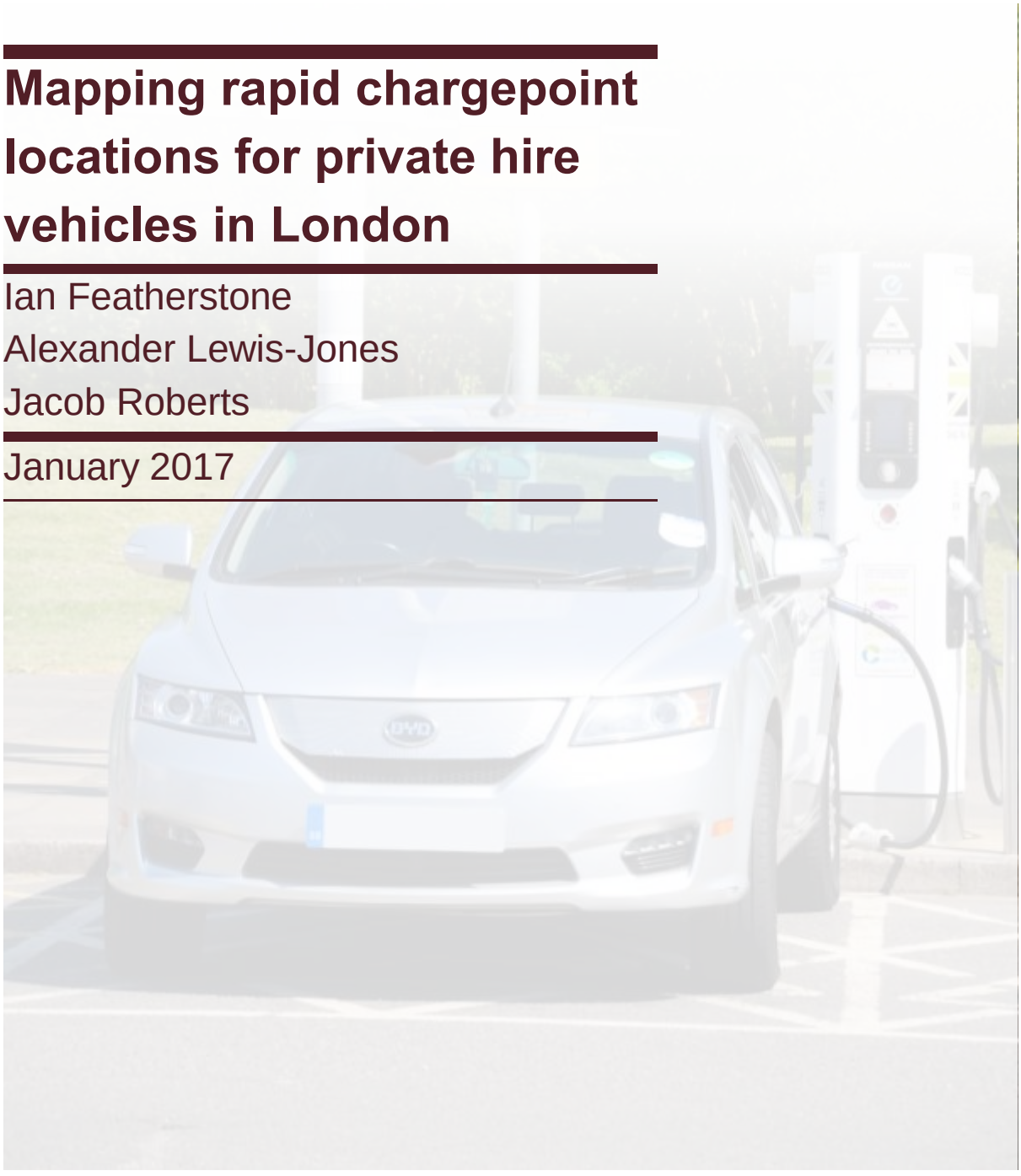
energy saving trust

Mapping rapid chargepoint locations for private hire vehicles in London

Ian Featherstone
Alexander Lewis-Jones
Jacob Roberts

January 2017



EXECUTIVE SUMMARY

INTRODUCTION

London's private hire industry consists of over 86,000 vehicles and Transport for London (TfL) is responsible for the licensing of private hire operators, drivers and vehicles[1]. TfL published its Ultra Low Emission Vehicle Delivery Plan in 2015 to set out the actions needed to increase ULEV uptake in London[2].

As part of a suite of measures to improve air quality in London, TfL is introducing an Ultra-Low Emission Zone (ULEZ) in central London from September 2020. Cars, motorcycles, vans, minibuses, buses, coaches and heavy goods vehicles will need to meet minimum exhaust emission standards or pay a daily charge when travelling in the zone. Private hire vehicles (PHVs) are subject to ULEZ. To further reduce emissions from the taxi and PHV fleets, and increase the number of vehicles capable of operating with zero emissions, TfL is introducing new PHV zero emission capable (ZEC) licensing requirements. Table 1 outlines the new requirements for PHV licensing:

Date	Requirement
1 January 2018	Newly licensed PHVs must be: • Euro 4 if a petrol hybrid. • Euro 6 if any other model.
1 January 2020	Newly licensed PHVs must be: • ZEC if younger than 18 months. • Euro 6 if older than 18 months.
1 January 2023	Newly licensed PHVs must be ZEC.

Table 1 - The current ratcheted requirements for PHVs operating in the ULEZ.

Energy Saving Trust (EST) was commissioned by TfL to set out the requirements of the private hire trade for rapid charging infrastructure, including identifying potential numbers of charge points, how the charge points may be used and illustrative locations for rapid chargepoints to enable the adoption of ULEVs by the private hire trade in London.

This study forms part of a wider suite of research being undertaken by TfL to understand the needs of all commercial users, including taxis, commercial vehicles and car clubs. This research, alongside the results of TfL's market and stakeholder engagement work, will be used to inform TfL's delivery strategy for rapid chargepoints in Greater London.

[1] Licensing information and data updated on a weekly basis is available on the TfL website: https://tfl.gov.uk/info-for/taxis-and-private-hire/licensing/licensing-information
[2] http://content.tfl.gov.uk/ulev-delivery-plan.pdf

The objectives of the study have been met by analysing PHV movements in Greater London and engaging with private hire operators (PHOs) to understand their perceptions about ULEV adoption in London.

BACKGROUND

It is important to consider the capabilities of vehicles currently available and those that could be available by 2020 when the ULEZ is introduced. Vehicle charging infrastructure has developed considerably over recent years, both in terms of charging speed and the ability to monitor usage and this report takes these developments into account throughout.

Plug-in vehicles which include plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs) are fuelled by grid electricity via a chargepoint. PHEVs typically provide a zero-emission driving range of 10-40 miles, BEVs powered only by electricity provide a real world driving range of between 10 and 150 miles.

Both PHEVs and BEVs need be charged from the mains electricity and while a cable fitted with a standard domestic 3 pin plug (BS1363) can be used, it is recommended that dedicated chargepoints are installed for home or workplace charging. The fastest home chargepoints will allow a BEV to be fully recharged in around 4-5 hours, this compares favourably with 12 hours or more when using a domestic 3 pin socket.

Most public chargepoints provide charging capability similar to the fastest home chargepoints, however this report assumes that vehicles will be charged by rapid chargepoints, providing the fastest rate of charge commonly available (43kW AC or 50kW DC). Rapid chargepoints are capable of recharging the battery in a BEV from empty to 80% capacity in 30 minutes and minimise vehicle downtime during the working day.

A PHV in London typically drives 70-100 miles a day, which approximates the range achieved in real world conditions by the most popular BEVs operated by early adopters of the technology in the private hire industry in London and elsewhere. This suggests that there is a realistic opportunity to adopt the vehicles in the London fleet. However, recharging the vehicles during the working day will be necessary due to variations in day to day business demand and a requirement for publically accessible charging infrastructure for those drivers who don’t have access to off-road charging, such as a private driveway.

Three often cited barriers to the adoption of ULEVs are vehicle range, cost and availability of charging infrastructure. The private hire trade in London, while expressing similar concerns accept that a transition to cleaner vehicles is necessary.

METHODOLOGY

The movement and distribution of PHVs in Greater London was determined using telematics data which monitors the location and activity of vehicles. Analysis of the data in combination with stakeholder interviews was used to determine illustrative locations for charging infrastructure and the appetite of operators to adopt ULEVs.

To analyse the potential for ULEV adoption, vehicles currently in use by PHOs in the stakeholder group were matched against the nearest equivalent BEVs currently available. Currently there are no PHEVs suitable for adoption as private hire vehicles in London which can be rapid charged and it is considered that there will be few, if any available in 2020. A wider choice of BEV models is however anticipated, with greater range capabilities than typical today.

The stakeholder interviews with PHOs were structured to determine the nature of the individual operations and the operator's views on the viability of operating ZEC PHVs in Greater London. Aspects covered the number of vehicles operated, vehicle ownership model, vehicle use including geographical coverage and mileage and any experience of trialling or operating ULEVs.

TELEMATICS ANALYSIS

A data sample from 1,748 cars was provided by four of the contributors. These fleets represent a cross section of the private hire industry in London, in terms of vehicle fleet composition, operational model and geographic coverage.

The vehicles used by the fleets was analysed and three common vehicle types emerged which were matched with currently available BEV equivalents.

The telematics and vehicle data was passed to Route Monkey where the vehicle range capability of the BEVs was matched with the routes taken and mileage covered by the vehicles each day. This analysis allows illustrative locations for chargepoints to be identified along with the number of times each chargepoint would be used over a period of time.

The vehicle movement analysis identifies a need for a wide spatial distribution of chargepoints across Greater London to service the requirements of the private hire trade. The density of the required chargepoint network increases with proximity to central London, mirroring the frequency of journeys. A number of the illustrative locations fall on or near to major arterial routes into London as well as in proximity to the north and south circular roads. The mapping would appear to support the view of many of the operators interviewed that rapid chargepoints are required on arterial roads and the north and south circular to support commuting and longer distance fares.

It is estimated that a total of 140 chargepoints sited at up to 78 locations will be required to meet the anticipated number of rapid charge capable PHVs on the road at the end of 2020.

There is an opportunity for the taxi and car club trades and other commercial operators to use the network, increasing chargepoint utilisation across the large geographical area, thus making it more commercially attractive to investors and network operators.

STAKEHOLDER INTERVIEWS

Energy Saving Trust (EST) held interviews with six organisations in the private hire trade (Addison Lee, eConnect Cars, GLH, Karhoo, Tristar, Uber). These were chosen to represent a range of businesses across the industry, from executive travel to pure electric fleets.

All of the organisations interviewed have experience of using petrol electric hybrid vehicles or, in the case of eConnect Cars, Battery Electric Vehicles (BEVs) only. All would be happy to use ULEVs in their businesses assuming the perceived and actual barriers can be overcome.

PHOs recognise that pure electric vehicles are desirable, assuming vehicle specification, range and charging concerns can be overcome. Most companies are trialling BEVs in London or elsewhere. Uber, for example, trialled 50 BEVs during 2016. The industry is, therefore, starting to understand the implications of using the vehicles.

Driver feedback is positive in terms of vehicle performance and the running costs of petrol electric hybrid vehicles and where licenced, BEVs. However, a number of issues have been identified that will need to be addressed for the widespread adoption of ULEVs (plug-in hybrid as well as pure electric) throughout the private hire industry.

For PHOs whose drivers purchase their own vehicles, the typical barriers of cost and reliability still exist. On the other hand, for those PHOs which purchase their own vehicles and rent them to drivers, these barriers can be mitigated, by the willingness of drivers to pay a small premium for ULEVs in exchange for lower running costs. Range was not found to be an overt concern, as the majority of journeys take place within Greater London and fall within the range of a typical BEV.

Drivers' working patterns, hours worked and geographical locations covered vary between operators, however there is a concentration of activity in the West End, the City of London, North West London and to and from Heathrow airport. Breaks taken during quiet morning and afternoon periods provide opportunities for charging and many live outside London and commute into the city to work. Most drivers take their vehicles home at the end of their shift.

Operators are concerned about the current shortage of charging infrastructure in London, **which is being addressed by TfL investing in a rapid charging network.** Rapid charging is the preferred option for operators, however a frequently mentioned barrier is the lack of home or between shift charging options available to drivers. Charging at this time is the most cost effective and also ensures that vehicles begin their shift on a full charge. For drivers with off-street parking, a

chargepoint can often be installed at home. Currently drivers can benefit from the OLEV Electric Vehicle Homecharge Scheme providing a 75% contribution to the cost of a chargepoint and its installation up to £500 including VAT (from 1st March 2016).

It became apparent that the majority of drivers do not live in a property with off-street parking[3]. It was suggested by all interviewees that the provision of home-charge capability for drivers without off-street parking is a consideration that needs to be addressed.

TfL and the London boroughs are investing through the Go Ultra Low City Scheme to deliver 1,150 on-street residential chargepoints in London for ULEV drivers without access to off-street parking.

RECOMENDATIONS & CONCLUSION

Based on the interviews with operators and the results of the vehicle route analysis the measures listed should be considered to encourage the uptake of ULEVs in London's private hire industry.

1. **Continue dialogue between chargepoint providers and the trade.** There is a limited understanding of the plans to increase the number of chargepoints in London and current TfL dialogue with the trade could, perhaps through a working group, encourage trade involvement with the network operators once appointed. This group could also be a platform for technical help where vehicles currently on the market may be technically suitable but the operator does not currently allow their use. Further engagement with the trade to determine their actual requirements and encourage the adoption of the vehicles is therefore required.
2. **Investigate on-street home-charging requirements.** The importance of home-charging capability for the drivers was frequently made, as this was considered the most convenient and cost-effective time and place to charge. However, a barrier exists where PHV drivers live in properties where no off-street parking is available, leaving them with no means by which to charge. It is believed that this applies to the majority of drivers, but knowledge of this is limited. Further research is recommended.
3. **Install infrastructure ahead of demand.** Concerns were expressed about the existing chargepoint infrastructure in Greater London. These concerns focus on the perceived lack of growth in London's fast and rapid chargepoint network and the poor reliability record of the existing infrastructure. It is recommended that the network of fast and rapid chargepoints in London be expanded to exceed early demand.

[3] It should be noted that data is not routinely collected by PHOs on whether their drivers live in properties with off-street parking. This statement is based on the assumptive opinion of PHO management, but these opinions were made with a good degree of confidence.

4. **Provide charging infrastructure for PHEVs.** With the ZEC requirement for new PHVs in the ULEZ mirroring the OLEV Plug-in Car Grant performance requirements, it is a possibility that operators and drivers will opt for plug-in hybrids with limited electrically driven range and drive them as a conventional hybrid. A fleet of ZEC vehicles powered only by their internal combustion engines is not desirable and the provision of on-street charging infrastructure enabling end of shift charging is as important for PHEVs as it is BEVs. We recommend therefore that additional fast chargepoints are installed alongside the rapid chargepoints where possible, allowing recharging of PHEVs during the working day.
5. **Monitor reliability of existing infrastructure.** Regardless of how comprehensive the current or future chargepoint network will be, if it is not perceived to be reliable PHOs have expressed that they will not use the public chargepoint network and their uptake of ULEVs will be limited.
6. **Engage with ULEV manufacturers.** There is a limited number of BEVs available which satisfy the passenger and luggage capacity requirements of many operators. It is recommended that engagement with the vehicle manufacturers takes place to identify models which will become available in the future which meet the requirements of PHOs. In the absence of a wider range of models being available, the uptake of BEVs will be limited.
7. **Work with private hire operators to secure incentives for drivers.** This could include signposting to information about ULEVs, including the Electric Vehicle Home Charge Scheme, Go Ultra Low City Scheme provision of residential charging, driver training, chargepoint operation and other material explaining the environmental and financial benefits of ULEV adoption.
8. **Further explore the opportunities for geo-fencing.** The ability to geo-fence PHEVs to ensure they are predominantly driven by electricity in the ULEZ could further reduce the emissions of pollutants in London.
9. **Engage with the taxi trade and commercial vehicle operators.** The vehicle movement analysis identifies a need for a wide spatial distribution of chargepoints across Greater London to service the requirements of the private hire trade. In order for the less frequently used chargepoints to be economically viable for operators to install, they will need, particularly in the early years of the ULEZ, to be used by the taxi trade and the wider business community.

CONCLUSION

There is a great opportunity to migrate the London private hire trade to ULEVs over the ten-year replacement cycle of the fleet following the introduction of the ULEZ. The distances driven by PHVs on a daily basis provide drivers moving to ULEVs with a significant saving in terms of “fuel” cost. There is an appetite within the trade to accelerate this rate of adoption assuming that a reliable, cost effective rapid chargepoint network is put in place.

CONTENTS

INTRODUCTION

London's private hire industry consists of over 86,000 vehicles and Transport for London (TfL) is responsible for the licensing of private hire operators, drivers and vehicles[4]. TfL published its Ultra Low Emission Vehicle Delivery Plan in 2015 to set out the actions needed to increase ULEV uptake in London[5].

As part of a suite of measures to improve air quality in London, TfL is introducing an Ultra-Low Emission Zone (ULEZ) in central London from September 2020. Cars, motorcycles, vans, minibuses, buses, coaches and heavy goods vehicles will need to meet minimum exhaust emission standards or pay a daily charge when travelling in the zone. Private hire vehicles (PHVs) are subject to ULEZ. To further reduce emissions from the taxi and PHV fleets, and increase the number of vehicles capable of operating with zero emissions, TfL is introducing new PHV zero emission capable licensing requirements. Table 2 outlines the new requirements for PHV licensing:

Date	Requirement
1 January 2018	Newly licensed PHVs must be: • Euro 4 if a petrol hybrid. • Euro 6 if any other model.
1 January 2020	Newly licensed PHVs must be: • ZEC if younger than 18 months. • Euro 6 if older than 18 months.
1 January 2023	Newly licensed PHVs must be ZEC.

Table 2 - The current ratcheted requirements for PHVs operating in the ULEZ.

ULEVs are considered to be Zero Emission Capable (ZEC), in that, for extended periods of time they can run without emissions. Models currently on sale are typically battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs).[6] A transition from internal combustion engine (ICE) vehicles to ZEC vehicles will also mean a transition from liquid and gas refuelling infrastructure to electric recharging infrastructure. To support this transition, TfL is investing in charging infrastructure, including a rapid chargepoint network across London which will be available to PHVs and other ULEVs[7].

This report seeks to understand where this chargepoint infrastructure would be most suitably located. Energy Saving Trust (EST) has engaged with the private hire industry to understand PHV movements across Greater London and the perceived and actual barriers to the adoption of ULEVs. In doing so, this report forms a robust

[4] Licensing information and data updated on a weekly basis is available on the TfL website: https://tfl.gov.uk/info-for/taxis-and-private-hire/licensing/licensing-information
[5] http://content.tfl.gov.uk/ulev-delivery-plan.pdf
[6] Further detail on the vehicle types is available in the Glossary of Terms, in the Appendix.
[7] ULEV Delivery Plan, http://content.tfl.gov.uk/ulev-delivery-plan.pdf

understanding of steps to take to make this aspect of the implementation of the ULEZ a success.

PROJECT OVERVIEW

EST was commissioned by TfL to set out the requirements of the private hire trade for rapid charging infrastructure, including identifying potential numbers of charge points, how the charge points may be used and illustrative locations for rapid chargepoints to enable the adoption of ULEVs by the private hire trade in London.

This study forms part of a wider suite of research being undertaken by TfL to understand the needs of all commercial users, including taxis, commercial vehicles and car clubs. This research, alongside the results of TfL's market and stakeholder engagement work, will be used to inform TfL's delivery strategy for rapid chargepoints in Greater London.

PROJECT OBJECTIVES

The project identifies illustrative locations for rapid chargepoints to support the uptake of ZEC PHVs in London and highlights where cost efficiency may be increased by siting infrastructure such that it could be used by multiple drivers and operators. The research achieves this overall objective by:

1. Analysing PHV movements in Greater London and the feasibility for transitioning these movements to ULEVs.
2. Engaging with PHOs to understand their engagement with and perceptions regarding ULEV adoption in Greater London.

CONTRIBUTORS

EST is an independent, not-for-profit organisation, organised as a social enterprise with charitable status. It has engaged with hundreds of organisations, helping them to reduce fleet-related emissions and costs.

For telematics data analysis, EST worked with Route Monkey, a vehicle scheduling business specialising in electric vehicle route analysis and optimisation.

For stakeholder engagement and telematics data provision, EST is grateful to the following organisations within the private hire industry for their contribution to the project:

- Addison Lee
- eConnect Cars
- GLH
- Karhoo
- London Private Hire Car Association

- Tristar Worldwide Chauffeurs
- Uber

BACKGROUND

This section summarises the vehicle categories and chargepoint infrastructure referred to throughout this report and the opportunities and barriers to ULEV adoption by the private hire trade.

Vehicle and chargepoint technology is covered in greater detail in Appendix 1.

ELECTRIC VEHICLES

Conventional vehicles burn their fuel in an internal combustion engine (ICE) which drives the wheels via a gearbox. This is the most common form of vehicle on the road today and includes vehicles running on road fuel gas (such as LPG).

Plug-in vehicles are distinctive in that they are fuelled by grid electricity via a chargepoint. A plug-in hybrid electric vehicle (PHEV) resembles a conventional hybrid (such as a Toyota Prius, popular in the private hire trade in London) but has additional battery capacity which enables a longer electrically driven range, typically 10 to 40 miles. Once the battery charge is depleted the vehicle operates as a conventional hybrid.

A battery electric vehicle (BEV) or a pure EV is powered only by electricity and is usually fitted with a larger battery than a PHEV to provide a significant driving range usually between 80 and 150 miles in real world driving conditions.

This report uses the TfL definition Zero Emission Capable (ZEC) which includes any vehicle capable of being driven over significant distances without any tailpipe emissions.

The UK Government and the Office for Low Emission Vehicles (OLEV) define ZEC vehicles which fall into the categories in table 3 below, as Ultra Low Emission Vehicles (ULEVs). Grants of 35% of the cost of a car up to the limits shown in the table are currently available for their purchase.[8]

[8] Further information on OLEV grants available on the OLEV website: https://www.gov.uk/plug-in-car-van-grants/what-youll-get

	Category 1	Category 2	Category 3
CO_2	< 50g/km	< 50g/km	50 – 75g/km
Zero emission range (miles)	70 +	10 – 69	20+
Maximum grant	£4,500	£2,500	£2,500
Price cap	-	£60,000	

Table 3 - ULEV categories for cars and purchase grants available; source OLEV.

CHARGING

An electric vehicle needs be charged from the mains electricity and while a cable fitted with a standard domestic 3 pin plug (BS1363) can be used, it is recommended that dedicated chargepoints are installed for home or workplace charging which are usually rated at 16 amps (providing c. 3.5 kW) or optionally for faster charging, at 32 amps (providing c.7kW). At 7kW a typical BEV would be recharged in around 4-5 hours.

OLEV currently provide a series of grants for charging infrastructure:

- The Electric Vehicle Homecharge Scheme[9] offers individuals who are the registered keeper, lessee or have primary use of an eligible vehicle up to 75%, capped at £500 incl VAT, off the total capital costs of a chargepoint and associated installation costs.
- The OLEV Workplace Charging Scheme[10] provides grants for installing chargepoints of £300 per socket, for up to 20 sockets. This scheme may be useful for private hire operators with suitable premises.

Additionally, many vehicle manufacturers subsidise home chargepoints, car dealers will be able to provide details of offers currently available.

Public chargepoints are usually rated at 3.5 or 7 kW, however faster charging rates at 22kW are available in some locations. Not all ZEC vehicles are able to take advantage of this faster rate of charge however, which will recharge a typical BEV in less than two hours.

[9] https://www.gov.uk/government/collections/government-grants-for-low-emission-vehicles#electric-vehicle-homecharge-scheme
[10] https://www.gov.uk/government/publications/workplace-charging-scheme-guidance-for-applicants-installers-and-manufacturers

This report assumes that vehicles will be charged by rapid chargepoints providing the fastest rate of charge commonly available (43kW AC or 50kW DC).

Figure 1 below illustrates the benefits of rapid charging the time available for charging a vehicle is constrained.

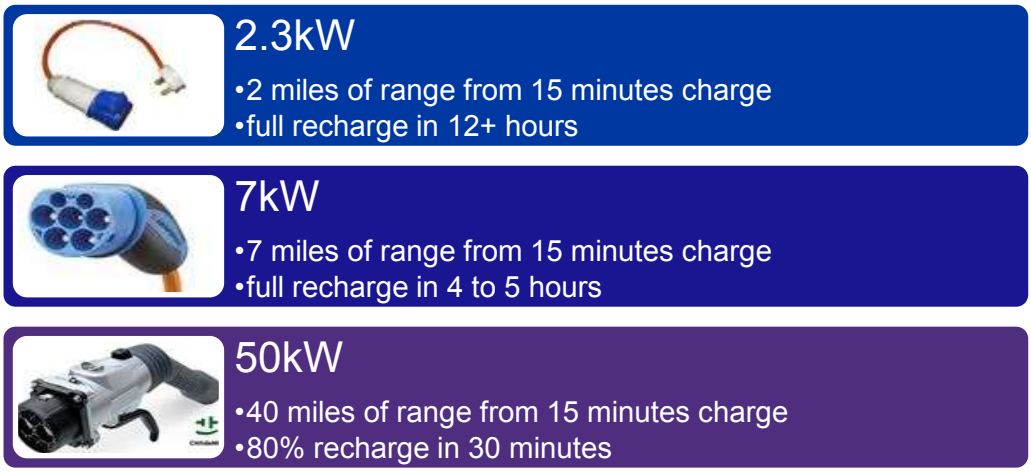


Figure 1 - Charging speed and typical increases in range from a 15 minute charge. Actual mileage gains and time taken to charge will vary by vehicle model.

ULEV ADOPTION – OPPORTUNITIES AND BARRIERS

With a vehicle parc exceeding 86,000 vehicles, converting the London private hire fleet to ULEVs has great potential to make a significant positive contribution to air quality in the city. Buses, taxis and PHVs all operate in highly populated areas and reducing the air pollutant emissions (primarily oxides of nitrogen (NOx) and particulate matter) of these vehicles is therefore particularly beneficial.

A PHV in London typically drives 70-100 miles a day, which approximates the range achieved in real world conditions by the most popular BEVs operated by early adopters of the technology in the private hire industry. This suggests that there is a realistic opportunity to adopt the vehicles in the London fleet. However, recharging the vehicles during the working day will be necessary due to variations in day to day business demand (mileage driven) and the fact that many drivers will not have off-shift access to charging infrastructure (a chargepoint located on a private driveway, for example). They will need therefore to be able to rely on a reliable, publically available, chargepoint network.

It is commonly considered that there are three main barriers to the mass-market adoption of ULEVs:

- Range
- Cost
- Availability of charging infrastructure

RANGE

Range is generally regarded as the greatest concern facing prospective ULEV buyers. Within this issue, there are three main factors. First is that the maximum range of BEVs on a single charge is not perceived to be sufficient to make long distance journeys. Second is that BEVs are perceived to take a considerable length of time to charge, with even the fastest chargers still requiring roughly 30 minutes for an 80% charge. Lastly, the network of charging locations – both urban and extra-urban – is still developing and is perceived as being sparse and unreliable, which can lead to 'range anxiety'.

For PHOs in London, the maximum range of BEVs is of lesser concern than it may otherwise be for many other commercial and private users. This is because the vast majority of fares accepted by PHVs begin and end within the boundaries of Greater London and as private hire journeys are booked in advance, operators are able to allocate longer distance fares to a vehicle where range is no issue, such as an ICE vehicle, a conventional hybrid or a PHEV. This also minimises the risk of a journey being allocated to a vehicle with insufficient battery charge to complete the fare.

Similarly, the time needed to recharge a BEV is often of less concern to PHOs than it might be for other organisations. In an industry where demand peaks and troughs during the day, finding time to recharge is not generally regarded as an insurmountable challenge and, at worst, is a worthy sacrifice for the potential fuel-associated cost savings and health benefits to the inhabitants of the city which ULEVs bring.

The main concern expressed by London's PHOs at the present time centres around the existing chargepoint network. In order to operate BEVs, PHOs require fast (20kW DC/22kW AC) or, more ideally, rapid (43kW AC/50kW DC) charging infrastructure to minimise impact on working time. Slow chargers (3.5kW AC) and lower specification fast chargers (7kW AC) are of limited use to PHOs operating BEVs except for charging vehicles off-shift or where there is a significant period of downtime during the working day. The network of fast and rapid charging infrastructure in London is currently not sufficient, in capacity or coverage, to meet the requirements of PHOs in London were they to adopt BEVs across the board. This is why TfL is investing to increase the amount and range of charging infrastructure in London**.** The existing infrastructure has a reputation for being unreliable although this has improved significantly in the recent past. This perceived or actual unreliability is not conducive to running a business in the private hire industry – where confidence in vehicle availability to meet customer requirements is vital for service continuity.

COST

For private vehicle owners, the upfront cost of purchasing an ULEV may be a barrier to their adoption. In the context of private ownership, return on investment (ROI) is often difficult to calculate, if a consideration at all, making the long-term cost savings associated with purchasing an ULEV somewhat uncertain. However, for PHOs and their drivers, fuelling costs are well known and form a significant proportion of overall operating costs. Combining known fuelling costs with mileage projections puts PHOs in a position where they can forecast, with a degree of accuracy, the financial viability of operating ULEVs.

In discussions with London PHOs who purchase their own vehicles and rent them to drivers, it is appreciated that the upfront cost of purchasing ULEVs can be balanced by the overall return on investment (ROI) allowing a business case to be made. Factoring in other mitigated expenses, such as the charge to enter London's ULEZ from 2020 onwards, it is evident that upfront cost is not a significant barrier to ULEV adoption for PHOs who purchase vehicles to lease to their drivers. Reduced fuelling costs are assumed for BEVs; one operator interviewed has operated conventional petrol hybrid executive cars alongside equivalent diesels and reports that their fuel consumption is slightly better than the diesel models when operated in Greater London. This bodes well as more PHEV derivatives of vehicles popular in the private hire trade in London become available.

Upfront cost may be a greater barrier for PHOs where the drivers purchase their own vehicles. In discussions with operators it became apparent that they often exercise only limited control over the vehicles their drivers purchase or rent. With that in mind, as is the case with private vehicle buyers, the upfront cost of the vehicles may be a significant barrier to their adoption which may not be overcome by a simple ROI calculation. It is likely that drivers will require incentives and support from their respective PHOs until the overall savings available are recognised.

RELIABILITY

A common misconception is that ULEV technology is new, unfamiliar and therefore potentially unreliable. In many respects, the opposite is true. In mechanical terms, with far fewer moving parts, there is less to go wrong and certain items such as brake pads and discs should last significantly longer due to the use of regenerative braking.

The most significant concern raised by operators and drivers is the life of the battery. Manufacturers provide extensive battery warranties and some manufacturers, Nissan, for example, quote a price for replacement batteries. It is encouraging that early adopters of the technology in the industry are rapid charging their vehicles on a daily basis and reporting negligible battery degradation.

PHOs who purchase vehicles and rent them to drivers can exercise considerable buying power. One of the companies interviewed replace their vehicles every three

years, during which period battery longevity is unlikely to become an issue and a significant warranty period remains available to subsequent owners of the vehicles.

Concerns relating to battery longevity are more relevant to PHOs whose drivers purchase their own vehicles, particularly where cars are purchased second hand, reducing the remaining term of any warranty.

METHODOLOGY

Quantitative and qualitative research methods have been adopted in the preparation of this report. Analysis of the movement and distribution of PHVs in Greater London through telematics analysis was combined with stakeholder interviews to determine illustrative locations for charging infrastructure and the appetite of operators to adopt ULEVs. These are outlined in detail in the following sections.

TELEMATICS ANALYSIS

To understand PHV movements around Greater London, telematics data covering a number of private hire fleets was analysed. Telematics describe technologies which can be used to capture vehicle data, typically monitoring the location and activity of a vehicle. PHOs commonly install telematics systems into their vehicles to enable them to understand the location and availability of their fleet. Specific information collected for this report is listed in Table 4 below.

Information	Format
Vehicle identification	VRN
Time/Date stamp	Time/Date
Journey start location	Postcode/ coordinates
Journey stop location	Postcode/coordinates
Journey distance	Miles

Table 4 - Information obtained from telematics data used for analysis.

A data sample from 1,748 cars was provided by four of the contributors. These fleets represent a cross section of the private hire industry in London, in terms of vehicle fleet composition, operational model and geographic coverage.

The stakeholders' businesses varied widely and there were considerable variations in the datasets. Key differences included:

- Vehicles operated (make and model)
- Timespan (both date and duration of the data)
- Format (how the data was structured)
- Detail (the number of fields covered in the data).

These differences were taken into consideration and datasets standardised to allow a combined analysis of the four fleets' data.

VEHICLE SPECIFICATION

To analyse the potential for ULEV adoption, the specifications of the vehicles currently in operation within the stakeholder group were matched against equivalent

BEVs based on those currently available. Currently there are no PHEVs suitable for adoption as private hire vehicles in London which can be rapid charged and it is considered that there will be few if any available in 2020. More likely is the wider availability of BEV models with greater range capabilities than typical today.

It was acknowledged that in a number of cases like-for-like BEV equivalents are not currently available. In these examples an equivalent BEV was assumed, using a simulated specification in line with the specifications of vehicles expected to be on the market within five years[11].

STAKEHOLDER INTERVIEWS

To understand the current views of private hire operators in relation to the adoption of ULEVs, semi-structured interviews were carried out with the participants listed in the Project Overview section.

Semi-structured interviews were chosen to both identify specific data and explore the barriers and opportunities for the uptake of ULEVs. The flexible framework of the interview allowed for a two-way conversation that maximises the potential for usable data.

Interviews with PHOs were structured around the following themes to determine both the nature of the individual operations and the operator's views on the viability of operating ZEC PHVs in Greater London.

1. Fleet data including the number of vehicles operated and ownership model
2. Vehicle use including geographical coverage and typical daily mileages
3. Experience of trialling or operating ULEVs.

Operators willing to provide telematics and vehicle data were provided with the specification of the information required.

[11] Details of vehicle specification data are available in the Appendix.

TELEMATICS ANALYSIS

Telematics data was provided by four of the fleets participating in the study for analysis. This section describes the ZEC alternative models used for the analysis as well as presenting the findings of the analysis carried out by Route Monkey.

VEHICLE SPECIFICATIONS

Vehicle models operated in the private hire industry vary based to a greater or lesser extent on the specific service they provide. Categories of common vehicles emerged from analysis of the vehicles used by the fleets. A BEV equivalent was selected in each case based on vehicle size and seating capacity as illustrated in figure 2.

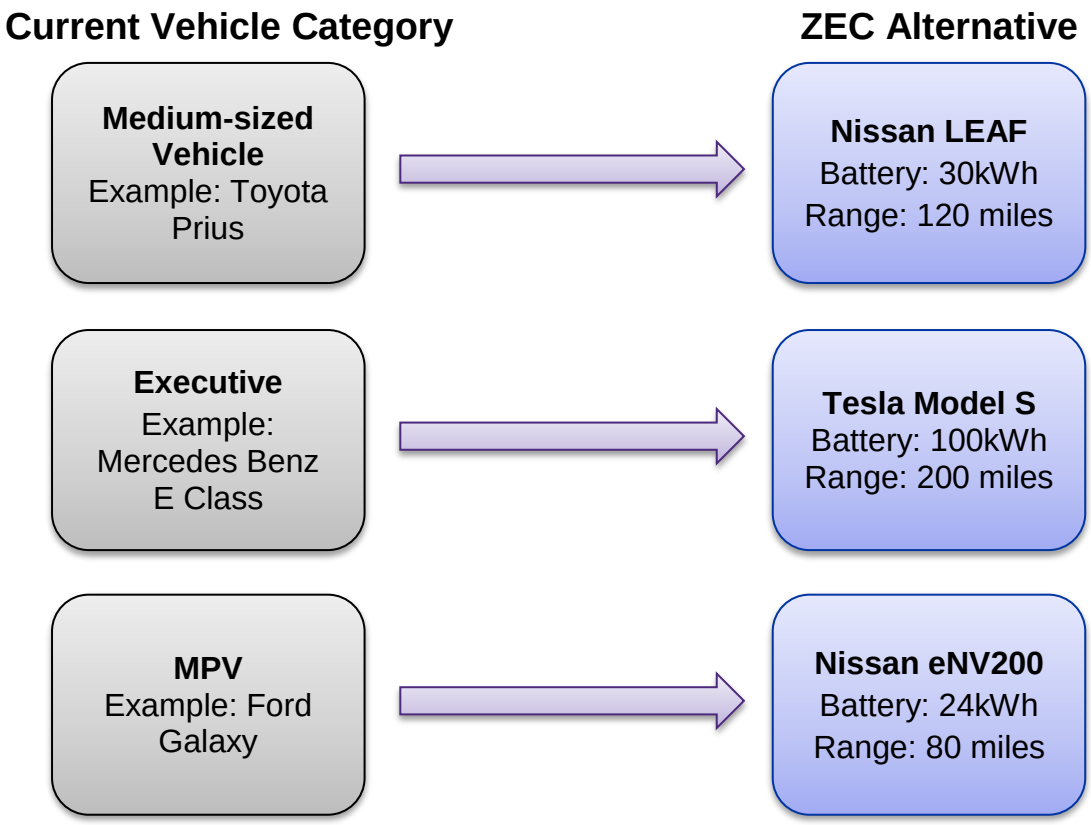


Figure 2 - Vehicle categories and selected ZEC alternatives' specifications. These specifications were used to inform the telematics analysis.

It should be noted that range assumptions made are either real world estimations in the case of the Nissan Leaf and eNV200 or the minimum real world range for future executive vehicles expected to be launched by 2020 by a number of manufacturers, and likely to be of a comparable size and energy consumption to the Tesla Model S.

ROUTE AND CHARGEPOINT ANALYSIS

The telematics data available does not identify whether PHV drivers have access to overnight charging. An overnight charge would make a dramatic difference to the adoption potential of plug in vehicles. Furthermore, not all datasets came with home postcodes for the drivers of the journeys sampled. Because of this, the analysis assumed that no drivers had access to an overnight charge, giving the extreme end of the requirement for publically available chargepoint infrastructure.

The telematics and vehicle specification data was passed to Route Monkey to establish vehicle feasibility and illustrative chargepoint locations. The following summarises the methodology employed by Route Monkey for this analysis:

- Data quality checked to ensure that it included full postcode or longitude and latitude coordinates to enable vehicle movements to be determined and that the data spanned the period requested
- Existing fleet list reviewed to determine the appropriate BEV specification was used in each case
- 30 minute rapid charging events were assumed and incorporated into route analysis
- Route Monkey algorithms applied to the journey data to generate mileage and route results
- Routes not suitable for ULEVs were identified
- Routes identified as potentially suitable for a ULEV were run through additional algorithms to generate potential chargepoint location(s) for that route
- Locations where existing rapid charging infrastructure is already installed were identified for recharging the vehicles being analysed[12]
- New locations where charging infrastructure is required were identified
- Data was filtered to identify and discount routes not requiring a chargepoint within the M25
- Data was scaled to seven days to allow comparison between fleets and show expected weekly chargepoint usage
- Utilisation analysis was performed to determine the total number of rapid charges across all participants which are scheduled to take place at each chargepoint
- Summary chargepoint map was produced to display proposed locations
- Heat map of chargepoint locations mapped together with individual co-ordinates, a reference number and utilisation forecasts.

The findings from Route Monkey's report, including the chargepoint heat map, are summarised in the next section.

[12] It should be noted that some of the existing infrastructure as identified is not fully publically available, for example there may be access or time of use restrictions for rapid chargepoints located on vehicle dealer premises.

These findings were used to propose a total number of rapid chargepoints required across the anticipated 2020 private hire ZEC fleet. To establish this, a number of assumptions and calculations had to be made. Figure 3 provides an overview of this process[13].

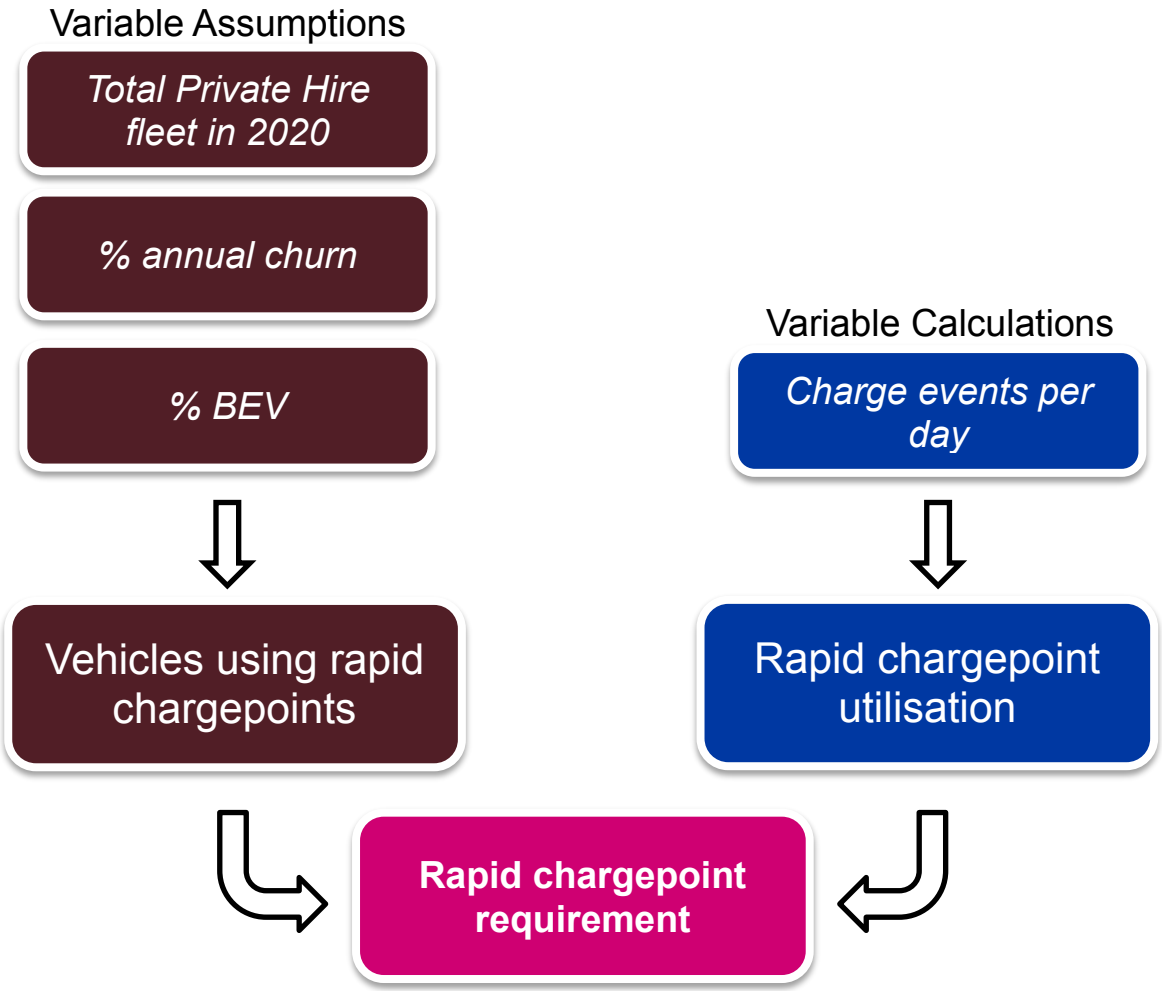
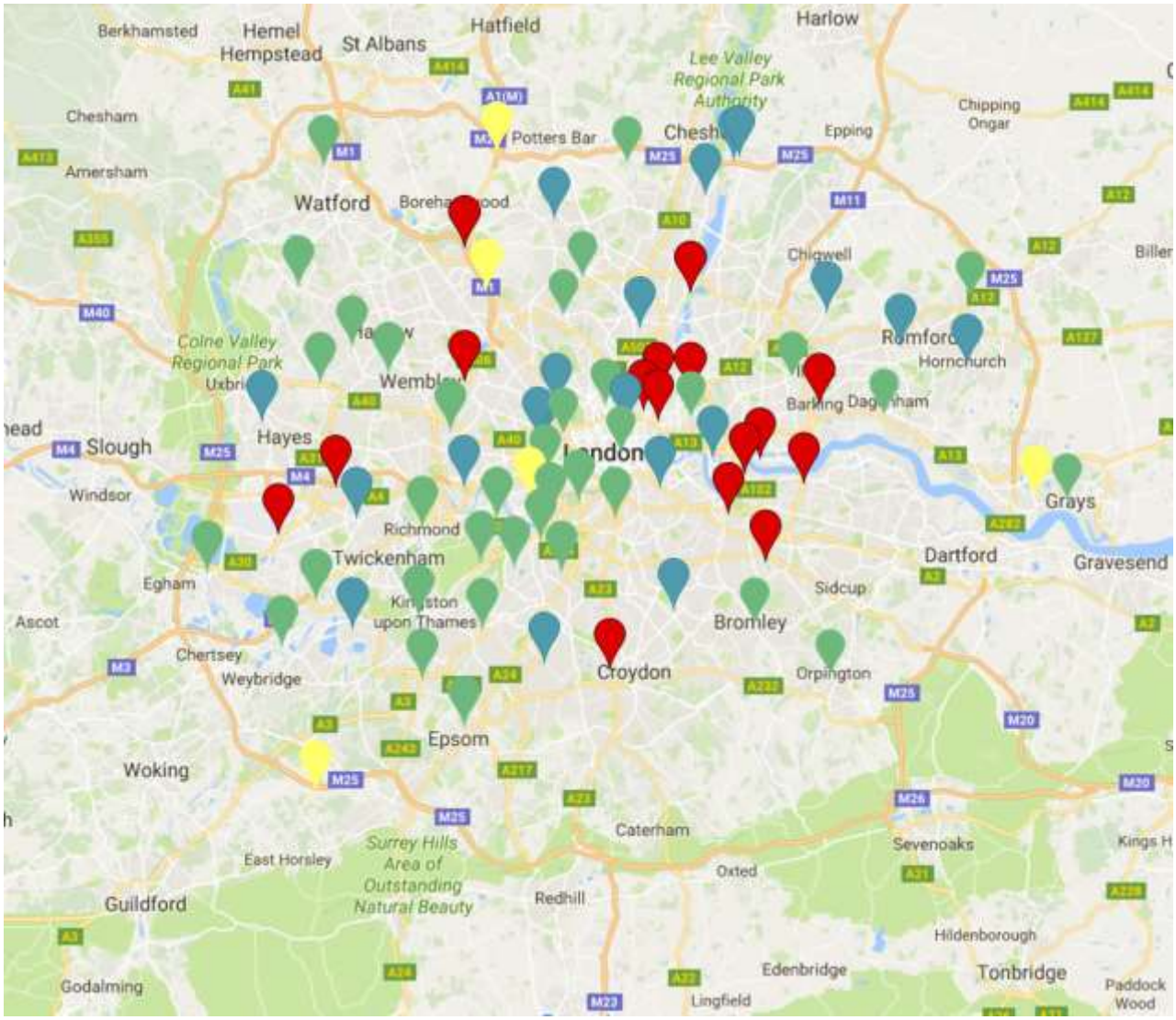


Figure 3 - Key variables considered to calculate rapid chargepoint requirements.

[13] Annual churn relates to all vehicles being licenced as PHVs and covers both new licences and the renewal of licence when a vehicle is replaced.

ILLUSTRATIVE CHARGEPOINT LOCATIONS

The analysis of the consolidated telematics data identifies a requirement for a total of 78 chargepoint locations across Greater London to serve these four fleets. A map, figure 4 below, was created to illustrate the total number of rapid charge events each week, across all vehicles analysed, which are scheduled to take place at each chargepoint.



Charge events per week (30 minutes duration)	
High	**30+charges**
Medium	**10-29 charges**
Low	**3-9 charges**
Rare	**1-2 charges**

Figure 4- Map of illustrative rapid chargepoint locations and expected utilisation levels.

The density of the required chargepoint network increases with proximity to central London, mirroring the frequency of journeys. A number of the illustrative locations fall on or near to major arterial routes into London as well as in proximity to the north and south circular roads. The mapping would appear to support the view of many of the operators interviewed that rapid chargepoints are required on arterial roads and the north and south circular to support commuting and longer distance fares.

TOTAL NUMBER OF CHARGEPOINTS REQUIRED

It is estimated that a total of 140 chargepoints will be required to be in place to meet the needs of the anticipated number of rapid charge capable PHVs on the road at the end of 2020, when ZEC licensing requirements for PHVs are introduced. This number is derived from the assumptions made in table 5 below.

Charging events per day	10
PHVs licenced in London	86231
% Churn (10 year age limit)	10
% BEV (current share of ULEV market)	33
Rapid charge EVs	2846
Chargepoints required	**140**

Table 5- Number of chargepoints required in first year of ULEZ operation and assumptions considered.

As the number of vehicles increases, the utilisation of each chargepoint will also rise, therefore although the total number of chargepoints will need to increase the expansion of the network won't need to be at the same rate as the initial delivery. Should 20 charging events per chargepoint per day be assumed then the number of chargepoints required across the 78 locations reduces from 140 to 106.

There is an opportunity for network operators to increase the number of charge events per day, perhaps by offering lower prices at periods of low demand. In initial years, some locations will host chargepoints with lower utilisation rates. Operators will need to ensure that these chargepoints remain economically viable as they will have an important role to play in the spatial distribution of chargepoints required by the private hire industry.

Many of the illustrative locations will require multiple chargepoints to be installed by 2020. This will help achieve economies of scale for the infrastructure including the electrical upgrades which will be necessary at these sites. It will also provide a better, more reliable offering for drivers, effectively reducing the possibility of queues for chargepoints and providing alternatives should a chargepoint be out of use.

Shared use of the chargepoints by other vehicle operators such as the taxi trade and organisations using plug-in commercial vehicles (which will be the case with chargepoints provided through TfL's rapid charge network) will increase the viability

of the sites which would be used less frequently by the private hire trade in the first years of operation of the ULEZ.

STAKEHOLDER INTERVIEWS

Six organisations were interviewed ranging from one currently running a fleet of pure electric vehicles to a company primarily involved in the executive travel business. The interviews were conducted on a semi-structured basis to ensure that the results represent the range of views across the topics covered.

FLEET COMPOSITION

The number and type of vehicle driven by the operators interviewed fall predominantly into the following categories:

- Medium sized car, typified by the Toyota Prius which is extremely popular with drivers in London, being fuel efficient in city driving conditions
- 7 seat MPV, typified by the Ford Galaxy, operated in significant numbers by Addison Lee, but similar vehicles are also used by other operators
- Executive cars, typified by Mercedes E-class. Again these cars are in use in a number of the private hire fleets across London.

Although the majority of cars operated by the interviewees fall within the above groupings with certain models represented in large numbers, a broad range of vehicle makes and models are in use.

The model of vehicle ownership is also varied, with some operators owning and renting cars to their drivers, some operating a driver ownership only model and others a mixture of the two. Where the driver ownership model is in place there are usually company imposed restriction on the models which are acceptable in addition to TfL's private hire vehicle licensing requirements. It is important that PHOs are aware of the specification and suitability of ZEC models and include them on company approved lists of vehicles.

One operator reported that due to the recent increase in the number of drivers who own their cars in London, they were taking on these drivers and their cars in contrast to their preferred model of vehicle ownership.

VEHICLE USE

Drivers' working patterns, hours worked and locations covered vary significantly across the operators. However, there is a concentration of activity in the West End, the City of London, North West London and to and from Heathrow airport. Some operators have a local bias and one has work concentrated in areas where public transport, across boroughs for example, is limited. This flexibility in operation

emphasises the importance of the industry as an integrated part of public transport in London.

Drivers tend to take breaks during quiet morning and afternoon periods, but many are still available should a job become available. No locations were identified as regular break locations. However, with the amount of business generated by Heathrow, the recently commissioned Authorised Vehicle Area (AVA) for drivers awaiting incoming flights is an exception.

Operators report that many of their drivers live outside London and commute in to work, however there are concentrations of drivers in some London boroughs. Most drivers take their vehicles home at the end of their shift.

ADOPTION OF ULEVS

All of the operators interviewed are interested in low emission vehicles and there is a wide experience of hybrid technology and an understanding of its benefits in the trade. It is also accepted that BEVs are desirable from an environmental viewpoint, particularly in regard to air quality.

There is an appreciation of the vehicle technology by all the interviewees, with a range of understanding of the detailed specification of vehicles, including electric driving range, charging rates and chargepoint compatibility.

Although there are BEV alternatives available in the medium car class, the wider lack of like-for-like ULEV alternatives is a particular concern, both in the case of PHEVs and BEVs which offer adequate driving range, passenger and luggage accommodation and perceived quality.

Examples given include:

- Six or more seats
- Adequate rear headroom
- Internal cabin size
- Boot capacity
- Aesthetic appeal, distinctiveness & perceived quality.

Asked about the flexibility around these features, PHOs were very clear that ULEVs would need to fit their business before they were adopted. There is currently little or no appetite to do the opposite and fit their business around ULEVs. For this reason, the current range of available ULEV models is currently a barrier to the widespread early adoption of ULEVs in London’s private hire industry. However, as the market develops further, models will undoubtedly become available which satisfy the operators’ standards.

CHARGING INFRASTRUCTURE

The lack of chargepoints available for PHOs in London was universally cited as a concern as well as the perception that existing chargepoints are not reliable. Operators would like to see TfL progress with installing chargepoint locations prioritised for the private hire industry to give them confidence that ULEVs will be viable. Currently most operators are assuming they will be using PHEVs to meet the ZEC licensing requirements; their generally positive experience of operating conventional hybrids appears helpful in this regard. The zero-emission driving range of PHEVs currently on the market is limited and so consideration is needed about how to ensure these vehicles can maximise the use of electric drive in London.

Suggested chargepoint locations include popular journey destinations particularly the business districts of central London, the West End, Canary Wharf and Heathrow Airport. This view is shared by the majority of those interviewed although one operator mentioned that much of their work is based in areas at a distance from public transport options. Chargepoints at travel hubs should be of an appropriate power output and optimally placed; a car park location, although suitable for commuters, may not be convenient for the private hire trade.

Operators indicated a clear preference for rapid chargepoints to minimise down time. Concern was raised over the ability to charge during a shift, this was higher among operators that offered a just-in-time pick-up rather than those that offered services that arrived in advance of pick-up, and, therefore, have more time parked.

Most interviewees concede that vehicles are not continually working throughout their shift although work patterns differ between the organisations. The unpredictable nature of journeys is a concern (particularly for companies with fewer commercial contracts) unless a comprehensive charging network is established.

The frequently mentioned barrier to ULEVs being adopted by London's PHOs was the lack of home or between shift charging options available to drivers. Regardless of whether PHOs own and lease their vehicles or their drivers purchase their own vehicles, it is a common practice that PHVs are taken home by their respective drivers following shifts. When ULEVs are adopted by PHOs it would be at this point that the most cost-effective charging could take place. Drivers charging at home would also provide the security of ensuring that the vehicles begin their shift on a full charge. On some occasions, this single overnight charge could be sufficient for a full shift; therefore, the capability to charge at home is a very important component to making the vehicles widely viable. For drivers with off-street parking, this capability can be gained by installing a chargepoint at home. Currently drivers can benefit from the OLEV Electric Vehicle Homecharge Scheme providing a 75% contribution to the cost of a chargepoint and its installation up to £500 including VAT (from 1st March 2016).

In discussions with PHOs in London, it became apparent that the majority of their drivers most likely do not live in a property with off-street parking[14]. This presents an issue in what measures can be taken to ensure drivers without off-street parking can still charge their ULEV at home. It was suggested by all interviewees that the provision of home-charge capability for drivers without off-street parking is a consideration that needs to be addressed.

TfL and the London boroughs are investing through the Go Ultra Low City Scheme to deliver 1,150 on-street residential chargepoints in London for ULEV drivers without access to off-street parking.

[14] It should be noted that data is not routinely collected by PHOs on whether their drivers live in properties with off-street parking. This statement is based on the assumptive opinion of PHO management, but these opinions were made with a good degree of confidence.

RECOMMENDATIONS & CONCLUSIONS

RECOMMENDATIONS

Based on the interviews with operators and the results of the vehicle route analysis and mapping, we recommend that the following measures are considered to encourage the uptake of ULEVs in London's private hire industry.

CONTINUE DIALOGUE BETWEEN CHARGEPOINT PROVIDERS AND THE TRADE

There appears to be a limited understanding in the trade of the plans to increase the provision of charging infrastructure in London. In combination with differing levels of understanding of the technical aspects of ULEVs this creates an impression that little is being done to help operators prepare for the ZEC licensing requirements. TfL has regular dialogue with the private hire industry in London and could seek, perhaps through a working group, to focus on the development of the plans in place to install infrastructure and encourage trade involvement with the successful operators of the network once appointed. This group could also be a platform for technical and driver training, helping PHOs and drivers migrate to the technology.

INVESTIGATE ON-STREET HOMECHARGING REQUIREMENTS

It was suggested by all PHOs interviewed that drivers without off-street parking need to be afforded some capability of charging an ULEV outside of their working hours. The initial challenge that this presents is determining, to some degree of accuracy, how many PHV drivers in London live in properties without off-street parking and which areas of London have the greatest concentration of those drivers. Presently, none of the businesses we spoke to routinely collect this information. Without knowing how many drivers are affected by this issue and where the hotspots are located, it will be difficult to provide the necessary infrastructure to ensure that the majority of PHV drivers can charge at home. It is therefore recommended that research could be undertaken to determine where on-street residential parking is required for PHV drivers in London and provide guidance to installers and boroughs as to the likely demand. This can help inform boroughs who are investing in charging infrastructure, including through the Go Ultra Low City Scheme.

INSTALL INFRASTRUCTURE AHEAD OF DEMAND

The PHOs interviewed have each expressed some degree of concern as to the perceived lack of progress made in improving the public chargepoint network in London. This is especially the case in the context of fast and rapid charging. This lack of confidence may not entirely prevent the adoption of ULEVs in London's private hire industry – the business case is arguably strong enough to overcome that – but it will certainly cause PHOs to act with a degree of caution. This may potentially

slow the uptake of ULEVs, particularly BEVs. By installing infrastructure to outweigh early demand, some PHOs have stated that they would be likely to more rapidly convert their fleets to ULEVs. This is why TfL has commissioned this piece of work to inform its investment in charging infrastructure in London.

PROVIDE CHARGING INFRASTRUCTURE FOR PHEVS

This report has focussed on the requirement to provide rapid charging infrastructure for the private hire trade. Rapid charging will be necessary to provide PHVs driven in electric mode for the majority of journeys taking place in Greater London. Many operators will adopt PHEVs, in part because there is already a wide and growing choice of vehicles, but also because a comprehensive charging network is not essential for their operation. However, a fleet of ZEC vehicles being powered only by their internal combustion engines is not desirable. The provision of on-street charging infrastructure enabling drivers to charge at the end of their shift is equally important for these vehicles. Additionally, we would recommend that where possible, rapid chargepoint locations are equipped with 7 to 22kW AC charging infrastructure to enable drivers of PHEVs to charge their vehicles during their working day. At the moment the majority of PHEV models are not rapid charge compatible, which means that significant periods of time on charge are required to replenish their batteries. However, if attractive tariffs are offered there is still a place for opportunity charging, particularly at quiet periods during the working day.

MONITOR RELIABILITY OF EXISTING INFRASTRUCTURE

Regardless of how comprehensive the current or future chargepoint network will be in London, if it is not perceived to be reliable the operators have expressed the view that they will not use it. TfL has worked with existing private operators to significantly increase the reliability of the public charging network and will continue to monitor it in the interests of ULEV drivers.

ENGAGE WITH ULEV MANUFACTURERS

The limited number of ULEV models suitable for use by the trade (BEVs in particular) available on the market is not one which transport policymakers have direct control over. However, the significance of this barrier should not be understated and will not necessarily be overcome simply by allowing the market to develop. It is recommended that TFL engage with the manufacturers most heavily represented, alongside PHOs. This is important for two reasons. Firstly, to understand the manufacturers' current and future plans for ULEVs and to ascertain whether and when models viable for use in London's private hire industry will become available. Secondly, to provide a degree of guidance to the manufacturers as to exactly what is required of vehicles and the concerns of operators. This guidance could equally be of value to manufacturers, on the basis that the private hire industry in London

numbers in excess of 86,000 vehicles and that drivers will need to replace current models with ULEVs.

WORK WITH PRIVATE HIRE OPERATORS TO SECURE INCENTIVES FOR DRIVERS

For PHOs whose drivers purchase their own vehicles, barriers of cost and reliability are considerably more substantial. It is recommended that TfL encourages such operators to provide some degree of incentive and support to their drivers in order to overcome the barriers of the upfront cost and perceived reliability concerns. As a minimum this could include signposting to information about ULEVs, including the Electric Vehicle Home Charge Scheme, Go Ultra Low City Scheme provision of residential charging, driver training, chargepoint operation and other material explaining the environmental and financial benefits of ULEV adoption.

FURTHER EXPLORE THE OPPORTUNITIES FOR GEO-FENCING

The ability to geo-fence PHEVs such that they are predominantly driven by electricity while operating in the ULEZ could be further explored. Where PHEVs are operated by PHOs, the successful use of this technology could further reduce the emission of pollutants by vehicles operating in the ULEZ.

ENGAGE WITH THE TAXI TRADE AND COMMERCIAL VEHICLE OPERATORS

From the vehicle movement analysis there is a requirement for a wide spatial distribution of chargepoints across Greater London to service the requirements of the private hire trade. In order for the less frequently used chargepoints to be economically viable for operators to install, they will need, particularly in the early years of the ULEZ, to be used by the taxi trade and the wider business and public sector community in London. Use at times less popular with commercial operators should be encouraged by private buyers of vehicles, perhaps through lower off-peak charging tariffs.

CONCLUSION

In conclusion, there is a great opportunity to migrate the London private hire trade to ULEVs over the ten-year replacement cycle of the fleet following the introduction of the ZEC licensing requirements. The distances vehicles drive on a daily basis are both high enough to provide drivers with a significant saving in terms of “fuel”, yet low enough to allow the use of BEVs subject to the provision of an adequate network of charging infrastructure. The challenge is to provide an adequate number of chargepoints while offering investors in and operators of the network an adequate return on investment.

In our discussions with operators, there is an appreciation of the environmental benefits gained from migrating to a fleet of ZEC private hire vehicles. Subject to their concerns being overcome in relation to a rapid chargepoint network and a greater level of provision for charging at the end of a shift, the migration of the majority of the fleet could be completed well within the 10-year age limit following the introduction of the ZEC requirements.

APPENDIX 1 TECHNICAL BACKGROUND

This section summarises the vehicle categories and chargepoint infrastructure referred to throughout this report.

ELECTRIC VEHICLES

Figure 5 outlines the current range of drivetrain technologies used to power vehicles. While other technologies, such as hydrogen fuel cells, continue to be developed, the technologies in the diagram are broadly representative of the market for lighter vehicles, including vans and cars.

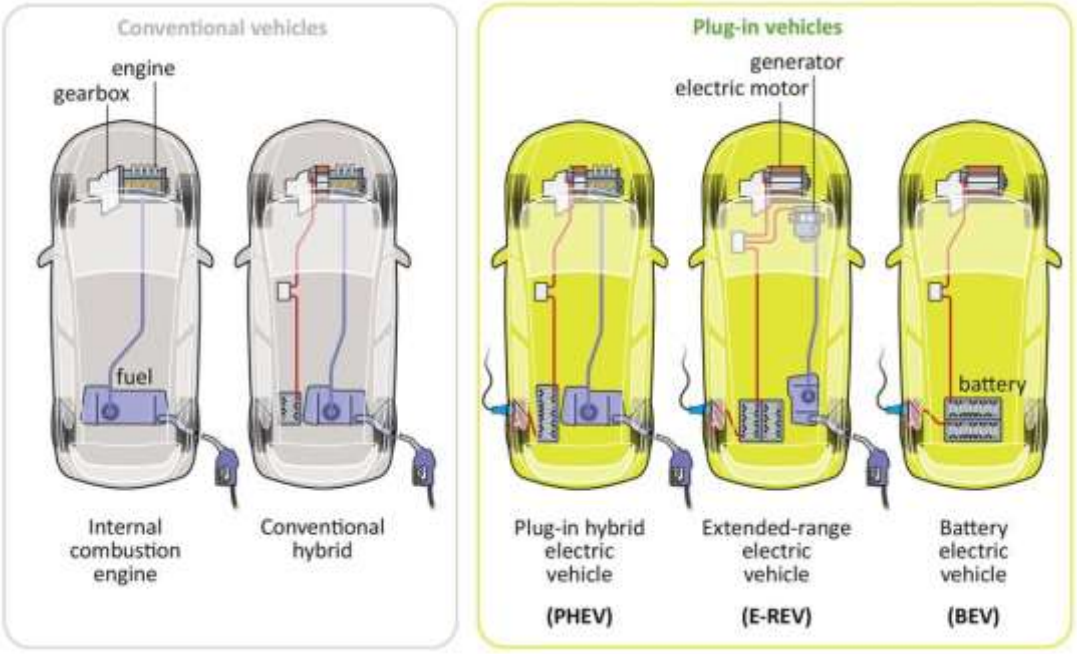


Figure 5 - Drivetrain technologies. Source: The Office for Low Emission Vehicles.

Conventional vehicles burn their fuel in an internal combustion engine (ICE) which drives the wheels via a gearbox. This is the most common form of vehicle on the road today. Vehicles running on road fuel gas (such as LPG) are included in this description.

Conventional hybrids have a storage battery in addition to the ICE which is charged by regenerative braking (converting the kinetic energy of the car into electricity which is stored in the battery). This stored energy is then used to drive an electric motor which can assist the ICE to drive the wheels or drive them entirely for a short distance (usually less than a mile). Using energy generated by slowing the vehicle

down to help drive it when accelerating, or driving at low speeds, aids efficiency and therefore reduces fuel consumption.

Plug-in vehicles are distinctive in that they are fuelled by grid electricity via a chargepoint.

A plug-in hybrid electric vehicle (PHEV) resembles a conventional hybrid with additional battery capacity enabling a longer electrically driven range, typically 10 to 40 miles. Once the battery charge is depleted the vehicle operates as a normal hybrid.

An extended-range electric vehicle (E-REV) is a battery electric vehicle equipped with an ICE which acts as a generator when the battery charge is depleted, providing electricity to drive the wheels. An E-REV typically has a larger battery and greater electrical driven range a PHEV.

A battery electric vehicle (BEV) or a pure EV is powered only by electricity and is usually fitted with a larger battery than a PHEV or E-REV to provide a significant driving range usually between 80 and 150 miles in real world driving conditions.

This report uses the TfL definition Zero Emission Capable (ZEC) which includes any vehicle capable of being driven over significant distances without any tailpipe emissions.

The UK Government and the Office for Low Emission Vehicles (OLEV) define ZEC vehicles which fall into the categories in table 6 below as Ultra Low Emission Vehicles (ULEVs). Grants of 35% of the cost of a car up to the limits shown in the table are currently available for their purchase.[15]

	Category 1	Category 2	Category 3
CO_2	< 50g/km	< 50g/km	50 – 75g/km
Zero emission range (miles)	70 +	10 – 69	20+
Maximum grant	£4,500	£2,500	£2,500
Price cap	-	£60,000	

Table 6 - ULEV categories for cars and purchase grants available; source OLEV.

CHARGING

[15] Further information on OLEV grants available on the OLEV website: https://www.gov.uk/plug-in-car-van-grants/what-youll-get

An electric vehicle needs be charged from the mains electricity and while a cable fitted with a standard domestic 3 pin plug (BS1363) can be used, vehicle manufacturers usually restrict the current available to no more than 10amps resulting in long recharging periods, usually 10 to 12 hours for a typical BEV.

For home charging it is recommended that a dedicated chargepoint is installed which is usually rated at 16 amps (providing c. 3.5 kW) or optionally for faster charging, at 32 amps (providing c. 7kW). At 7kW a BEV typical of the models currently being used by some PHOs would be recharged in around 4-5 hours. Currently the OLEV Electric Vehicle Homecharge Scheme[16] offers individuals who are the registered keeper, lessee or have primary use of an eligible vehicle up to 75%, capped at £500 incl VAT, off the total capital costs of the chargepoint and associated installation costs. Additionally, many vehicle manufacturers subsidise home chargepoints. The OLEV Workplace Charging Scheme[17] provides grants for installing chargepoints of £300 per socket, for up to 20 sockets. This scheme may be useful for private hire operators with suitable premises.

Public chargepoints are usually rated at 3.5 or 7 kW, however faster charging rates at 22kW are available in some locations. Not all ZEC vehicles are able to take advantage of this faster rate of charge which will recharge a typical BEV in less than two hours.

This report is assuming that vehicles will be charged by rapid chargepoints providing the fastest rate of charge commonly available. Rapid chargepoints are usually 43kW AC or 50kW DC. In the UK, three rapid charge protocols are in use by mainstream manufacturers:

3. CHAdeMO is primarily used by Japanese vehicle manufacturers, including Nissan and Mitsubishi, as well as Citroen, KIA and Peugeot

[16] https://www.gov.uk/government/collections/government-grants-for-low-emission-vehicles#electric-vehicle-homecharge-scheme
[17] https://www.gov.uk/government/publications/workplace-charging-scheme-guidance-for-applicants-installers-and-manufacturers

4. Mennekes (Type 2) is the recommended standard for public 3.5 and 7kW chargepoints. It can also be used for fast AC charging at 22kW or rapid AC at 43kW. Renault uses this connector for rapid charging the Zoe.

5. Combined Charging System (CCS or Combo) is currently used by BMW and Volkswagen group. Most American and European manufacturers, including Ford, General Motors and Porsche have indicated that they will use CCS.

Carrying a charging cable in the vehicle is only necessary when using AC public chargepoints which deliver no more than 22kW. Rapid chargepoints have tethered connectors and are therefore similar in use to a conventional fuel pump.

Figure 6 - Rapid chargepoint incorporating all three protocols.

Figure 7 below illustrates how useful rapid charging is when the time for charging a vehicle is constrained.

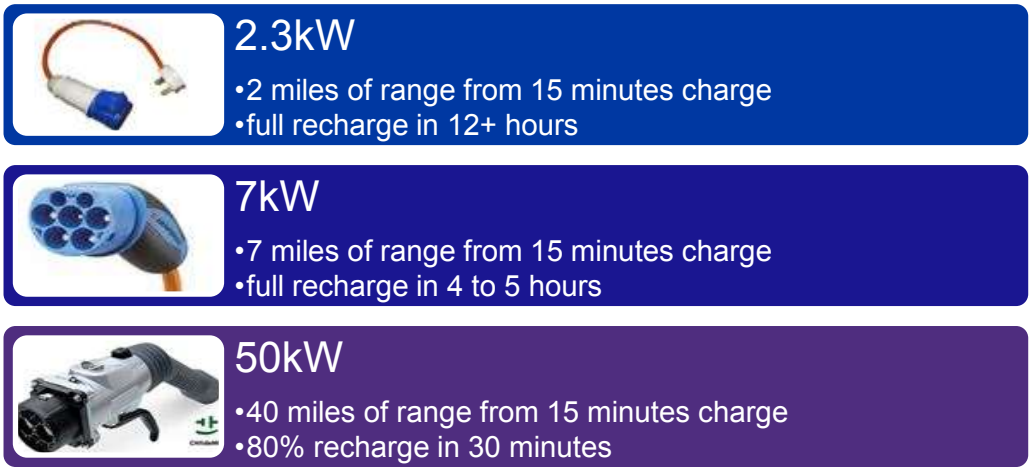


Figure 7 - Charging speed and typical increases in range from a 15 minute charge. Actual mileage gains and time taken to charge will vary by vehicle model.

APPENDIX 2 GLOSSARY OF TERMS

Term	Definition
AC	Alternating current
Battery electric vehicle (BEV or pure-EV)	A vehicle powered only by electricity. The vehicle is charged by an external power source and incorporates regenerative braking which helps to extend the available range.
CHAdeMO	A charging protocol for delivering a DC supply to plug-in vehicles. CHAdeMO is primarily used by Japanese vehicle manufacturers, including Nissan and Mitsubishi, as well as Citroen and Peugeot.
Charging event	The time when a vehicle is connected to a chargepoint while power is transferred
Combined Charging System (CCS or Combo)	A charging protocol for delivering a DC supply to plug-in vehicles. It is currently used by BMW and VW. Most American and European manufacturers, including Ford, General Motors and Porsche have indicated that they will use CCS.
Conventional hybrid	Vehicles primarily powered by petrol or diesel which also have a storage battery charged by regenerative braking. This stored energy is then used to drive an electric motor which can assist the conventional engine to drive the wheels or drive them entirely for a short distance (usually less than a mile).
DC	Direct current
Extended range electric vehicle (E-REV)	A vehicle which combines a battery, electric motor and an ICE. The electric motor always drives the wheels with the ICE acting as a generator when the battery is depleted.
Fast charging	Charging a plug-in vehicle at typical rates of 7kW AC, 20kW DC or 22kW AC
Geofencing	A software feature that uses (GPS) to define geographical boundaries.
Go Ultra Low City Scheme	£13m funding from the Government Office for Low Emission Vehicles awarded to London to improve charging infrastructure by 2020 and showcase the benefits of ULEVs
kW	Unit of power
kWh	Unit of energy
Mennekes (Type two)	The recommended standard for public 3.5kW and 7kW AC chargepoints. It can also be used for fast AC charging at 22kW or rapid AC at 43kW.
NOx	Oxides of nitrogen. NOx is primarily made up of two pollutants,

	nitric oxide (NO)and nitrogen dioxide (NO2).
Opportunity charging	Re-charging a plug-in vehicle during daily use (rather than overnight at home or depot). Typically requires a fast or rapid chargepoint.
Plug-in car grant / plug-in van grant	Grant funding to support private and business buyers looking to purchase a qualifying ultra-low emission car or van.
Plug-in hybrid electric vehicle (PHEV)	Similar to a conventional hybrid, with a larger battery and the ability to charge the battery from an external power source.
Private hire operators / vehicles	Operators licensed by TfL including minicab, executive car and chauffeur-driven services. Private hire vehicles cannot be hailed in street and must be pre-booked with a licensed private hire operator.
Rapid charging	Charging a plug-in vehicle at typical rates of at least 43kW AC or 50kW DC
Regenerative braking	Converting the kinetic energy of the car into electricity which is stored in the battery.
Slow or standard charging	Charging a plug-in vehicle at typical rates of no more than 3.5kW AC
Taxi	Black cabs licensed by TfL which can be hailed in the street or from one of around 500 ranks situated at prominent places including rail, Underground and bus stations.
TCO (total cost of ownership or whole life cost)	The full cost of owning or operating a vehicle, including purchase / lease cost, fuel, tax, insurance and residual value.
Ultra Low Emission Vehicle (ULEV)	ULEV is the collective term for BEVs, PHEVs, E-REVs and hydrogen fuel cell electric vehicles (FCEVs)
Ultra Low Emission Zone (ULEZ)	A scheme to help reduce the impact of road transport on London's air quality. More information is available at www.tfl.gov.uk/ultra-low-emission-zone. Information on proposals to change ULEZ is available at www.tfl.gov.uk/airquality-consultation.
Zero Emission Capable (ZEC)	Vehicles which are able to operate with zero or near zero tailpipe emissions.