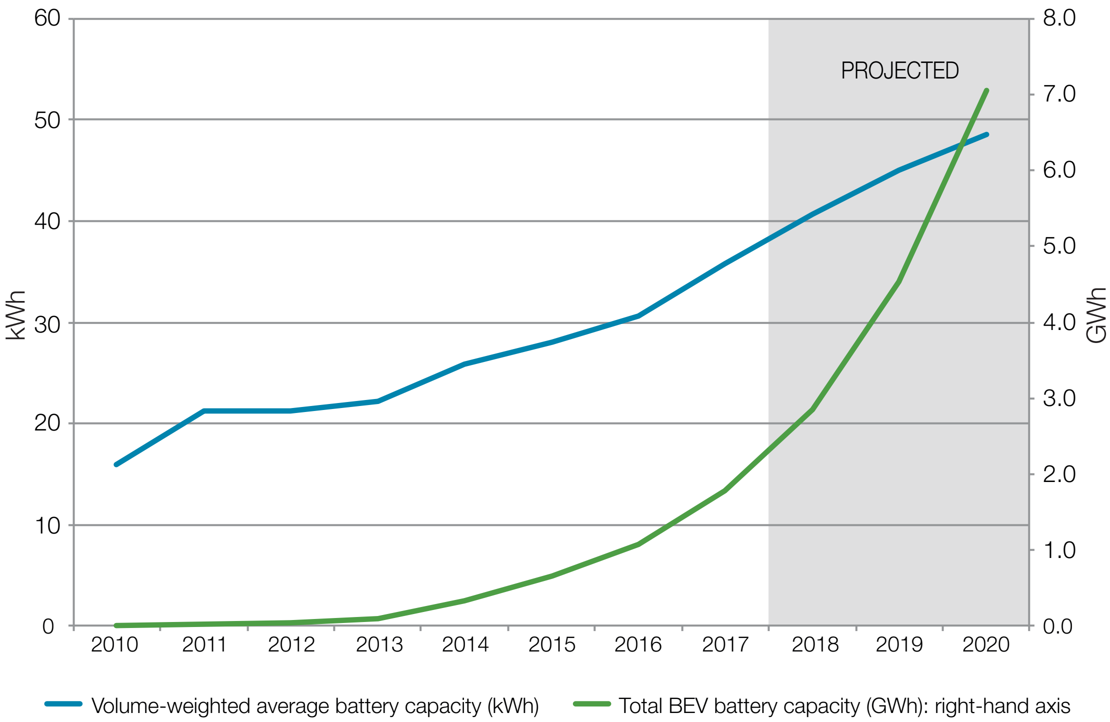
However, a great many issues remain unresolved concerning V2G, including:

- the maximum output to grid;
- the effect on vehicle battery life of discharge profile;
- the minimum effective plugged-in time;
- the minimum number of vehicles to make any network practical;
- the overall economics, including financial benefits to EV owners;
- the contractual obligations for EV owners; and
- whether a DC or AC connection to vehicle is required (whether the inverter is in chargepoint or in vehicle).

It is to be hoped that current trials taking place in the UK and elsewhere, combined with the rapidly increasing total BEV battery capacity available (7 gigawatt-hours (GWh) projected for 2020 – see Figure 3.13) will allow the viability of V2G in the UK to be finalised.

If viable, changes to both the on-board vehicle charger and electric vehicle supply equipment (EVSE) are likely to be required. To ensure that these become available in sufficient quantity in BEV owners' garages to allow V2G or V2X to maximise the benefits of this process, no time must be lost in using the AEVA to specify these requirements once the relevant test results have been analysed. It is also essential to ensure that V2G takes full account of the needs of the EV owner and the vehicle battery, *and not just the grid, electricity supplier and aggregator*. Resolution of these issues is required before any meaningful application of the powers in the AEVA can be relevant to V2G.

Figure 3.13: Average historical and projected BEV battery capacity and total BEV fleet battery capacity



$$\text{Volume-weighted average battery size} = \frac{\text{(vol car 1 x car 1 battery size) + (vol car 2 x car 2 battery size) etc}}{\text{total number of cars}}$$

Figure 3.13 shows the effect of the increase in both average battery capacity and BEV sales between now and 2020 on the rapidly increasing energy storage available for V2G use.

However, V2X remains a simpler concept than V2G, and therefore capable of being adopted earlier (Armand Peugeot Chair & Catalonia Institute for Energy Research, 2016). With V2X, the vehicle could discharge to a domestic, Workplace or Grazing location storage battery. As we have seen, such a storage battery (or other energy storage device) is likely to become part of the development not only of the CPN, but of the grid as well (IRENA, 2017). This V2X process inserts an additional storage device between the grid and the vehicle battery, reducing or removing the requirement for larger power transfers in either direction from the vehicle battery, thereby protecting vehicle battery life and increasing the attractiveness of the process to EV owners. In this V2X scenario, each energy transfer becomes local, removing many of the V2G concerns and simplifying the process. Such local energy storage could be located at an EVCH.

In addition, should an aggregator choose to offer such local energy storage sites grid connection, it is the aggregator who would deal with the grid connection issues, which might result in much simpler contracts for the individual EV owner or local Workplace or Grazing energy storage owner. In addition, such aggregators would be connecting to the local storage device rather than directly to the vehicle, improving flexibility of supply.

For example in Home, Workplace and some Grazing locations, the combination of solar panels, local energy storage and EV battery capacity provides a highly flexible energy supply and management system to augment the grid. Such combinations should receive financial encouragement from the Government, as they encourage both the transport and power sectors towards greater decarbonisation (IRENA, 2017).

Most V2X (including V2G) technology seems to be at the trial/test phase, and it is not yet clear when these results can be evaluated and conclusions drawn to allow meaningful proposals to be enacted by the AEVA. However, there might be no difference between V2G and V2X with regard to the specification of the smart aspect of the charger, which would allow AEVA to specify this charger in 2019: creating this specification and adopting this technology, particularly for Home charging, is likely to be on the critical path for early access to V2G and V2X benefits.

There is also an opportunity for the Government to encourage energy storage through the OLEV WCS grants, which should be updated in 2019 to include the requirement of smart chargers. This grant could be increased if energy storage is installed at the same time. This might also work for the OLEV EVHS.

When it comes to Grazing charging, all future installations should be encouraged to include a relevant amount of energy storage for every chargepoint installed.

As for Rapid charging, although the number of Rapid chargepoints is far fewer than the number of 7 kW chargepoints used for Home, Workplace and Grazing charging, their instantaneous load demand on the grid is far higher; moreover, 86% of this demand occurs in the daytime, between 8 a.m. and 8 p.m. (Figure 3.13). This load will become even more significant to the local grid as Rapid chargepoints increase in number and charge rate, rising from single 50 kW to multiple 50 kW, multiple 150 kW or even multiple 350 kW. Reducing charge rates at these chargepoints to reduce the demand on the grid is not feasible, as this would remove the whole point of Rapid charging.

The advantages of decoupling this load by using energy storage, so that it does not take energy directly from the grid, are obvious from the point of view of the grid operator, but less so for the CPN operator. Therefore the most obvious solution is for energy storage to be installed by the DNO as part of the site electrical supply, as they are the main beneficiaries. The

Journey CPN operators also need to be encouraged to use such storage for V2X applications, and such Journey sites need the flexibility to be able to *accept* energy from EVs as well as supply it. This will of course require attractive supply-side pricing for EV owners.

In summary, future energy systems will rely on a large array of services based on effective, economical electricity storage. This plethora of service needs, with varying performance requirements, suggests an important role for many different storage technologies (IRENA, 2017).

Projects such as Smart Electric Urban Logistics, delivered by UK Power Networks (2017) as part of their wider 'Innovation' programme, are hoped to provide the data to allow future electricity network decisions to be made, but the available time is very short if EV sales growth continues at the expected rate.

There is an opportunity for the AEVA to be used not only to ensure that the rapidly expanding demand for electrical power for EVs can be met by the UK's twentieth century grid, but also to encourage emergence of the new technologies that the grid will require in the twenty-first century. This would appear compatible with Ofgem's current view of "taking a more holistic view regarding what regulatory arrangements are appropriate for the future energy system" (2018: 28).

4. The Relevance of the Automated and Electric Vehicles Act (2018)

The Automated and Electric Vehicles Act (2018) received Royal Assent on 19 July 2018. The Act gives the government powers to impose certain requirements on public chargepoints and how they are used. This section will suggest how these provisions could best be used to address the issues raised in this document, whilst also pointing out concerns about how the Act might be applied.

4.1 Matching supply to demand

Regulations deriving from AEVA sections 10.3 and 10.4 should be used to specify that all future Rapid chargepoints installed on the CPN should be direct current only, and with a minimum of one CHAdeMO and one CCS connector.

4.2 Ensuring that the chargepoints are attractive to use, and that users have the necessary facilities

Regulations deriving from AEVA sections 10.3 and 10.4 should be used to specify that all future CPN 'Journey' chargepoints have, as a minimum:

- adequate weather protection at the chargepoint;
- adequate lighting at the chargepoint;
- good cable management;
- somewhere to sit in the warm and dry other than the vehicle;
- toilet facilities;
- food and drink facilities;
- a good-quality Wi-Fi connection; and
- well-marked bays to reduce ICE blocking.

For 'Grazing' locations, the minimum requirements should be:

- adequate weather protection at the chargepoint; and
- adequate lighting at the chargepoint.

4.3 Ensuring that the chargepoints are reliable

Regulations deriving from AEVA (section 10.3) will allow the government to take immediate action not only to specify maximum repair times (for example 48 hours), but also to set standards for chargepoint manufacture and testing. However, when applying the powers in section 10.3 of the AEVA, it should be remembered that enforcing a specification which is UK-specific will only increase costs to UK EV drivers.

Defining a technical specification is an important part of making chargepoints more reliable. It is therefore critically important that this specification is itself 'SMART'–**S**pecific, **M**easurable, **A**chievable, **R**esults-focused, and **T**ime-defined.

If there is no reliable data connection to CPN chargepoints, sections 13, 14 and 15 of the AEVA will be unworkable. Currently, the data connection with many chargepoints is intermittent, and it is therefore essential that the stability and strength of the data connection to all CPN chargepoints is specified in the Regulations deriving from section 10.3.

4.4 Ensuring that the installations are commercially viable

It must be made clear whether the requirements of the AEVA apply only to new chargepoints, or whether they will apply retrospectively to *all* chargepoints, requiring a retrofit campaign which would fit all existing chargepoints with additional functionality to meet the requirements. (This might not, however, be technically possible.)

There also needs to be clarity on the requirements of the AEVA for Grazing chargepoints. This would include not only the chargepoint mechanical, electrical and durability specifications, but also data requirements and details concerning smart charging (including whether reverse charging will be required), as Grazing charging would appear suitable for local V2X networks.

The AEVA requirements will add cost to the CPN chargepoint installation programmes, and may incur delays to its progress, as chargepoints to the new specification will need to be designed and tested.

4.5 Ensuring that the demand on the grid can be managed

Smart charging is an essential part of grid management. Section 15 of the AEVA lists the powers granted under the Act which, unlike other sections of the Act, can be made to apply to all chargepoints, not just those on the CPN. The important move to smart Home charging, which the AEVA will introduce, must be dealt with in a more effective way than the equivalent roll-out of smart electricity meters. Similar setbacks in the roll-out of smart home chargers could be disastrous to an embryo industry trying to encourage the sale of EVs. To potential EV purchasers, the concept of a 'fuel station' at home will be new, and the installation and grant process must be straightforward and effective.

The OLEV Electric Vehicle Homecharge Scheme and Workplace Charging Scheme grants should be continued until they can be replaced by equivalent grants which ensure that all future Home and Workplace chargepoints are smart technology enabled and capable of reverse charging to support V2X capability.

For both Grazing and Rapid charging, regulations derived from section 15.2(f) of the AEVA would allow the government to require specified energy storage to be provided with every chargepoint installed. This part of the Act also constitutes also an excellent opportunity for the Department for Transport (DfT) and Department for Business, Energy & Industrial Strategy (BEIS) to collaborate with each other, to their mutual benefit. Sections 3.5.1 and 3.5.2 indicate that by working together, the transport and power sectors could achieve greater levels of decarbonisation. For example, BEIS might work with the electricity DNOs to ensure that the electricity supply to Rapid chargepoint locations included appropriate energy storage. DfT would be working with OEMs to provide second-life EV batteries for this energy storage. The government might provide some short-term financial incentives to encourage such energy storage for Rapid charging (which would be considerably less expensive than the alternative of building more power stations).

The powers granted under the AEVA in sections 14 and 15 appear to address only some of the V2G and V2X issues in the UK, the rest appearing dependent on the wholesale electricity market. Resolution of this would again appear to require the transport and energy sectors to work closely together.

It is also essential to ensure that V2G takes full account of the needs of the EV owner and the vehicle battery, and not just those of the grid, electricity supplier and aggregator. Most

V2X (including V2G) technology seems to be at the trial/test phase, and it is not yet clear when these results can be evaluated and conclusions drawn to allow meaningful proposals to be enacted by the AEVA.

In contrast, changes to both the on-board vehicle charger and the electric vehicle supply equipment are likely to be required, and no time must be lost in using the AEVA to specify these requirements once the relevant test results have been analysed. However, it may be possible to freeze the specification of the smart aspect of the EVSE early in the process, which would allow OLEV to create, using the AEVA, a specification for this charger in 2019: doing so will reduce the amount of legacy EVSE, and creating this specification is likely to be on the critical path for the task of providing early access to V2G and V2X benefits.

5. Conclusions

The UK is about to undergo the biggest revolution in personal mobility for over a century, and we are not well prepared. The disruptive change, to electric propulsion and eventually automated (driverless) vehicles, is promoting fear, uncertainty and doubt in the minds of those facing it, which is everyone who currently drives a motor vehicle.

The discussion about the infrastructure changes required to support electric vehicles (EVs) is therefore clouded by misinformation, usually prompted by the desire to avoid change. But this change has already started, and is gathering pace – it is not going to go away, and this report has attempted to clarify some of the issues.

EV charging is as different from fuelling an internal combustion engine (ICE) vehicle as fuelling an ICE vehicle is from fuelling the horse that preceded it. Despite this, there is a perception that the 'refuelling process' for an EV should be as close as possible to that of an ICE vehicle. This is not the objective of the current public chargepoint network (CPN), and as technology continues to develop, is unlikely the future CPN would want to be constrained in this way.

This report began by considering that existing ICE drivers believe that a "shortage of public charging points" for EVs is the main reason why they are not considering an EV as their next vehicle. This has been shown to be misleading, as the subject is much more complex that this simple 'sound bite' would imply. Even the measure of success inferred – the number of chargepoints available – is so crude as to be meaningless.

It can thus be seen that there has been a significant failure to communicate the ways in which personal mobility is likely to change over the next ten years, in particular the whole subject of the move away from ICE vehicles to EVs. There is an urgent need to improve this communication.

Having identified 'Journey' and 'Grazing' – 'Journey' charging is where the primary reason for being at the location is to charge the vehicle; and 'Grazing' charging for which the driver is at the location primarily for another purpose – as the two fundamental forms of public EV charging, and discussed the issues related to each, it is clear that *all* those involved in the provision and operation of the CPN need to improve their current performance. This will include not only government, but also in particular the EV original equipment manufacturers (OEMs), CPN operators, and the electricity generation and supply industry.

However, this represents only a small part of the EV refuelling requirement: home and workplace charging are as important as the CPN in ensuring a smooth transition to EVs. It is therefore essential that local councils and developers ensure that all new houses are built with provision for 7 kW EV charging in every home. In addition, new industrial and commercial units should have a minimum of 25% of their parking spaces fitted with a 7 kW charger.

Noting these requirements for new domestic, commercial and industrial property emphasises how different the EV 'refuelling' process is, and how wide-ranging the changes required – it is not just a change at the roadside.

The issues that this report identified include the following requirements.

For CPN operators, provision of, at Journey locations:

- adequate weather protection at the chargepoint;
- adequate lighting at the chargepoint;
- good cable management;
- somewhere to sit in the warm and dry other than the vehicle;
- toilet facilities;
- food and drink facilities;
- a good-quality Wi-Fi connection; and
- ell-marked bays to reduce ICE blocking.

At Grazing locations, provision of:

- adequate weather protection at the chargepoint; and
- adequate lighting at the chargepoint.

More generally, there is a need for the following changes to be implemented:

- Stop installing 43 kW AC (alternating current) connectors on Rapid chargepoints. Remove the AC cable from any remaining chargepoints so equipped before installation to prevent blocking by plug-in hybrid electric vehicles (PHEVs).

- Budget for the installation of at least one fully specified electric vehicle charging hub per year: liaise with the Office for Low Emission Vehicles (OLEV) about possible financial support.
- Work with chargepoint manufacturers to improve reliability. Ensure functionality meets all the requirements of the forthcoming Automated and Electric Vehicles Act (2018) (AEVA) regulations.
- Install Rapid and Grazing chargepoints *only* at the rate necessary to match demand, measured by EVs per chargepoint (battery electric vehicles (BEVs) only in the case of Rapid chargepoints). This rate is indicated in Figures 3.3 and 3.8 of this report.
- Build business cases to investigate the benefits (in terms of additional income) of energy storage, and work with the Distribution Network Operator (DNOs) to install such storage with every Rapid chargepoint.
- Engage with OEMs to seek to establish the demand for 100 kW+ enabled vehicles, and whether a business case (and at what price premium) can be made for such chargepoints.
- Engage with OLEV on AEVA requirements.

For OEMs:

- Accept that selling EVs will, at least for a few years, require dealers to explain much more about the vehicle, especially about how to charge it, than with an ICE car. Set up dealer training programmes accordingly.
- Do everything within their power to get more BEVs to the market by the end of 2020: the lack of choice is hindering the move away from ICE vehicles. Make sure that the BEVs that are available are produced in sufficient quantity to meet customer demand.
- Stop providing charge cables with a domestic 13A plug and, within the price of the vehicle, provide the Type 2-to-Type 2 charge cables instead.
- Either provide and install an approved home charger within the price of the car, or facilitate the installation of an additional-cost home charger as part of the sale process.
- Ensure that *all* EVs have an on-board AC charger of at least 7 kW.
- Engage with the CPN operators on high-capacity charging to ensure that they have a business case for installing such chargepoints.

For DNOs:

- Engage with CPN operators on the subject of energy storage for demand-side management, particularly in the case of Rapid chargepoints at Journey locations.
- Engage with OEMs about the use of second-life EV batteries for such energy storage.

The continuing confusion in the media about what constitutes an ‘EV’ has allowed a surge in sales of first-generation PHEVs with small electric-only ranges to imply that the UK is well advanced on the path to decarbonisation. It is these vehicles, many of which are never charged, that are creating the perceived demand for public charging. As we have seen, because of their small battery capacities and the inadequate Rapid charging provision provided by the OEMs, only Grazing charging is relevant for these vehicles.

Far from their being a shortage of Rapid chargepoints at Journey locations, there is no good business case for the installation of more Rapid chargepoints to meet current (low) demand for BEV Journey charging.

The viability of such chargepoints depends on the number of charges per day, and it will be the significant increase in the number of 'second-generation' BEV models available in the UK from 2019/20 that will eventually bring about enough customers to make such investments worthwhile.

Until about 2020, BEV sales in the UK will be limited by the poor availability of new vehicles – there is an embarrassingly small choice for potential buyers. Next year, 2019 will at last see new models appear, and this will continue to accelerate through into 2020. It will not be until that time that potential purchasers can expect to see a choice of BEVs in every market segment. This availability problem is exacerbated at the moment by a shortage of supply of the existing vehicles.

The way that the UK generates and manages its electrical energy supply has been moving away from the early twentieth century concepts to a wider energy mix with renewables now responsible for about 25% of generating capacity (BEIS, 2018b). Improvements in technology, not least battery technology, now mean that cost-effective energy storage is available to make this energy available at any time, not just when it is generated.

There is untapped potential to increase the rate of decarbonisation in the UK if the energy and transport sectors work more closely together, both on demand-side management (including V2G (vehicle-to-grid) and V2X (vehicle-to-everything)) and the use of second-life EV batteries for energy storage. This potential has been recognised by Ofgem and others: it is a further indication of the breadth and magnitude of the forthcoming changes.

There are huge potential benefits for the UK offered by the change to automated and electric vehicles, as the government have identified in their document 'The Road to Zero'. However, without a strong co-ordinating body to project-manage this programme across all the sectors involved, success is unlikely. Since the government expects private industry to deliver nearly all of it, the programme must, as a minimum, motivate the different sectors to have common objectives, with a common message for the bewildered public.

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