REPORT

PIV Charging Types and Roadmap

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Executive summary

This report sets out a forecast for the future of plug-in vehicle (PIV) charging, based on a review of published roadmaps and a series of interviews with key stakeholders. Stakeholders from 24 organisations including governmental bodies, automotive OEMs and their supply chains, charger installers and charger OEMs were interviewed. Their responses have been collated to provide a clear picture of the future needs of plug-in vehicle charging when considering connection to distribution networks. Key findings are:

Conclusions

C1. There will be a rapid adoption of 7 kW home charging units but most households will not upgrade beyond this due to the limitations of residential electricity supplies.

C2. At present, a large number of residential customers use Mode 2 charging cables connected to 13 Amp sockets, rather than standalone EV charge points.

C3. Where three phase supplies are available, or there is significant value in charging multiple vehicles, customers are likely to install 22 kW AC chargers.

C4. Battery capacity for typical electric vehicles will approximately double to around 40 kWh by 2020 and is not expected to increase significantly beyond this point, particularly for smaller vehicles. However, it should be noted that luxury vehicles will be fitted with higher capacity batteries.

C5. Increased battery capacity is a means to overcome range anxiety. It is expected that approximately 200 miles of range (equivalent to 40-50kWh battery capacity for a typical vehicle) will overcome range anxiety. However, this is relatively untested.

C6. Beyond 2020, average battery capacity will continue to increase due to a transition in the GB PIV uptake away from plug-in hybrid vehicles towards battery electric vehicles.

C7. Whilst residential charging will continue to be the most common form of charging, increased availability of public, workplace and rapid charging will change customer behaviour and may reduce energy required from home charging in the longer term.

C8. There is an increasing focus on delivering charging solutions to customers without access to off-street parking. Products to meet this need will emerge in the near future.

C9. Stakeholders are agreed that controlled charging is required to facilitate greater uptake of PIVs. There is a need for a standard mechanism to allow a utility to access the flexibility available where PIV charging can be delayed or reduced.

C10. Controlled charging must be customer-centric and pass some of the benefit of the flexibility back to participating customers. Clear and consistent messaging is vital to ensure the technology is accepted and perceived as an enabler.

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Abbreviations

AC	Alternating Current
BEAMA	British Electrotechnical and Allied Manufacturers' Association
BEV	Battery Electric Vehicle
CCS	Combined Charging System [PIV Charging Connector]
DC	Direct Current
DECC	Department of Energy and Climate Change
DNO	Distribution Network Operator
DSR	Demand Side Response
ENA	Energy Networks Association
EU	European Union
EV	Electric Vehicle
GB	Great Britain
IEC	International Electrotechnical Commission
LowCVP	Low Carbon Vehicle Partnership
OCPP	Open Charge Point Protocol
OEM	Original Equipment Manufacturer
OSCP	Open Smart Charge Protocol
NIA	Network Innovation Allowance
PHEV	Plug-in Hybrid Electric Vehicle
PIV	Plug-in vehicle
SDRC	Successful Delivery Reward Criteria
SMMT	The Society for Motor Manufacturers and Traders
UK	United Kingdom
USA	United States of America
ULEV	Ultra Low Emission Vehicles
V2G	Vehicle to Grid

1. Introduction

1.1 Background

This technical review paper is presented as a deliverable for the Smart EV project (NIA Project Reference NIA_SSEPD_0026 "Management of plug-in vehicle uptake on distribution networks").

The Smart EV Project is providing a viable solution to the challenges of plug-in vehicle (PIV) uptake in GB, following a previous innovation project by Scottish and Southern Energy Power Distribution and EA Technology: My Electric Avenue (the public facing name of the Low Carbon Networks Fund, Tier 2 project Innovation-Squared EV[1]). My Electric Avenue identified the potential to avoid £2.2billion of cost for electricity customers, by 2050, if demand side response was rolled out for PIV charging. However, My Electric Avenue also signposted that the industry currently lacks a standardised mechanism to access this response.

1.2 The Smart EV Project Aims

The Smart EV Project will seek to address the issues outlined above. The outputs will be:

1. Provision of industry agreed material to inform an ENA Engineering Recommendation (or equivalent) available to third parties for supply and manufacture of the home end and/or substation end controllers (the Solution).
2. A functional specification describing the system components and operation to allow vendors to produce a compliant Solution.
3. Evidence of UK PIV industry acceptance of the Solution, including OEM engagement and clear path to adoption.
4. Customer Messaging Strategy to facilitate customer understanding and buy-in to PIV controlled or smart charging and network demand response tools to improve customer acceptance of the solution(s).

1.3 Report Structure

Following a summary of the scope and objectives of this report, a summary of recent PIV roadmaps is presented as background to the information gathering conducted for this work (Section 3). The approach used to capture a representation of industry opinion is then set out, including identification of stakeholders and question definition (Section 4). The key themes from interview responses are drawn out to answer the objectives of this report (Section 5). Notes from the interviews have been collated, by stakeholder group, and are set out in Appendix II.

2. Scope and Objectives

The scope of this report is to set out the current environment for plug-in vehicle (PIV) charging in Great Britain, specifically considering charging power, battery capacity and charge locations. This is informed by interviews with a range of industry stakeholders. This aim of the report is to provide supporting information to for the development of a standard for PIV charging in GB.

The objectives of this report are:

- To understand and map the charging and battery capacities both current and coming to market
- To understand PIV charging locations and scenarios
- To report on additional input from stakeholders, relevant to the wider Smart EV Project

[1] See: www.myelectricavenue.info

There are a number of limitations to this work, notably:

- Information set out is based on published roadmaps and stakeholder input. Whilst stakeholders were suitably experienced and qualified, their views are necessarily limited to their experience.
- Questions were targeted towards light vehicles (cars and vans) and slow or fast charging. This work does not include heavy vehicles or rapid charging (defined as chargers with power greater than 22 kW), excepting where interview respondents suggested that it influences residential and commercial charging.

3. Plug-in Vehicle Roadmaps

A number of organisations have published roadmaps for low carbon transport. This section summarises their findings.

3.1 Roadmaps for Low Carbon Transport

Four roadmaps are set out below, summarising the current industry consensus on the future uptake and technology development for low carbon transport.

This section summarises the key results from the roadmaps set out in Table 1, relating to the Smart EV project. Specifically charging capacity (kW), battery capacity (kWh), charging locations and scenarios.

Table 1 Low Carbon Transport Roadmaps

Publisher	Year	Title	Description
Department of Energy and Climate Change (DECC)[2]	2016	Overview of the Electric Vehicle market and the potential of charge points for demand response	This report was prepared by ICF Consulting to provide an overview of the EV market in the UK. Projects between 3% and 8% of UK car sales will be EVs by 2020 and combines the LowCVP roadmap[5] with National Grid's Future Energy Scenarios[3] to give a picture of EV uptake beyond 2020. Emphasis on the role of charging at consumer homes.
The Society for Motor Manufacturers and Traders[4] (SMMT)	2016	Ultra Low Emission Vehicles (ULEV) Guide 2016	Industry publication, focused on cars, covering the full range of ULEV vehicle types with a detailed focus on current technologies and a wide range of issues - relating to ULEVs - which may concern consumers. Projections for the future are based on the widely used Automotive Council roadmaps[6].
Low Carbon Vehicle Partnership (LowCVP)[5]	2015	Transport Energy Infrastructure Roadmap to 2050	Roadmap produced through collaboration across the automotive sector. Aim was to direct investment, research and policy towards the UK's strategic objectives, and the solutions required to meet these. Starting point for this roadmap was the previous work by the Automotive Council[6].
Energy Technologies Institute[7]	2013	The Energy Infrastructure "Roadmap" for Transport	Roadmap setting out options for light vehicles in the UK to 2050. Setting out high level figures and implications for sectors beyond transport.

3.2 Ultra-Low Emission Vehicles

The work by the SMMT[4] is the most up to date summary of the current market for ULEVs in the UK. The SMMT refers to four distinct categories of plug-in vehicle (PIV):

- Battery Electric Vehicles (BEVs)
- Plug-in Hybrid Electric Vehicles (PHEVs), battery range exceeding 10 miles but which can also be powered by an internal combustion engine
- Extended-Range Electric Vehicles, battery range around 40 – 100 miles but with an on-board generator capable of charging the battery.

[2] ICF International (2016) "Overview of the Electric Vehicle market and the potential of charge points for demand response" prepared on behalf of the Department of Energy and Climate Change.
[3] National Grid (2015) "Future Energy Scenarios". Available: http://fes.nationalgrid.com/
[4] The Society of Motor Manufacturers and Traders Limited (2016) "Ultra Low Emission Vehicles Guide 2016". Available: http://www.smmt.co.uk/2016/03/ultra-low-emission-vehicles-guide-2016
[5] Low Carbon Vehicle Partnership (2015) "Transport Energy Infrastructure Roadmap to 2050 – Main Report". Available: http://www.lowcvp.org.uk/initiatives/transportroadmap/RoadmapsHome.htm
[6] Automotive Council UK (2013) "Automotive Council Roadmaps". Available: http://www.automotivecouncil.co.uk/wp-content/uploads/2013/09/Automotive-Council-Roadmaps.pdf
[7] Energy Technologies Institute (2013) "The Energy Infrastructure "Roadmap" for Transport". Available: http://www.eti.co.uk/wp-content/uploads/2014/03/0054_HEVC2013_ETI_final-toPrint.pdf

- Fuel Cell Electric Vehicles, hydrogen based technology which is out of scope of the Smart EV project

As of 1 March 2016 there were 36 models of PIV on the UK market, with an additional six models anticipated in the following year[4].

3.3 Vehicle Charge Power

PIV chargers in the UK are typically characterised as defined in Table 2:

Table 2 Existing Solutions for Controlled Charging

Charge Term	Standard	Fast		Rapid		"Super Rapid"	
Alternative Terms	Slow Normal	Faster		Quick		"Super-Fast" "Super Charge"	
Power Transfer	≤3kW	≤7kW	≤22kW	≤43kW	≤50kW	>43kW	>50kW
	Single Phase	Single Phase	Three Phase	Three Phase	DC	Three Phase	DC
Typical Charging Time	8 - 12hrs	3 - 4hrs	1 - 2hrs	80% in 20 - 30mins		< 20 - 30mins	

When considering the future trends for domestic and workplace charging, there is a clear limitation for single phase customers at 7 kW. The roadmap set out by LowCVP[5] indicates that residential charging will see significant uptake (over 300,000 chargers by 2020; and 10-15 million by 2050), but is not expected to exceed the 7 kW capacity for an individual charge point. The results of the LowCVP work are summarised in Figure 1. It should be noted that in some areas these figures have been shown to underestimate market uptake. For example, the prediction of 500 rapid charger sites by 2020 has already been surpassed (see Section 3.5 for more information).

It is difficult to establish figures for total number of domestic charge points in the UK, or their charge power as statistics are not available for numbers of installed private charge points. The maximum capacity for a typical domestic customer in GB is 7 kW, due to the restriction of a single phase supply and typical cut-out fuse sized at between 60 A (13.8 kW) and 100 A (23 kW) for the total household supply.

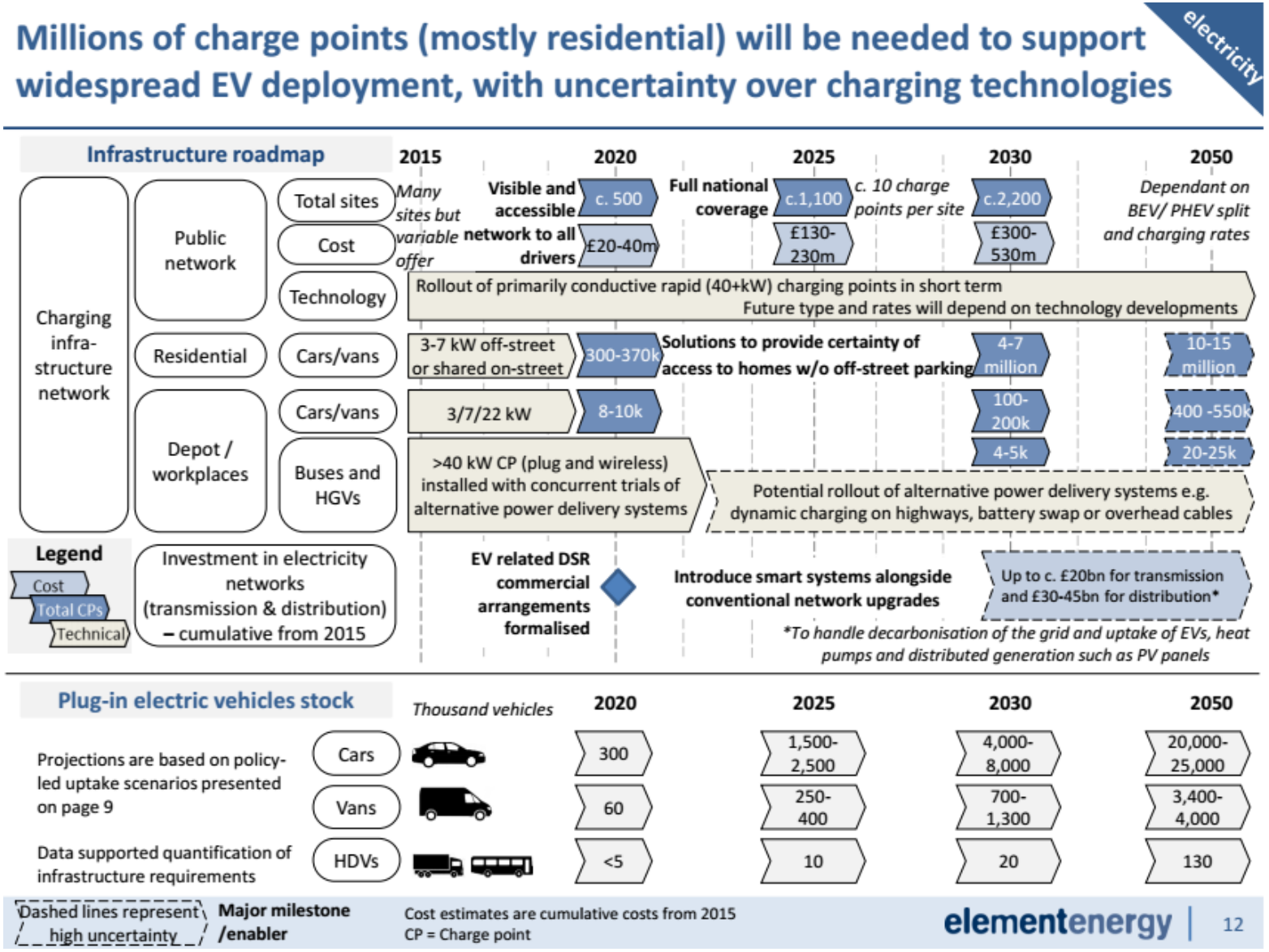

Figure 1 Roadmap for PIV Chargers ©LowCVP 2015[5] (note "public network" refers to rapid charging sites)

3.4 Battery Capacity

There is a trend towards increased battery capacity in those PIVs which have been on the market for a relatively long period. BMW recently announced an increase in battery capacity for the i3[8], and Nissan has increased the battery capacity available in the LEAF[9]. Table 3 shows a summary of battery capacities for the PIVs on the UK market, as of March 2016.

Table 3 Battery Capacity of PIVs on the UK Market

	Battery Capacity (kWh)		
Vehicle Type	**Average**	**Minimum**	**Maximum**
Battery Electric	27.4	14	90
Plug-in Hybrid Electric Vehicle	7.7	1	26.5
Extended Range Electric Vehicle	19	16	22

The roadmaps reviewed for this section do not comment on the future trends for PIV battery capacity. This is discussed further in Section 5. However, there is an obvious incentive in terms of vehicle range to increase battery capacity where possible.

3.5 Charge Location and Scenarios

The majority of PIV charging is conducted at consumers' homes[7,10]. Both the LowCVP and DECC reports[5,2] indicate that this is likely to continue as the dominant location for PIV charging, with a significant minority of charge points located at places of work. However, it is difficult to access figures for the total number of PIV chargers installed in the UK due to the lack of published information about home and commercial charge points

3.5.1 Public Charging

As of 17 May 2016, there were 6,055 public charger points at 4,018 locations across the UK. Of these, 915 were rapid charge points and the remainder fast or slow chargers[11]. The distribution of public charging infrastructure across the UK is shown in Figure 2.

Public charging infrastructure is not evenly distributed. For example, 19% of public charger points are installed in Greater London (13% of UK population[12]). Whereas, 3% of charge points are installed in Wales (5% of UK population). While this uneven distribution has not been studied, it is likely that national, regional and local government policies have created local incentives for specific areas. For example, the Plugged-in Places scheme provided matched funding for charge point infrastructure in

[8] https://www.press.bmwgroup.com/global/article/detail/T0143924EN/the-bmw-i3 Accessed: 17/05/2016
[9] http://newsroom.nissan-europe.com/EU/en-gb/Media/Media.aspx?mediaid=142570 Accessed: 17/05/2016
[10] EA Technology "My Electric Avenue SDRC 9.8 Report" (2015). Available: http://myelectricavenue.info/project-deliverables
[11] Zap Map "Charging points and electric vehicles" (2016)
[12] Office for National Statistics (2015) "Annual Mid-year Population Estimates: 2014". Available: https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates

eight areas across the UK which resulted in over 4,000 charge points being installed[13]. The Go Ultra Low Cities scheme has recently awarded £40 million, split between four city regions, to install charge points and other infrastructure to support ULEVs[14]. It is not possible to comment on the future for charge locations and scenarios based on published information and this is discussed further in Section 5.

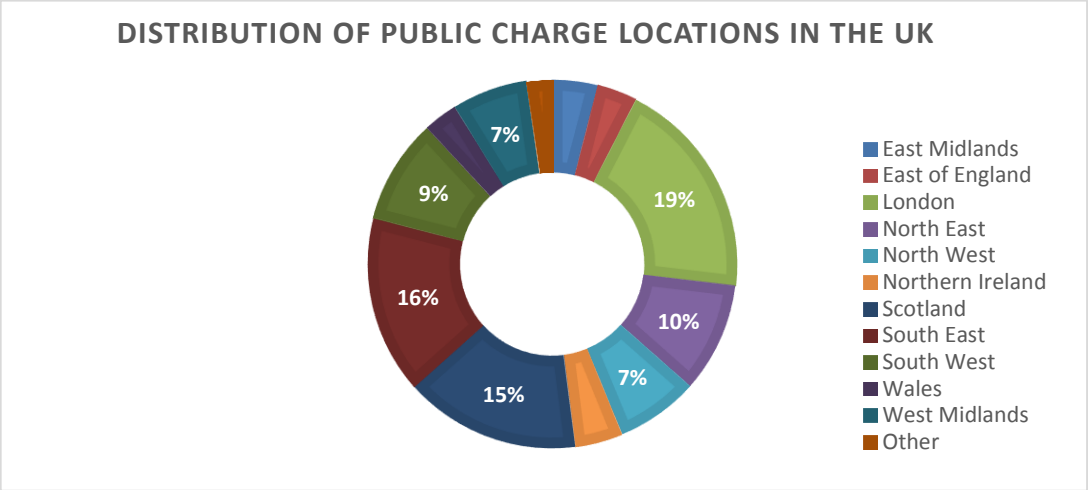

Figure 2 Distribution of Public Charge Locations, May 2016[15]

3.5.2 Workplace Charging

When considering workplace charging, LowCVP forecasts that 400,000 – 550,000 workplace chargers will be installed by 2050, for cars and vans. In addition, LowCVP predicts that workplaces will install fast chargers up to 22 kW, presumably making use of the more readily available three phase supplies in those settings. Whilst the uptake of workplace charging is forecast to be significantly less than that for home charging, workplace charging is expected to form a clear part of the charging ecosystem.

Summary of Reviewed Roadmaps

- All roadmaps agree that the significant uptake in PIVs will continue for the foreseeable future.
- Domestic charge points will continue as the predominant location for consumer charging. Charge power at these locations is expect to be between 3 kW and 7 kW.
- Charging at places of work will continue to become more common, including charge powers of up to 22 kW using three phase supplies.
- There is a lack of information regarding future trends for battery energy storage capacity. However, recent market announcements strongly indicate a continuation of the trend towards increased battery capacity.

[13] UK Government (2013) "Guidance: Plugged-in Places". Available: https://www.gov.uk/government/publications/plugged-in-places/plugged-in-places
[14] Go Ultra Low (2016) "Go Ultra Low Cities winners announced". Available: https://www.goultralow.com/go-ultra-low-cities-winners-announced/ Accessed 22 June 2016
[15] Zap-Map. Available: https://www.zap-map.com/statistics/#region Accessed 18 May 2016

4. Approach

4.1 Overview

This report aims to set out an overview of the way forward for PIVs, from the perspective of the automotive and charging industries. This has been achieved through confidential interviews with senior individuals at relevant organisations. The outcomes of these discussions have been aggregated by stakeholder group to protect confidentiality, and are summarised in Section 5.

4.2 Stakeholders

The scope for this work is limited to stakeholders in the automotive and PIV charging sectors. The consultation phases of the Smart EV project will include stakeholders from the utilities sector and customer groups. However, the objective of this report is to set out a roadmap for PIV charging, which is best-served by consulting with stakeholders with direct expertise.

This work aimed to capture the views of as wide a range of qualified respondents as possible. Approaches were made through a number of channels, including:

- Contacts built up through delivery of the My Electric Avenue project
- Referrals from other interviewees
- Referrals from project partners
- Direct approaches

Stakeholder responses were collated by grouping stakeholders into five categories. Allocation to categories was based on the stakeholders' responses to interview questions and should not be interpreted as a comment on the nature of the organisation. For example, BEAMA is a representative organisation, not a Charger OEM; their responses were given from the perspective of their members who are Charger OEMs. Therefore, we collated BEAMA's results with PIV Charger OEMs as this was deemed the most appropriate allocation.

The categories and responding organisations are summarised in Table 4. It should be noted that a number of factors led to the relatively low response rates for automotive and charge point OEMs. These included availability of appropriately qualified staff, the high sensitivity of future plans for product roll-out and the non-UK design base for a number of companies.

In addition to the respondents below, a number of organisations have indicated willingness to participate in this work. However, these responses have not been delivered in time for completion of this report. Where possible, late responses will be incorporated into later reports for the Smart EV project.

Table 4 Stakeholders Interviewed for this Task

Group	Numbers		Organisations Interviewed
	Approached	Interviewed	
Automotive OEMs	18	5	Aston Martin Ford London Taxi Company Renault Volvo Cars
Automotive Supply Chain	8	5	Ensira Consulting Fleetdrive Electric Ricardo Tanya Sinclair Transport Research Laboratory
PIV Charger OEMs	14	6	BEAMA EO Charging ICU Charging Equipment Rolec The New Motion Zaptec
PIV Charger Installers	4	4	Elm EV EV Charging Solutions Franklin Energy Mobility House
Governmental and other groups with an overview of the PIV charging industry	6	5	Department of Energy and Climate Change Low Carbon Vehicle Partnership Office for Low Emission Vehicles Transport for London Transport Systems Catapult

4.3 Question Definition

A common questionnaire was used for each interview respondent, some respondents were able to answer from their own product development programmes, others commented from the perspective of the wider industry. The questionnaire was defined to meet the objectives of this task (specifically targeting the future of charge power, battery capacity and charging locations). In addition to meeting the primary objectives of this report, questions were also included relating to controlled PIV charging and to alternative sources of information. A copy of the questionnaire used is shown in Appendix I.

4.4 Interviews

In order to maintain consistency, each interview was conducted via telephone, in sessions of up to 30 minutes, by the same consultant from EA Technology. Interview notes were shared with respondents, who were given the opportunity to make amendments if required.

The confidential nature of the interviews allowed the respondents to be open with their responses. However, it is important to note a number of key limitations to the interview responses:

- Responses were the opinion of the individuals concerned. However, they were suitably senior and experienced that those views are expected to align well to organisational strategies.
- Automotive OEMs exercise considerable care with future strategy and product roadmaps. Most respondents were not in a position to reveal specific plans for the future, beyond those already announced.
- Charger manufacturers are relatively small, agile, companies with significant capability for innovation. A number of respondents indicated that their organisations' current strategies could change quickly if the market shifted.

5. Key Themes

This section draws out the key themes based on the summary of responses given in Appendix II. The first three themes align to the objectives of this work, the remainder are those which have been identified following analysis of responses.

5.1 Charge Power

There was a remarkable degree of consensus across the stakeholders surveyed when discussing the future of PIV charger power requirements. The overriding motivation for specifying charge power is to enable charging within a reasonable timeframe (suggested to mean around 10 hours) despite the trend for increased battery capacities. However, it was also reported that a large proportion of customers in the UK use Mode 2 charge cable, connected to a standard 13 Amp socket, rather than a standalone charge point.

Considering 'slow' and 'fast' charging – AC charge points up to 7 kW (single phase) and 22 kW (three phase) – it is expected that 7 kW chargers will become the standard installation for residential customers. It is unlikely that chargers with capacity above 7 kW will be installed routinely for residential customers, due to the limitations of domestic electricity connections.

Three groups are likely to be an exception to this general rule:

- Residential customers without access to a charge point, who currently use a Mode 2 charge cable connected to a 13 Amp socket.
- Residential and commercial premises with existing three phase connections, particularly commercial premises with fleets which include PIVs.
- Residential customers purchasing luxury PIVs, some of whom are anticipated to be willing to fund the cost of a three phase connection to their homes.
- Residential or commercial sites with multiple PIVs whose charging needs cannot be met with a single 7 kW charger and whose electrical connection makes multiple 7 kW chargers unfeasible.

Rapid charging is beyond the scope of this work. However, it is important to note that there will continue to be a drive for increased charge power from rapid chargers. Both to complement slow/fast charging and to facilitate longer journeys or increased vehicle usage, such as for commercial vehicles or car share schemes. User behaviour regarding the balance of rapid and home charging will influence the infrastructure required to facilitate home and office charging.

Summary: PIV Charge Power

- There will be a rapid adoption of 7 kW home charging units but most households will not upgrade beyond this due to the limitations of typical domestic electricity supplies.
- At present, a large number of EV customers use Mode 2 charging cables connected to 13 Amp sockets, rather than standalone EV charge points.
- Commercial and residential properties are likely to install 22 kW chargers if a three-phase supply is available or if sufficient benefit is found due to number of vehicles requiring charge or use of premium vehicles.
- Rapid charging will continue to complement residential and commercial charging and a watching brief should be maintained on consumer behaviour in this respect.

5.2 Battery Capacity

There is a current trend for increasing battery capacity, with a number of automotive OEMs having recently announced increased battery capacity for existing models[8,9]. The motivation for this behaviour is widely understood: To enable greater range and reduce range anxiety. There are various perspectives on the link between battery capacity and range which are set out in Section 5.6.

It is expected that BEV battery capacity for typical vehicles will approximately double by 2020 to around 40 kWh. However, it should be noted that luxury vehicles are fitted with higher capacity batteries. This may be supplemented by a move from PHEVs to BEVs. Despite the current popularity of PHEVs, a number of respondents expected that there would be a transition towards BEVs over time.

Therefore, we conclude that it is reasonable to expect that battery capacity will approximately double for typical BEVs by 2020; while subsequent growth in average battery capacity will be caused by a market transition away from PHEVs in favour of BEVs.

Summary: PIV Battery Capacity

- It is expected that BEV battery capacity for typical vehicles will double to around 40 kWh by 2020, but there will be limited customer demand for increased battery capacity above that point. However, it should be noted that luxury vehicles are fitted with higher capacity batteries.
- Beyond 2020, average battery capacity will continue to increase due to a transition in the UK PIV market away from PHEVs towards BEVs which typically have higher battery capacities.
- The underlying demand for increased battery capacity is to facilitate greater range. Existing battery capacities, for smaller BEVs, are already sufficient for the needs of the majority of customers. However, a range of at least 200 miles is likely to be required to overcome range anxiety and support a minority of customers who do require this range.

5.3 Charger Location and Scenarios

Home charging is the predominant scenario for PIV charging; there are estimated to be 60,000 domestic chargers in the UK compared to 8,000 public units. Initial PIV uptake, and hence charging location, occurred in 'pockets' across the country. This is influenced by location specific government incentives and the range limitation of early PIVs, which encouraged uptake by drivers with low mileage requirement and access to off-street parking.

PIV uptake and location is not driven by targeted marketing from the automotive sector. However, the economics of PIV ownership have driven a particular group of customer to become early adopters. Early PIV adopters are characterised by access of off-street parking, relatively high income, and a relatively low mileage requirement (often due to urban location or access to an alternative vehicle). There is increased availability of both lower cost BEVs and PHEVs which are based on 'normal' vehicles. Availability of these newer PIVs is shifting the demographic for PIV users away from that of early adopter. However, the immature markets both for charge points suitable for on-street parking, and for second hand PIVs, means the demographic shift away from the early adopter will take a number of years.

The trend for increased availability of workplace charging will continue, as employers install workplace parking, driven by the reduction in fleet costs which can be achieved. Additionally, charging at public charge points will become more prevalent due to market focus on customers without access to off-street parking, particularly in London. This is likely to involve 3 - 7 kW charging near customer homes and increased availability of rapid charging stations. It is not known how customers will use this infrastructure, but where multiple customers share a group of PIV chargers, the usage of that equipment will be markedly different from usage of existing residential chargers.

Summary: Charging Locations and Scenarios

- Residential charging is, and will continue to be, the predominant charging scenario.
- Increased workplace charging, availability of rapid charge points, and infrastructure to serve customers without off-street parking will alter the use patterns of customers from those observed in studies to-date.
- There is no focus from the automotive sector toward a particular demographic group or location. However, the economics of PIV ownership have created an early adopter demographic. Drivers of new PIVs do not necessarily conform to the early adopter demographic and the early adopter demographic will be slowly diluted over the next five years.

5.4 Importance of the Customer

It was widely acknowledged that demand-side response (DSR) through controlled PIV charging appears to be the most cost-effective mechanism to facilitate widespread PIV roll-out. However, respondents were consistent in the requirement that the customer be placed at the centre of development of technologies and business models for this DSR.

There is a clear expectation that a proportion of the value generated by customer response must be received by the customer. Although it was noted that this need not necessarily be a direct payment; incentives such as reduced energy bills or non-financial incentives such as insurance, parking or access to low-emission zones were cited as feasible mechanisms.

There was also a clear concern from respondents that DSR for PIVs could result in a reduction in the quality of the customer experience when using PIVs. If this is the case, then customers will not accept the curtailment of charging for their PIV. Customer requirements for charging are based on required range and retaining confidence in the availability of that range. It is vital that DSR is conducted in a manner which allows customer requirements to be met.

This reinforces the importance of the customer engagement work being conducted as part of the Smart EV project. It is necessary to find an appropriate means of rewarding customers for the value they provide and an appropriate message to ensure controlled charging is viewed as an enabling technology rather than a restrictive technology.

Summary: Importance of the Customer

- A customer-centric approach is necessary to ensure support from all stakeholders for widespread use of controlled charging, particularly in ensuring customers always have access to sufficient range for their needs.
- A proportion of the value provided by the customer flexibility must be used to reward and/or incentivise customers for participation.
- Work is needed to ensure that messaging for customers and stakeholders conveys the value being delivered by controlled charging and avoids the technology being viewed as restrictive.

5.5 Implementation of Controlled Charging

All respondents agreed that controlled charging will become more prevalent as PIV uptake continues, due to the need to facilitate installation of more PIV chargers and the opportunity to build a business case to monetise the value of customer flexibility.

There was awareness of a number of standards and protocols which support uptake of V2G and controlled charging technologies. One standard, IEC EN 61851[16], has been widely adopted by automotive OEMs and allows charge points to limit the charge power used by PIVs. This clearly indicates that existing PIVs can deliver controlled charging, if connected to a suitable charge point.

The capability to instruct charge points to respond to grid requirements is available through a combination of the Open Charge Point Protocol[17] (OCPP) and Open Smart Charging Protocol[18] (OSCP). However, these are not universally adopted and do not provide some of the functionality which is desirable to charge point operators. Additionally, a number of trials and OEMs are investigating provision of demand response through direct interface between utility back office systems and automotive OEM backend systems; this would not require a smart charger.

Summary: Implementation of Controlled Charging

- PIVs currently on the market are capable of varying charge power in response to instruction from a smart charge point, standardised through compliance with IEC EN 61851-1.
- There is no standard mechanism for a utility to access the flexibility available within the PIV. However, a number of protocols and trial systems exist which could partially meet this need if adopted by GB industry as a whole.
- There is consensus that controlled charging can provide value to customer, utilities and automotive stakeholders and has the capability to support increased uptake of PIVs in GB.

5.6 Range Anxiety

The underlying motivation for increased battery capacity, and by extension increased charger power, is the requirement to find a means to overcome range anxiety for consumers. However, there were

[16] BS EN 61851-1:2011 "Electric vehicle conductive charging system. General requirements" Available: http://shop.bsigroup.com/ProductDetail/?pid=000000000030186705
[17] Open Charge Alliance "Open Charge Point Protocol 1.6". Available: http://www.openchargealliance.org/downloads/
[18] Open Charge Alliance (2015) "Open Smart Charging Protocol 1.0". Available: http://www.openchargealliance.org/downloads/

differing views from stakeholders on the means to achieve this. Particularly as the 80-100 miles of range offered by the first generation of BEVs is widely regarded as sufficient for upwards of 90% of customer driving needs.

The automotive sector regards overcoming range anxiety as a key means to facilitate increased PIV uptake. Respondents suggested that the following mechanisms can contribute to reducing range anxiety:

- Increased battery capacity and vehicle range
- Increased availability of rapid charge points along key transit routes
- Increased availability of slow or fast public and workplace charge points
- Visibility of other consumers, particularly friends and family, using PIVs without experiencing range problems.

Each of these means of reducing range anxiety has different levels of cost and difficulty. Automotive stakeholders have highlighted that increased battery capacity adds significant cost to a vehicle, particularly for smaller models. A number of respondents suggested that a real-world range of around 200 miles is expected to be sufficient to overcome range anxiety for most customers, when combined with available public charging infrastructure and visibility of other consumers using the vehicles. However, some respondents suggested that 200 miles would be too great a range and that consumers would be better served by lower cost vehicles. Other respondents highlighted that for luxury vehicles 200 miles of range may be insufficient, while large vehicles will need greater battery capacity to deliver equivalent range.

Summary: Range Anxiety

- The underlying driver for increased battery capacity and charge power is to overcome customers' range anxiety.
- The majority of customer need is served by the range of existing PIVs. The upward trend in battery capacity is due to a need to meet the final 5% - 10% of customer need and to overcome range anxiety.
- Range anxiety can be countered in a number of ways, including increased availability of infrastructure and increased customer familiarity.
- It is expected that battery capacity will stop increasing for most vehicles when 200 miles of range can be offered. However, this has not been tested by the market and it is possible that customers will continue to demand increased range beyond 200 miles, or opt for lower cost vehicles with reduced range.

5.7 Future Technologies

Interview respondents were asked about anticipated future developments which may impact PIV charging in the longer term. Respondents agreed that PIVs and chargers would follow an incremental development cycle, facilitated by the ongoing reduction in cost of PIV batteries and cells. However, respondents did give opinions a number of key technologies which may become mainstream.

5.7.1 Inductive Charging

There have been a number of trials and prototype systems demonstrating the technical feasibility of inductive – or wireless – charging[19]. Respondents who discussed inductive charging were confident that it would be technically feasible but held differing views on the relative costs and benefits.

The benefits of inductive charging were cited in two areas:

- Convenience for customers enabling a more seamless experience for PIV charging
- Allowing opportunistic charging at locations where vehicles regularly stop for short times

These benefits could remove an obstacle to PIV uptake in customer experience and in range for PIVs with high utilisation such as light commercial vehicles; this could drive significant uptake of inductive charging. The technology could also become an optional extra, probably associated with luxury vehicles and remain relatively niche. It is also possible, as a number of respondents suggested, that the benefit case for inductive charging cannot be made and it will be rarely deployed.

From the perspective of distribution network operators (DNOs), the uptake of inductive charging has little impact on residential charging demand. The efficiency loss associated with the technique may drive slightly higher power requirements, but the fundamental demand is unlikely to be significantly different to plug-in charging.

5.7.2 Vehicle to Grid

There was clear understanding amongst respondents of the difference between vehicle to grid (V2G) and controlled charging applications. Technology for V2G was recognised as at a late stage of development and under trial. This is supported by moves towards standardisation such as through IEC 15118[20].

There was a clear difference in opinion between respondents. Some respondents did not expect the additional cost for charger and on-board inverter to deliver sufficient value for customers. Others viewed V2G as a means to support PIV roll-out by providing an ongoing revenue stream to customers.

The Smart EV project must ensure that its outputs both allow for widespread uptake of V2G technology, which is likely to be based on IEC 15118. However, it must also allow for a future scenario where some – or all – of the PIV market is not equipped for V2G.

Summary: New Technologies

- Inductive charging would deliver value to customers. However, the scale of roll-out depends on the value customers find relative to the eventual cost. The uptake, or not, of inductive charging is unlikely to have significant impact on the demand on DNO networks.
- Vehicle to grid technology is close to market readiness but different stakeholders perceive its value very differently. The Smart EV project must produce outputs compatible with any level of V2G uptake.

[19] EA Technology (2016) "UK and International Charging Options" Smart EV Deliverable 1
[20] BS EN ISO 15118-1:2015 "Road vehicles. Vehicle to grid communication interface. General information and use-case definition" Available: http://shop.bsigroup.com/ProductDetail?pid=000000000030315971

6. Conclusions

C1. There will be a rapid adoption of 7 kW home charging units but most households will not upgrade beyond this due to the limitations of residential electricity supplies.

C2. At present, a large number of residential customers use Mode 2 charging cables connected to 13 Amp sockets, rather than standalone EV charge points.

C3. Where three phase supplies are available, or there is significant value in charging multiple vehicles, customers are likely to install 22 kW AC chargers.

C4. Battery capacity for typical electric vehicles will approximately double to around 40 kWh by 2020 and is not expected to increase significantly beyond this point, particularly for smaller vehicles. However, it should be noted that luxury vehicles will be fitted with higher capacity batteries.

C5. Increased battery capacity is a means to overcome range anxiety. It is expected that approximately 200 miles of range (equivalent to 40-50kWh battery capacity for a typical vehicle) will overcome range anxiety. However, this is relatively untested.

C6. Beyond 2020, average battery capacity will continue to increase due to a transition in the GB PIV uptake away from plug-in hybrid vehicles towards battery electric vehicles.

C7. Whilst residential charging will continue to be the most common form of charging, increased availability of public, workplace and rapid charging will change customer behaviour and may reduce energy required from home charging in the longer term.

C8. There is an increasing focus on delivering charging solutions to customers without access to off-street parking. Products to meet this need will emerge in the near future.

C9. Stakeholders are agreed that controlled charging is required to facilitate greater uptake of PIVs. There is a need for a standard mechanism to allow a utility to access the flexibility available where PIV charging can be delayed or reduced.

C10. Controlled charging must be customer-centric and pass some of the benefit of the flexibility back to participating customers. Clear and consistent messaging is vital to ensure the technology is accepted and perceived as an enabler.

Appendix I Questionnaire

Smart EV Project – First Consultation

Background

EA Technology is consulting to understand the current and future charging trends for electric and plug-in vehicles (PIVs). This work is delivered as part of the Smart EV Project on behalf of UK Distribution Network Operators with Scottish and Southern Energy Power Distribution acting as project lead. The Project is motivated by the results of the My Electric Avenue Project which showed that controlled PIV charging has the potential to save electricity customers over £2billion by 2050.

This consultation will inform a roadmap of plug-in vehicle charging types, battery capacities, charging locations and scenarios. It will inform the wider Smart EV Project in developing the content which will lead to a standard for controllable PIV charging, based on this stakeholder engagement. More information on this Project is available in the attached project summary.

We will complete the questionnaire below during our conversation. All information recorded will be treated as strictly confidential unless agreed otherwise.

1. Contact Information

Contact Name and Role	
Organisation Name	
Telephone Number	
Email	
Best description of organisation	Automotive / Utility / Charger Manufacturer / Installer / Supply Chain / Other
Affiliation to industry body and role, if relevant	

2. Plug-in Vehicle Charging

2.1 Could you describe how electric and plug-in vehicles fit within your organisation's strategy and any products/services currently on the market?

2.2 What vehicles or charging types (e.g. charge power, battery capacity, connector types) are your organisation currently deploying?

2.3 Do you focus on particular locations (either geographically or customer demographic) for your current products or services?

3. The Future

3.1 Can you tell us what difference any products or services in your pipeline, but not yet on the market, are likely to make to your answers to Section 2?

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3.2 Can you tell us whether you think there will be significant change to your answers to Section 2 in the longer term (i.e. 5+ years)?

4. Controlled Plug-in Vehicle Charging

4.1 Do your current products or services include support or capability for controlled charging? If so, in what form?

4.2 Do you expect vehicle charging to be remotely controlled or influenced in the future? If so, do you have any comments on the business model for these systems?

4.3 Are you aware of, or developing products or services based on, particular protocols or technologies for controlled plug-in vehicle charging? Please detail if so.

5. Other Information

5.1 Are there any trials or projects in this area which we should know about, either past, current or planned?

5.2 We are looking to consult as widely as possible, is there anyone in your network we should speak to?

5.3 Would you like to be kept informed of Smart EV Project progress?

Thank you for your time. We will share a draft copy of your answers and welcome any comments or corrections you wish to make.

If you have indicated you would like to be kept informed, we will be in touch in June with the next stage in the Smart EV Project

Appendix II Summary of Consultation Responses

This section sets out the collated responses of the respondents, grouped as set out in Table 4. The responses are summarised for each of the key objectives of this report.

Automotive OEMs

Five automotive OEMs, of eighteen contacted, provided a direct response to the Smart EV consultation within the allocated timeframe. Their responses are summarised below, as they relate to the key outcomes of this report.

Plug-in Vehicle Charge Power

Respondents indicated charge power for their vehicles ranging from 3.7kW to 43kW AC with some vehicles capable of higher power DC charging. A mixture of domestic socket, Type 1, Type 2 and rapid charging connectors were also reported. The Type 1 connector is adopted for commonality between the EU and USA. However, there is a growing EU tendency towards standardised adoption of the three phase Type 2 connector. This indicates a fragmented market for PIV charging in terms of connectors and infrastructure. However, there was widespread support and reported compliance with IEC 61851[16] as a means for interaction between PIVs and charge points.

A number of respondents indicated that their organisations were developing capability for increased charge power beyond that available in their current products, particularly for rapid charging. The key motivation for this is a requirement to minimise the time required to charge PIVs, despite increasing battery capacities. Whilst automotive OEMs are reluctant to set out their product roadmaps, for obvious commercial reasons, several expected 7kW AC charging to be commonplace for domestic customers. It was also widely recognised that upgrading electrical capacity to customers is expensive in GB and 7 kW charging is likely to be the highest charge power available to the majority of residential customers.

In contrast to the reports of increasing charge power, one respondent highlighted that around 50% of PIV customers in the UK currently use a Mode 2 charger connected to a 13 Amp domestic socket. Whilst this type of charging clearly limits the available charge for the consumer, its prevalence requires attention when considering controlled charging solutions.

Battery Capacity

Respondents reported PIV battery capacity of between 1.4kWh (for a PHEV) and 23kWh (for a BEV). There was a clear consensus that increased battery capacity was desirable as a means of overcoming customers' range anxiety. However, there were also a number of comments highlighting that a range of around 100 miles is likely to be sufficient for the majority of customers, with daily charging. It was also noted that rapid charging provides an effective means to facilitate longer journeys without increasing battery size. There were a number of comments on the significant cost associated with increased battery capacity and it remains to be seen whether the benefits of increased battery capacity continue to merit the additional vehicle cost.

Charging Location and Scenarios

Automotive OEMs were largely consistent in their response that they do not focus on particular geographies or customer demographics for developing or marketing PIVs. There appears to be a consensus that the PIV market applies across the customer groups associated with individual models. One respondent indicated an ambitious target for EV registration, indicating their commitment to the EV industry. Only one automotive OEM noted that it would expect a different customer demographic for PIVs from its current internal combustion engine models.

There was a strong awareness of charging scenarios from the respondents, broadly falling into three areas:

- 3/7kW AC charging at customer homes and public infrastructure
- Charging, up to 22kW, at commercial premises with a focus on overnight charging
- Rapid charging for vehicles with high utilisation or as a means to enable longer journeys

One respondent suggested they were observing developments in inductive charging whilst another noted that developments in hydrogen fuel vehicles could reduce the demand for rapid vehicle charging.

Controlled Charging

A number of respondents indicated that their vehicles are capable of supporting controlled charging through compliance with IEC 61851[16]. There was a clear separation of thinking from the automotive sector as to controlled charging (i.e. varying charge power to support the grid) and vehicle to grid applications (i.e. bi-directional power flow). There were mixed responses to the need for both controlled charging and V2G, although there was good awareness of IEC 15118[20], and some awareness of OSCP[18] as a means of facilitating controlled charging. Key comments were:

- The economic case - for individual consumers - for both controlled charging and V2G is unproven and customers are unlikely to demand this functionality in their vehicles without clear benefit to them. However, it should be noted that the expected benefit to all customers from controlled charging (£2.2 billion[10]) was acknowledged.

- Respondents agreed that acceptance of any controlled charging solutions by customers would be essential for its success. For this reason, a clear and positive customer focused approach to developing a solution would be preferred by automotive OEMs.

- The cost of V2G capability is non-negligible and automotive OEMs will be reluctant to roll this out without pull from consumers.

- There may be limited desire for controlled charging or V2G from consumers in higher socio-economic groups as the financial incentive may be too small to influence these customers.

- There is a current economic case for load management for fleet customers as the grid connection for a site can create an upper limit on the number of PIVs within a fleet.

- A number of vehicles already include communication and interfaces to allow the OEM and customer to access information and control charging remotely.

- There is concern that increased standardisation could create confusion for the customer, this perception reinforces the need for a clear, robust, customer-engaged messaging strategy.

Finally, respondents expressed concern over liability for damage to the grid if a PIV fails to respond to a reduced charging signal. This indicates requirement for clear commercial agreements and appropriately apportioned responsibility.

Automotive Supply Chain

Six companies from within the automotive supply chain were interviewed, each of which had a focus or expertise in PIVs. These included research agencies, consultants and leasing partners.

Plug-in Vehicle Charge Power

The current prevalence for 3 kW and 7 kW AC charging was acknowledged. There was acknowledgment of a trend towards 7 kW being the default charge power. Two respondents referred to a scenario where 22 kW charging was more common to facilitate reasonable charge times (i.e.

overnight) for larger battery sizes. This was expected particularly at the luxury end of the domestic market and for fleet operators, considering that the cost of increasing household capacity could be prohibitive.

The requirement for availability of high-powered (>50 kW) rapid charging networks was cited by two respondents.

Battery Capacity

The current market norm for battery electric vehicles (BEVs) was cited as 20 – 24 kWh for the majority of vehicles. It was expected that this will increase over time, with one respondent forecasting a doubling of typical battery capacity by 2020. Another factor, highlighted by one respondent is the predicted shift away from PHEVs towards BEVs in the near future, with a corresponding increase in battery capacity.

However, there was a counter argument that the underlying requirement for battery capacity is driven by vehicle range. This requirement can be met in a number of ways, and it is important to note that increased charger infrastructure is a key alternative being explored.

Charging Location and Scenarios

Current locations for PIV charging were noted to be heavily influenced by government incentives, particularly the Plugged-in Places and the Go Ultra Low Cities schemes. Two respondents noted the prevalence of early adopters in the current user base for PIVs, but commented that this is now changing to a wider user base. The current availability of PHEVs for company car fleets is particularly driving this shift; a recent survey was reported to show that 5% of new fleet cars are PHEVs compared with 1% in the general new car garage.

Controlled Charging

The need for controlled charging to support the grid was recognised by all respondents. Two commented that there is an ongoing transition in business model within the automotive sector towards provision of mobility services (such as car clubs or short-term leasing schemes), rather than the traditional model of manufacturing vehicles for sale or lease. The respondents expected that this transition is likely to influence the requirement for grid support in ways which are difficult to anticipate. There was some recognition of the available technologies, specifically OCPP[17]. One respondent stated that standardisation can lag behind the development of technology, citing the importance of futureproofing any ongoing Standards work. However, the main focus from this group was the requirements of customers.

Respondents expected the majority of customers should not be sacrificing anything to enable controlled charging; referencing those customers whose PIV will be fully charged for their next journey whether load is shifted away from peak times or not. This was noted alongside a shift in customer demographic from early adopters to mainstream consumers, who generally may have higher expectations and less understanding of technical limitations. It was also noted that a variety of customer incentives will be key, including access to parking or low-emissions zones. The opinion of one respondent is that customer acceptance is the largest barrier to wide scale controlled charging although another respondent was sceptical of the feasibility of using financial incentives as a means to encourage customers to participate in controlled charging.

PIV Charger OEMs

Five PIV charging equipment manufacturers, of twelve contacted, and one UK based trade body representing the interests of charger OEMs were interviewed for the Smart PIV consultation within the allocated timeframe. Their responses are summarised below, as they relate to the key outcomes of this report.

Charger Capacity

The majority of charging OEMs favour Type 2, Mode 3 connection equipment. This is a three phase connection, compliant with IEC 61851[16] for providing a conductive charging system for AC and DC voltages and control pilot communications. Several manufacturers also supply Type 1 charging equipment which provides similar functions for a single phase system. All respondents offered equipment capable of supplying a range of charging powers from an AC connected network, varying from single to three phase power.

Most charging equipment manufacturers suggested that there is little interest in increasing capacity for AC connected systems beyond 7 kW, at least in the near term future. However, it was suggested that 100% uptake of BEVs would create demand for "super-rapid" chargers capable of delivering in 120 – 300 kW. Another respondent indicated that charging time is a key concern for customers and charging power must increase to engage new customers. Several manufacturers have interest in developing DC charging systems, capable of reducing charging times to address these concerns.

Charger Location/Demographic

The majority of respondents focus on providing domestic scale equipment with supplementary public charging equipment sales. This is driven by the larger volume of sales in the domestic sector; manufacturers suggested slow chargers are common in 'long-stay' locations, such as the workplace or home environment. One respondent reported that they have a UK wide supply area but focus on the demands of 'Go Ultra-Low Cities'[14] where the market encourages PIV uptake. Rapid charging equipment is more readily manufactured for public spaces and short-stay locations, several manufacturers have products specifically for this marketplace. One respondent indicated that rural areas suffered from a lack of charge points and supporting PIV infrastructure limiting the number of vehicles in these areas. A view taken by one respondent is that large scale roll-out of charge points will encourage PIV uptake as it may alleviate range anxiety for customers.

When asked about future perceptions of charger locations and demographic targets, chare point OEMs had varying intentions. Some were focused on continuing to provide domestic solutions whilst others were keen to expand into the public sector. One manufacturer stated that updated building regulations and planning permissions will require the installation of charging stations, which may significantly drive market demand for charging solutions, although they acknowledge issues with existing infrastructure. Several respondents have identified the opportunity to provide on-street public charging with one OEM preparing innovative proposals for the wide scale roll-out of public slow chargers.

Controlled Charging and Future Technologies

OEMs provided their perception of current and future PIV charging options. One technology identified is inductive charging (wireless power transfer); opinion on this technology varied with some expressing interest while others are actively avoiding development. Respondents agreed that it is of interest for future products but is dependent on automotive OEM decisions and would first require standardisation and technology trials; no OEMs have imminent manufacturing plans.

OEMs expressed interest in the development of bi-directional equipment for providing V2G solutions. They are also considering the potential implications of this technology but have indicated no firm intentions.

Controlled charging mechanisms are of interest to the majority of charger OEMs, with most already offering a variety of solutions, including multiple charger load balancing, charging timers and software for the control of internet or locally connected charging stations. There was a trend amongst respondents to use cloud connected management systems to deploy controlled charging solutions for 'intelligent' charging stations. The majority of OEMs indicated that load control had future relevance and expected increasing demand from installers for equipment capable of providing smart charging.

Respondents indicated that most OEMs would quickly respond to market requirements for controlled charging, they also held expectations of how controlled charging could influence the market. For instance, the cost of interrupting services to customers is expected to be the responsibility of the DNO, and that the DNO may stipulate controlled charging as a requirement for connecting Fast or Rapid chargers. Some respondents indicated that a barrier to controlled charging would be customer acceptance and that meeting customer expectations is a significant challenge. Finally, several respondents indicated their support for open protocols such as OCPP for implementing system agnostic communications capable of delivering smart charging solutions.

PIV Charger Installers

Four PIV charging equipment installers provided a direct response to the Smart EV consultation within the allocated timeframe. Their responses are summarised below, as they relate to the key outcomes of this report.

Charger Capacity

Respondents offer a range of charging options, varying from single phase 3 - 7 kW chargers, to three phase 22 kW chargers. The majority of respondents also offer high capacity DC charge points for reduced charging times. It was indicated that the Type 2 connection is the most commonly installed, although several respondents also offered Type 1 leads and adapters. It was indicated that in the UK single phase chargers are common for domestic situations whilst three phase chargers were usually installed in public settings. One respondent's main focus is commercial charging ventures, supplying three phase 22 kW AC and 50 kW DC chargers.

Perceptions of future charger types varied. Whilst some respondents indicated scepticism to the development and uptake of inductive charging options, others were actively investigating its application. Views also varied regarding the future of charging capacity, the consensus being that DC chargers will continue to supply rapid charging solutions whilst AC charging capacity will remain at similar levels. Respondents also indicated an expectation for higher capacity DC chargers to react to increasing driver expectations. All respondents were of the opinion that Type 2 charging connections were likely to continue as the dominant style for slow/fast charging.

Charger Location

Respondents indicated that the majority of charging equipment installation occurs at domestic properties with the public and commercial sector supplementing sales. One respondent highlighted that the domestic market benefits from well positioned rapid charge points; likely due to increased PIV sales due to reduced range anxiety. Where businesses were targeted for installations, the target demographic was mainly larger companies capable of hosting multiple installations.

One respondent indicated that major cities and areas of high footfall were the main target locations for rapid charger installations. Several installers indicated that their geographic scope was limited due to regional ties such as local depots or language barriers.

Concerning future deployment of chargers, the majority of respondents indicated intentions to expand into the public and commercial marketplace.

Controlled Charging and Future Technologies

The majority of respondents indicated familiarity with controlled charging solutions, a common form described was load balancing of multiple charging stations in one location. Respondents stated that these solutions are more common in commercial/public settings with multiple locally connected stations; one respondent currently offers a cloud based system for local load balancing. One respondent had taken part in a domestic controlled charging trial with an automotive OEM to maximise charging at lower electricity prices.

Respondents broadly agreed that demand for controlled charging solutions is rising and back office connectivity is increasingly important, one respondent indicated OEM retrofits may provide a viable solution. One respondent indicated that the requirement to provide charging infrastructure for 20% of car park spaces within London, initiated by the London Plan[21], could significantly drive demand for controlled charging.

The consensus amongst respondents was that V2G technologies are of interest to the market. One respondent is focusing future efforts on providing V2G solutions considering DC bi-directional charging. Several respondents also exhibited interest in energy storage solutions, potentially making use of retired vehicle batteries, to enable rapid DC charging and V2G capability.

Groups with an Overview of the Industry

Three organisations with high-level remits to influence transport strategy were interviewed. These stakeholders provided insight from a perspective which was neutral on technology and open minded when considering the results of existing projects or initiatives. Two organisations also supplied documentation summarising their work in the area of PIV charging.

Plug-in Vehicle Charge Power

The current landscape for residential and commercial customers was described as 3 kW and 7 kW AC chargers. The importance of a rapid charge network, particularly for commercial vehicles, was stressed. It was expected that 7 kW charging would be the upper limit for the majority of residential customers and, by extension, make up the majority of PIV chargers in the UK.

The high level view of these respondents was reflected with one comment that the majority of PIV uptake predictions assume a scenario where all cars are battery electric by 2050. However, it was also pointed out that there is an alternative scenario, supported by a number of automotive organisations, where advanced liquid fuels are able to facilitate ULEV roll-out with an alternative to PIVs. In this scenario, a large proportion of vehicles would be BEVs by 2050, but there would be a significant proportion of other vehicle types using alternative drive train technologies.

The requirement to make PIVs available to the 30% of households without off-street parking was discussed. However, it was considered too early to predict what charge power would be deployed in technologies which enable charging for customers without off-street parking.

Battery Capacity

The roadmaps referenced in Section 3 were cited as the key information regarding battery capacity. Noting the change in vehicle types including the ratio of PHEV to BEV vehicles and the uptake of ULEVs for taxis and private hire vehicles.

Charging Location and Scenarios

It was reported that there are approximately 8,000 public PIV charge points in the UK, and up to 60,000 residential chargers. However, it was noted that it is difficult to verify the number of residential chargers. It was reported that there are currently areas with high PIV uptake in London, Scotland and the Midlands, and a cluster of 22 kW charger points in Northern Ireland. The predominant location for PIV charging was reported to be at customer homes.

[21] London Plan Policy 6.13, Electric Vehicle Charging Points, Available: https://tfl.gov.uk/info-for/urban-planning-and-construction/transport-assessment-guide/guidance-by-transport-type/electric-vehicle-charging-points

When considering London, one respondent reported a study indicating a correlation between PIV uptake and the following factors:

- High household income
- Employment
- Previous purchase of a hybrid vehicle
- Local EV incentives such as parking.

Controlled Charging

The respondents viewed controlled charging of PIVs as something which could support increased uptake and were broadly sympathetic of the need for controlled charging. One respondent made reference to the My Electric Avenue project, by stating *"My Electric Avenue outputs showed controlled charging is key to supporting lowest cost roll out of EV infrastructure".* There was no clear preference for business model or technology to enable this capability although one respondent noted that customer engagement over controlled charging would be best suited to utilities. It was noted that customer benefit is key for the technology to be viewed as an enabler, rather than restrictive.

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