Plug-in Electric Vehicle Uptake and Infrastructure Impacts Study

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Final report

A report commissioned by Transport for London and prepared by

elementenergy

WSP | PARSONS BRINCKERHOFF

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Executive summary

Background

Electric vehicles (EVs), including Plug-in Hybrid Electric Vehicles and Battery EVs, produce fewer harmful air pollutants (none in the case of BEVs) and less carbon dioxide compared to conventional internal combustion engine vehicles. There are a number of alternative vehicle technologies available, and increasing numbers of charge points, making EVs an increasingly viable and affordable alternative to non-electric cars and vans, and EV sales in London have surged in 2014-2015.

Alongside the Greater London Authority (GLA) and the UK Government, Transport for London (TfL) recognises that uptake of EVs to replace internal combustion engine vehicles will be an important part of the strategy to mitigate against climate change and improve urban air quality, alongside mode shift away towards walking, cycling and public transport.

To date it has been largely possible to satisfy the charging requirements of EVs through public charge point networks and domestic charge points. However, the predicted increase in EV stock, and the low provision of off-street parking in London, will make on-street charging increasingly important, particularly for residents charging overnight and to a lesser extent for commuters charging during the day. The provision of sufficient capacity and appropriate types of on-street charging provision will be a critical component in realising the expected levels of EV growth.

As the transport authority for London, TfL has a role to play in supporting the switch to and operation of EVs in London, and will require an understanding of the likely needs and impacts associated with vehicle charging. Element Energy and WSP Parsons Brinckerhoff have been commissioned by TfL to predict the spatial distribution of EVs in London over the next decade, and to assess what infrastructure will be needed to support this uptake.

It should be noted that the analysis only considers the uptake of EVs in place of cars that would be used under a baseline increase in car sales (roughly in line with national projections). The recommendations and policy changes do not encourage uptake in driving from those who currently walk, cycle or take public transportation.

Objectives

This study has the following objectives:

1. **Map where EV uptake is most likely to occur across London for cars, vans, powered 2 wheelers and taxis**
2. **Map the energy and power demand from EVs across London, to inform the London Energy Plan**[1]

PHASE 1

3. **Understand the infrastructure demand and impacts**

PHASE 2

In **Phase 1** of the study, the predicted uptake of EVs in London was distributed across London according to where they are likely to be based, and where they will charge, in 2020 and in 2025. Projected distributions of the energy and power demand from EV charging in 2020 and 2025 were mapped based on these results. **Phase 2** of the study used the results of Phase 1 to understand the implications for charging infrastructure demand, and the possible impacts of different charging solutions, in London in 2020 and 2025.

[1] As part of this study, energy and power demand from EVs have been assessed at Lower-Level Super Output Layer (LSOA) level, up to 2050. The results will be published as part of the London Energy Plan.

Overall scope and approach

For the purposes of this study, the term “electric vehicles” refers to: Battery electric vehicles (BEVs); and Plug-in hybrids & Range-extended electric vehicles (both referred to as PHEVs).

This study considers the uptake and impacts of electric cars (including private and commercial cars, and private hire vehicles, but excluding car club vehicles), taxis (i.e. Hackney Carriages), vans and powered-two wheelers. These vehicle types cover over 90% of mileage from road transport in London.

To enable an assessment of the impacts of EV uptake, Phase 1 of the study maps the possible locations and energy demand associated with EV charging. Two main charging types are mapped. **Residential & depot based charging** at the vehicles’ primary locations is likely to account for the majority of future energy demand for the vehicle types in scope, with the expectation that this will mainly take place overnight. Some car and van users are likely to recharge at or near **workplaces**, with an estimated 5% of the energy demand for electric cars and vans coming from this type of charging. Only vehicles based in London are included; potential demand from EVs commuting into London, from outside London, is not included in the energy demand modelling[2].

Possible demand for rapid charging at **destinations** is also considered in this study in terms of the different street types that are likely to require this type of charging infrastructure. However, due to the uncertainty around usage and future locations of destination charging, this is not included in the mapping of energy demand and charging locations.

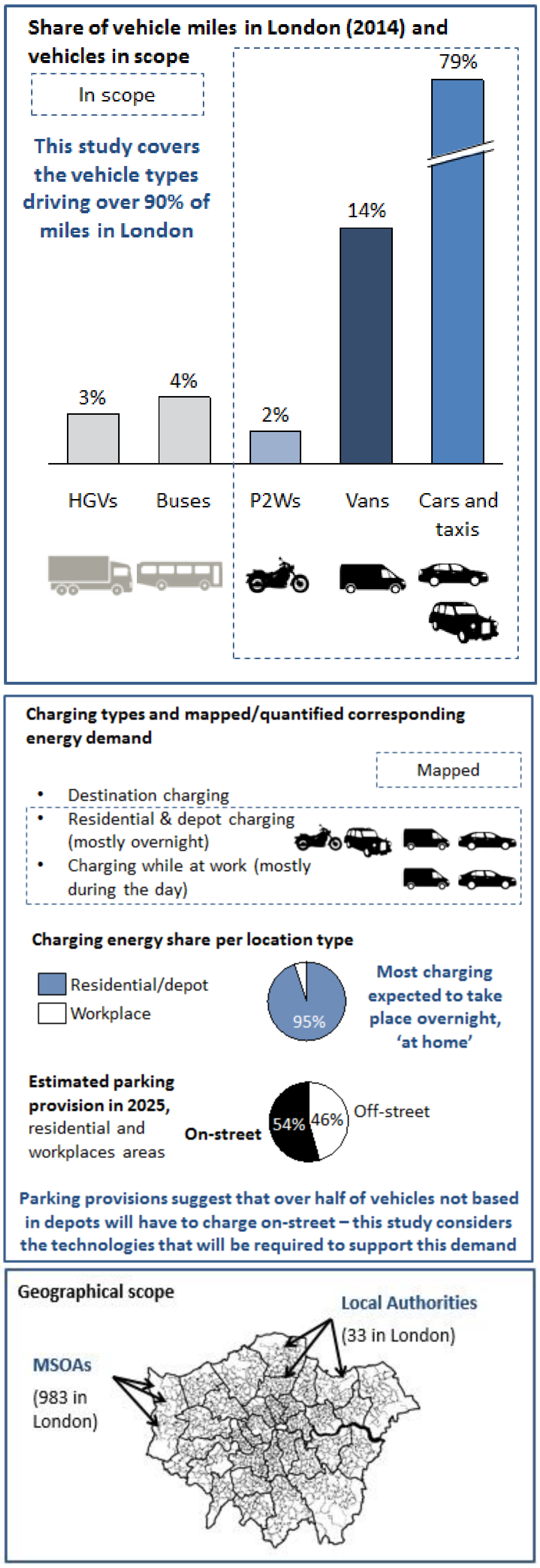


Figure 1 Summary of overall scope

These charging types inform where future EVs will need to park. In Phase 2 of this study, the off-street parking provision across London is estimated, and the resulting demand for on-street charging solutions is assessed. Finally, the impacts of charging are assessed in terms of the need for additional grid reinforcements, effects on parking supply and operation, space and street-scape. Throughout the report, EV uptake and impacts are considered at Middle-Layer Super Output Layer (MSOA) level, producing a highly location-specific analysis of the effects of potential EV uptake in London.

[2] This could include up to 30% of commuter trips into London. Source: Origin and destination data - Method of travel to work: Driving a car or van - 2011 Special Workplace Statistics - MSOA Level (England and Wales) - Open Government License

Phase 1 – Mapping electric vehicle uptake, charging locations and energy demand

Approach

The approach to Phase 1 of the study is summarised in Figure 2, and is described below.

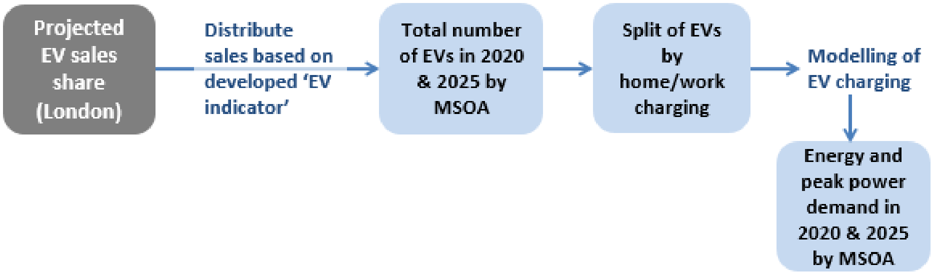


Figure 2 Approach to mapping EV uptake, charging and energy demand

Two scenarios for car and van uptake are considered in the study, each assuming a very high level of EV uptake to 2025, in line with a trajectory that leads to 100% sales share of new cars and vans before 2050. This reflects the high level of UK EV uptake recommended by the Committee on Climate Change in order to achieve national CO_2 emissions reduction targets for 2050.

The **Baseline scenario** assumes that there will be some remaining dependency on liquid fuels even in 2050, with consumers preferring PHEVs to BEVs. The **High BEV scenario** assumes a more rapid uptake of EVs, with an increasing ratio of BEVs to PHEVs.

Uptake of taxis and powered two wheelers is the same in both scenarios, following an ambitious trajectory. Both scenarios assume that there will be significant increases in model choice and consumer acceptance by 2020, across all vehicle types.

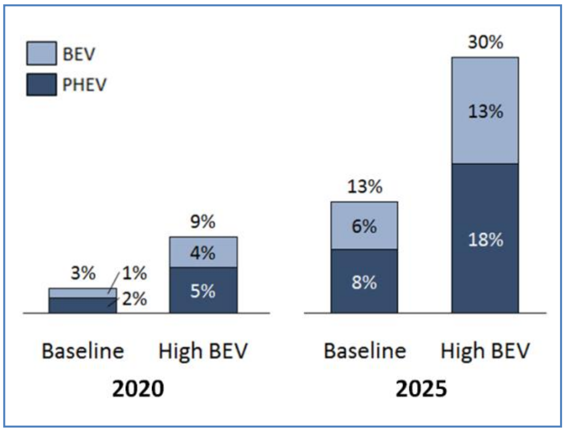
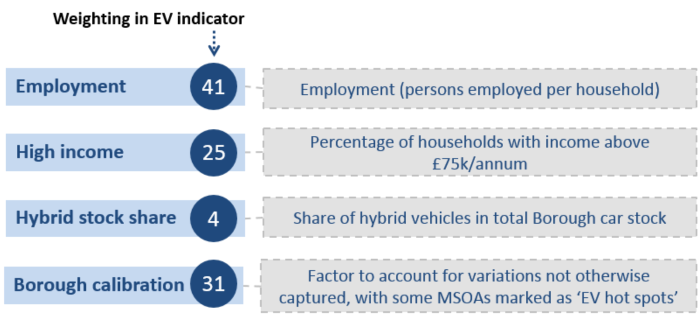


Figure 3 Plug-in share of new car sales in 2020 and 2025

An EV indicator was developed, designed to predict the locations of future EV adopters. The EV indicator is comprised of several factors that correlate with the car sales share of EVs in each MSOA: employment level, historic hybrid sales share and income. These factors are combined and weighted to give the maximum correlation with the current EV sales share. Projections of these factors are then used to predict how electric car sales will be distributed across London in 2020 and 2025[3]. In the case of vans, taxis



[3] It is assumed that the distribution of total car sales across London will not change in 2020 and 2025. This implies that there is no particular shift towards other transport modes or other car ownership models in

and powered two wheelers, there have been too few sales to infer geographic trends for future distributions, and therefore the distribution across London follows current distributions of vehicle sales.

EV sales are translated to EV stock figures for each MSOA, forming the basis for the distribution of residential & depot based charging. All vehicles are assumed to use these methods to meet the majority of their energy needs. Some cars and vans also use workplace charging; locations for this are allocated based on origin-destination data for driver-commuters within London.

Observed electricity demand profiles for these charging types form the basis for calculating the peak power demand in each MSOA, and daily energy demand is informed by typical mileages and energy consumption figures for each vehicle type. Likely improvements in vehicle performance over the next decade are accounted for.

It is assumed that both residential & depot-based charging and workplace charging use "slow" charging or the lower end of "fast" charging, i.e. at 3-7kW. There is a lack of data around the use of rapid charging (43-50kW) and 22kW fast charging in terms of frequency of use and location of future infrastructure, and so this is not included in the energy mapping. The energy considerations of rapid charging have been investigated by two separate research studies conducted for TfL which will be published later this year[4].

Results

The overall distribution of EVs in the High BEV scenario is shown in Figure 4. It should be noted that the share of different vehicle types differs across MSOAs: in some cases, there is a high uptake of electric cars but a relatively low uptake of vans or taxis.

Figure 5 shows the energy demand distribution for the High BEV scenario in 2020 and 2025. The distribution is similar to the distribution of the residential & depot charging demand (which is based on the registered locations of EVs, illustrated in Figure 4), because this is the main charging mode. However, the energy demand pattern differs slightly from the stock distribution (Figure 4) due to the different mix of vehicle types and corresponding differences in energy consumption.

Figure 4 below illustrates the variation in composition of projected electric vehicle fleets in two MSOAs with high total numbers of EVs: Havering 014 and Richmond upon Thames 023. It also shows the typical daily energy demand for different electric vehicle types. As shown below, taxis and vans have much higher daily energy consumption than cars because of their higher mileage and higher consumption on a kilometre basis (heavier vehicles). Therefore, when comparing MSOAs with a high total number of EVs, those with a relatively high share of e-taxis and e-vans will have a greater energy demand than those with a high share of cars.

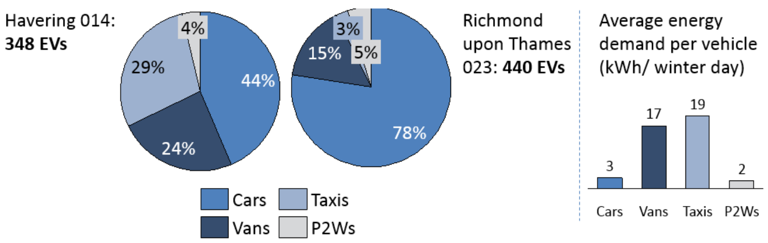


Figure 4 Variation in vehicles and energy demand across two MSOAs with high EV uptake (High BEV scenario, 2025)

specific areas of London. Total car sales projections are in line with national projections by DfT (c. 5% increase in 2015 sales by 2025). This is also true for vans and P2Ws. Taxi stock projections have been approved by TfL.

[4] 'Rapid Charging Network Study' (Element Energy) and 'A feasibility study into a rapid chargepoint network for plug-in taxis (Energy Saving Trust)

Havering 014 and Richmond upon Thames 023 both have a relatively high predicted EV stock in the scenario shown (as can be seen by locating these MSOAs in Figure 5). However, Havering 014 has a higher share of taxis (as shown in Figure 4) and therefore the total daily energy demand is higher than the energy demand from Richmond upon Thames 023. This difference can be seen by comparing the two MSOAs indicated in Figure 6.

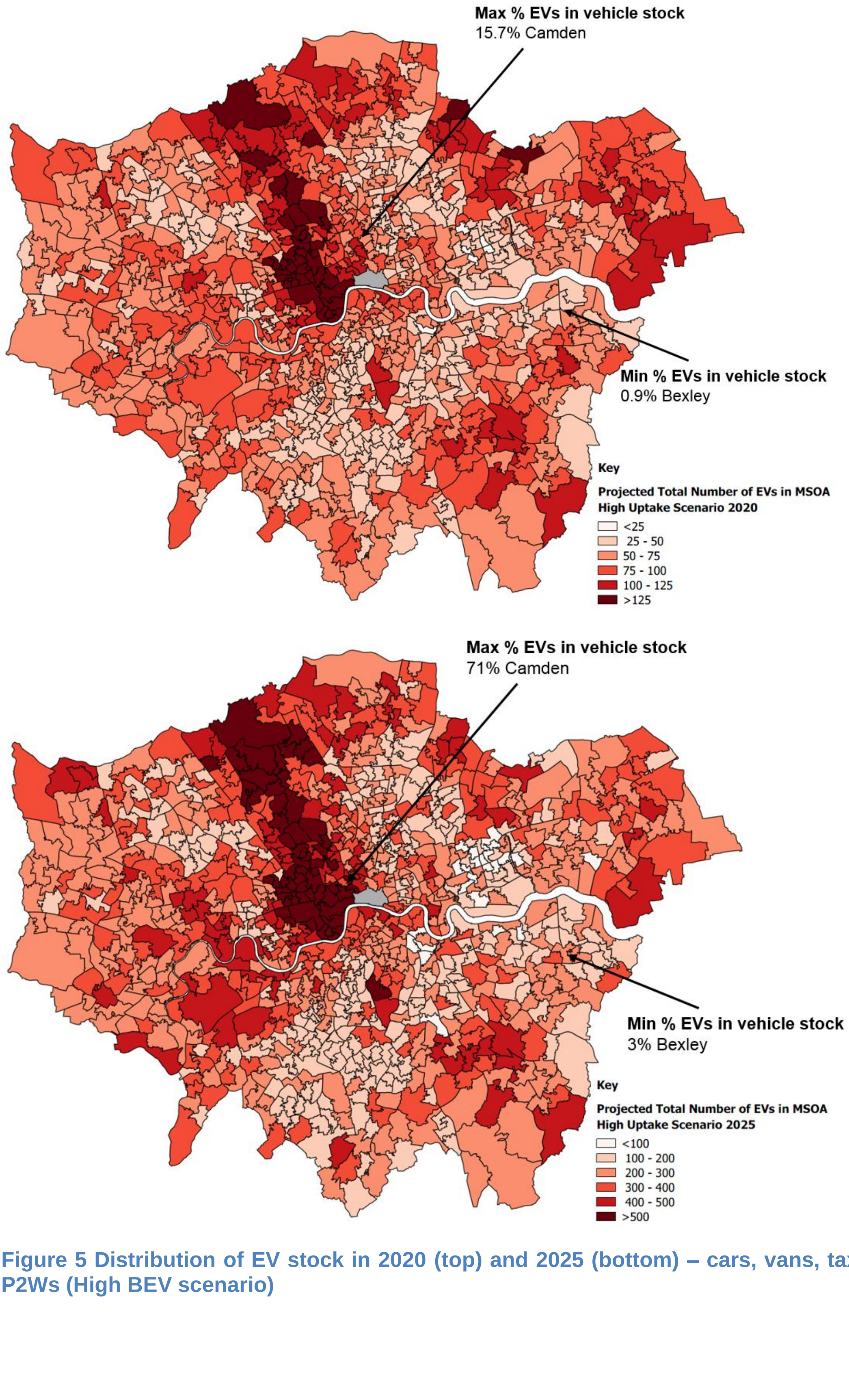
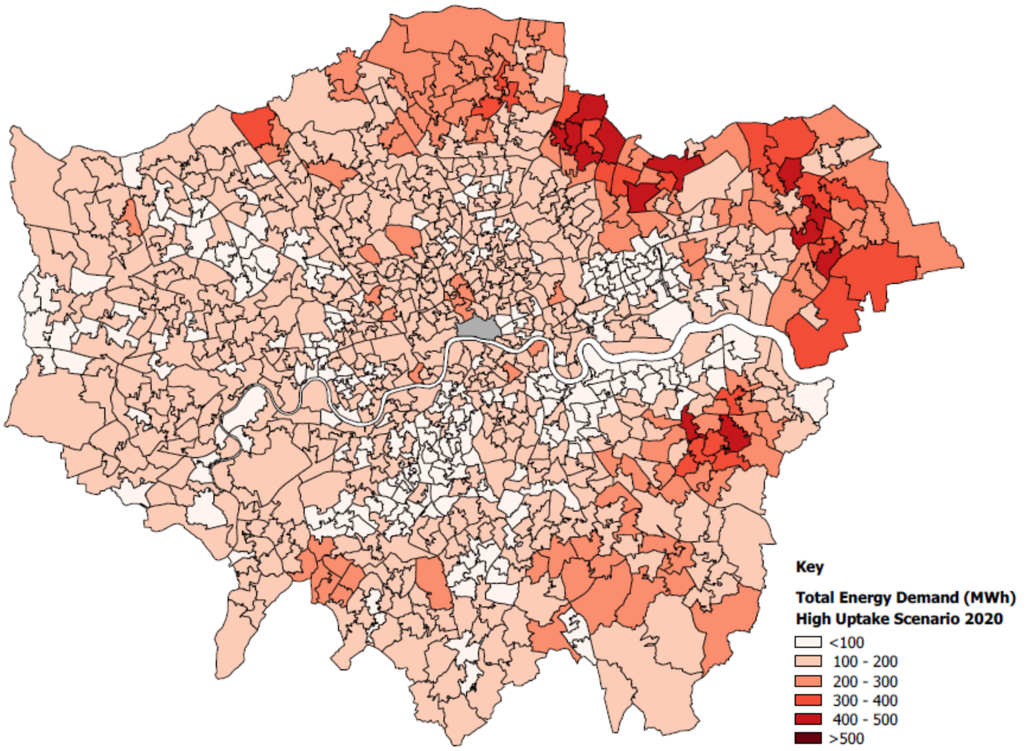


Figure 5 Distribution of EV stock in 2020 (top) and 2025 (bottom) – cars, vans, taxis and P2Ws (High BEV scenario)



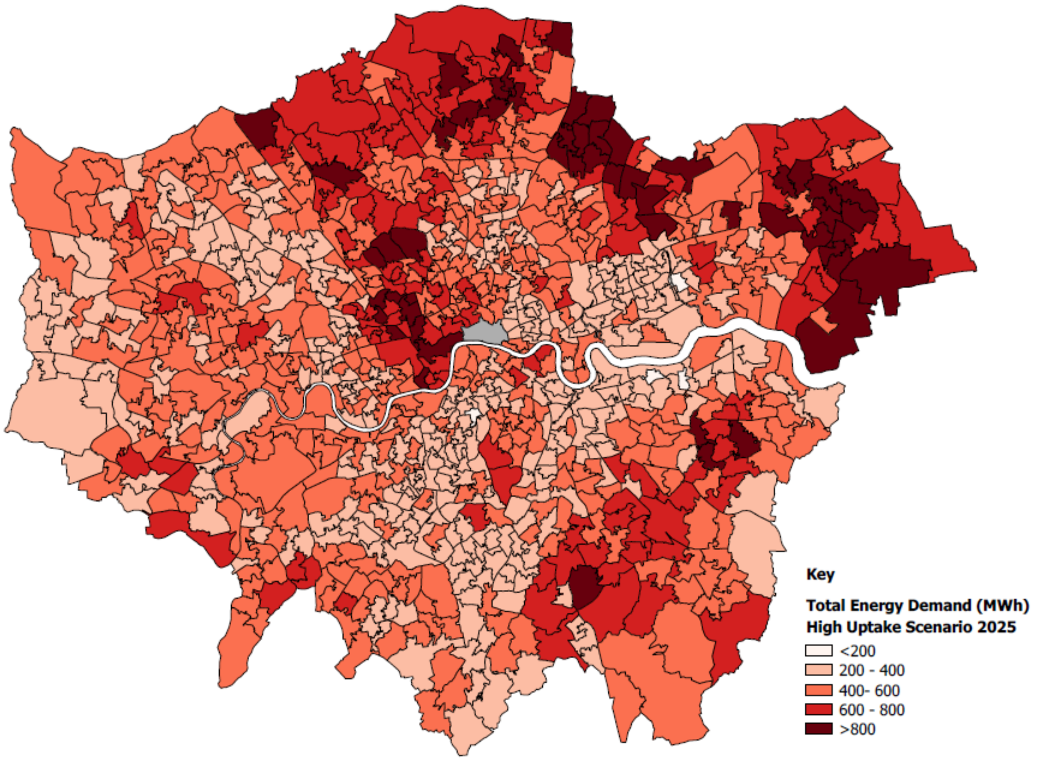


Figure 6 Total annual energy demand from EV charging, 2020 (top) and 2025 (bottom) (High BEV scenario)

Phase 2 - Charging infrastructure requirements and impacts

Overall approach

Figure 7 summarises the overall approach to Phase 2.

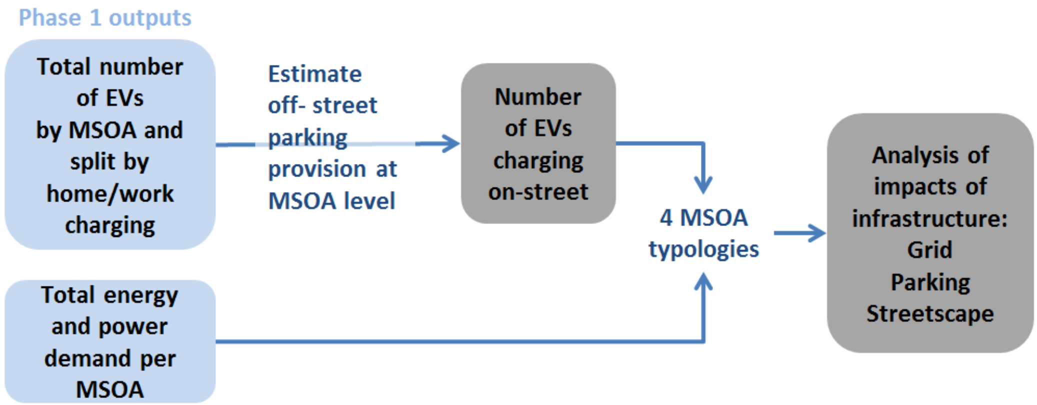


Figure 7 Approach to assessing charging infrastructure requirements and impacts

Using the results from Phase 1, Phase 2 first determined the number of EVs in each MSOA that would need to charge on-street or off-street for residential and workplace locations. EV users will charge at home and/or work if off-street parking is available, as it is relatively easy for residents and EV commuters that have access to off-street parking to charge at their own convenience, and they can generally benefit from charging at a lower cost than those charging on-street.

Off-street charging:

- Charging while parked in a driveway, garage or car park

On-street charging:

- Mostly charging while parked on the carriageway (i.e. in bays on side of the road). For the purposes of this report on-street parking also includes off-carriageway parking, e.g.: dedicated rapid charging bays in taxi ranks, and rapid charging on forecourts or in dedicated 'hubs'

However, by analysing projected uptake compared to provision of off-street parking this study estimated that **over 60% of EVs based in residential areas will need to charge on-street**. A scenario was developed for the mix of future charging solutions required to meet this demand, informing the assessment of the key impacts and considerations for charging in different areas. Rather than assessing these impacts for each MSOA, four typologies were developed based on MSOA-level population density and off-street parking provision. These typologies were designed to account for both inner and outer London, and for areas with high and low numbers of EVs charging on-street. Impacts were then assessed across these typologies.

Summary of on-street and off-street charging provision

In the chosen policy-led EV uptake scenarios (Baseline and High BEV), the parking provision in London suggests that at least 60% of electric cars, vans and taxis not based in depots will require a solution to charge on-street in residential areas. For car and van commuters seeking to recharge while at work, the situation is likely to be less severe, but it is estimated that c. 20% of these vehicles require an on-street solution for workplace charging.

For residential charging, the estimated number of EVs charging on-street ranges from approximately 20,000 (Baseline scenario, 2020) to around 166,000 (High BEV scenario, 2025). This represents between 0.7% and 5.6% of the total London stock of cars, vans and taxis.

The total number of EVs charging at workplace locations is assumed to be c.15% of cars and of vans: c.4,500 to c.39,000 vehicles in total (2020 Baseline scenario and 2025 High BEV scenario, respectively). The estimated number of EVs charging on-street while at work ranges from approximately 900 (Baseline scenario, 2020) to 8,200 (High BEV scenario, 2025).

Range of charging solutions

The table below lists the range of charging solutions that are currently available, or may become available in the near future, for on and off-street parking in residential and workplace locations.

Table 1 Potential solutions for primary charging

	Residential locations: on-street & off-street charging	Workplace locations: on-street & off-street charging
Immediate charging solutions (located at a property or within immediate walking distance)	• Driveway • Domestic charging on-street (using cable from property to vehicle)[5] • Parallel networks: servicing single or multiple requests from residents within a highly localised area • Street furniture connections	• Employer car park • Depot
Local charging solutions (located within a reasonable walking time, which may be 10 minutes from a residential property and up to 15-20 minutes from a workplace)	• Source London charge points • Parallel networks: single or clustered facilities – could be provided in response to demand or planning-led to respond to anticipated demand	• On-street: - Source London charge points - Parallel networks: servicing single or multiple requests from residents within highly localised area - Street furniture connections • Off-Street: - Public/private car parks
Remote charging solutions (outside of the catchments described above but could still constitute the primary source of charging)	• Rapid charge points – owners of EVs are unlikely to use remote charging stations (away from their residential or workplace area) unless the locations have rapid charging facilities. The exception to this would be at a location where they would already be driving to and parking for a period of time (e.g. a shopping centre or cinema) but this is likely to be occasional opportunity charging rather than the regular, primary method of charging.	

It is expected that Immediate charging solutions will be the preferred choice for EV owners without access to off-street parking. It is likely that in MSOAs with relatively high off-street parking availability, there will be fewer parking restrictions, thereby enabling Immediate charging solutions with dedicated EV bays. Local and Remote charging solutions may still be used by some EV drivers in these areas if there are particular restrictions on parking. However, these charging solutions are likely to play a more significant role in areas closer to the centre of London. Although car ownership is generally lower in these areas, those who do own EVs are

[5] These "trailing cables" may be required to meet demand for on-street charging before alternative solutions become commercially available, but are not seen as a long term solution.

likely to face more severe parking restrictions and greater competition for space due to the high population density. Faster charging solutions such as Remote rapid charging will be less dependent on specific EV parking bays and are therefore likely to be more useful in parking-constrained areas, compared to areas of outer London where space for parking is more available.

Across different areas of London, new developments could present the opportunity to embed the provision of charging facilities – whether parking is provided or not – and typically offer access to the lowest installation cost of charging solutions. This could potentially alleviate some of the competition for access to EV charging.

Street types and associated infrastructure need

The future roles and locations for different charging types were considered in relation to recognised street categories. The Roads Task Force has proposed a classification for this purpose and based their concept on the relative balance of movement and place function; these are shown in Figure 8. TfL has worked with boroughs to classify the entirety of London's road network by applying this typology in a consistent manner. This framework has been used in this study to tailor recommendations on the most appropriate type of charging infrastructure for comparable locations across the capital and promote greater consistency in service provision.

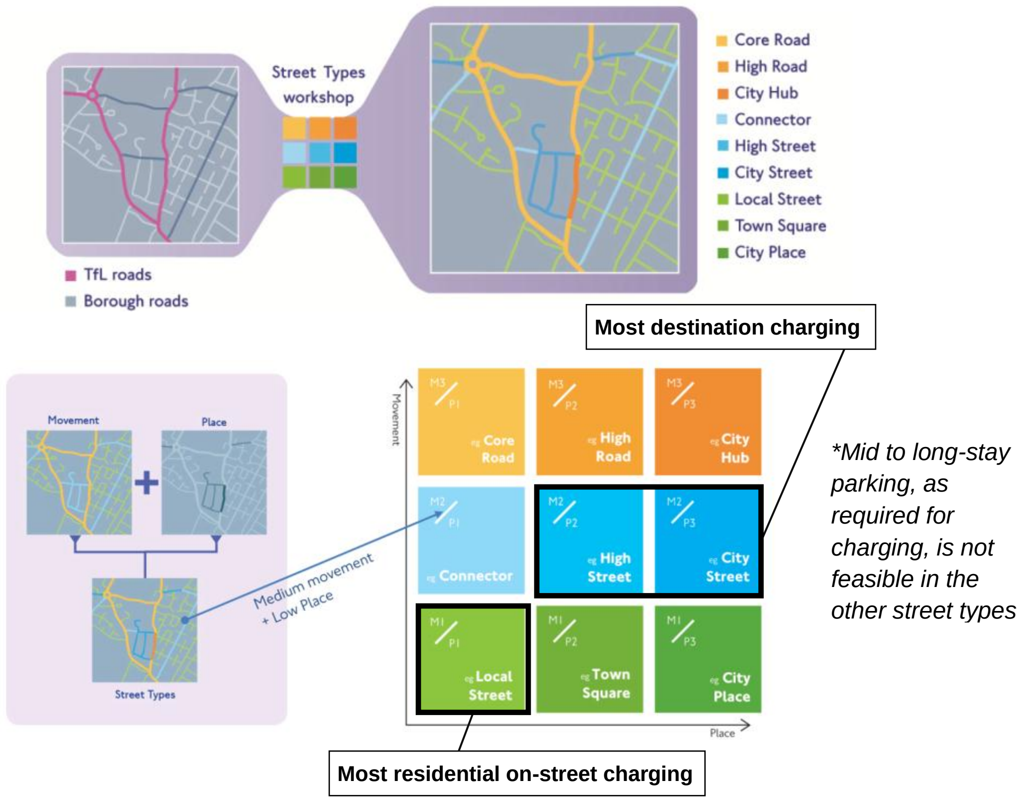


Figure 8 Street Types for London and expected charging type focus

The Immediate and Local on-street residential facilities will mainly be located on Local Streets, which make up over 80% of the Capital's total road network (by length) and are where the majority of people in London live.

Most workplace charging will take place off-street in depots or car parks so on-street charging will be minimal. On-street workplace and destination charging, likely to be for topping up during the day rather than fully charging, will take place in locations where parking is available. Therefore, the on-street locations are most likely to be in High Streets or City Streets with some located on Town Squares and City Places if appropriate to the local environment. Off-street destination charging points will be located in off-network destination 'places' such as shopping malls, retail parks and larger supermarkets.

TfL's approach to deploying a rapid charge point network is that rapid charging facilities will be located in 'hubs' or in dedicated locations such as taxi ranks. As this infrastructure will relate mainly to off-carriageway charging, 'Remote' (i.e. rapid) charging will not relate to any specific Street-Types.

As the main on-street charging type that has been mapped in this study, residential charging, is only feasible on Local Streets, much of the impact assessment focuses on the infrastructure requirements for this Street Type. To assess these requirements and associated impacts in 2020 and 2025, London MSOAs were categorised according to the key determinants which influence charging solutions: population density and access to off-street parking. MSOAs were assigned to one of four 'Typologies', based on whether they have low or high population density and whether they have low or high availability of off-street parking[6]. The typologies are shown in Figure 9 below.

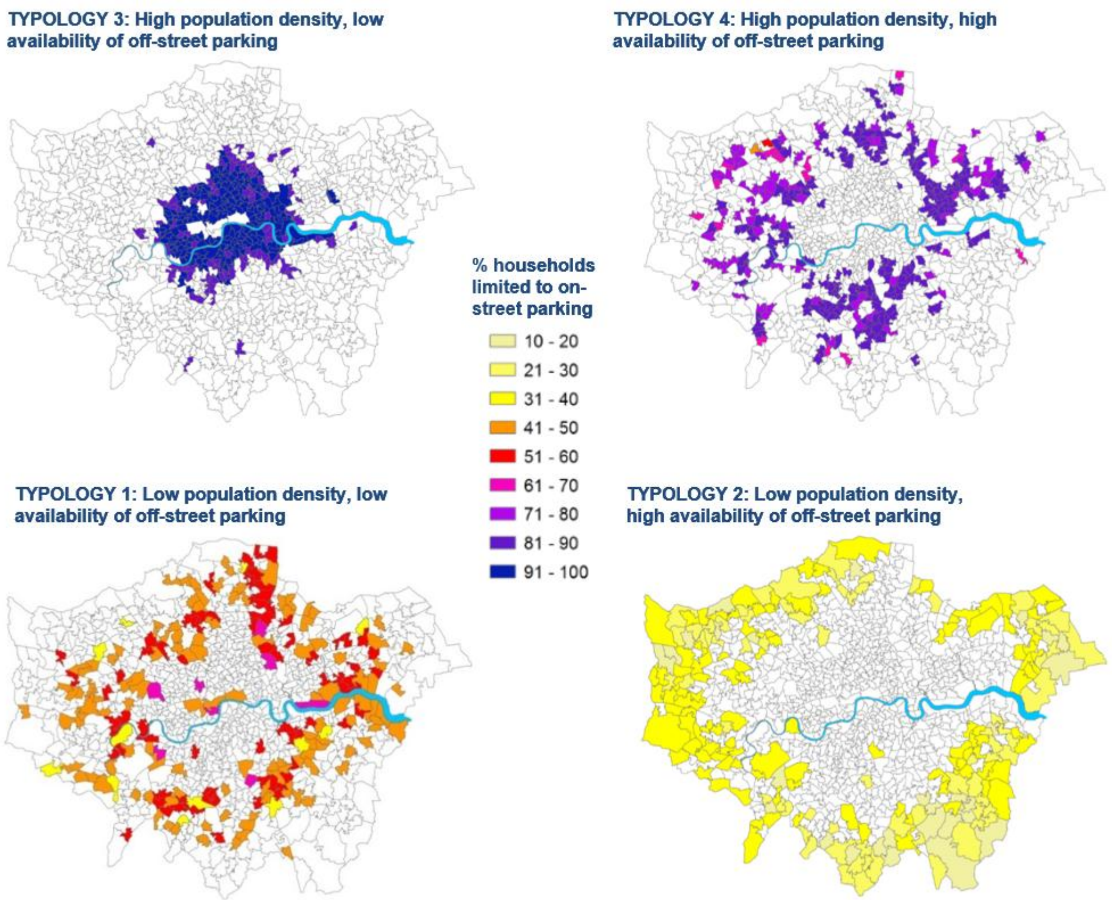


Figure 9 Assigning MSOA typologies

[6] Low population density being defined as under 65 people per hectares, low availability of off-street parking being bottom 50% of MSOAs

As shown in Figure 9, the share of households with access to off-street parking varies dramatically across the city: in typology 3 MSOAs (mostly in central London), 81-100% of households do not have access to off-street parking, compared to only 10-40% of households in typology 2 MSOAs. This implies that the impacts of EV uptake and charging in these MSOAs will also vary, particularly as the projected London EV stock is relatively evenly distributed between MSOAs in inner and outer London (see Figure 4).

It is important that the step-change required in the delivery of EV infrastructure over the next 10 years is not achieved at the expense of non-EV owning households, as many of these are likely to be lower income households (with a lower density of new car buyers. The impacts on parking and street-scape are likely to be most significant in MSOAs with high concentrations of EVs, low levels of access to off-street parking, and where extensive parking restrictions are already in place. For each MSOA typology, the maximum density of EVs (among MSOAs within that typology) was identified, according to various metrics shown in Table 2 below. These metrics for maximum EV density were used to quantify the parking and street-scape impacts, and the corresponding implications for charging infrastructure.

Table 2 Metrics of EV uptake for different MSOA typologies (Baseline scenario, 2025)

Typology	Average % EV stock needing on-street charging	Maximum no. of EVs per MSOA	1 EV charged on-street per X households (maximum)	X EVs per 500m of minor road (maximum)
1 – Low population density, low availability off-street parking	51%	375	15	22
2 – Low pop. density, high availability off-street parking	38%	264	20	14
3 – High pop. density, low availability off-street parking	78%	376	12	30
4 – High pop. density, high availability off-street parking	54%	318	19	11

The EV stock projections and the metrics shown in Table 2 were used to assess the following impacts and considerations for each typology:

Impacts:

Grid impacts:

- With additional load from EVs, interventions may be required to ensure that the distribution networks are not overloaded. This will depend on the existing network capacity and on the anticipated additional power demand from EVs.
- Impact assessment included residential, depot and workplace charging at 3kW and 7kW. Rapid (43-50kW) charging networks (and fast 22kW) were not included in the demand modelling due to the lack of data around their usage patterns (this will be looked at separately by TfL). Possible clusters of demand (such as depots adopting several EVs) have also not been captured in the assessment.

Parking impacts:

- There will be a need to designate spaces for EVs in order to provide the assurance that users will be able to access charging facilities when and where they need them
- Owing to the scarcity of parking and road space in London, this may lead to tension with other non-EV users

Streetscape impacts:

- Potential issues resulting from visual intrusion from charging facilities installed in large numbers in residential streets

Considerations:

Charge point/network operation:

- There will be a number of charging providers, which has implications for inter-operability between networks and consistency of operation for the user
- The increased complexity with multi-operator and multi-network charging could also create issues such as the increased administrative burden for local authorities to liaise with different organisations

Technical feasibility:

- Some charging solutions are new to the market, and it is not yet certain whether they can be installed in large quantities across London

Commercial viability:

- EV users are likely to have to pay for charging in the future, and EV demand will be sensitive to price. This will need careful consideration to avoid disincentivising prospective EV buyers
- Commercial operators will want to concentrate their resources on those locations that have a high usage rate, and so in areas with lower numbers of EVs requiring on-street charging, users may find it more difficult to access charging facilities
- Commercial risk will be influenced by whether a demand responsive or planning-led approach is adopted. Different charging types and different areas of London will be more suitable for one type than the other

Planning and consultation:

- Authorities will need to decide the extent to which a planning-led approach to charging should be adopted
- Policies will be needed to respond to user requests for charge points

A traffic light approach was used to qualify the severity of the key impacts in each typology. This approach is summarised in Table 3. Grid impacts for each typology are determined based on the ratio of power capacity to projected peak power demand from EVs, while parking and streetscape impacts are determined on the basis of the various metrics for projected EV density, and density of EVs charging on-street (as shown in Table 3). These metrics are calculated from the projections of EV stock, from Phase 1.

Table 3 Qualifying key impacts for MSOA typologies

IMPACTS ASSESSMENT - APPROACH	GRID (% of EV power demand compared to power capacity)	PARKING (Effects on parking pressure, revenues, competition for space with non-EV users)	STREETSCAPE (Visual and physical intrusion of charging facilities, impact on footways)
CONTRIBUTING FACTORS:	• Number of EVs and charging profiles → Peak power demand	• Density of EVs charging on-street, cost of parking in MSOAs, charge-point network operation…	• Density of EVs charging on street, mix and cost of different charging solutions…
Green (no mitigation action required)	• **0-10%** • Existing spare capacity in the local network expected to cope with this additional load without the need for enhancement works	• Little change to parking situation	• Small, manageable changes in streetscape
Amber (mitigating actions required – low priority)	• **10-20%** • Some low level enhancement works may be required based on this level of load increase (e.g. redistribution of loads between different feeders or substations; reinforcement of individual feeders)	• Increased competition for parking • Risk that not all EVs can charge when convenient • Small reduction in parking revenues due to free EV bays • Increased enforcement burden on Boroughs for EV-only bays	• Reduction in footway space for pedestrians due to trailing cables and other charging adaptations • Minor visual intrusion in some areas • Degradation of footways in some areas
Red (mitigating actions required - high priority)	• **>20%** • Some requirement for medium to high level enhancement works likely based on this level of load increase (e.g. upgrade of secondary or, in extreme cases, primary substations)	• High level of competition for parking and charging spaces • Many EVs unable to charge when required due to competition • Significant reduction in revenues due to free spaces for EVs • Increased enforcement burden on Boroughs	• Severe reduction in footway space for pedestrians due to trailing cables and other charging adaptations • Complaints about visual intrusion • Costly utilities works • Safety issues from degradation of footways

Results

A high level assessment of the severity of the impacts is shown in Figure 10 below. The parking impacts in 2025 are reduced compared to 2020, as it is assumed that new vehicle and charging technologies will enter the market, bringing reduced charging times, greater numbers of vehicles accommodated at each charging point, and possible advancements in parking management. These developments will be required to maximise utilisation of charging points and accommodate demand for on-street EV charging, and related demand for parking. In addition, outstanding issues regarding the practicalities of designating bays are likely to be resolved in these timeframes.

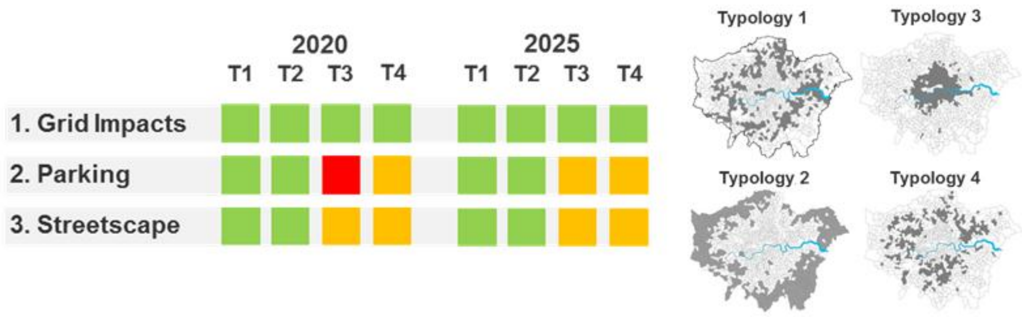


Figure 10 High level impacts across MSOA typologies

The EV demand for on-street residential and workplace charging for typical MSOAs within each typology are described in summary sheets, in Sections 5.5 to 5.8 of the report.

As shown in Figure 10 above, the impacts are most acute for Typology 3 MSOAs (i.e. most of inner London) which will have a high demand for EVs, but low availability of off-street parking, and minimal spare capacity within on-street parking areas. This Typology represents the worst case MSOAs, where high population and low off-street parking provision combine to provide the highest parking stress. The EV demand and the associated impacts for each of the Typologies are described in detail in Sections 5.2, and 5.5-5.8 of the main body of the report.

Key conclusions & recommendations

There are multiple impacts, considerations and potential mitigations to account for when planning for the delivery of EV charging infrastructure in London. Street type, population density and housing type are all factors which play a crucial part in determining what type of charging is appropriate on-street, and as these vary significantly across London there will be a variety of solutions.

This study quantified the level of EV uptake in MSOAs across London and categorised the MSOAs into one of four typologies which informed the assessment of impacts and interventions regarding the provision of charging infrastructure. The most acute impacts are likely to be experienced in Typology 3 MSOAs, where in the High BEV scenario for 2025, it is estimated that in a particular MSOA there will be up to there will be up to 806 EVs charging on-street: requiring one charging facility every 7 metres.

It is important that the step-change required in the delivery of EV infrastructure over the next 10 years is not achieved at the expense of non-EV owning households, many of which are likely to be lower income households with a lower density of new car buyers. Parking capacity and streetscape impacts are the main cause for concern. Energy and power demand from EVs is forecast to be relatively low by 2025 and as such is unlikely to be an issue - although rapid charging has not been included in the energy modelling and could lead to concentrated areas of demand in higher EV demand areas. Possible clusters of demand (such as depots adopting several EVs) have also not been captured in the assessment due to a lack of data on depot locations.

Recommendations regarding the key interventions and mitigating measures that are required are described as follows:

(For Boroughs and Local Authorities)

- To maximise the utilisation levels of EV bays and thereby reduce parking stress, there should be flexibility in the use of parking spaces between EVs and other vehicles.
- To create a consistent and effective system will require the development of policy and standards regarding the approach and adoption of demand-led or planning-led charging facilities.
- New policy and/or legislative changes may be required to designate and enforce EV bays, as well as access domestic charge points from the street.
- Fundamental uncertainties regarding the technological feasibility of charging types such as street furniture connections need to be addressed, for example by trials and liaison with technology providers and electricity Distribution Network Operators (DNOs).
- Minimising the down-time of charge points will increase utilisation; therefore it will be important to ensure that effective maintenance processes are in place (e.g. through procurement contracts).
- Certain charging types will be a more attractive and commercially viable proposition in certain areas of London. Their implementation may be financed privately and their operation sustained through subscription and/or pay per use methods. In other areas, however, at least in the short-term, a certain level of financial support from public sources may be required to install and operate charge points.
- Timely and effective collaboration between delivery and operation stakeholders will be critical to ensure that there is the required interoperability and consistency between charging facilities and networks. This is essential in giving the public the required confidence that they will be able to access suitable charging facilities where and when they need them, and at an acceptable cost.

(For charge-point operators)

- Consolidation of charging network communications and access through a single, interoperable interface will help EV users understand their charging and payment options, which bays they are permitted to access and during which hours, and can provide real-time information on when they are available. An integrated booking system could help to reduce parking pressures once the concentration of EVs increases; there is currently mixed evidence of customer demand (and operator appetite) for booking systems, as numbers of EVs already on the road are still low, even in areas of relatively high EV uptake[7].
- Minimising the down-time of charge points will increase utilisation; therefore it will be important to have effective maintenance processes in place.
- The increased burden that will fall on boroughs to liaise with operators and administer certain elements of the process (e.g. creation of Traffic Management Orders) needs to be factored into the commercial model.

Of the myriad actions and interventions that will be required to deliver the charging infrastructure, some should be afforded a higher priority than others to negate the biggest risk to delivery: a disconnected network which London residents cannot use easily and that does not have the flexibility to adapt to future growth and innovation.

[7] Rapid charging network study, Element Energy for TfL, 2015

The key impacts which require more immediate mitigation are certainty of access to charging facilities, technological feasibility/suitability of certain charging types and network operation/interoperability. This will require the development of policy/standards.

Delivery responsibilities and actions will need to be defined in detail for each part of the planning, implementation and operational process, but clearly, as the delivery of the infrastructure on the highway will largely be the responsibility of boroughs, they will need to be the driving force in ensuring that the demand of future EV drivers is met.

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Note about the study

This study was originally carried out in 2015, based on electric vehicles sales up to 2014. Sales of electric vehicles have however greatly increased in 2015, and sales data have been made available at a more disaggregated level by the Department for Transport up to 2015Q3. Therefore, the results of the study were updated in 2016.

Acronyms

BEV	Battery Electric Vehicle
CCC	Committee on Climate Change
CP	Charge Point
CPZ	Controlled Parking Zones
DfT	Department for Transport
EE	Element Energy
EV	Electric Vehicle
FCEV	Fuel Cell EV
FORS	Fleet Operator Recognition Scheme
GLA	Greater London Authority
GVW	Gross Vehicle Weight
HC	Hackney Carriage
LA	Local Authority
LEVR	Low Emission Vehicle Roadmap
LSOA	Lower level Super Output Area
MSOA	Middle level Super Output Area
NTS	National Travel Survey
OLEV	Office of Low Emission Vehicle
P2WL	Powered two wheeler
PFI	Private Finance Initiative
PHEV	Plug-in Hybrid EV
PHV	Private Hire Vehicle
PTAL	Public Transport Accessibility Level
REEV	Range Extended EV
RTF	Road Task Force
TfL	Transport for London
TMO	Traffic Management Order
UK	United Kingdom
ULEV	Ultra Low Emission Vehicle

1 Introduction

1.1 Background

The EU sets statutory limits on air pollution and requirements for reducing CO_2 emissions, and in order to contribute towards these the previous London Mayor made commitments in his Air Quality and Climate Change Mitigation and Energy Strategies to contribute towards achieving EU air quality limit values and reducing CO_2 emissions by 60 per cent from a 1990 baseline. The new Mayor, Sadiq Khan, has made clear his commitment to cleaning London's air and is consulting on a set of bold new measures to go further and faster than the previous Mayor in reducing air pollution from road transport. He has also stated his ambition for London to be a Zero Carbon City by 2050.

Electric vehicles (EVs) emit fewer harmful air pollutants and less carbon dioxide compared to conventional internal combustion engine vehicles. There are a number of alternative vehicle and charging technologies available and emerging, making EVs an increasingly viable and affordable alternative to non-electric cars and vans. TfL, alongside the Greater London Authority (GLA) and the UK Government, recognise that uptake of EVs will be an important part of the strategy to mitigate against climate change and improve urban air quality.

In May 2009, the then Mayor of London published his Electric Vehicle Delivery Plan, which committed to deliver a range of initiatives to encourage the uptake of EVs, with a target of 100,000 EVs on London's roads as soon as possible. . In July 2015, TfL published a new Ultra Low Emission Vehicle (ULEV) Delivery Plan, which builds on the 2009 EV Delivery Plan and sets out 15 new actions designed to overcome the barriers to ULEV uptake and to stimulate the market for EVs in London. The ULEV Delivery Plan had three core strands of activity to achieve the uptake of EVs: infrastructure; vehicles; and incentives, marketing and communication. Continued investment in EVs is crucial if the full benefits of this technology are to be realised and TfL's ongoing commitment reflects a wider public and private consensus. TfL's commitment is underlined by a commitment in the new Mayor's manifesto to work with the private sector to deliver the charging infrastructure to support a major expansion in EVs.

Since the publication of the EV Delivery Plan in 2009, the EV market has changed and will continue to change. These changes will include: market growth; new funding from OLEV (the Office of Low Emission Vehicles); availability of new vehicles, with greater range; the development of the Source London network; and the further development of charging technology. Through this and other studies, TfL seeks to understand what these changes mean for EV uptake in London in order to inform its future policy and strategy to achieve the greatest benefits for improving air quality and reducing carbon dioxide emissions.

1.2 Objectives

TfL has commissioned Element Energy and WSP Parsons Brinckerhoff to understand the likely spatial distribution of Electric Vehicles in London over the next decade, and to assess what infrastructure is likely to be needed to support this uptake.

This study is intended to inform the development of TfL's electric vehicle charging infrastructure strategy, and the Mayor's London Energy Plan. It will enable TfL to inform the direction of public and private sector investment in infrastructure, and improve TfL's understanding of the potential planning and energy requirements of increasing EV uptake. These requirements will be influenced by where and how EV users recharge their vehicles. This study will help to identify any mitigation measures needed to address the impacts of EVs and their related charging infrastructure.

This study has the following specific objectives:

- To map where EV uptake is most likely to occur across Greater London, looking at where EVs can replace conventional vehicles for both private users and commercial fleets, and the locations of both home/depot charging and destination charging
- To understand the issues related to urban realm (i.e. streetscape, competition for parking), planning policy (such as parking policy) and the electricity distribution network and how the impacts, and potential solutions, may vary across the city
- To provide evidence-based, strategic advice to inform future public and commercial investment in EV infrastructure
- To inform energy infrastructure investment plans (i.e. from the GLA and utility providers) for addressing the impacts of electric vehicles on electricity infrastructure by feeding into the development of the London Energy Plan.

1.3 Scope and approach

This study considers the impacts of plug-in electric vehicle uptake over the next decade, and looks specifically at possible scenarios for uptake in 2020 and 2025. By exploring the possible impacts at different stages of vehicle uptake, this report provides an insight into potential strategies for mitigating these impacts at different stages of EV uptake. Projections of uptake and energy demand are also available for 2030, 2040 and 2050, as part of the GLA London Energy Plan[8].

Cars, vans and taxis account for 93% of mileage in London[9]. This is reflected in the scope of this study, which centres on predicting the uptake and impacts of electric cars and vans, including both privately owned and company owned vehicles. This does not include car clubs, which are currently being considered in a parallel study commissioned by TfL. Taxis (Hackney Carriages, as opposed to Private Hire Vehicles[10]) and powered two wheelers are in the scope of the study – however, only the overnight residential recharging of taxis is projected and mapped[11]. Private Hire Vehicles are included as part of the private and company owned car fleet. Buses and heavy commercial vehicles are outside the scope of the study. Only vehicles registered in London are included in the scope of the study.

For the purposes of this study, the term “electric vehicles” refers to:

- Battery electric vehicles (BEVs);
- Plug-in hybrids and range-extended electric vehicles (both referred to as PHEVs for simplicity)

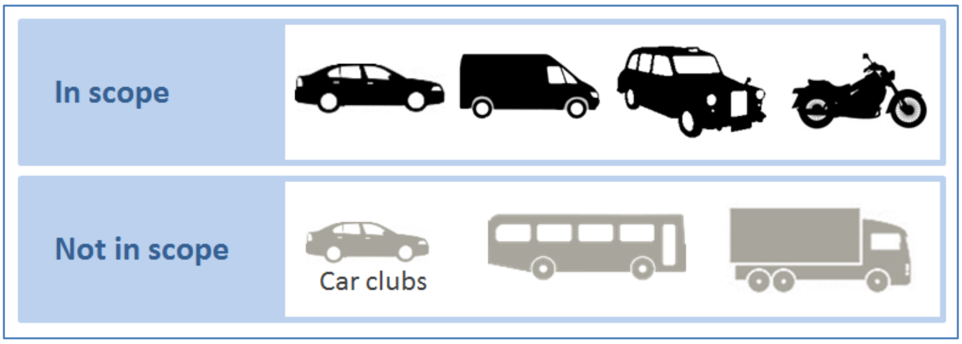


Figure 11 Vehicles in the scope of this study: light vehicles

One of the factors that will influence the overall impacts of future EV uptake will be the location and timing of charging events. This study focuses mainly on the impacts associated with charging that starts at the end of the day, at vehicle primary locations (mainly residences, and some depots), as this

[8] http://data.london.gov.uk/
[9] DfT, 2015 - Table TRA0106. Road traffic (vehicle miles) by vehicle type and region in Great Britain.
[10] Private Hire Vehicles are considered as part of the overall fleet of private and company cars.
[11] The use of rapid charging networks by taxis is currently being explored in a parallel study (A feasibility study into a rapid chargepoint network for plug-in taxis, Energy Saving Trust, 2015)

is likely to account for the majority of charging events. The likely requirements and impacts of charging at vehicle destinations during the day are also considered, in particular in relation to charging at or near to workplaces. Only vehicles based in London are included here. Potential demand from EVs commuting into London, from outside London, is not included in the energy demand modelling[12], as it is assumed that the majority their energy demand will come from charging at their primary locations (i.e. outside London). Demand for destination charging (i.e. at other destinations such as shopping centres, supermarkets, and private car parks) is assessed using a more qualitative approach, compared to the first two types of charging event.

Over the next decade, demand shifting (e.g. through differential electricity tariffs) may have a role to play in determining the impacts of EV charging. For example, the shape of the overall load profile from residential charging may become flatter, due to the impact of demand side response measures. However, this study assesses future impacts based on the assumption that there will be no demand shifting. A parallel study commissioned by the GLA assesses the potential for demand responsiveness from EVs, and considers how much of the energy demand (as estimated in this study) could be shifted to different times of day.

Uptake and impacts of EVs are considered for the 33 Local Authorities (32 Boroughs and City of London) under the umbrella of the GLA. EV uptake and the associated impacts are likely to vary within each Local Authority (LA), due to variation in demographics, parking availability and loading of distribution networks. All LAs can be divided into MSOAs (Middle-Layer Super Output Areas), each containing 2,000-6,000 households. By assessing uptake and impacts for the MSOAs, this study reveals the potential differentiation within each LA. The impacts are also considered in terms of street types, and in terms of the potential infrastructure demand for a typical street within an MSOA, depending on the level of EV uptake.

The impacts of the projected EV uptake are assessed according to the following factors: Charge point/network operation and interoperability; grid impacts; technical feasibility; commercial viability; parking; planning & consultation, and streetscape. For the assessment of these impacts, MSOAs are split into four typologies, according to different levels of population density and the availability of parking. This enables a comparison of the key impacts between the different typologies, and supports the assessment of overall impacts at a London level.

The overall approach to this study is summarised in Figure 12. The projected overall level of uptake in London is based on two different scenarios for ambitious EV uptake (explained in detail in section 2.2.2). The resulting share of EVs in London sales and stock are then distributed across London to create a map[13] of uptake by MSOA, based on the predicted concentrations of EV sales. Future total vehicle sales and stock are distributed at MSOA level based on recent distributions – this assumes that there is no change in the overall distribution of car ownership across London. The projected EV sales share is applied to the MSOA level sales share. The charging locations of the EV stock in 2020 and 2025 are then defined, based on assumptions regarding EV user charging patterns, and the resulting energy and power demand are mapped. Based on these results, the impacts and infrastructure demand for EV charging are then assessed, across MSOAs and for London as a whole.

[12] This could include up to 30% of all car/van driver commuter trips ending in London. Source: Origin and destination data - Method of travel to work: Driving a car or van - 2011 Special Workplace Statistics - MSOA Level (England and Wales) - Open Government License

[13] In the maps created for this study the City of London is greyed out as the specific characteristics of this local authority (high commercial land use, low residential) mean that its particular housing make up and car ownership breakdown do not fit with the modelling assumptions. Therefore the results are not comparable with the other local authorities.

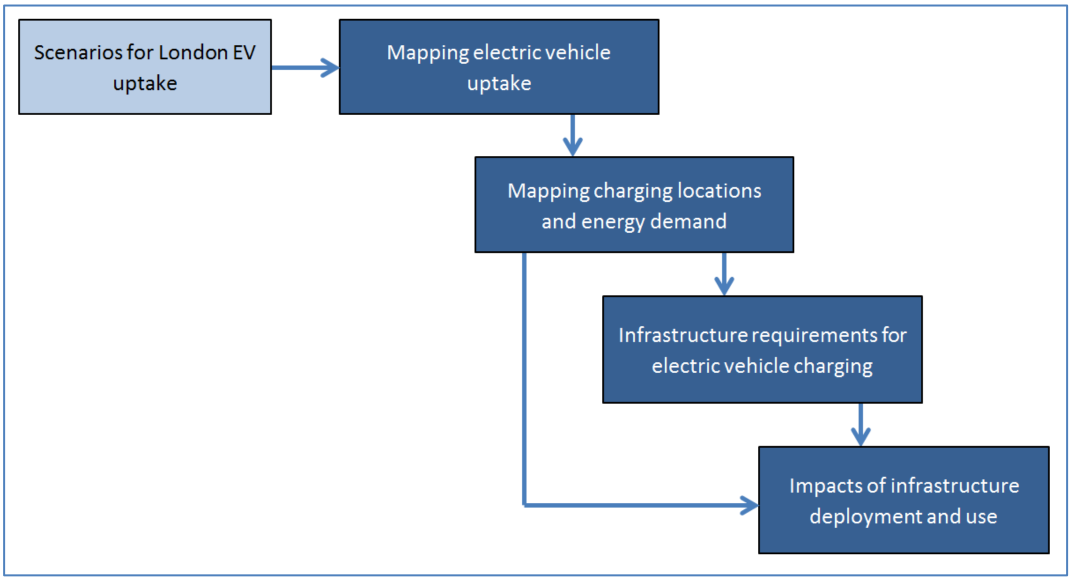


Figure 12 Approach to this study

1.4 Structure of the report

The structure of this report reflects the overall approach taken to this study, as defined above.

Chapter 2 defines the **approach to mapping and projecting the future distribution of EVs**, and includes maps of EV uptake in London at MSOA and Borough level, in 2020 and 2025. Assumptions for total EV uptake in London are also explained here.

Chapter 3 discusses the main **charging event types considered in this study** (overnight charging in residential areas and depots, and daytime charging at/near workplaces) and explains the assumptions made in identifying when and where these charging events will take place across London. The resulting energy demand from each charging type is then mapped at MSOA level.

Chapter 4 examines the **charging infrastructure requirements associated with the predicted vehicle uptake and charging patterns,** particularly in terms of off-street and on-street charging. This includes an assessment of the number of EVs parked on-street and the solutions that could be employed to enable them to recharge.

Chapter 5 examines the **impacts of these infrastructure requirements**, in terms of parking pressure, electricity demand on the grid, potential conflict with other residents over space and streetscape/street clutter. Impacts are differentiated by area types across London (defined by parking provision and population density).

Finally, chapter 6 summarises the key findings of this study.

2 Mapping electric vehicle uptake

2.1 Electric vehicles in London: current status

2.1.1 Current uptake of electric vehicles

Plug-in vehicles currently account for a small but increasing share of road vehicles in London. Figure 13 summarises the London sales share of plug-in vehicles in 2012-2015, for the vehicle types in the scope of this study: cars, vans, and powered two wheelers (P2Ws)[14]. Electric Hackney Carriages are also in the scope of this study but are yet to come to market[15].

Electric vehicle development to date has been focused mainly on cars, and this is reflected in the relative maturity of the electric car segment compared to other vehicle types. As indicated in Figure 13, 2014 and 2015 saw a surge in national sales of plug-in cars that was mirrored in London, and which, judging from registrations for the Plug-in Car Grant to date in 2016[16], is set to continue. The market share of EVs in London is higher than in the UK average, reflecting the local incentives (congestion charge exemption, free parking and charging in some Boroughs).

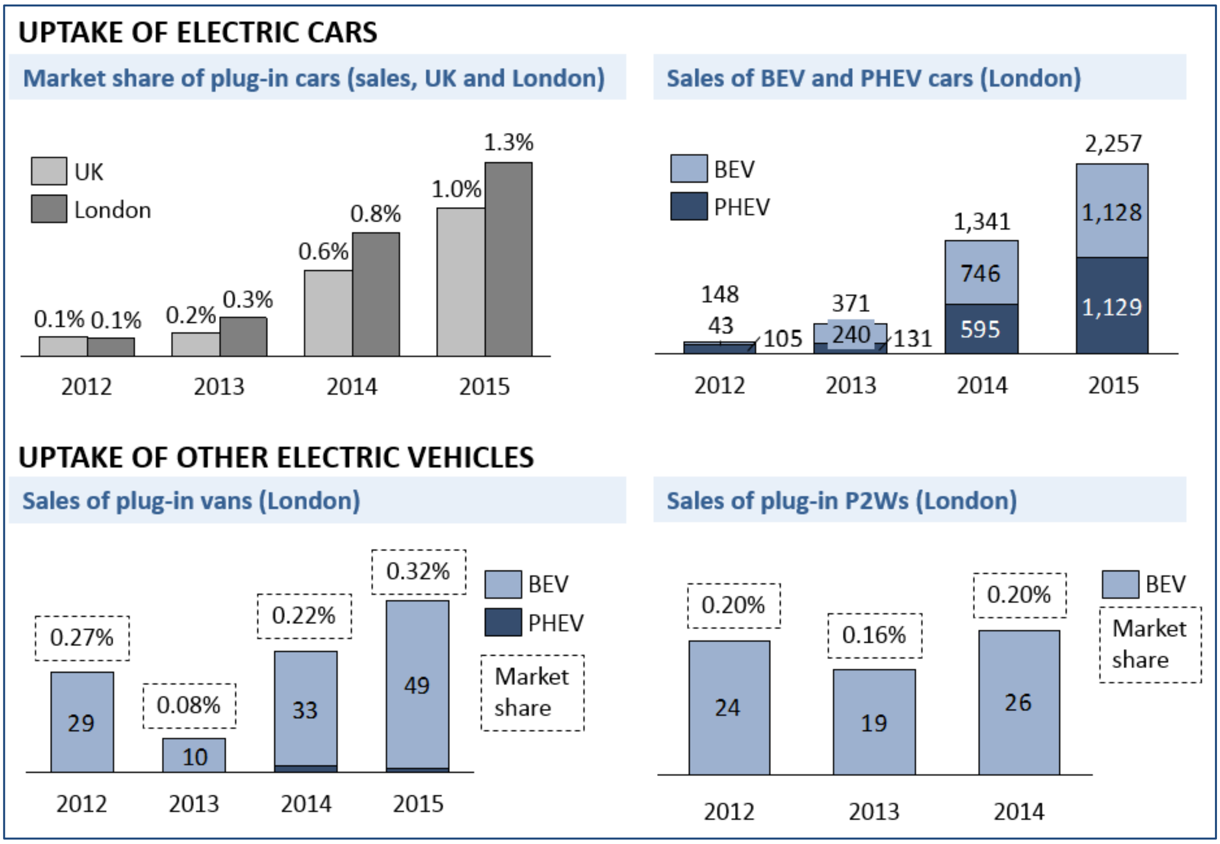


Figure 13 Sales of electric vehicles in the UK and London, 2012-2015

At this early stage of market development, the split of EV sales between battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) across different vehicle types reflects the availability of different models (which changes year on year), rather than accurately reflecting the long-

[14] Car club vehicles, buses and trucks are not considered in this study

[15] At least three PHEV models are expected to come to the market in the next few years, from LTC, Karsan and Metrocab.

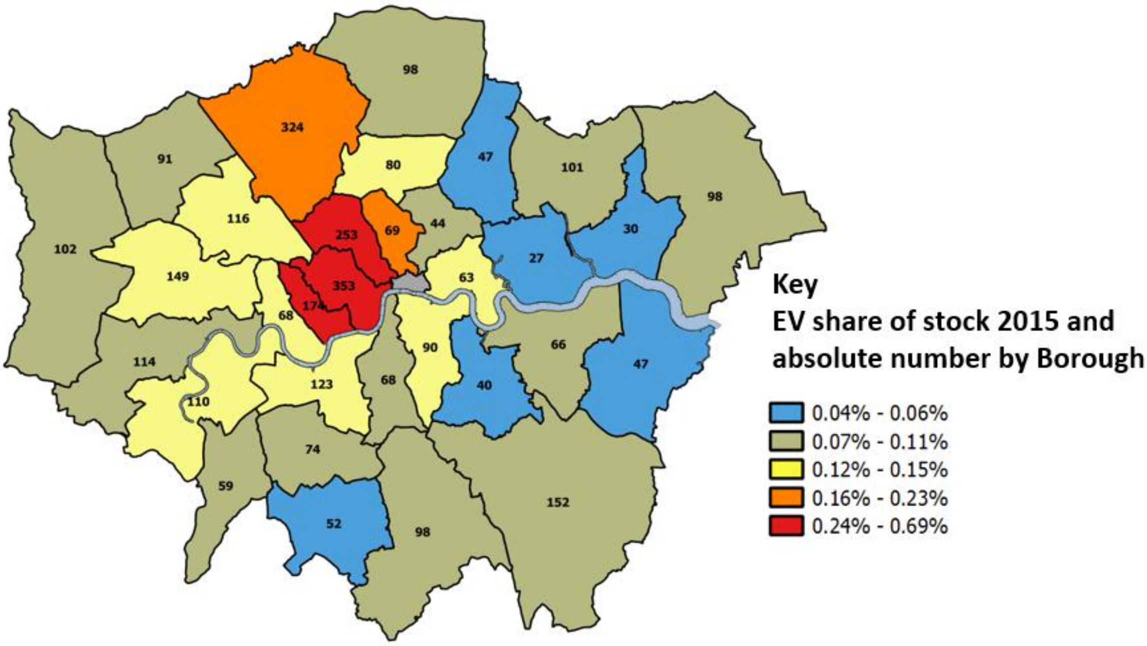
[16] SMMT data shows that 29,185 ultra-low emission vehicles were registered between January and September 2016, a 37% rise on registrations in the same period last year.

term demand for these technologies. There is currently only one PHEV van available for purchase in the UK: the Mitsubishi Outlander PHEV 4Work, which only became available at the end of 2014. Reflecting this, there were only 3 PHEV van sales in London over 2014-2015. There are no PHEV powered two wheelers currently available (or expected to come to market). Consumer research indicates that customers show a preference for PHEVs due to their greater range flexibility[17], and as the market develops this is starting to be revealed in recent EV sales; in Q1 2015, sales of the Mitsubishi Outlander PHEV overtook sales of the Nissan Leaf BEV, which had previously been the top selling EV in the UK[18].

EV sales are currently unevenly distributed across London, in absolute terms and also when considered as a share of the total sales in a particular area. Figure 14 presents the uptake of electric cars as a share of car stock in 2015Q3 again, but this time at MSOA level. This MSOA map reveals that, within Boroughs, the level of EV uptake is very uneven, going from 'hot spots' to virtually no uptake. For vans, plug-in sales are still too low for clear trends to be identified, but most Boroughs have seen some sales, as shown in Figure 15.

In order to assess the charging implications and impacts of future EV uptake across London, this study considers where EV sales will be concentrated in the future, and the effect that this will have on the distribution of EV stock across this city. The approach to predicting the distribution of EV uptake is based on current sales distributions (i.e. as shown in Figure 14 and Figure 15), particularly for cars, where uptake is more significant. This will be discussed in detail in section 2.2.

[17] Element Energy survey of 2,000 new car buyers, for DfT. Report to be published in 2015.
[18] http://www.racfoundation.org/data/plug-in-grant-eligible-vehicles-licensed-by-quarter



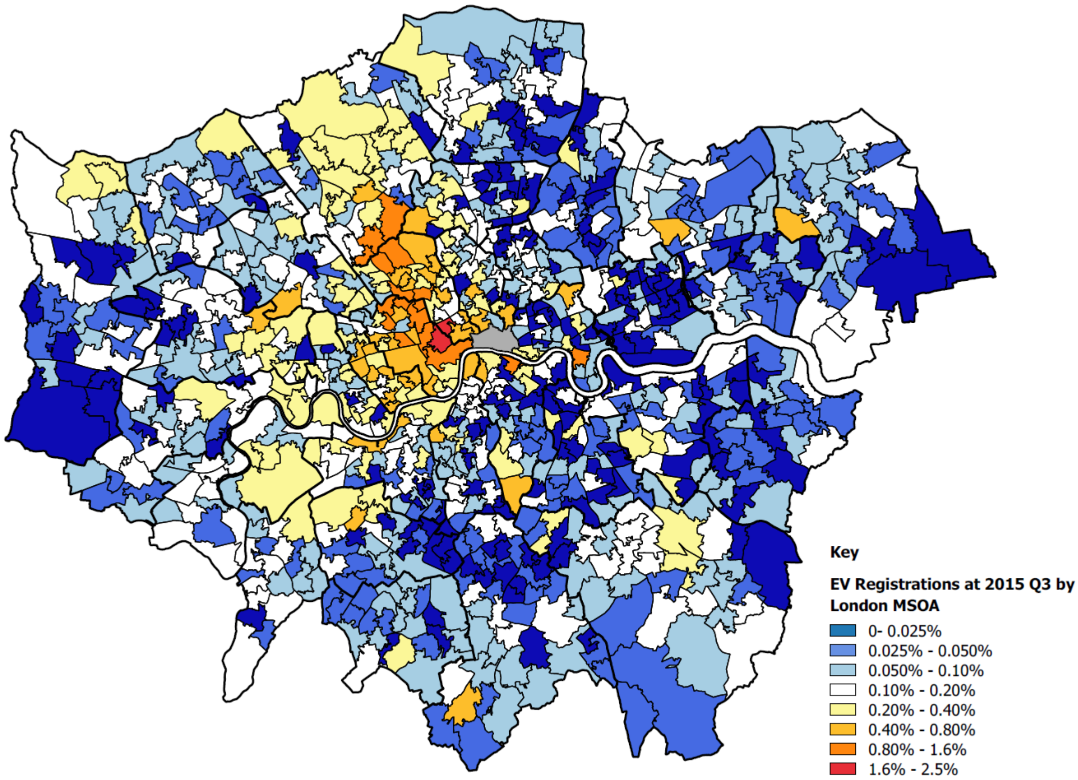


Figure 14 EV registrations (cars) at 2015 Q3 by London borough (top) and MSOA (bottom)

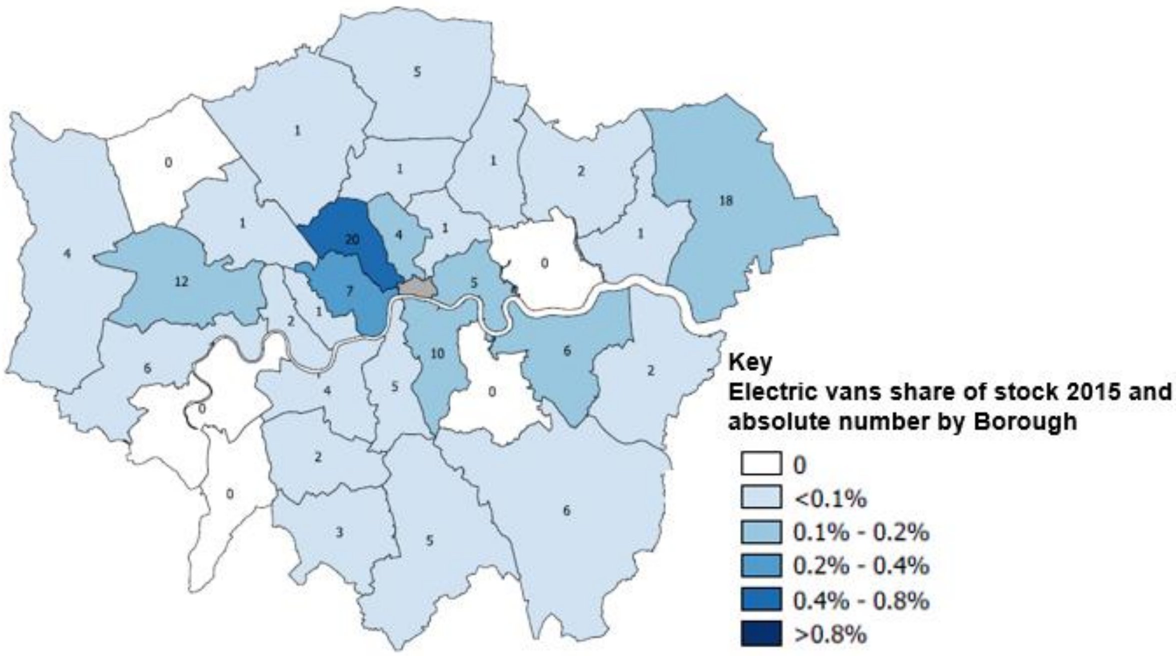


Figure 15 Electric vans share of stock in 2015, and absolute number by Borough

2.1.2 Characterising EV buyers

This section describes the method used to map the distribution of EV buyers in a way that can be used to predict how it may change in the future.

Analysis of EV uptake often centres on discussion of the "adoption curve", which measures the extent of technology adoption in terms of access to different customer segments. Using this concept, attitudinal surveys can be analysed to identify the characteristics of these customer segments, including those considered to be likely candidates for near-term EV adoption. In a recent survey of 2,000 new UK car buyers[19], respondents were segmented according to factors such as: attitudes towards new car technologies and new technologies in general (most positive for earliest adopters); attitudes towards the environment (fairly low awareness for rejecter groups); perceptions of impact of cars on social status; and attitudes towards fuel use, including willingness to pay upfront for lower running costs. However, these attitudinal population characteristics cannot be directly mapped to geographical locations, as there is no data linking attitudes of new car buyers to their addresses. The survey also identified mappable demographic characteristics for each segment, such as income, age, employment status, and access to off-street parking. On this basis, there was little differentiation between early adopter groups and certain other segments – for example, in this survey of new car buyers, the "early adopters" had similar income to the "rejecters" (as shown in Figure 16). Similar observations were made for annual mileage and other demographic factors. This indicates that demographics alone cannot be used as a proxy for attitudes to EVs. While attitude-based segmentations may be a useful way of predicting the overall rate of EV uptake, they are unlikely to be helpful in predicting future distributions of EVs in London.

[19] Element Energy for DfT, Survey of consumer attitudes to plug-in vehicles, 2015

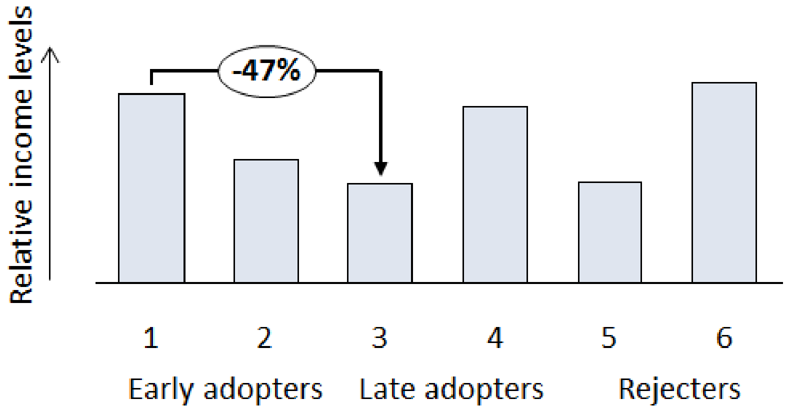


Figure 16 Relative income of new car buyer segments, Element Energy for DfT, 2015

Instead of attempting to identify EV buyer locations based on defined adopter types, this study therefore uses the current recorded locations of EVs as a proxy for areas with density of early adopters, to predict where uptake will be highest in the future. Where sufficient data is available, the approach is expanded by identifying mappable characteristics, such as employment, income, and housing type, which correlate with the current EV uptake across London.

Due to the low market share of electric vans, P2Ws and taxis (i.e. less than ten EV sales per Borough per year), it is unlikely that the current distribution of plug-in sales for these vehicle types across Boroughs is truly representative of relative demand. Therefore, the "correlation" approach has only been applied for cars, where sales have reached volumes approaching 50 EVs per year in some Boroughs[20], and a simpler approach is taken for other vehicle types.

The factors used to determine EV distributions (for all vehicle types) are described in detail below.

Defining electric car buyer locations

Previous attempts to map geographic variations in demand for electric cars have looked at various metrics, including level of car use, income, and Mosaic data, which classifies populations in terms of a range of demographic and lifestyle data[21]. Building on this approach, this study compares the current distribution of electric car sales across London Middle Super Output Areas (MSOA) with a range of other parameters (such as education level, employment and housing type), measuring the extent of correlation (in terms of geographic distribution) of each dataset with the market share percentages of electric cars. Matching data to the shares of new car sales, rather than absolute numbers of electric car sales, enables the emerging geographic trends for EVs to be applied to future car sales distributions, thus predicting the locations of EV buyers within the distribution of new car buyers. It is appropriate to consider new car buyers (specifically excluding second hand car buyers), as there have been relatively few EV sales to date, compared to the projected EV sales volumes, and since car owners keep their vehicles for about 4 years (on average), a substantial second hand EV market is unlikely to develop over the next decade.

A number of parameters were identified as having a relatively high correlation with EV sales share. **Employment levels** and **income** are both indicators of the likelihood of EV affordability, but employment has a higher correlation with EV sales share. While income may be a limiting factor for EV purchase in many cases, there is a significant range of incomes amongst likely EV adopters (as shown in Figure 16), and the income metrics available do not completely capture the proportion of the

[20] DfT vehicle registration data, 2015
[21] For example: TfL – Car Driver Segmentation, 2014; GLA - London's Electric Vehicle Infrastructure Strategy, 2009.

population with sufficient disposable income. However, while developing the EV indicator, it was found that employment levels provided a good correlation with EV uptake, in combination with other factors described below.

As is evident from the new car buyers' survey, affluence alone cannot distinguish early adopters from other segments of the population (see Figure 16). The distribution of early **hybrid car sales** shares (2010) was used as an additional indicator, acting as a proxy for positive attitudes towards new car technologies, effectively identifying early adopters within affluent areas.

Correlation of these parameters with EV sales was maximised by bringing several different factors together into a projectable "EV indicator". This involved normalising and adding together the various parameters, with different weightings applied to each parameter (as indicated in Figure 17).

A calibration factor was added to account for variations not otherwise captured. This is an empirically determined, three banded classification which applies at the Borough level (value provided in Appendix), and those MSOAs in which EV uptake is above that predicted by the socio-economic data used are designated as "EV hotspots". Variations not captured by other parameters could include provision of public charging infrastructure, local policies (e.g. parking permit tariffs, access to free parking for EVs) and housing make-up.

This enabled the identification of EV sales hotspots as the Boroughs with the highest overall "EV indicator" value, accounting for all the different correlating parameters.

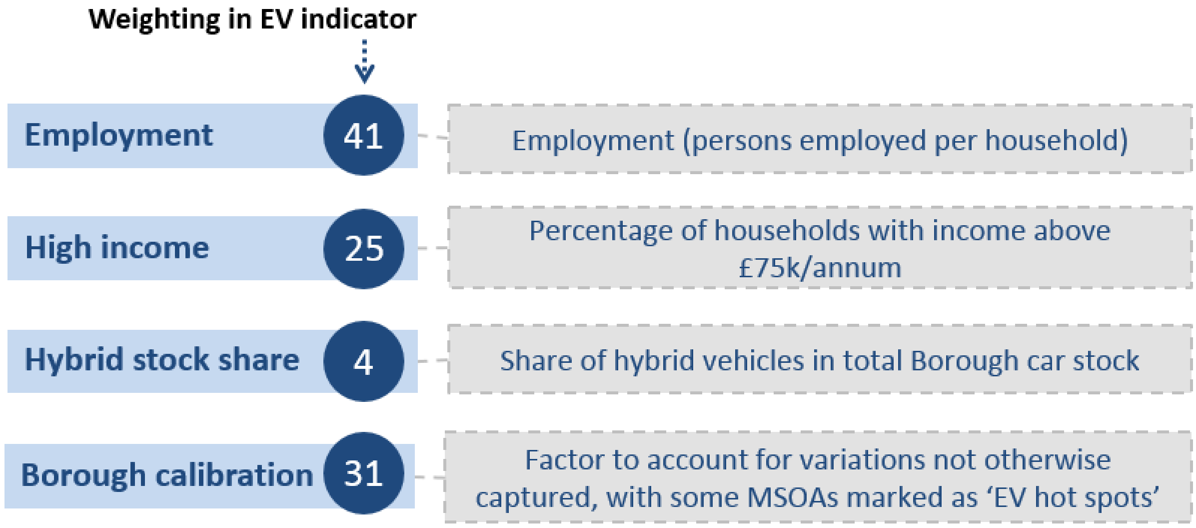


Figure 17 Parameters used in the "EV indicator" factor, correlating with 2015 sales share of plug-in cars

Weightings for the various factors were adjusted (through least squares regression) to achieve the greatest possible correlation with the EV sales share distribution across London, with employment levels having the greatest impact on the EV indicator value, followed by income. Inclusion of other parameters tested, such as education level (measured as a percentage of households with qualifications at a certain level), did not increase the correlation with EV sales.

Currently EV use is highly dependent on residential charging (usually relying on a garage or driveway), and therefore the availability of off-street parking has previously been used as a filter for identification of likely EV buyers. To some extent, off-street parking availability overlaps with affluence, which is already accounted for in the EV indicator, but the expected future parking availability is not explicitly used to filter out potential EV buyers. Instead, based on projections of EV uptake, this study identifies areas with low provision of off-street parking for residential EV charging in London, and considers how this could be managed through the provision of various on-street charging solutions. This is addressed in section 4.1 of this report.

Figure 18 shows the predicted EV stock distribution, based on the EV indicator described above, plotted against the actual stock distribution across Boroughs. Results and data have a correlation of 90% (R value 90%, R^2 value 81%).

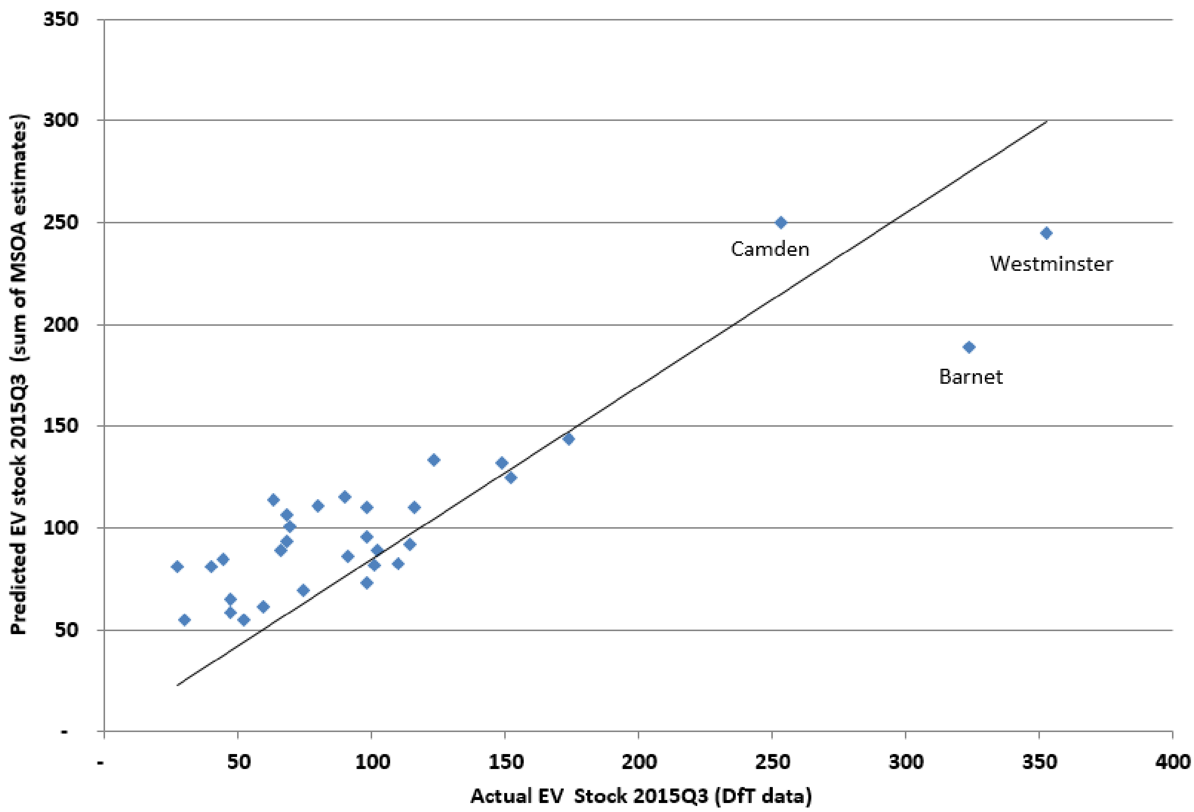


Figure 18 Predicted EV stock distribution vs actual stock distribution (2015Q3, 3,380 cars when excluding City of London, DfT data)

Defining electric van buyer locations

Although uptake of electric vans has increased in recent years, with 49 new registrations in London in 2015 (compared to 13 in 2011), registered stock per Borough is below 10 vehicles in almost all Boroughs. At this level, the entire EV uptake in some Boroughs may come from one organisation, and as such, the current distribution is unlikely to be representative of future demand. It is unlikely that attempts to correlate this low level of electric van sales to factors such as concentrations of certain business types, would yield meaningful results. Therefore, distributions of EV sales in the scenarios largely follow the current distribution of total van sales across Boroughs (shown in Figure 15).

Defining electric powered two wheeler buyer locations

As is the case with electric vans, the current uptake of electric powered two wheelers is too sparsely distributed to draw meaningful conclusions about future uptake, and therefore distributions of future EV sales follow the current distribution of total P2W sales across Boroughs.

Defining electric taxi buyer locations

There are currently no plug-in taxis registered in London. Predictions of uptake locations are based simply on the current distribution of taxi drivers at MSOA level.

2.2 Mapping future distributions of electric vehicles

2.2.1 Approach to identifying future electric vehicle adopter locations

The future distributions of electric vehicle sales, in terms of the share of total vehicle sales in each Borough and MSOA, are projected according to the factors described above (section 2.1.2[22]). For cars, the distribution is based on a number of different parameters (together creating an "EV indicator"), and so the various parameters are treated differently according to the information available (summarised in Figure 19):

- Where no projections are available, the parameter distribution is kept as per current values.
- Where projections are available, the parameter distribution is projected accordingly. This is the case for Employment figures only.

The weightings of each parameter within the EV indicator remain the same.

Indicator elements	Projections
Employment	Borough level GLA Economics projections applied across MSOAs
High income	No change, varies across MSOAs (no geographically disaggregated income projections available)
Hybrid stock share	No change in factor: hybrid vehicles share of stock (2015) is used to identify early adopter distribution; varies across MSOAs
Borough calibration	No change in the calibration factor; constant across MSOAs, with some MSOAs marked as 'EV hot spots' based on 2015 data

Figure 19 Changes to indicators for electric car uptake in 2020 and 2025

As indicated in Figure 19, the calibration factor does not change over time. This is due to the difficulty in predicting the location, scope and impact of the parameters underlying this factor, which could include provision of public charging infrastructure and local policies.

For vans, powered two wheelers and taxis, where the future EV sales shares are simply based on recent total vehicle sales distributions, the resulting EV sales share distribution is static over time.

Translating Borough level indicators to MSOA level

The impacts of EV uptake are likely to vary across Boroughs, due to variation in housing types, parking availability and loading of distribution networks. All Boroughs can be divided into MSOAs, each containing 2,000-6,000 households. Assessing uptake and associated impacts for these smaller areas will reveal the differentiation within each Borough.

In order to produce MSOA level projections of EV uptake, some assumptions were made for datasets that were only available at Borough level. This is the case of the Employment (which was measured on a per household basis) and calibration factors, for which values were applied evenly across the MSOAs of each Borough.

[22] Future total vehicle sales and stock are distributed at MSOA level based on recent distributions – this assumes that there is no change in the overall distribution of car ownership across London. The projected EV share is applied to the MSOA level sales share.

2.2.2 Projected distribution of electric vehicles in London

This study focuses on the future distribution of electric vehicles, rather than on predicting specific volumes of uptake. However, scenarios predicting the number of EVs in each area have been developed to quantify the possible impacts of uptake over the next decade, such as increased demand for energy, power and infrastructure (as will be discussed in chapters 3 and 4).

As illustrated in Figure 20, this study takes a top-down approach to quantify the level of plug-in vehicle uptake in 2020 and 2025. Scenarios for future vehicle sales volumes and overall EV sales share have been developed on the basis of the overall London fleet, and distributed to MSOA level using historic sales distributions (for total sales) and the projected EV indicator distributions (for the EV sales share).

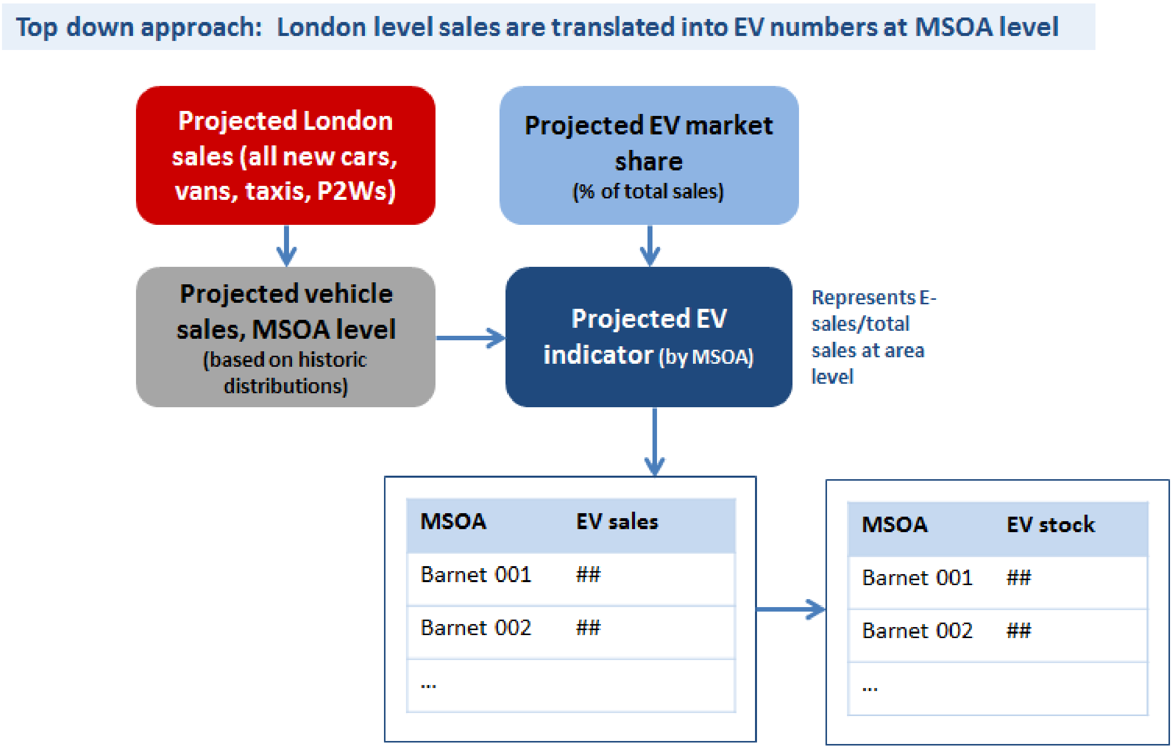


Figure 20 Approach to projecting EV sales at MSOA level

Projected London vehicle sales

Predictions for total sales volumes use current DfT data on registrations of cars, vans, taxis and powered two wheelers as a baseline from which to project future sales. Total sales of cars, vans and P2Ws are predicted to increase by 5% between 2015 and 2025, in line with projected national sales increases[23]. Sales of taxis (specifically Hackney Carriages) are predicted to stay approximately constant to 2025, in line with TfL licensing policy. Projected sales volumes for all vehicle types, in 2020 and 2025, can be found in the Appendix.

Projected London electric vehicle sales and stock

Table 4 summarises the assumptions for overall electric vehicle uptake in London used by this study.

The ranges of values shown for cars and vans in 2020 and 2025 are the result of two different uptake scenarios, described in further detail below. Both of the scenarios represent ambitious targets,

[23] Dft, Road Transport Forecasts, 2014

reflecting the high level of UK EV uptake recommended by the Committee on Climate Change in order to achieve national CO_2 emissions reductions targets for 2050.

Sales projections, both for the total London fleet and for the EV fleet, are translated into figures for vehicle stock by taking into account the current stock figures, the distribution of vehicle ages within the fleet, and typical scrappage rates for different vehicle types. Taxis follow slightly different scrappage assumptions, based on TfL age limit regulations.

Table 4 Projected sales and stock of plug-in electric vehicles in London

		2015	2020	2025
CARS	Plug-in sales	1,600	4,785 - 14,356	21,867 - 50,347
	Resulting share of total car stock (%)	0.14%	0.8% - 1.9%	3.4% - 8.2%
VANS	Plug-in sales	270	2,728	5,668 – 9,824
	Resulting share of total van stock (%)	0.2%	4.0%	12.2% - 17.8%
TAXIS	Plug-in sales	0	1,360	1,360
	Resulting share of total taxi stock (%)	0%	40.0%	70.0%
Powered two wheelers	Plug-in sales	259	701	2,909
	Resulting share of total P2W stock (%)	0.4%	2.1%	8.1%

In order to assess the impacts of EV uptake, assumptions around specific technology share are required: the share of battery electric vehicles (BEVs) and plug-in hybrids (PHEVs) in the fleet will affect the electricity demand. The two uptake scenarios use different assumptions for the vehicle technology share. Figure 21 illustrates the projected share of technologies in electric cars sales up to 2050 under the two scenarios underlying the results in Table 4, as well as indicating the overall EV share of total car sales. The assumed share of fuel cell electric vehicles (FCEVs) is included here, as even in a future world with very high overall sales shares of electric drivetrain vehicles, the relative uptake of BEVs and PHEVs will be affected by the extent of successful commercialisation and uptake of FCEVs.

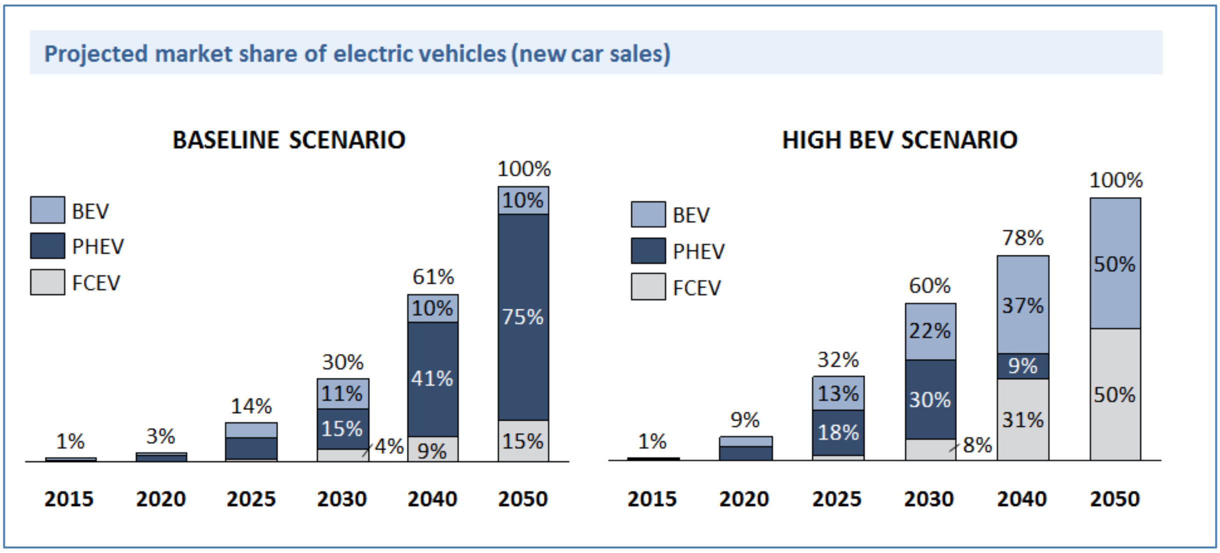


Figure 21 Scenarios for uptake of electric cars

Two uptake scenarios have been used for the study, both representing an ambitious level of ULEV (Ultra Low Emission Vehicle) uptake. In both scenarios, ULEVs represent 100 per cent of new car sales before 2050, as per the Committee on Climate Change (CCC) projections. This would deliver a stock that is almost entirely ULEV by 2050[24].

The two policy-led scenarios used in this study have been named the "Baseline scenario" and the "High BEV scenario" and are illustrated in Figure 21.

- The **'High BEV' scenario** assumes that the CCC recommended target of 60 per cent EV sales by 2030 is reached. In this scenario, PHEVs have a larger market share than BEVs in 2020 and 2025 (with a PHEV:BEV split of approximately 60:40), but in 2040 FCEVs increase significantly and between them BEVs and FCEVs capture all the sales by 2050 (FCEVs effectively fulfilling the long distance driving role of PHEVs).

- The **'Baseline' scenario** assumes a slower rate of ULEV market penetration, with 30 per cent EV sales reached by 2030. It also assumes that consumers prefer PHEVs over BEVs or FCEVs through to 2050 (in 2020 and 2025, the PHEV:BEV ratio is approximately 60:40, as in the High BEV scenario). The implication of this is that there would be a higher dependency on liquid fuels continuing to 2050.

The assumptions for electric van uptake under the two scenarios are summarised in Figure 22, with the technology breakdown showing the actual projected market share of BEV and PHEVs for the Baseline scenario and the High BEV scenarios respectively. As for electric cars, both scenarios are ambitious, with the Baseline scenario reflecting a higher dependency on liquid fuels compared to the High BEV scenario.

For powered two wheelers, only one uptake scenario was considered. The sales share of electric P2Ws[25] is predicted at 20% by 2025, and 80% by 2050. Full details of how the sales share increases to 2050 can be found in the Appendix.

[24] Both uptake scenarios are policy led, with the High BEV scenario in line with targets set out in the Committee on Climate Change's 4th Carbon Budget, The scenarios were validated in February 2015 by the LowCVP Fuels Working Group, including OLEV. Refer to: Element Energy, Ecolane and al. for the Committee on Climate Change, *Pathways to high penetration of EVs*, 2013 for comment and requirements for these scenarios to be achieved.

[25] All pure EVs, hybrid versions are not expected in this market segment where trip distances are short.

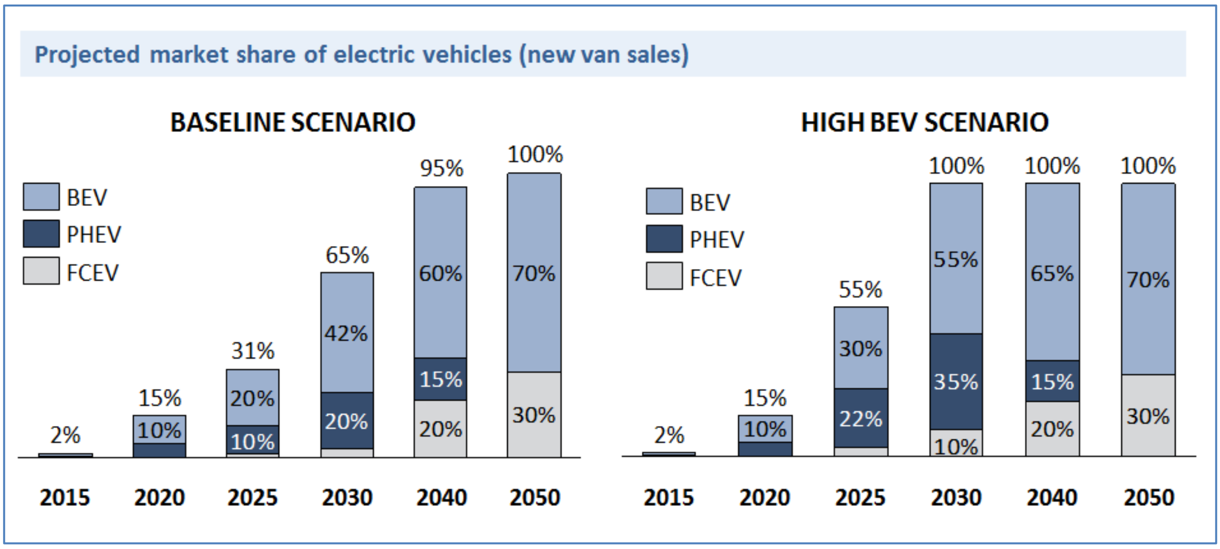


Figure 22 Scenarios for uptake of electric vans

Uptake of plug-in taxis (specifically, Hackney carriages) in London will be influenced by the new licensing conditions: from January 2018, 100% of new taxis will be required to be Zero Emission Capable[26]. Due to the high mileage associated with taxi operations, a high share of PHEVs is assumed, with uptake of BEVs starting only in 2030. A table detailing the projected sales volumes to 2050 can be found in the Appendix.

Projected electric vehicle sales and stock by MSOA

To determine EV sales at MSOA level in 2020 and 2025, the total London EV sales are split according to the projected distributions of EV uptake for each vehicle type, as described in section 2.2.1. The corresponding MSOA level stock projections are then determined by considering the historic stock to sales ratio for each area, and applying a normalised version of this ratio that ensures that the sum of EV uptake across MSOAs matches the London EV stock projections.

The share of different vehicle types differs across MSOAs: some examples of different vehicle splits in the High BEV scenario in 2025 can be seen in Figure 23 below. The two MSOAs used as examples here (Havering 014 and Richmond upon Thames 023) both have relatively high levels of predicted EV stock in this scenario, but the composition of the EV stock is very different. Due to the different energy demand of different vehicle types, this will affect the energy demand distribution.

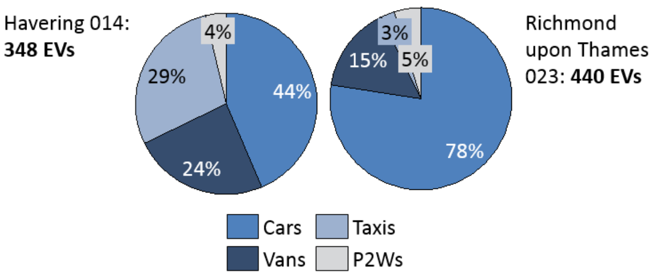


Figure 23. Example of vehicle type split of EVs across MSOAs with high EV uptake

Figure 24 and Figure 25 show the total distribution of EVs (cars, vans, taxis and P2Ws) at MSOA level in 2020 and 2025, for the High BEV scenario and the baseline scenario respectively. Figure 26 and Figure 27show the projected stock of EVs too, but this time in terms of share of the vehicle stock.

[26] A ZEC taxi is defined as having CO_2 emissions of ≤50gCO_2/km and minimum zero emission range of 30 miles (aligned with OLEV plug-in car grant requirements, subject to consultation).

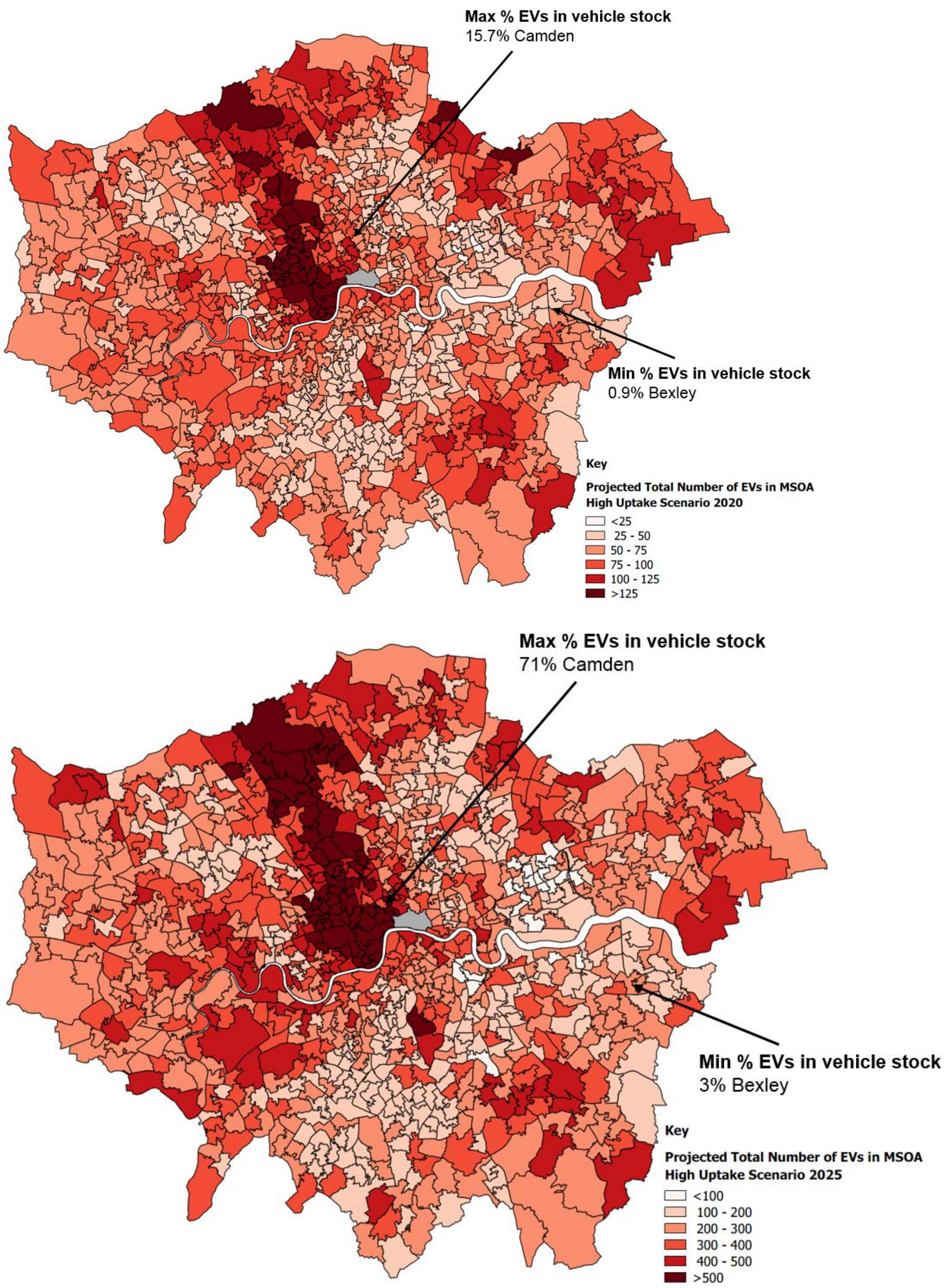
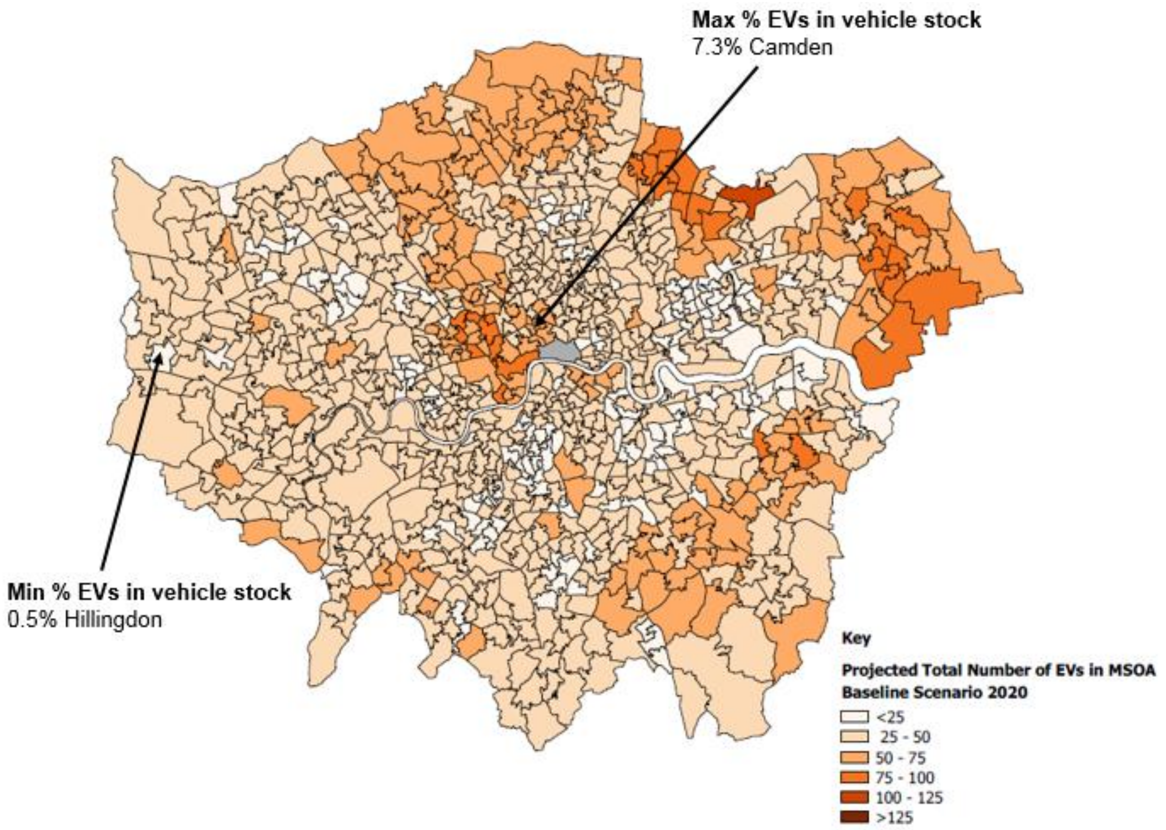


Figure 24 Distribution of EV stock in 2020 (top) and 2025 (bottom) – cars, vans, taxis and P2Ws (High BEV scenario)



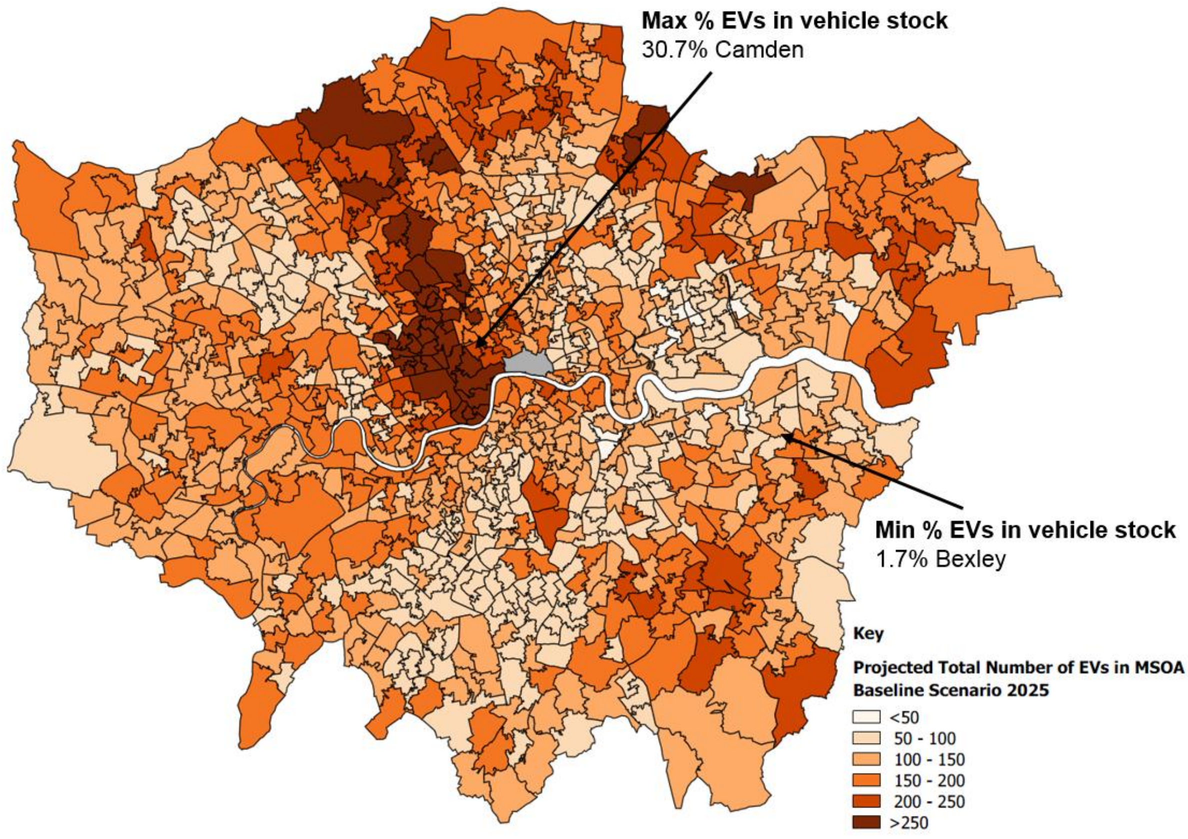
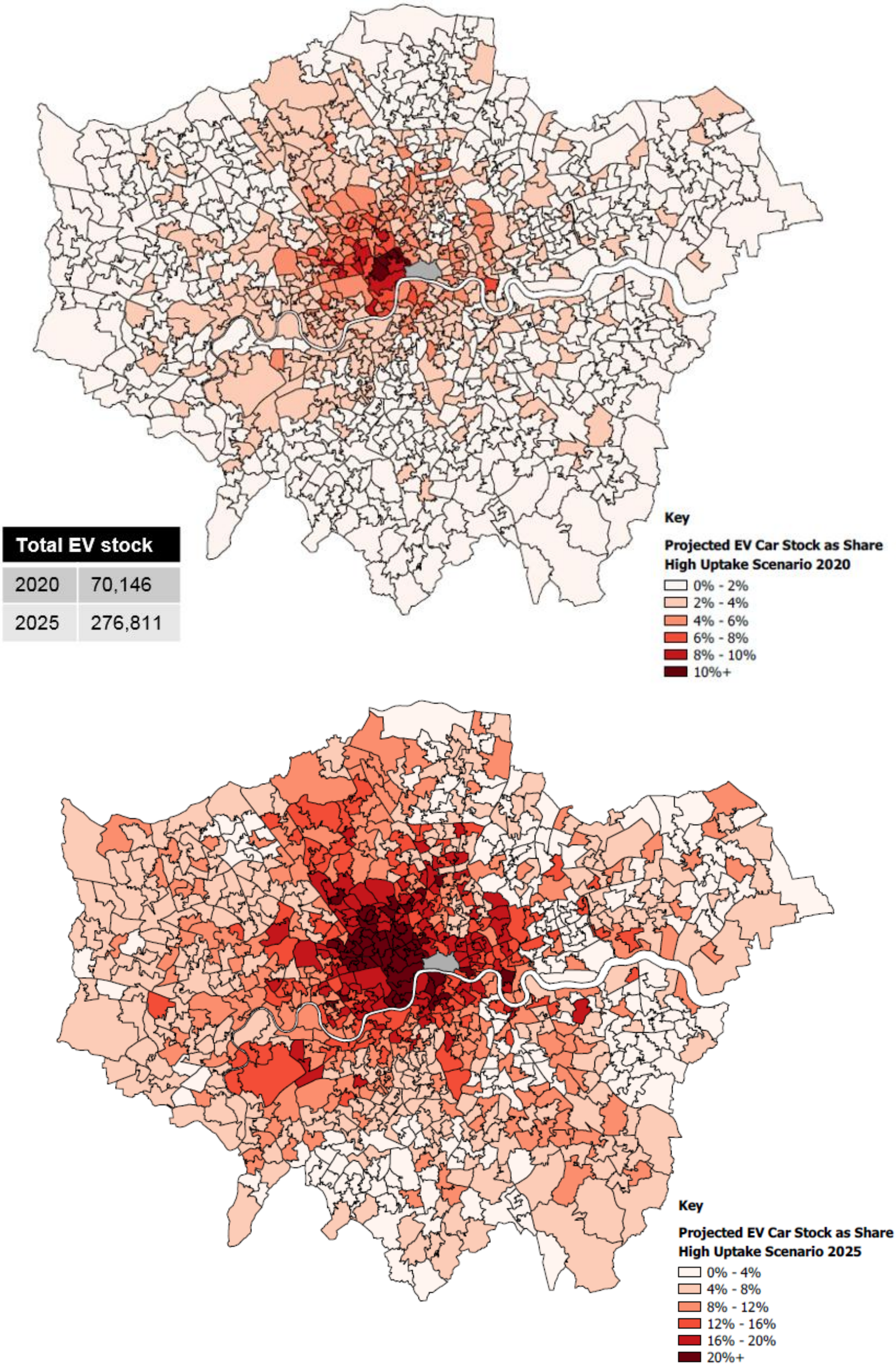
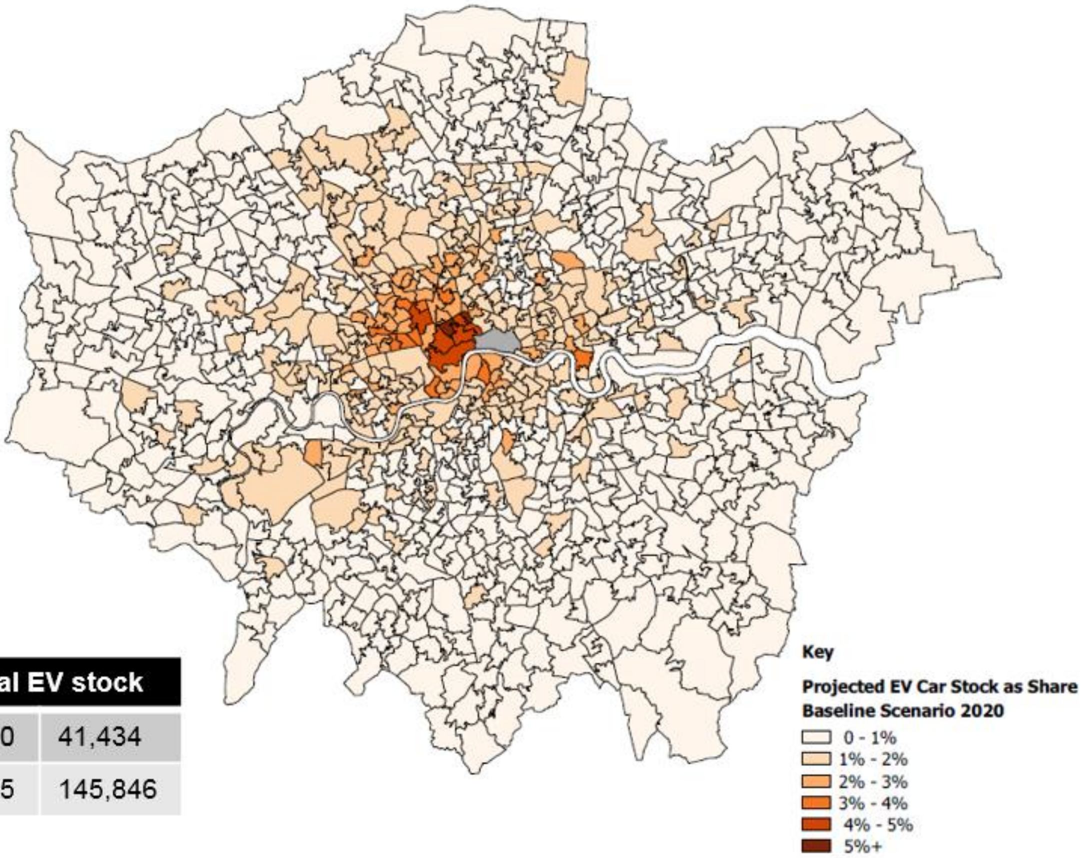


Figure 25 Distribution of EV stock in 2020 (top) and 2025 (bottom) – cars, vans, taxis and P2Ws (baseline scenario)



Total EV stock	
2020	70,146
2025	276,811

Figure 26 Share of EV stock in 2020 and 2025 – cars, vans, taxis and P2Ws (High BEV scenario)



Total EV stock	
2020	41,434
2025	145,846

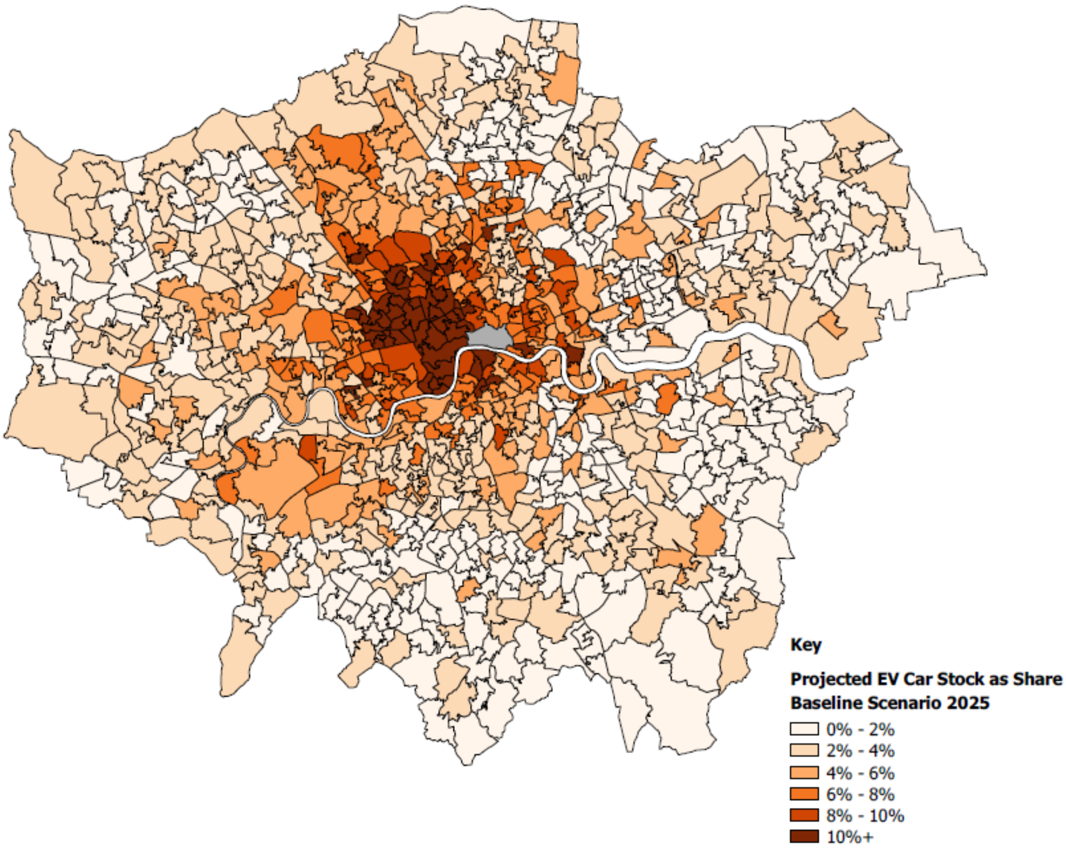


Figure 27 Share of EV stock in 2020 and 2025 – cars, vans, taxis and P2Ws (baseline scenario)

3 Charging locations and energy demand

3.1 Charging locations and charging profiles

Electric vehicle users currently have various options for charging: vehicles can be charged at home, at work, or at public charge points. A network of c. 1,400 public charge points now exists in car parks, supermarkets and other locations across London, and charging facilities are starting to be installed at motorway service stations. Company owned and operated fleet vehicles may also be charged using infrastructure within their depots.

Certainty of access to charging is a pre-requisite to the purchase of a plug-in vehicles and this is best provided by access to home charging or workplace charging. This means that EVs are primarily recharged at the end of the day, either domestically or at a depot, with charging commencing when vehicles complete their last journey of the day. To enable this type of charging, a charge point must be installed at home (in garage or driveway) or in a depot; a government grant is currently available to cover 75% of the costs for home charge-point installation[27].

In addition to **end of day/overnight charging**, some EV drivers may choose to charge during the day, in between various journeys. This could include **charging at or near workplaces**. Drivers of electric company cars and pool cars in particular may have the opportunity to recharge using infrastructure installed by employers, and private EV owners using their vehicle to commute could also benefit from additional charging while at work. Utilisation of workplace charge points is likely to depend on the price of charging.

Feedback from Boroughs suggests that price is also likely to influence the utilisation of charge points at public destinations (i.e. car parks, supermarkets, high streets – referred to as destination charging). Some existing infrastructure is currently free to use (and also provides free parking), and has seen relatively high utilisation compared to non-free charge points. In addition, drivers seem to use London public charge points opportunistically: rather than planning a journey based on the location of charge points, they will use a charge point if it happens to be in a convenient location (and at an attractive price). This reflects the fact that the majority of journeys are well within the electric range of most plug-in vehicles, and therefore there is little requirement for additional charging to supplement domestic or depot-based charging[28]. As such, public infrastructure for **destination charging** represents a small share of the total energy demand, and this is difficult to quantify and map.

One exception to this pattern of "opportunistic" charging could be motorway driving; drivers using their vehicles for long journeys may rely on motorway charging infrastructure to allow them to complete their journeys using their electric range. However, this is not relevant in the case of London and therefore is not considered in this study.

There are a range of charge point technologies available, supplying different levels of power and consequently providing different charging speeds. Residential and workplace charging is typically done at a "slow" charge rate i.e. 3kW, or at 7kW at most, whereas public charge points are typically between 7kW and 50kW. The charging rate can influence the power profile resulting from EV charging in a particular area.

Table 5 summarises the different charging types/locations and indicates the range of charge point technologies that are typically used.

[27] As of October 2015, customers may receive up to 75% of the capital costs of the charge point and installation, capped at £500. Electric vehicle homecharge scheme: guidance for customers 2016, OLEV website: https://www.gov.uk/government/publications/electric-vehicle-homecharge-scheme-guidance-for-customers-version-20

[28] Only 13% of car driver trips made in London are above 10km, according to LDTS data (car driver trips by length, borough of origin and purpose, LTDS 2011/12 to 2013/14 average).

Table 5 Charging locations and typical charging power rates

	Residential	Depot	Day workplace	Public urban	Public intercity
Typical power rate (kW)	3kW, 7kW	3kW, 7kW (for cars and vans)	3kW, 7kW	7kW (up to 50kW) [3kW legacy stock]	22kW-50kW

Figure 28, below, summarises the different charging types considered in this study, and indicates how they will be referred to in this report.

Location type	Residential areas /depots	At or near workplace	Other destinations (e.g. car parks, high streets, supermarkets)
Time of day	Mostly starting at the end of the day	While at work	Daytime
Assumptions for energy demand mapping	All vehicles recharge this way	15% of cars and vans recharge this way	Energy demand not mapped – qualitative approach in section 4.3
Reference label	**Residential /depot charging**	**Workplace charging**	**Destination charging**

Figure 28 Summary of charging locations and timings considered in this study

The following sections discuss the charging locations examined in detail in this study, including some of the assumptions made in order to calculate how energy and power demand from EVs will be distributed over the next decade.

3.1.1 Residential and depot charging

For the purposes of this study, it is assumed that all vehicles in scope (cars, vans, taxis and powered-two-wheelers) will be plugged in to recharge at their registered address. In the case of vans, it is assumed 60% will charge overnight in residential areas and 40% will charge overnight in off-street depots, based on the analysis of end of day location of vans[29].

The total energy demand within each MSOA is calculated based on the estimated mileage and energy consumption for the vehicles based in that area. An overall demand profile for residential and depot-based charging is estimated based on charging data for electric cars and vans under the UKPN Low Carbon London trial in 2014[30], and is then applied to the total daily energy demand, The resulting profile shape, based on weekday charging, is shown in Figure 29.[31]

[29] Element Energy analysis of DfT Survey of Company Owned Vans, as referenced in *Pathways to high penetration of EVs*, 2013

[30] UKPN for Low Carbon London, *Impact and opportunities for wide-scale Electric Vehicle deployment*, 2014. Based on week day demand, average profile shape of 54 EVs - mostly 3kW chargepoints. This data implies a diversity factor of c.10, due to the fact that not all EVs will charge at the same time, or on the same day. Assumptions on rate of charge (kW) to 2050 can be

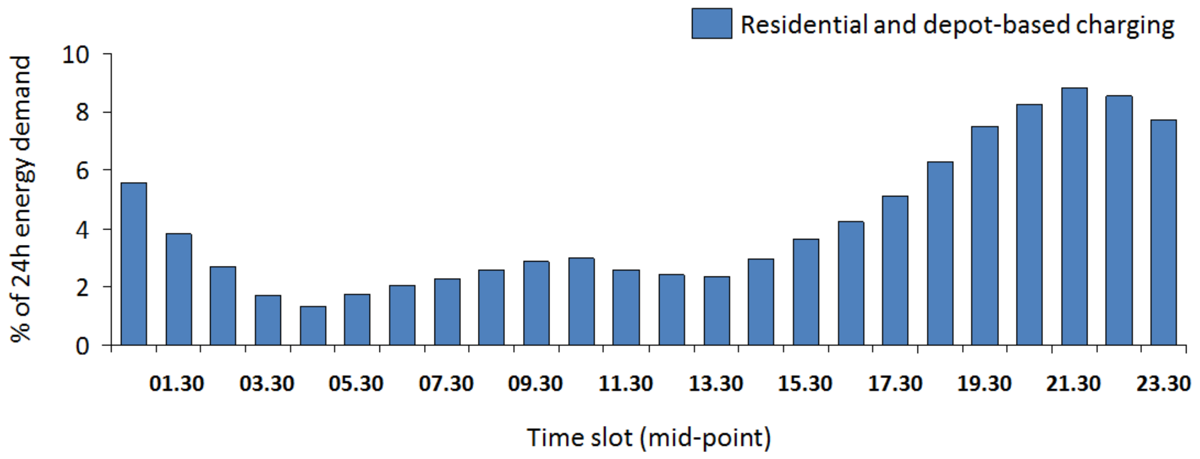


Figure 29 Profile shape applied to MSOA level energy demand from residential and depot-based EV charging

3.1.2 Workplace charging

The modelling of energy demand assumes that 15% of electric cars and vans registered in each MSOA use daytime workplace charging, in addition to overnight recharging at residences and depots. Taxis are unlikely to use workplace charging as they are usually privately operated, and powered two wheelers will rely on residential charging for their relatively small charging needs. For the purposes of this study, it is assumed that on commuting days (5 out of 7 days per week) half of the daily charging energy demand for these vehicles comes from daytime workplace charging. As a result, an estimated 36% (5/7 x 50%) of the total energy demand for these vehicles is met by workplace charging.

The charging profile applied here, shown in Figure 30, is also based on data from the 2014 UKPN trial[32]. This is used to calculate the energy demand in a typical weekday.

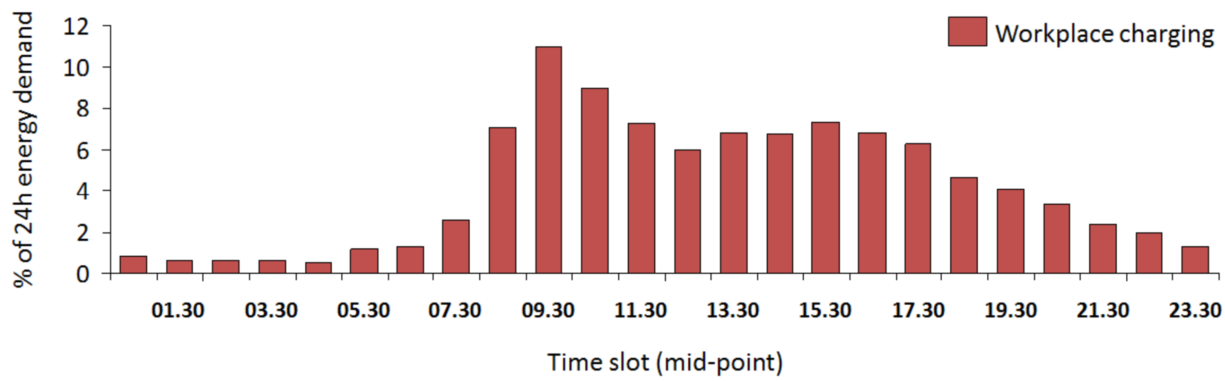


Figure 30 Profile shape applied to MSOA level energy demand from workplace EV charging

found in the Appendix. Higher rates of charging can result in either a higher or lower peak power demand for a given total energy demand, depending on the diversity of charging start times.

[31] Power and energy demand have been calculated on a weekday basis. Since the baseline electricity demand at the weekend is more evenly distributed over a day, compared to during the week, demand from EV charging at the weekend is unlikely to cause further impact on the electricity network.

[32] UKPN for Low Carbon London, Impact and opportunities for wide-scale Electric Vehicle deployment, 2014. Based on week day demand, average profile shape of 16 EVs connected to 1-phase - mostly 3kW charge points. This data implies a diversity factor of c.16, due to the fact that not all EVs will charge at the same time, or on the same day. Assumptions on rate of charge (kW) to 2050 can be found in the Appendix.

3.1.3 Destination charging infrastructure

As discussed above, 'opportunistic' destination charging is likely to account for a relatively small share of the total energy demand from EVs, and specific locations and times cannot be inferred from currently available data. However, some of the charging taking place while at home or at work will not be met by privately owned infrastructure, but by public charge points instead (or in the case of taxis, possibly by a 'dedicated' rapid charging network). The shortfall of private charge points, and thus need for public infrastructure, is analysed in section 4, along with the resulting impacts on different street types.

3.2 Mapping energy and power demand from residential, depot-based and workplace charging

In this study, the impacts of energy and power demand are assessed at MSOA level. Due to this level of aggregation (typically covering 2000-3000 households), a top-down approach was applied to estimations of energy and power demand for each charging location type.

3.2.1 Calculating energy demand from electric vehicle charging

Each vehicle type (battery electric car, plug-in hybrid car, battery electric van, etc.) was assigned a typical daily energy demand, according to the calculation summarised in Figure 31 below. Daily mileages were calculated based on annual DfT traffic data and vehicle registration data, and figures for energy consumption and the proportion of electric miles were based on Element Energy's recent work for Department for Transport. The energy consumption of EVs (kWh/km) is assumed to be higher in winter, reflecting the higher use of auxiliary components (heating, lights). Complete tables of assumptions can be found in the Appendix, or at the GLA's London data store as part of the London Energy Plan[33].

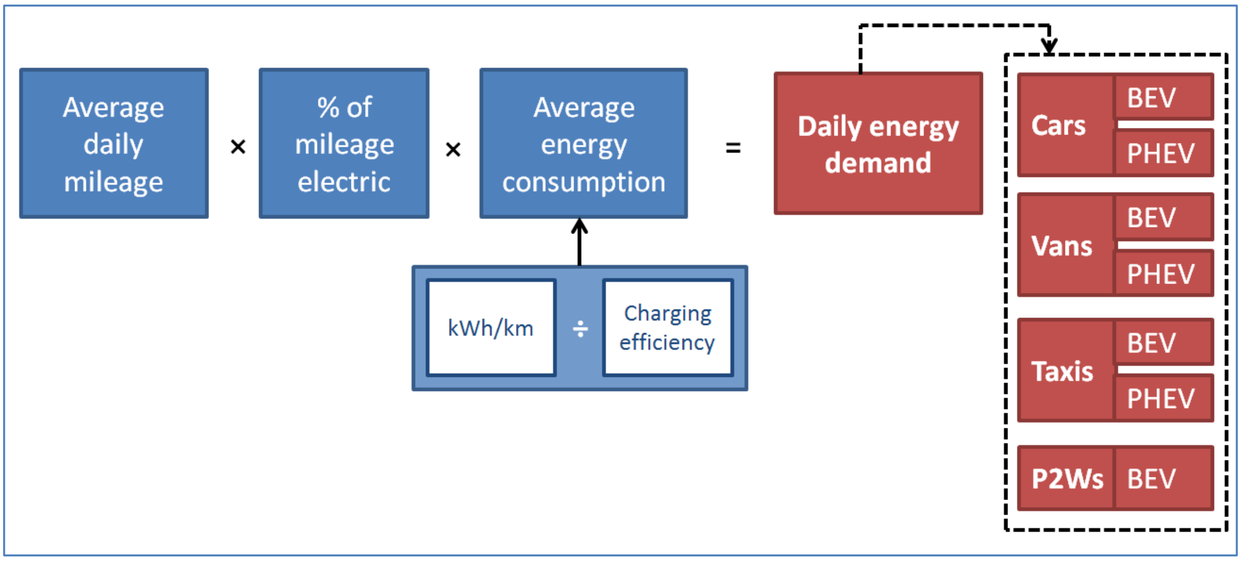


Figure 31 Approach to calculating daily energy demand per EV

Combined with the projections of EV stock (described in section 2.2), the daily energy demand figures were used to calculate the total daily energy demand in each MSOA from both residential/depot-based charging, and daytime workplace charging.

[33] The energy and power demand modelling used to inform this study are also one of the inputs to the GLA's London Energy Plan. The inputs will be published on the London data store following validation by stakeholder groups.

Demand from residential/depot based charging was mapped directly from EV stock distributions by MSOA, as this occurs at (or near) the vehicles' registered addresses. In order to calculate the geographical distribution of daytime demand for charging at/near workplaces, the distribution of recent commuter journeys (made by car or van) between MSOAs[34] was combined with the projected EV stock by MSOA. The resulting distribution of EV commuter destinations was used to identify the number of EVs charging while at work, based on the assumption that 15% of cars and vans would use this charging mode.

Due to the fact that this 15% of cars and vans were assumed to use residential charging as well, the at/near workplace charging demand from vehicles registered in a particular MSOA[35] was accounted for in the calculation of total residential/depot charging demand for that MSOA. This is illustrated in Figure 32, which summarises the approach to calculating MSOA level energy demand for each charging location.

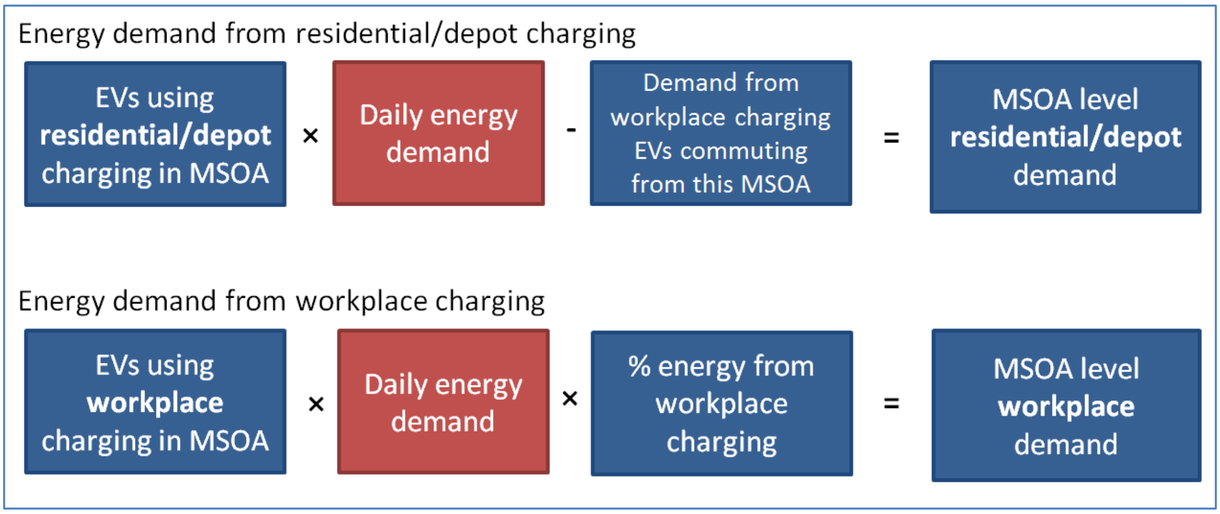


Figure 32 Approach to calculating energy demand per charging mode, per MSOA

The total energy demand distribution, shown in Figure 34 and Figure 35, broadly reflects the distribution of the residential & depot charging demand (which is based on the registered locations of EVs), as this is the main charging mode. However, the energy demand pattern differs slightly from the stock distribution (shown on page 17 in Figure 24 and Figure 25) due to the different mix of vehicle types and corresponding energy consumption. As shown in Figure 33 below, taxis and vans have much higher daily energy consumption than cars. Therefore, when comparing MSOAs with a high total number of EVs, those with a relatively high share of e-taxis and e-vans will have a greater energy demand than those with a high share of cars.

[34] Origin and destination data - Method of travel to work: Driving a car or van - 2011 Special Workplace Statistics - MSOA Level (England and Wales) - Open Government License
[35] Based on total workplace charging energy demand (across MSOAs) and distribution of EV commuter origin MSOAs – see above

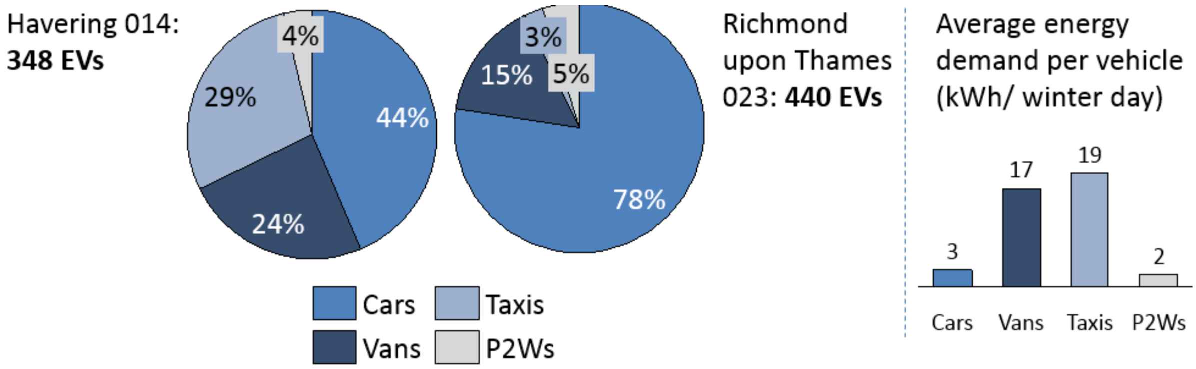


Figure 33 Variation in vehicles and energy demand across MSOAs (High BEV scenario, 2025)

The results shown represent the total annual energy demand. It captures differences between winter and summer demand (it is higher in winter than summer, due to additional energy demand from heating).

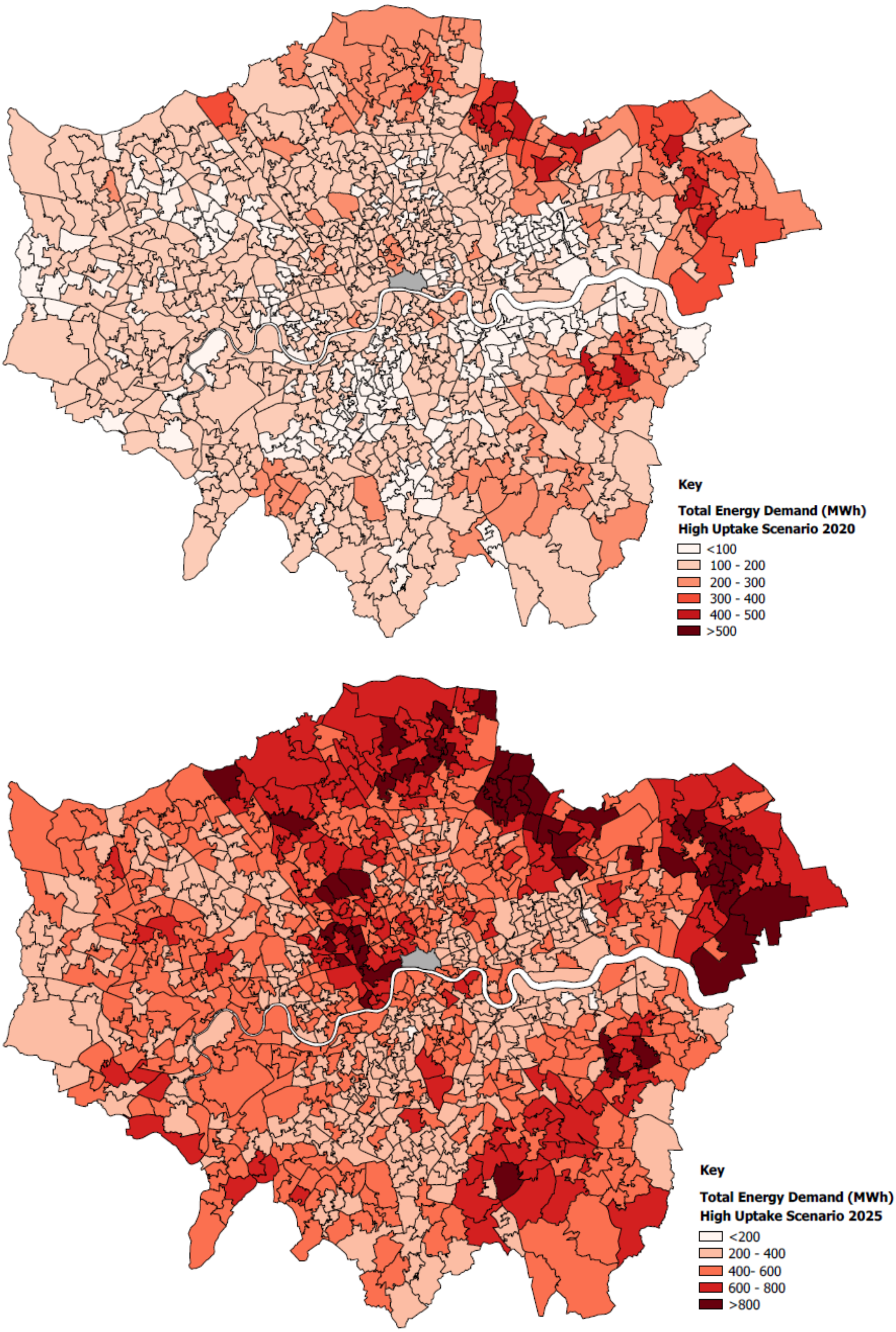
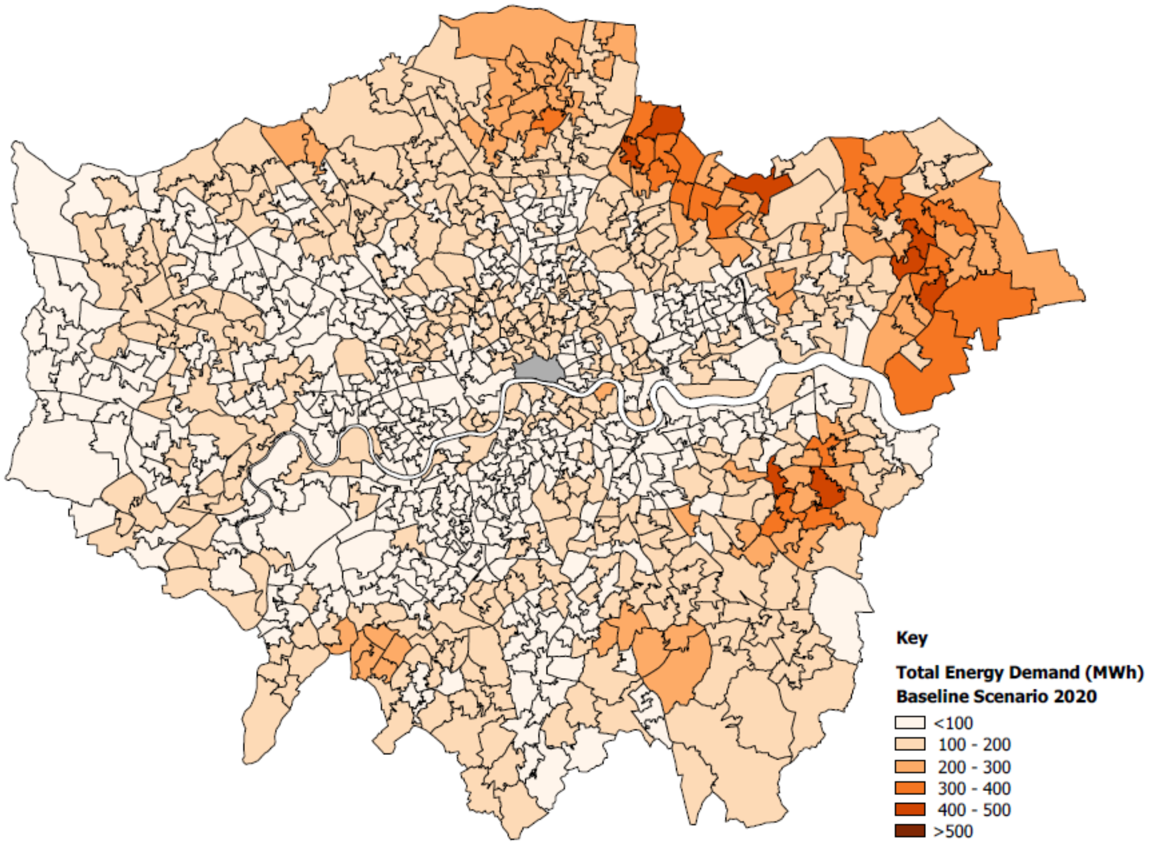


Figure 34 Total annual energy demand from EV charging, 2020 (top) and 2025 (bottom) (High BEV scenario)



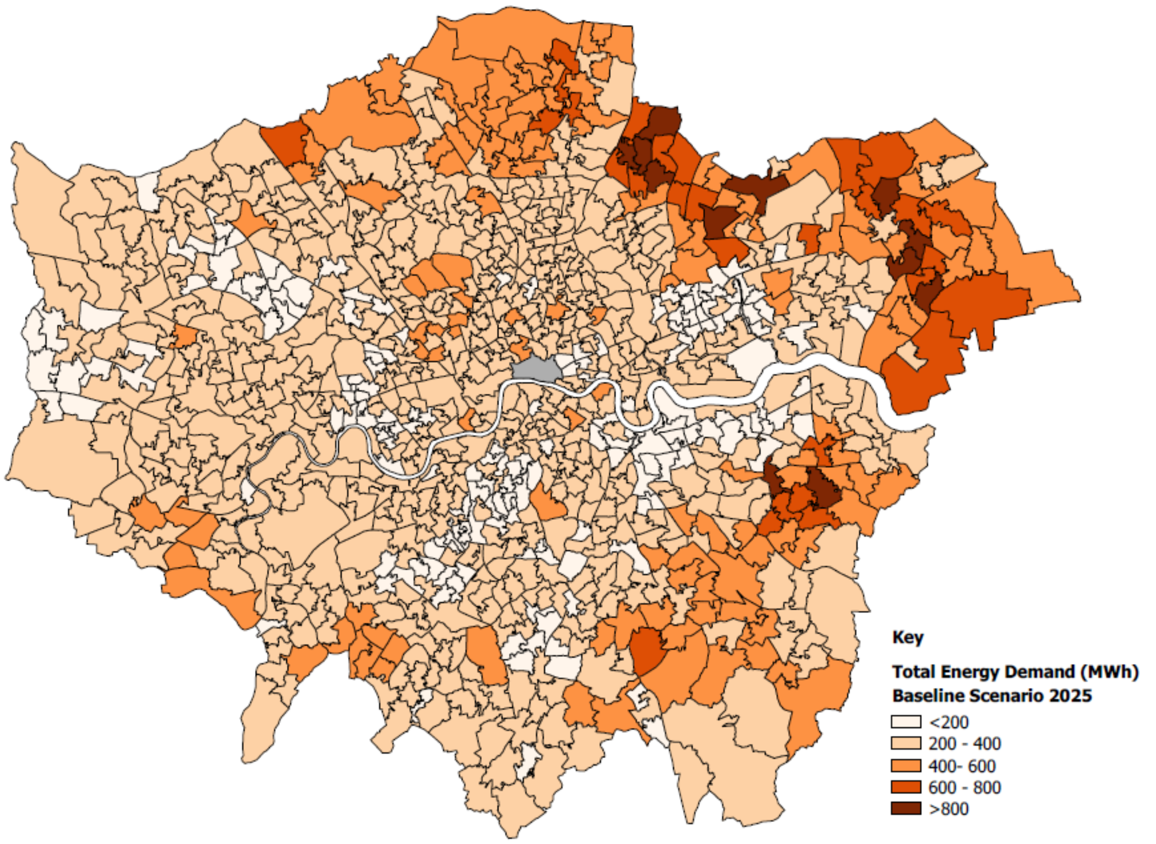
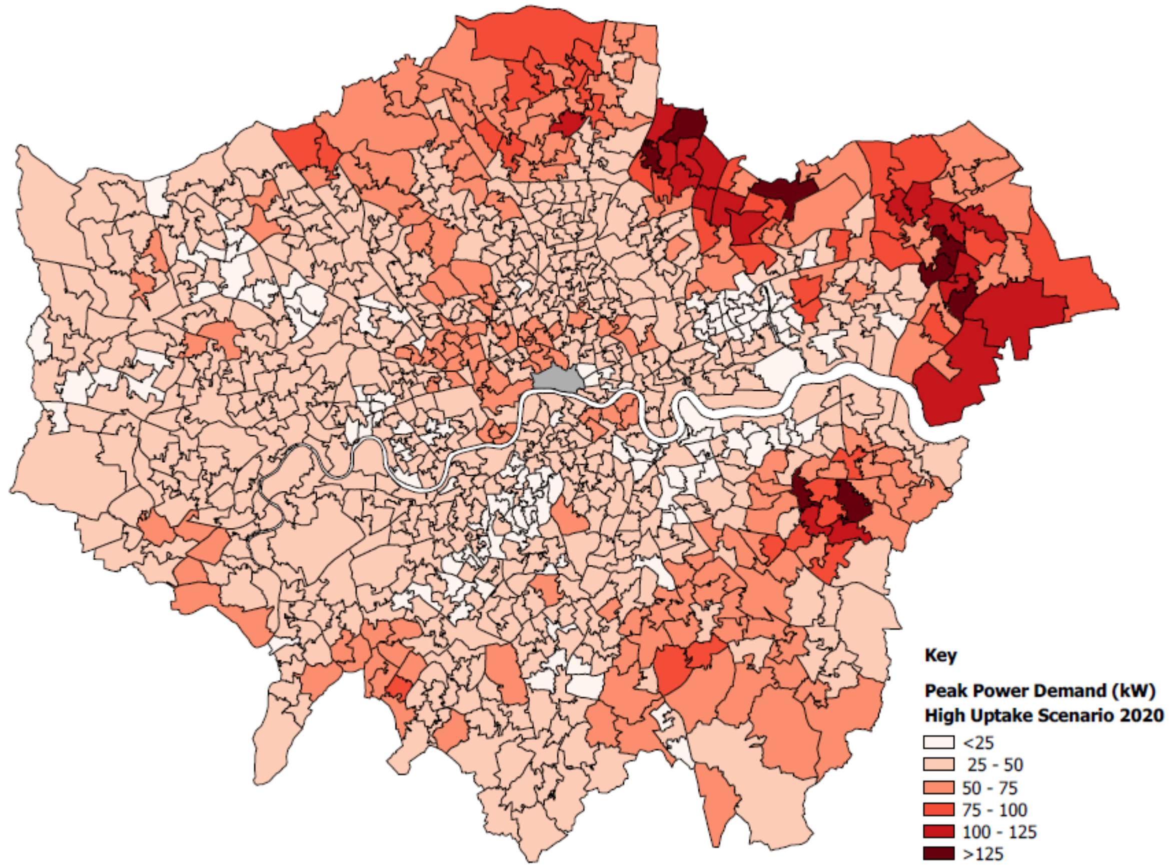


Figure 35 Total annual energy demand from EV charging, 2020 (top) and 2025 (bottom) (baseline scenario)

3.2.2 Calculating peak power demand from electric vehicle charging

Daily power profiles for each MSOA were created by combining the daily winter energy demand figures for each charging location type, with their respective 24 hour charging profiles (see Figure 29 and Figure 30– peaking at 9:30pm and 9:30am respectively) to determine the total average power demand in each hour of a typical winter day. For each MSOA, the demand peak was then identified as the maximum average power over that day. The estimated demand peaks resulting from the uptake scenarios are displayed in Figure 36 (High Bev scenario) and Figure 37 (Baseline scenario).

These estimates for energy and power demand at MSOA level have informed the assessment of the impacts of EV charging and implications for charging infrastructure, which is presented in Section 4, alongside a consideration of the other impacts of EV uptake (such as cost and positioning of required infrastructure).



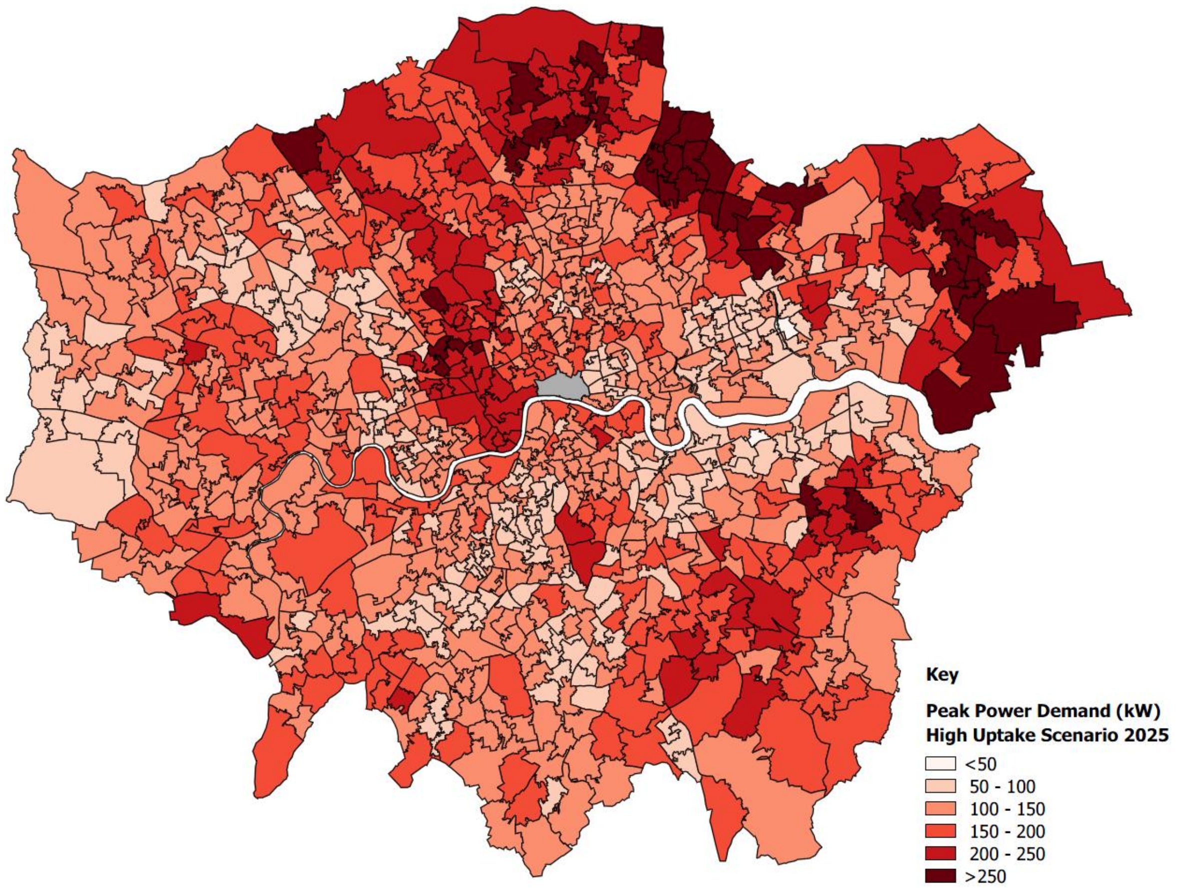


Figure 36 Peak power demand from charging for EVs in scope, 2020 (top) and 2025 (bottom) (High BEV scenario)

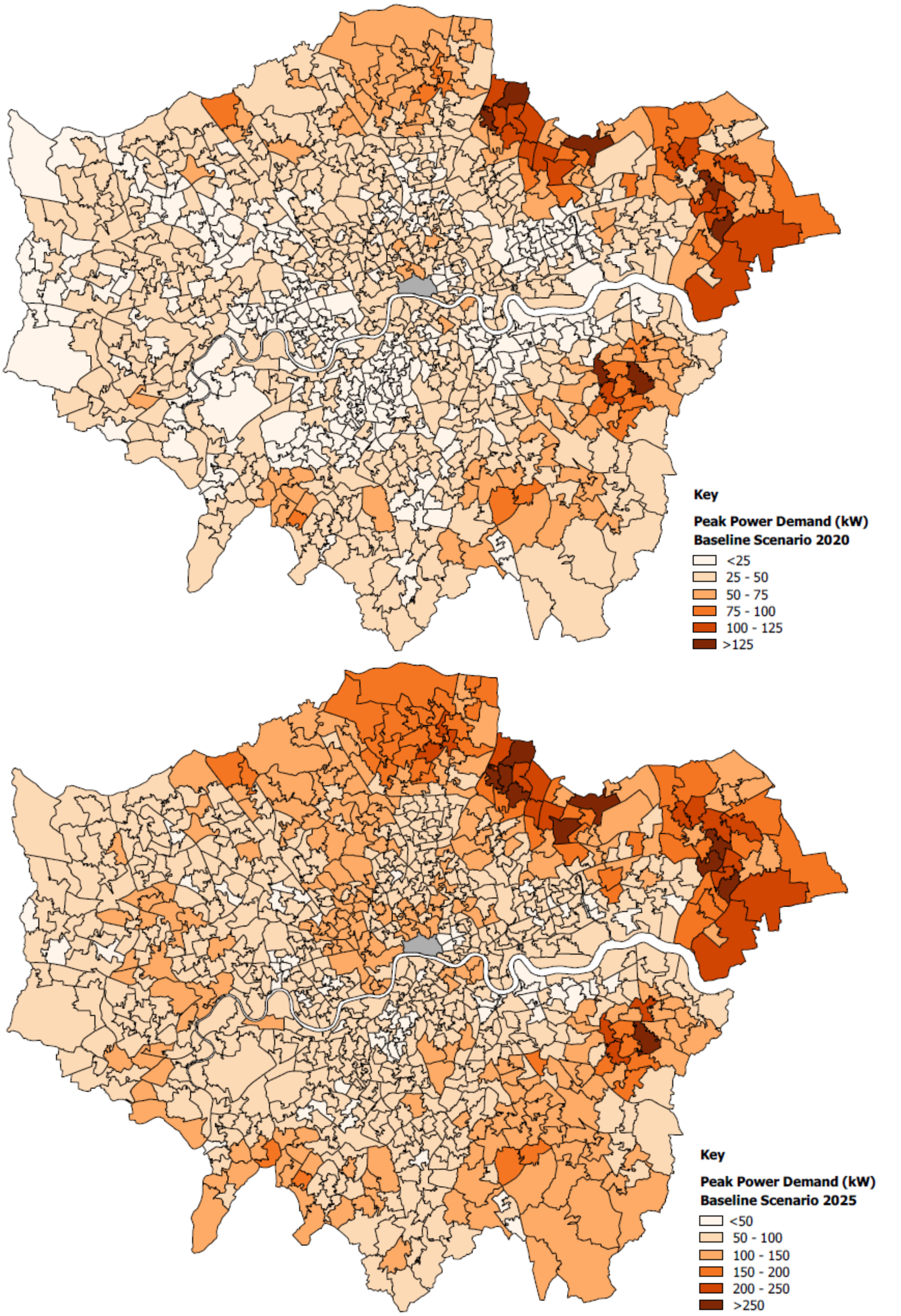


Figure 37 Peak power demand from charging for EVs in scope, 2020 (top) and 2025 (bottom) (Baseline scenario)

4 Charging infrastructure requirements and options

In 2009, the then Mayor of London launched his Electric Vehicle Delivery Plan, setting out his aim for a network of publicly accessible charge points in London. The target was 1,300 charge points by April 2013, and this target has now been exceeded. The charge points were introduced as part of Source London, which is a city-wide electric vehicle charging network with charge points in a variety of locations including streets, car parks and shopping centres. Previously managed by TfL, Source London is now privately run by BluepointLondon (BPL), a subsidiary of Bolloré IER who have plans to add more than 4,500 further charge points to the network by 2018.

At the moment charge points are largely concentrated in high streets and car parks, but as EV uptake increases most areas of London will require a mix of on-street and off-street public and private charging facilities. The type and catchment of these will be determined by factors which are specific to the locality, including:

- Availability of off-street parking;
- Housing type and density;
- Mix of land-uses, including workplaces;
- Parking capacity and parking restrictions;
- Extent of planned development; and
- Footway space.

Whilst for the vast majority of residents, charging at or close to home will be their primary source of charging, a secondary source for those commuting by EV is charging during the day at or close to their workplace. Additional, secondary sources of charging are available charge points at destinations such as supermarkets and high streets, which are likely to be used for 'top-up' charging for shorter periods during the day. The range of charging options is discussed further in Section 4.44.4.

4.1 Parking demand and availability

Those with off-street parking have unrestricted access to charge their vehicle when it is most convenient. They are most are likely to charge overnight, as most domestic chargers are 3kW 'slow' chargers and so full charging can take between 6-8 hours. Residents also benefit from the relatively low cost incurred to charge their vehicle using a domestic socket and are able to do so safely and securely. Charging in private car parks at workplaces may provide similar benefits to EV users, in terms of free or low cost charging, and fewer issues with availability and security compared to on-street parking. An additional benefit is that the installation of domestic/workplace chargers is relatively straightforward and affordable.

Therefore, EV users will generally charge at home and/or work if off-street parking is available. However residents without off-street parking will need to have access to on-street charging to enable them to purchase and use EVs.

Off-street charging:

- Charging while parked in a driveway, garage or car park

On-street charging:

- Mostly charging while parked on the carriageway (i.e. in bays on side of the road). For the purposes of this report on-street parking also includes off-carriageway parking, e.g.: dedicated rapid charging bays in taxi ranks, and rapid charging on forecourts or in dedicated 'hubs'

To date it has been largely possible to satisfy the charging requirements of EVs through public charge point networks and domestic charge points. However, the predicted increase in EV stock for 2020 and

2025 discussed in Section 2, and the low provision of off-street parking in London, will make on-street charging increasingly important, particularly for residents charging overnight and to a lesser extent for commuters charging during the day. The provision of sufficient capacity and appropriate types of on-street charging provision will be a critical component in realising the expected levels of EV growth.

Based on housing stock and population density data provided by the GLA and using statistics contained in the RAC report “Spaced Out: Perspectives on Parking Policy”[36], this study estimates that, across London, 64% of households do not have access to off-street parking, with 85% and 54% for inner and outer London respectively. This study estimates that these figures will increase to 66% (London-wide), 81% (inner) and 58% (outer) by 2020 and to 67% (London-wide), 81% (inner) and 59% (outer) by 2025. The methodology for these estimates is discussed in Sections 4.2 and 4.3.

The variation in off-street parking availability is shown at MSOA level in Figure 38

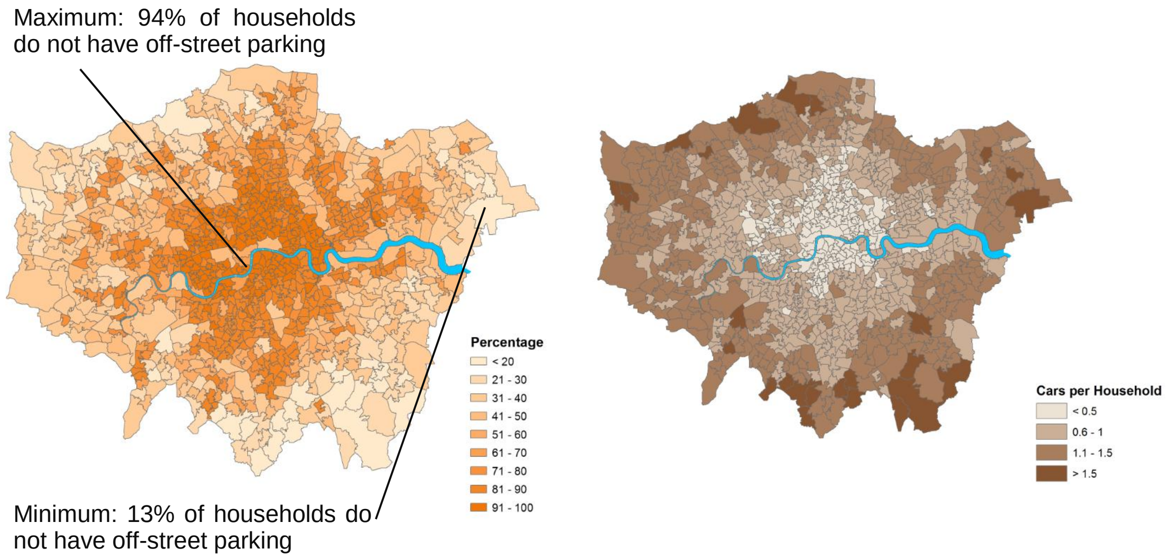


Figure 38 Percentage of households without off-street parking in 2015 (left) and average number of cars per household (right)

4.2 Split of on-street and off-street charging for residential & depot charging

As described in Section 3, it is assumed that all cars, taxis, P2Ws and 60% of vans will charge overnight in residential areas. The remaining 40% of vans will charge overnight in off-street depots. The demand for charging on-street in residential areas during the day will be a small proportion of the total demand in a 24 hour period, therefore this study focuses on overnight charging to inform the charging infrastructure requirements.

There is a lack of standardisation in the e-P2W market at the moment. Some P2Ws on the market have removable batteries which can be charged within homes. Those that do not have removable batteries charge via a cable with a 3 pin plug, but cannot charge via a Type 2 connector, which is the European standard for public charge points. It is therefore unlikely that many e-P2Ws will need or to

[36] “Spaced Out: Perspectives on Parking Policy” - RAC Foundation 2012. The report used NTS data to determine where cars are parked, and the percentage of available parking by type of housing for the nation as a whole. This was then adjusted to account for the higher density of housing in London. See Table 19 in the Appendix for details.

be able to use publicly accessible on-street charging in 2020 and 2025 in the same way as cars, vans and taxis, so are not included in the infrastructure estimations in this study.

4.2.1 Determining the extent of on-street and off-street residential charging

The overall approach for determining the proportion of EV users without access to off-street charging, and thereby to estimate the on-street/off-street EV stock at MSOA level, is shown in Figure 39.

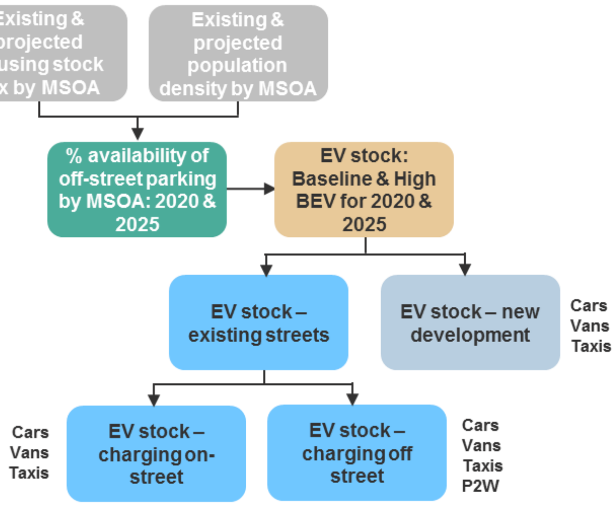
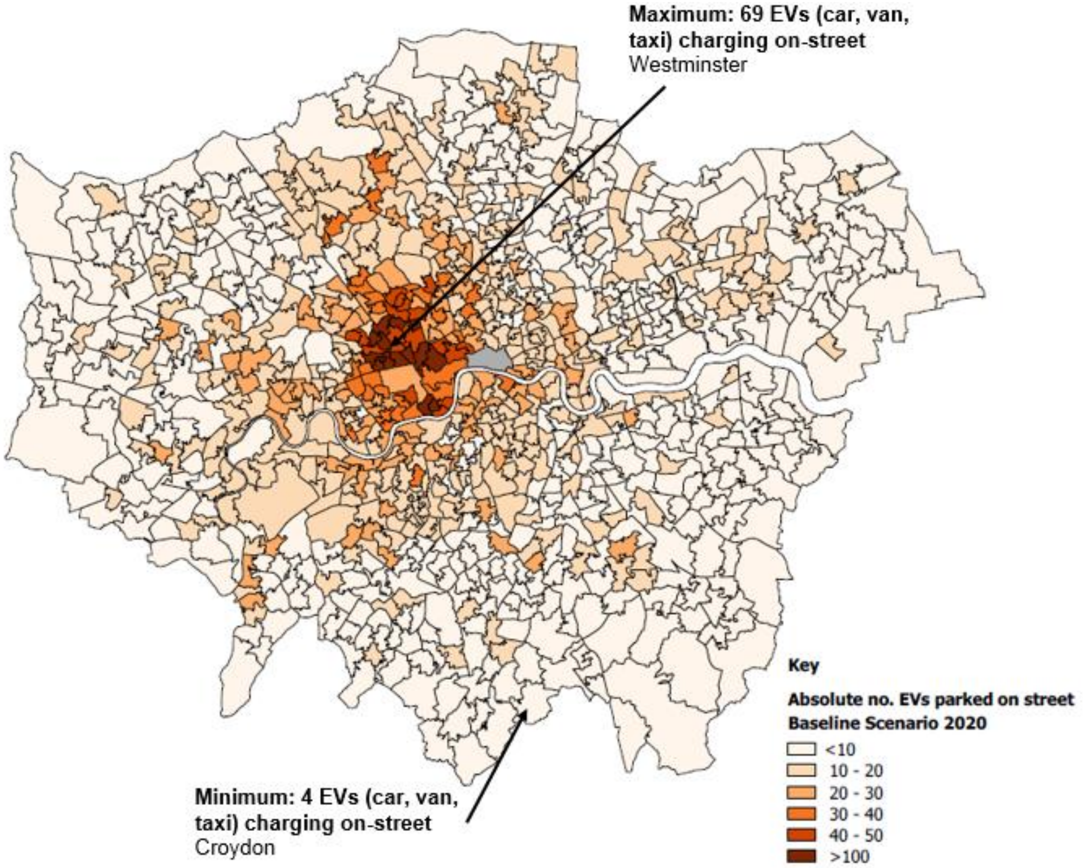


Figure 39 Approach to determining EV stock parking on-street or off-street at MSOA level

In the absence of data on the availability of off-street parking in London, figures for this at MSOA level were derived from GLA data on existing and projected future population density and housing stock. The percentage of off-street parking in an MSOA has been taken as a function of the population density (categorised as either low or high) and the proportion of the different types of housing (e.g. terraced, purpose built flats). Weightings were applied to the housing types, with detached housing being given the highest weighting as it has a higher proportion of off-street parking[37], to estimate the percentage availability of off-street parking per MSOA.

The figures derived for availability of off-street parking were applied to the Baseline & High BEV scenarios for 2020 and 2025 to determine the number of cars, vans and taxis that will need to charge on-street or off-street. Figure 40 and Figure 41show the total number of EVs (car, van and taxi) that will charge on-street in the Baseline and High BEV scenarios respectively.

[37] From 5% for purpose built flats in high density areas to 95% for detached houses in low density areas. Numbers derived from *Spaced Out – Perspectives on Parking Policy,* RAC Foundation, 2012



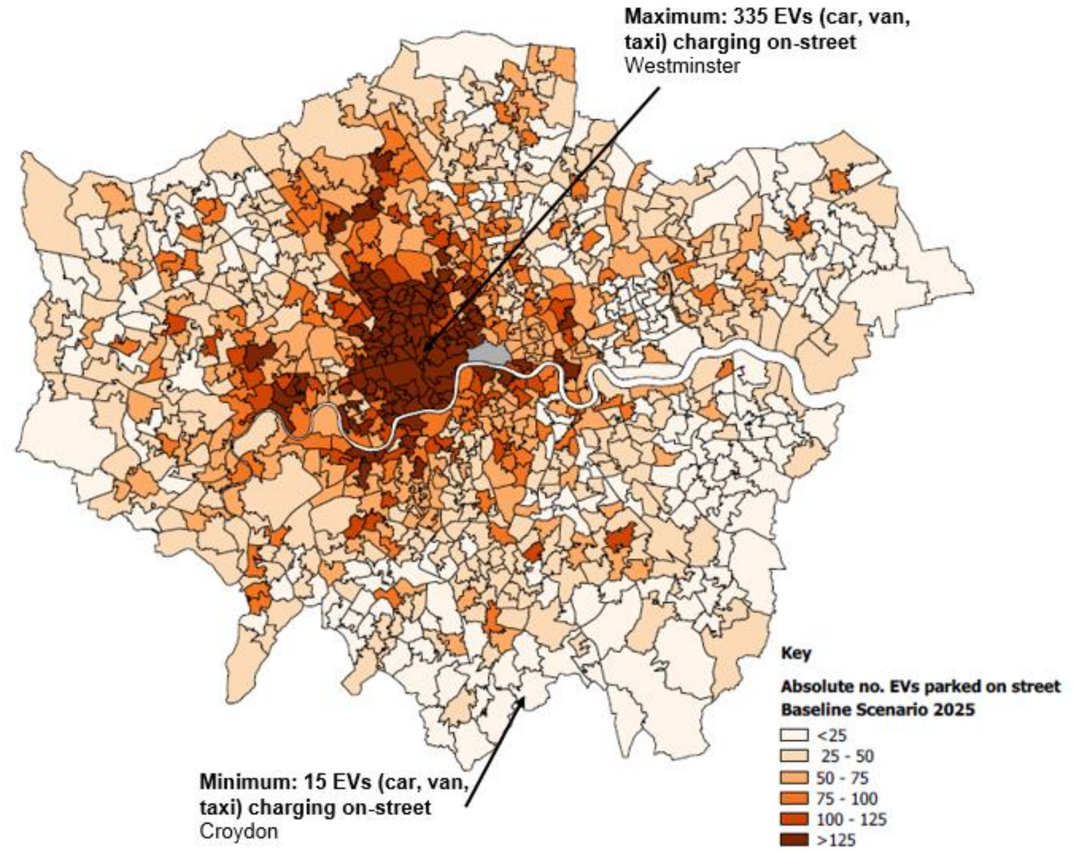


Figure 40 EVs (car, van & taxi) charging on-street per MSOA in 2020 (top) and 2025 (bottom) (Baseline scenario)

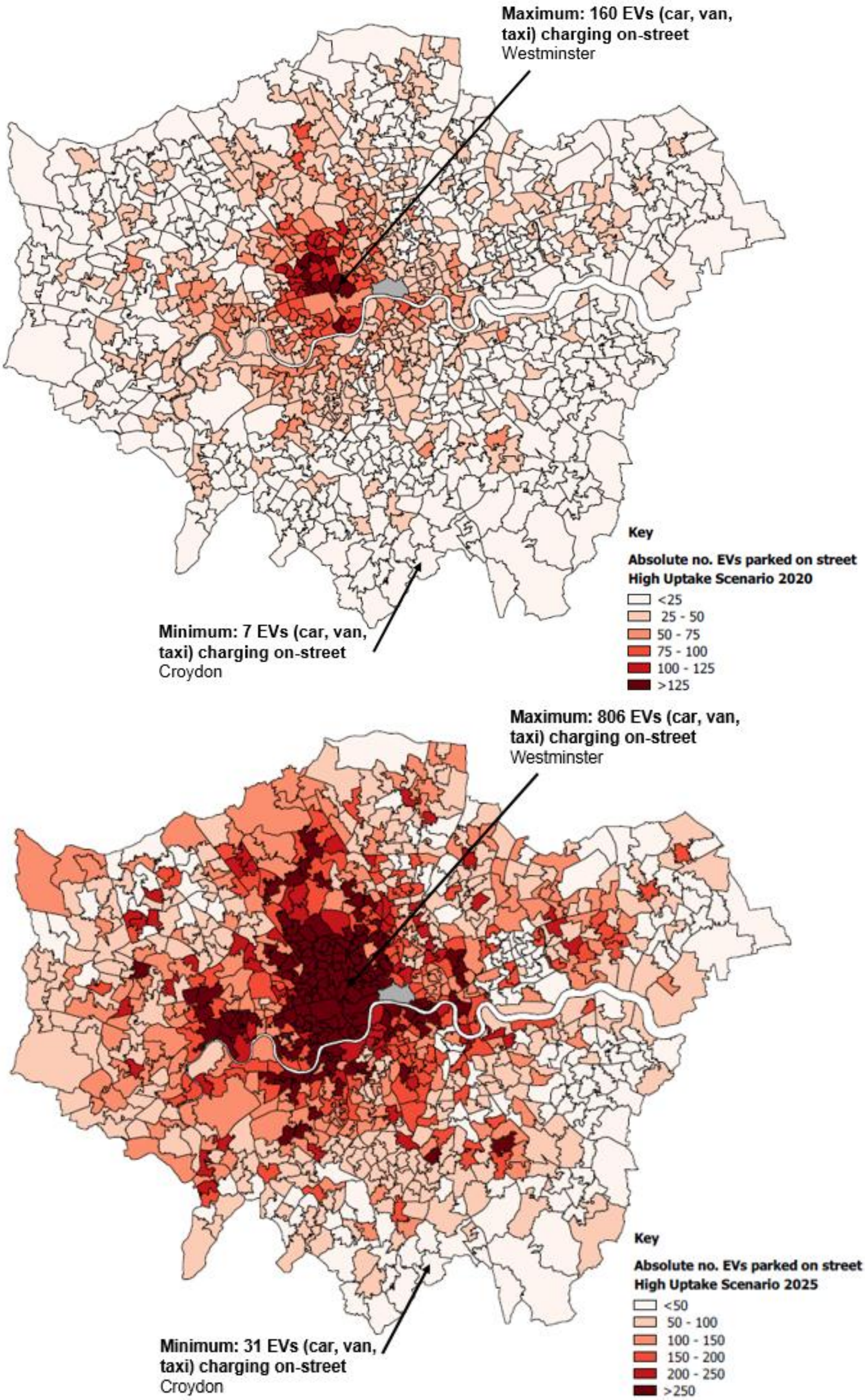


Figure 41 EVs (car, van & taxi) charging on-street per MSOA in 2020 (top) and 2025 (bottom) (High BEV scenario)

These heat maps illustrate the areas where high EV uptake will be coupled with limited off-street parking. In central London some areas see a high number of EVs on street not necessarily because the MSOA has a particularly high uptake of EVs but because the amount of off-street parking is very limited. The maps also show that in parts of outer London, where housing is less dense and off-street parking is more readily available, there will be few EVs parking on-street, even in the high uptake scenario for 2025.

To put this in perspective and illustrate how much kerbside space may be needed for charging on a given street within an MSOA, Figure 42 and Figure 43 show the average number of EVs that will charge on-street in the Baseline and High BEV scenarios per 500m of minor road in each MSOA. This has been calculated using Department for Transport road length statistics for 2014. As these are only available at local authority level, road length to MSOA level have been disaggregated based on the proportion of the borough's area that an MSOA represents. Using this approach, it has been established that there are between 4km and 121km of minor roads within MSOAs across London, with an average of 13km. The figures below are calculated from the amount of road by MSOA, not the average.

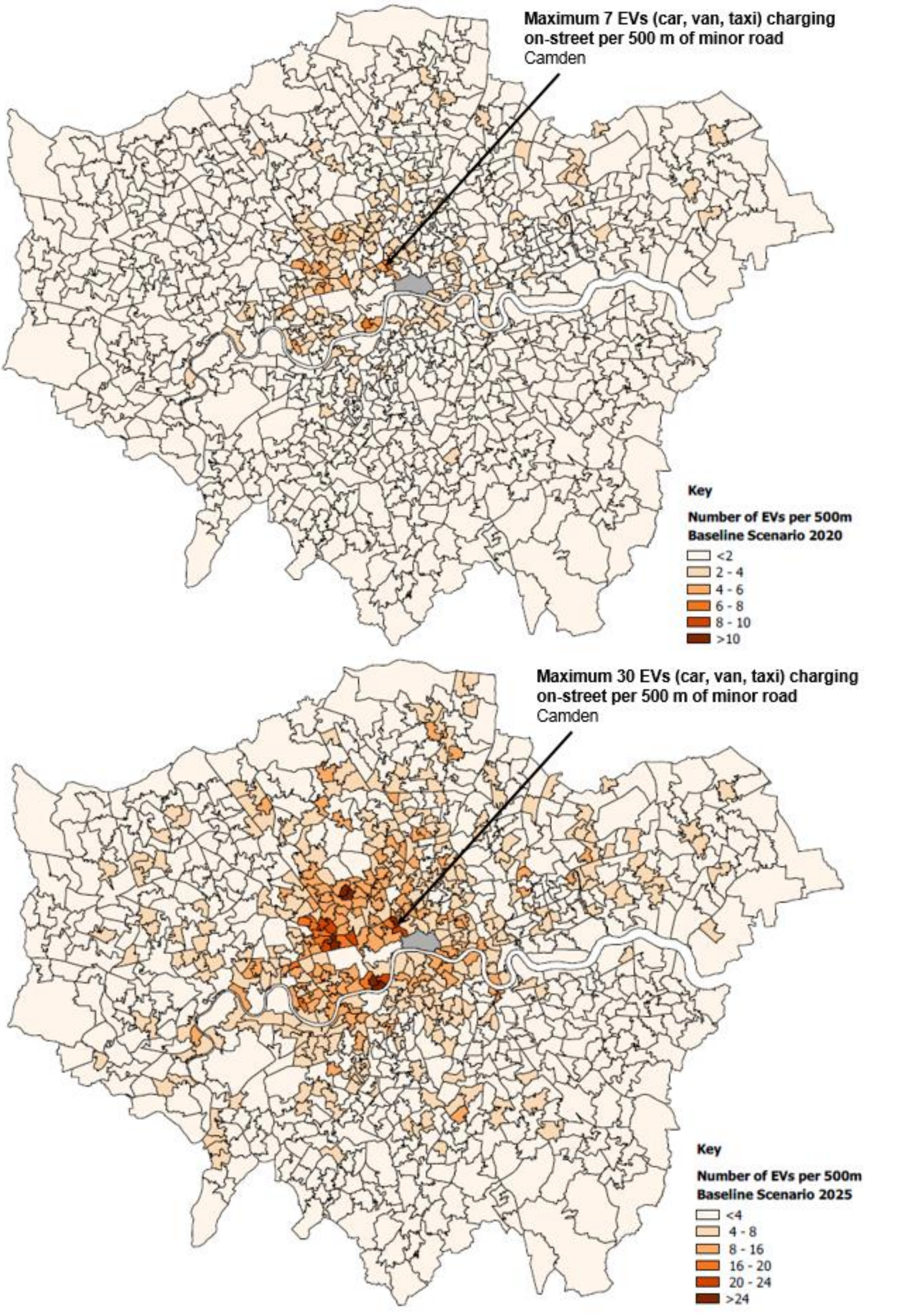
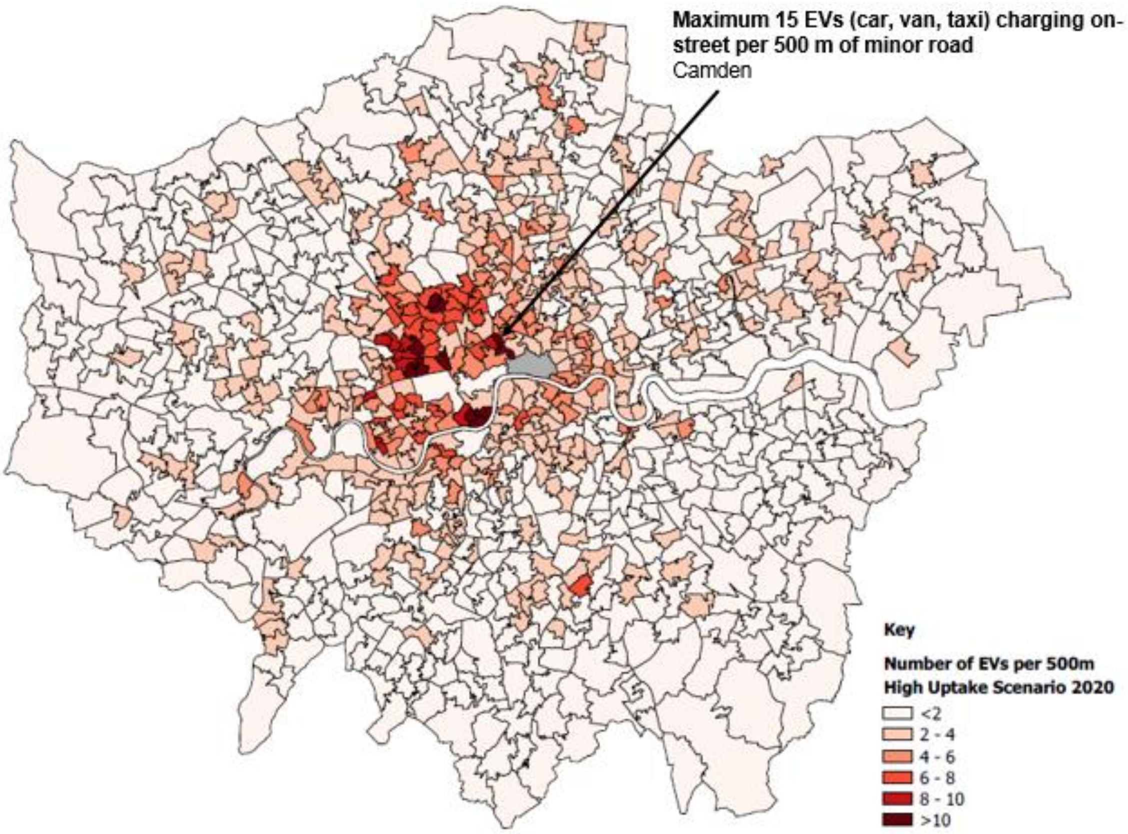


Figure 42 EVs (car, van & taxi) charging on-street per 500m of minor road in 2020 (top) and 2025 (bottom) (Baseline scenario)



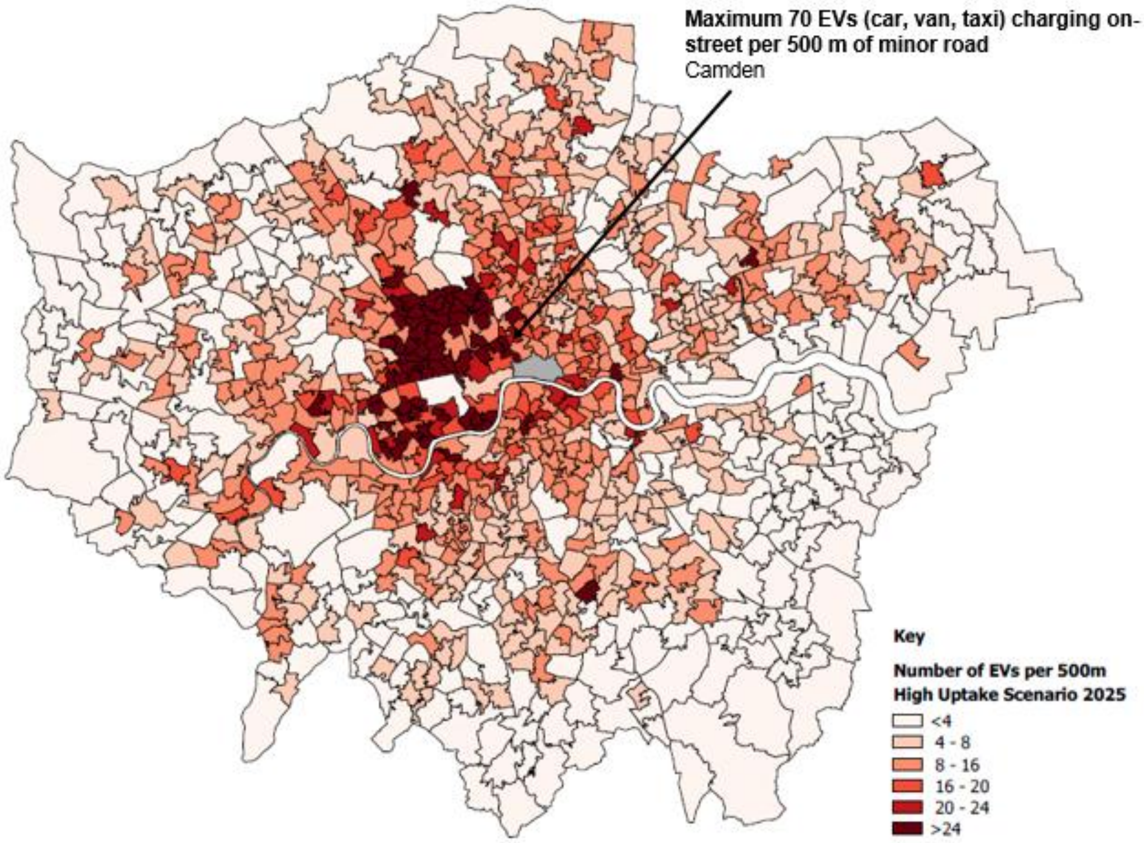


Figure 43 EVs (car, van & taxi) charging on-street per 500m of minor road in 2020 (top) and 2025 (bottom) (High BEV scenario)

4.2.2 Charging provision in new developments

This report focuses on the infrastructure requirements for existing streets, but it should be noted that potential charging provisions in new developments may impact the overall infrastructure demand: charging provisions included in these developments may alter the level of demand for different on-street charging solutions. Installing charging infrastructure in new developments is relatively simple, as the facilities can be installed as part of the development rather than retro-fitted into existing streets. Figure 44 shows the percentage of housing stock at MSOA level that is new development in 2020 and 2025, compared to a 2015 baseline[38], providing an indication of the areas which could be affected.

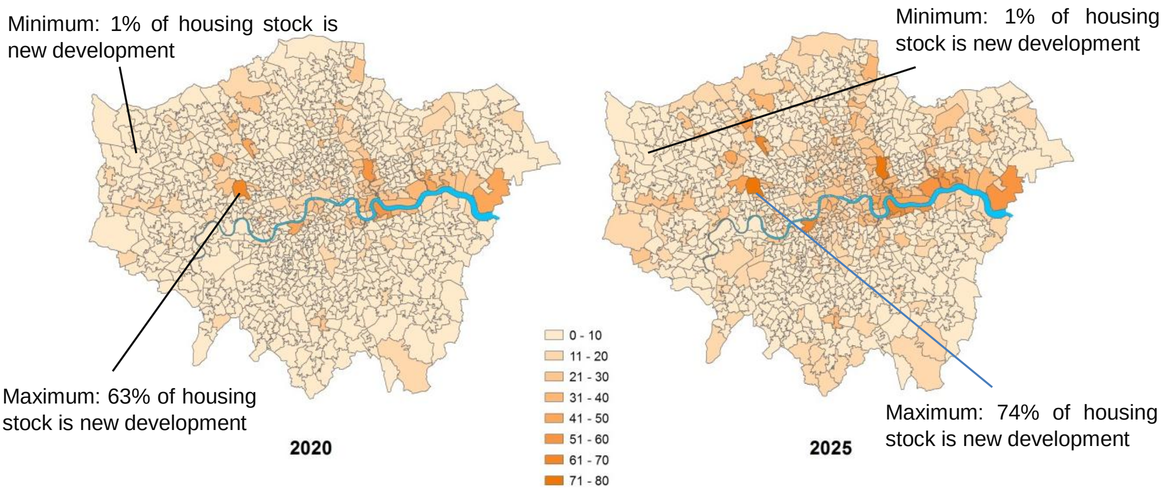


Figure 44 Percentage of housing stock that is new development (from 2015)[39]

The amount of new development has a direct impact on EV charging provision that local authorities and commercial operators need to provide, as new developments are likely to have built-in compatibility for charge points. These maps show the areas of London where there will be large amounts of new development, and as such some of the EV uptake can be accommodated by charge point infrastructure in new developments. However in some boroughs there are restrictions on parking allocations in new developments. In some cases there will be no parking in new developments, and so all EVs will still need to charge in existing parking spaces, whether that is off-street or on street.

4.2.3 Summary of on-street and off-street charging provision

A summary of the number of EVs charging on-street and off-street in residential areas across London in the two scenarios is shown in Table 6.

[38] Refer to **Error! Reference source not found.** in Appendix for the names of the opportunity areas

[39] Based on GLA London Housing Projections

Table 6 EVs charging on-street and off-street in 2020 & 2025 in residential areas for Baseline and High BEV scenarios (London-wide)[40]

	2020 EV uptake scenario				2025 EV uptake scenario			
	BASELINE		HIGH		BASELINE		HIGH	
	No.	%	No.	%	No.	%	No.	%
RESIDENTIAL LOCATIONS								
Existing streets:								
EV Cars charged on-street	**12,989**	66	**30,741**	66	**59,400**	67	**143,657**	67
% all car stock	*0.5%*	-	*1.2%*	-	*2.2%*	-	*5.3%*	-
EV Cars charged off-street	**6,640**	34	**15,716**	34	**28,967**	33	**70,055**	33
% all car stock	*0.3%*	-	*0.6%*	-	*1.1%*	-	*2.6%*	-
Total EV Cars	**19,629**	100	**46,457**	100	**88,367**	100	**213,712**	100
% all car stock	*0.7%*	-	*1.8%*		*3.3%*	-	*7.9%*	-
EV Cars+Vans+Taxis charged on-street	**20,665**	62	**38,417**	64	**77,492**	65	**166,082**	66
% all car stock	*0.7%*	-	*1.3%*	-	*2.6%*	-	*5.6%*	-
EV Cars+Vans+Taxis charged off-street	**12,458**	38	**21,533**	36	**41,755**	35	**85,513**	34
% all car stock	*0.4%*	-	*0.7%*	-	*1.4%*	-	*2.9%*	-
Total EVs	**33,122**	100	**59,950**	100	**119,246**	100	**251,596**	100
% all car stock	*1.1%*	-	*2.1%*	-	*4.0%*	-	*8.5%*	-
New development:								
EV Cars, Vans & Taxis	**2,196**	-	**4,080**	-	**5,171**	-	**11,072**	-

Of all EVs (cars, vans and taxis) parking in residential locations overnight, between 62% and 66% will charge on street. In the Baseline Scenario, EVs charging on-street represent 0.7% of the total stock of cars, vans and taxis in 2020, with almost 13,000 electric cars alone being charged on-street. By 2025, nearly 60,000 electric cars will be charging on-street in this scenario. In the High BEV scenario, by 2025, this figure is estimated at 143,657, and 5.6% of the London stock of cars, vans and taxis will be EVs charging on-street.

It is interesting to note that for both cars and all vehicles, in the baseline and High BEV scenarios, the split between EVs charging on and off street is approximately 60/40%. The impacts these charging patterns will have on London streets are discussed in section 4.

4.3 Split of on-street and off-street charging for workplace charging

As described in Section 3, this study defines 'workplace charging' as cars and vans charging at or near to workplaces, for which most of the charging will occur during the day. The following analysis does not include vehicles charging at depots overnight (covered in section 4.2), or vehicles commuting from outside of London[41].

The options for workplace charging can be categorised as follows:

- **On-street:**
  - Unrestricted parking (mostly located in residential streets)
  - Controlled Parking Zones (CPZ)
  - Pay & display parking
- **Off-Street:**
  - Public/private car parks

[40] Includes 60% of electric vans. The other 40% are assumed to park in depots overnight.
[41] This could include up to 30% of all car/van driver commuter trips ending in London. Source: Origin and destination data - Method of travel to work: Driving a car or van - 2011 Special Workplace Statistics - MSOA Level (England and Wales) - Open Government License

4.3.1 Determining extent of on-street and off-street workplace charging

The overall approach for determining the extent of on-street and off-street workplace charging and estimating the on-street/off-street EV stock at MSOA level is shown in Figure 45.

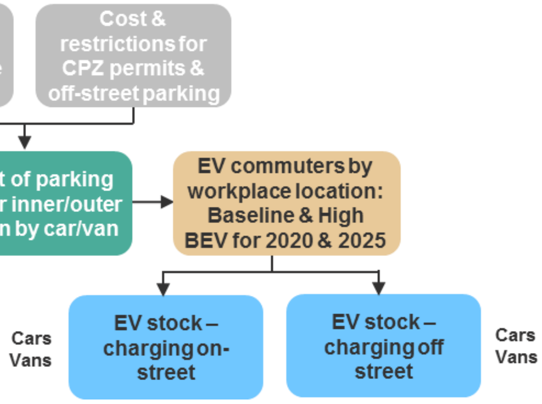


Figure 45 Approach to determining EV stock parking on or off-street at MSOA level

EV commuters will opt to park off-street in employer car parks where this is an option, as the parking is likely to be free, will be secure, and charge points will be available at least during part of the day. This should be sufficient to provide top-up charging given that workplace charging will be a secondary source of charging.

In the absence of data on the level of provision of employer parking across London, the proportion of EV commuters that will charge in the on-street and off-street parking categories described above were determined by taking account of the extent of restrictions that prevent them from parking on-street, and the general level of costs that will deter them from parking on-street.

To provide an indication of the extent of unrestricted parking areas, the coverage of CPZs and their restrictions for business permit parking (available to some employees) was estimated. The cost of pay and display on-street parking and car parks was also accounted for, including the fact that EV owners may benefit from free or reduced cost parking. As EV uptake increases, access to free parking may be revised, but this is not accounted for due to the uncertainty around when this could happen. The specific factors that informed our evaluation are listed below:

On-street - Controlled Parking Zones:

- Number of business permits are limited and are usually allocated for the purpose of business operation rather than satisfying commuter parking needs
- Business permits are often for commercial vehicles only
- There is usually a cost for business permits, albeit often discounted for EVs

On-street - Pay & Display parking:

- Relatively few dedicated EVs bays at present and users can only charge for limited periods
- Parking/charging in dedicated EV bays is usually free, but as the rate of EV uptake increases then this is likely to change
- The high costs for non-EV Pay & Display parking will discourage EV commuter parking

Off-street - public/private car parks:

- EV drivers can get a discounted season ticket in most areas but prices are still relatively high, starting from £300 per annum in outer London, to £3000+ in central London
- As with on-street Pay & Display parking, parking/charging in dedicated EV bays is usually free, but as the rate of EV uptake increases this is likely to change

Off-street - employer parking:

- Parking spaces with charging facilities likely to be available at least during part of the day
- Charging will be relatively safe and secure, and charging may be free to users
- In new developments, a certain proportion of parking spaces will to be set aside for charging, as set out in the London Plan parking standards

Table 7 shows the proportion of EV car and van commuters who are assumed to charge in the on-street and off-street parking categories for inner and outer London MSOAs. Pay and Display parking is not included as it is not considered to be a viable option for EV commuter parking due to relatively high tariffs.

Table 7 Proportion of EV (car, van) commuters that will park on-street or off-street

	Car		Van	
	Inner London	Outer London	Inner London	Outer London
On-street parking:	%	%	%	%
Controlled Parking Zones	5	5	15	10
Unrestricted parking	10	20	0	10
% on-street Total	15	25	15	20
Off-street parking:				
Private employee parking	75	65	85	80
Public/private car-park	10	10	0	0
% off-street Total	85	75	85	80
Overall Total	**100**	**100**	**100**	**100**

4.3.2 Summary of on-street and off-street charging provision

A summary of the number of EVs charging on-street and off-street at workplace locations across London in 2020 and 2025 in the two scenarios is shown in Table 8. The total number of EVs charging at workplace locations is 15% of those charging in residential areas.

Table 8 EVs charging on-street and off-street in 2020 & 2025 in workplace locations for Baseline & High BEV scenarios (London-wide)

	2020 EV uptake scenario				2025 EV uptake scenario			
	BASELINE		HIGH		BASELINE		HIGH	
	No.	%	No.	%	No.	%	No.	%
WORKPLACE LOCATIONS								
Cars:								
EV Cars charged on-street	**670**	21	**1,585**	21	**2,939**	21	**7,108**	21
EV Cars charged off-street	**2,479**	79	**5,867**	79	**10,899**	79	**26,358**	79
Total EV Cars	**3,148**	**100**	**7,451**	**100**	**13,838**	**100**	**33,466**	**100**
Vans:								
EV Vans charged on-street	**240**	18	**745**	18	**240**	18	**1,079**	18
EV Vans charged off-street	**1,066**	82	**3,303**	82	**1,066**	82	**4,787**	82
Total EV Vans	**1,306**	**100**	**4,048**	**100**	**1,306**	**100**	**5,866**	**100**
Cars + Vans:								
EV charged on-street	**910**	20	**2,329**	20	**3,179**	21	**8,187**	21
EV charged off-street	**3,545**	80	**9,170**	80	**11,965**	79	**31,145**	79
Total EVs	**4,455**	**100**	**11,499**	**100**	**15,144**	**100**	**39,332**	**100**

The following chart shows the percentage of cars charging on and off street at residential and workplace locations for the two scenarios.

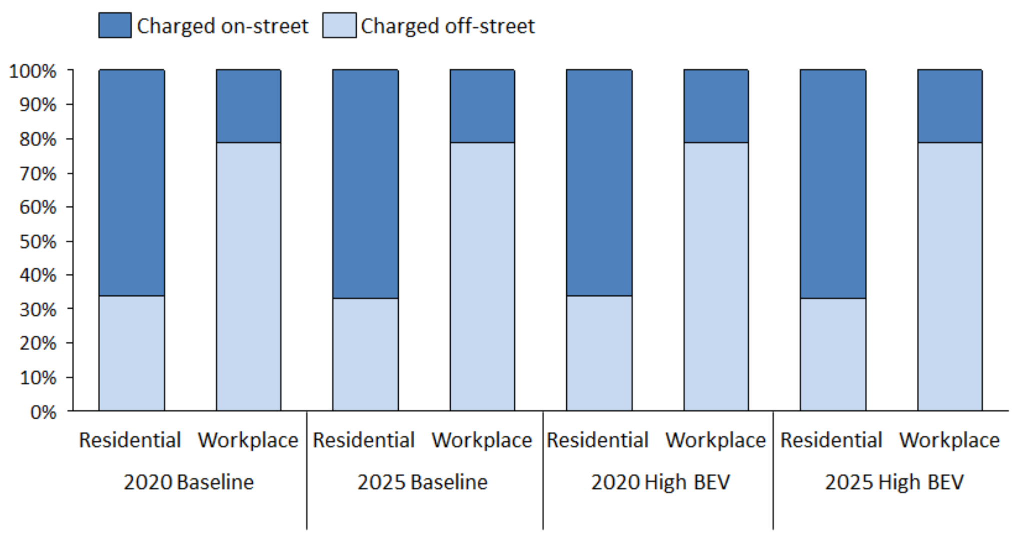


Figure 46 On & Off Street Charging: Residential & Workplace Comparison

As the figure shows, workplace cars are much more likely to charge off-street than residential cars.

4.4 Solutions for charging

The following section outlines the range of charging solutions that are currently available, or may become available in the near future, for on and off street parking. The options described here provide context for the discussion of impacts of plug-in vehicle charging in Section 4.

Range of charging solutions

In this section the focus is on on-street charging solutions, as it is likely that there will be higher demand for these than for off-street parking solutions (see Table 6). However, to show the interdependencies between the different charging solutions, off-street solutions for workplaces are also described. Off-street residential charging facilities (i.e. in garages and driveways) are not covered, as they are much more straightforward to install and can be done without local authority involvement or approval.

Off-street charging:

- Charging while parked in a driveway, garage or car park

On-street charging:

- Mostly charging while parked on the carriageway (i.e. in bays on side of the road). For the purposes of this report on-street parking also includes off-carriageway parking, e.g.: dedicated rapid charging bays in taxi ranks, and rapid charging on forecourts or in dedicated 'hubs'

The solutions will vary depending on whether they constitute the primary or secondary source of charging, and fall into one or more of the following categories:

- Residential charging
- Workplace charging
- Destination charging

Residential charging will be the primary source of charge and in most cases will be at or close to home. **Workplace charging** will be a secondary source which will facilitate charging for EV commuters at or close to workplaces. **Destination charging** will be a further secondary source and will provide for top-up charging at destinations which include supermarkets, high streets, leisure centres and other facilities with associated parking.

Most charging at home will take place overnight and most charging at workplaces and destinations will occur during the day. This has a bearing on the likely duration of stay and therefore the amount of charge the user requires and how quickly this charge needs to be delivered. The rate of charge is commonly categorised as 'slow', 'fast' or 'rapid', relating to the time taken to achieve a full charge for a typical BEV car: approximately 6-8 hours, 3-4 hours and 30 minutes respectively[42].

Most charging at 'destinations' will be made as part of short trips from the home, and as such there will be less reliance on these charging facilities to meet daily charging demands. In some cases, they will be located relatively close to a home or workplace in which case (subject to the costs levied to park and charge as well as their availability) they may be an attractive charging solution which could become a primary source of charging.

Secondary source destination charging has relatively minimal demand because the amount of time necessary to fully charge an EV means that most drivers will use residential charging as their main

[42] 'Slow' referring to 3kW, 'fast' to 7-22kW and rapid to 40+kW (typically 50kW)

type of recharging method. It guarantees they can park for the necessary hours to recharge the battery. Destination charging cannot be relied upon to charge their battery regularly. Given that, this section focuses on residential and workplace charging solutions.

There are many different types of facility for charging outside of garages, driveways and car parks, many of which can be clearly classified as ‘on-street’. The suitability of these for any given location is highly dependent on how close they need to be to where the EV owner lives or works. As such, they can be categorised as:

- Immediate charging provision (outside an EV owner’s house, on their street)
- Local charging (within walking catchment)
- Remote charging (likely to be outside walking catchment)

Immediate charging refers to facilities that are provided outside an EV owner’s house or close by on their street. It is probable that they would be provided in response to requests from a resident or group of residents.

Local charging facilities are identified as those which are located within a reasonable walk time, which may be 10 minutes from a residential property and up to 15-20 minutes from a workplace. These are more likely to be planning-led, installed in anticipation of a certain level of demand from EVs within their catchment area.

Remote charging refers to public charging facilities that may be outside of the catchments described above but could still constitute the primary source of charging. Given that they may not be located within walking distance, this means that charging overnight or charging for long periods of the day (i.e. enough time to achieve a full battery charge) is not feasible. As such, the required charge would need to be delivered very quickly, so the EV owner does not have to incur an unreasonable delay to their journey – this would require rapid charging. TfL’s approach to a rapid charge point network is that the facilities would be located off-carriageway in ‘hubs’ or dedicated locations such as taxi ranks. These would likely be less convenient for residents to use.

The range of charging solutions that are anticipated to be available in 2020 and 2025 for immediate, local and remote charging for residential and workplace locations are shown in Figure 47 and are listed in Table 9.

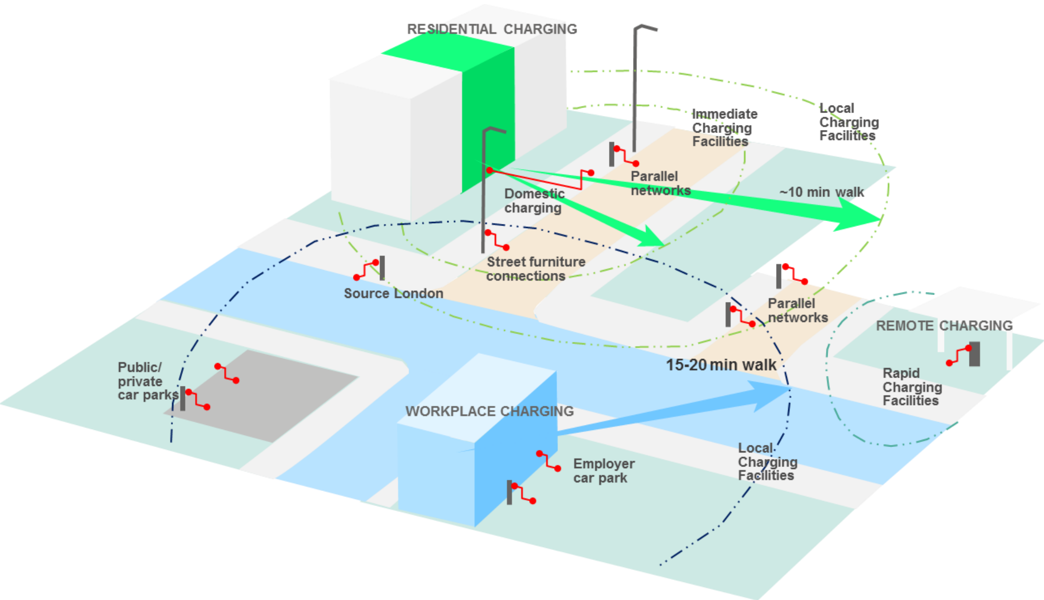


Figure 47 Range of charging solutions for immediate, local and remote charging in residential and workplace locations

Table 9 Range of charging solutions for immediate, local and remote charging

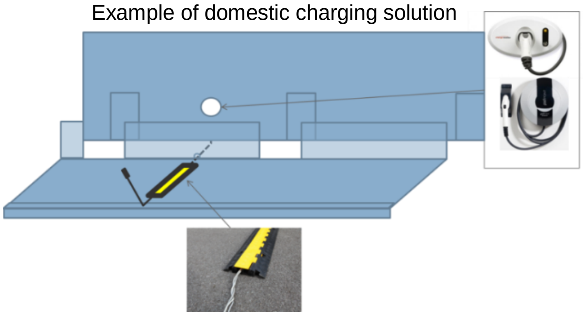
	Residential locations: on-street & off-street charging	Workplace locations: on-street & off-street charging
Immediate charging solutions (located at a property or within immediate walking distance)	• Driveway • Domestic charging on-street (using cable from property to vehicle) • Parallel networks: servicing single or multiple requests from residents within a highly localised area • Street furniture connections	• Employer car park • Depot
Local charging solutions (located within a reasonable walking time, which may be 10 minutes from a residential property and up to 15-20 minutes from a workplace)	• Source London charge points • Parallel networks: single or clustered facilities – could respond to current demand and/or be planning-led to respond to anticipated demand	• On-street: - Source London charge points - Parallel networks: servicing single or multiple requests from residents within highly localised area - Street furniture connections • Off-Street: - Public/private car parks
Remote charging solutions (outside of the catchments described above but could still constitute the primary source of charging)	• Rapid charge points – owners of EVs are unlikely to use remote charging stations (away from their residential or workplace area) unless the locations have rapid charging facilities. The exception to this would be at a location where they would already be driving to and parking for a period of time (e.g. a shopping centre or cinema) but this is likely to be occasional opportunity charging rather than the regular, primary method of charging.	

The main types of charging are described below.

Domestic charging (cable from property to vehicle)

A low technology and cost effective solution would be to permit residents to trail cables from their home charging unit over the public footway to their vehicle, covered by safe and secured rubber matting. Secured matting is regularly used in public spaces and areas of high footfall to cover wires on a temporary/semi-permanent basis.

Example of domestic charging solution



However, this is not seen as a long-term solution, but as a measure that is likely to be taken in order to meet demand for on-street charging before alternative solutions become commercially available. There is no definitive legal view concerning the legalities of permitting trailing cables over the footway, and the extent to which councils may retain liability. As such there have been differing interpretations across the country, though many local authorities have adopted the position that they cannot formally endorse permitting trailing cables as a policy.

Source London charge points

Source London is currently the dominant commercial network of publicly accessible charge points. The network includes a consortium of public and private sector organisations. There are currently more than c. 1,400 charge points in the network. Some

Example of Source London charge points

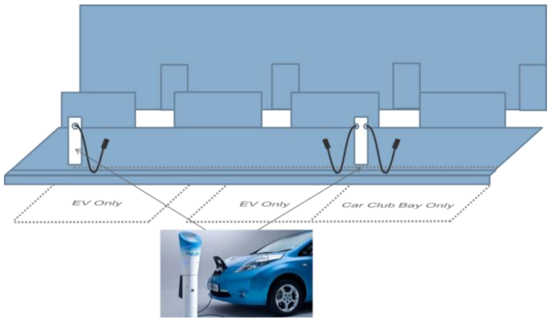
charge points are located on-street while others are found in supermarket or shopping centre car parks.

The operator BluepointLondon's aim is to increase the number of charge points to 6,000 by 2018, as well as launching an EV car club. It is understood that the focus of charge point deployment will be in clusters of four or more around attractors/destinations. In some cases it may be that this is within a reasonable proximity of where an existing EV owner or prospective buyer lives.

Parallel networks

An alternative model to the Source London public network would be for one or more third-party suppliers and operators to establish parallel charging network(s), but with otherwise conventional charge point technologies.

Example of parallel charging solution



This network could look to take on the role of providing on-street charging for residents, as a complementary network to Source London, geared towards and providing charge points principally for use overnight by residents. Such a model could be demand responsive (following requests from one or more residents) or planning-led if perhaps clustered within a catchment of potential demand.

Street furniture connections

Charging could be made through connections to street furniture which has an electrical connection. Lamp columns, in particular, have potential to provide charging facilities and this solution is being installed at locations in Europe. The system enables users to plug into existing electrical infrastructure (including lamp columns) using an intelligent charging cable. The charging cable includes a meter and communications that authorise the user to draw electricity and record the electricity used. The user details are recorded and the user is billed, with payment being made directly to the Distribution Network Operator. As of 2016, a trial is on-going in Hounslow (target of 24 units, market to start in 2017).

Example of lamp column charging solutions

Rapid charge points

In principle, rapid charge points (40kW+) could be installed in London, with a similar format to that of petrol stations, on the basis that their charging times are closer to the refuelling time for petrol/diesel vehicles than slow or fast chargers for EVs.

Example of Rapid Charging station in Europe. Source: Fastned

This model might be one option for residents who are not able to accommodate any form of on-street or domestic charger, particularly if they were paired with supermarkets or other amenities, so users could tie in routine trips to a rapid charger with other errands. TfL is currently establishing a rapid charging network (part of which will be dedicated to taxis, other part open to all vehicles), through a concession model. The commissioning of sites is expected to start in 2017.

Contribution of Charging Solutions to Meeting Future Demand

In order to determine their relative contribution to meeting the on-street charging demand in 2020 and 2025, the charging solutions have been scored against a range of suitability/feasibility factors (see Table 10). This has informed the development of the projected mix of on-street residential charging solutions shown in Figure 48. A parallel study was undertaken in consultation with a group of boroughs and TfL, aiming to identify short-term solutions for on-street charging in residential streets. The findings from this study have also informed the mix of charging solutions shown in Figure 48.

Table 10 Charging solutions rated by key factors for suitability/feasibility

Charging Solutions	State of Readiness	Costs - installation, operation and maintenance	Availability when need to charge	Cost to user	Convenience of Charging Apparatus	Access - dependency on access to specific EV bay	Technoligcal Constraints/ Challenges, risk of obsolescence	Impact on Parking Suppy	Streetscape Impacts	Fit with Car Clubs	Risks - Health & Safety and Legalities	Scalability
Source London	5	3	3	2	5	4	4	2	2	2	5	3
Parallel Networks	3	3	3	2	5	3	4	2	2	3	5	3
Street Furniture Connection	2	5	5	4	4	5	3	3	3	5	5	5
Cable to Vehicle	4	5	4	5	3	2	4	3	3	2	2	3
Rapid Charge Points	2	3	3	4	5	5	3	4	3	4	4	4

Poor		Satis factory		Good
1	2	3	4	5

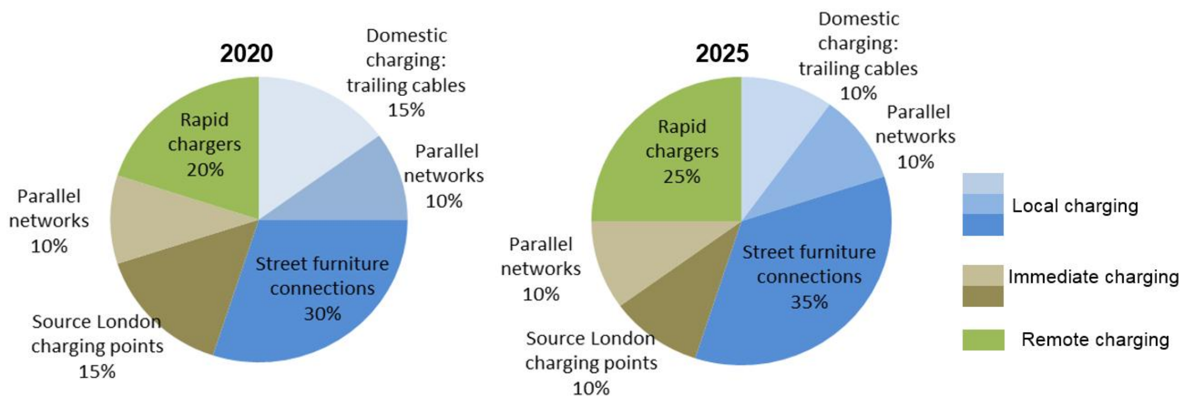


Figure 48 Expected mix of solutions for on-street residential charging in 2020 and 2025 (note that remote rapid chargers will be located off-carriageway)

The split between charging solutions shown in Figure 48 is an indication of how the mix of charging solutions may look in 2020 and 2025. The authors estimate that, currently, the majority of EVs without home charging are using a trailing cable, and possibly a few rely on the Source London network[43].

The projections shown above are based on research into international case studies as well as consultation with commercial operators, local authorities and industry experts for a parallel study. This is intended to be a general picture of future charging solutions; in reality the share of charging types will vary by Borough. The use of each solution is dependent on factors such as availability of off-street parking, parking policy, viability of street furniture and destination charging locations – all of which vary by London Borough. As both pie charts show, it is expected that there will be technological advancements which allow rapid charging and street furniture connections to become a viable option for residential charging. Therefore the ability for London Boroughs to accommodate the likely demand for on-street residential charging is dependent on the street furniture being viable, and on the necessary developments in technology.

[43] There are no strict records of how these EVs recharge, only that their number is low: the plug-in car grant survey indicates that over 90% of UK respondents have home charging facilities (and some work and on-street charging access too) and only 3% have on-street access only.

5 Impacts of plug-in vehicle charging in London

5.1 Street types and associated infrastructure need

As described earlier, the range of charging solutions will vary by the type of area. As we are focusing on on-street charging in this section of the report, it is useful to consider the charging types in relation to a categorisation of different streets.

The Roads Task Force proposed a classification for this purpose and based their concept on the relative balance of movement and place function; these are shown in Figure 49. TfL has worked with boroughs to classify the entirety of London's road network by applying this typology in a consistent manner. This framework has been used in this study to tailor recommendations on the most appropriate type of charging infrastructure for comparable locations across the capital and promote greater consistency in service provision.

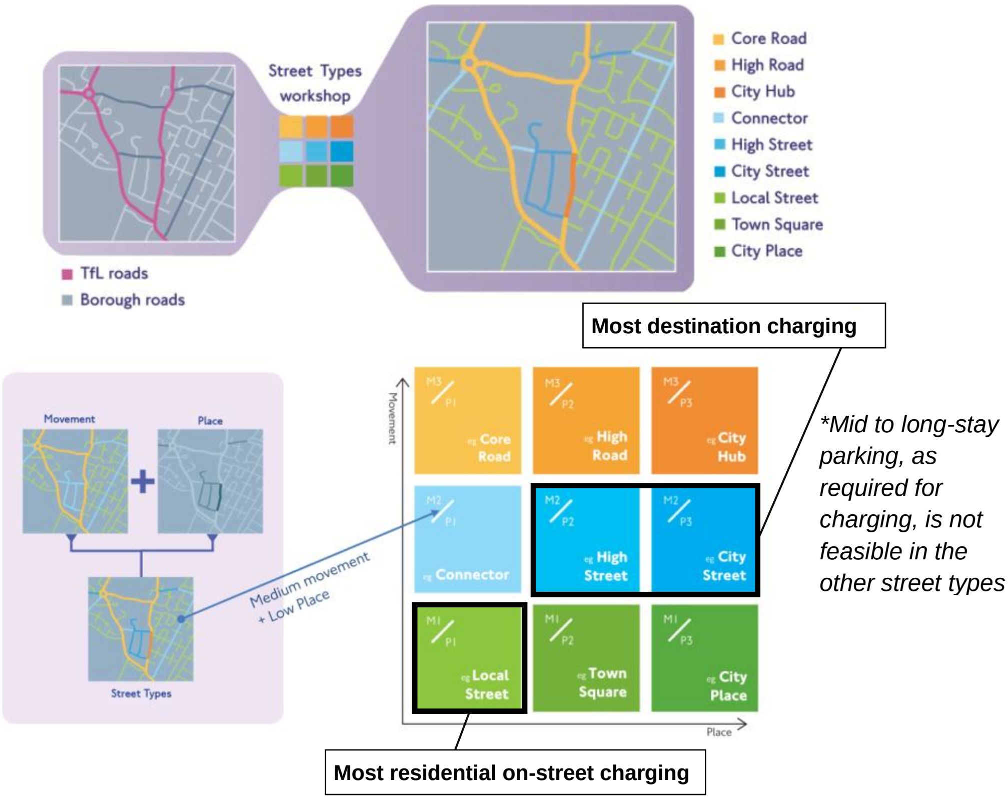


Figure 49 Street Types for London and expected charging type focus

Immediate and Local on-street residential and workplace charging facilities will mainly be located on Local Streets, which make up over 80% of the Capital's total road network (by length) and are where most people in London live.

Most workplace charging will take place off-street in depots or car parks so on-street charging will be minimal. On-street workplace and destination charging, likely to be for topping up during the day rather than fully charging, will take place in locations where parking is available. Therefore, the on-street locations are most likely to be in High Streets or City Streets with some located on Town Squares and City Places if appropriate to the local environment. Off-street destination charging points will be located in off-network destination "places" such as shopping malls, retail parks and larger supermarkets.

TfL's approach to deploying a rapid charge point network is that rapid charging facilities will be located in 'hubs' or in dedicated locations such as taxi ranks. As this infrastructure will be off-carriageway, 'Remote' (i.e. rapid) charging will not relate to any specific Street-Types.

As the main on-street charging type that has been mapped in this study, residential charging, is only feasible on Local Streets much of the impact assessment focuses on the infrastructure requirements for this Street Type. To assess these requirements and associated impacts in 2020 and 2025, London MSOAs were categorised according to the key determinants which influence charging solutions: population density and access to off-street parking.[44].

The typologies are shown in Figure 50. Typologies 1 and 2 generally represent outer London and constitute 42% of MSOAs. Typologies 3 and 4 generally cover inner London and contain 58% of MSOAs.

The impacts of EV charging, as laid out in section 5.2, are assessed for each of these Typologies.

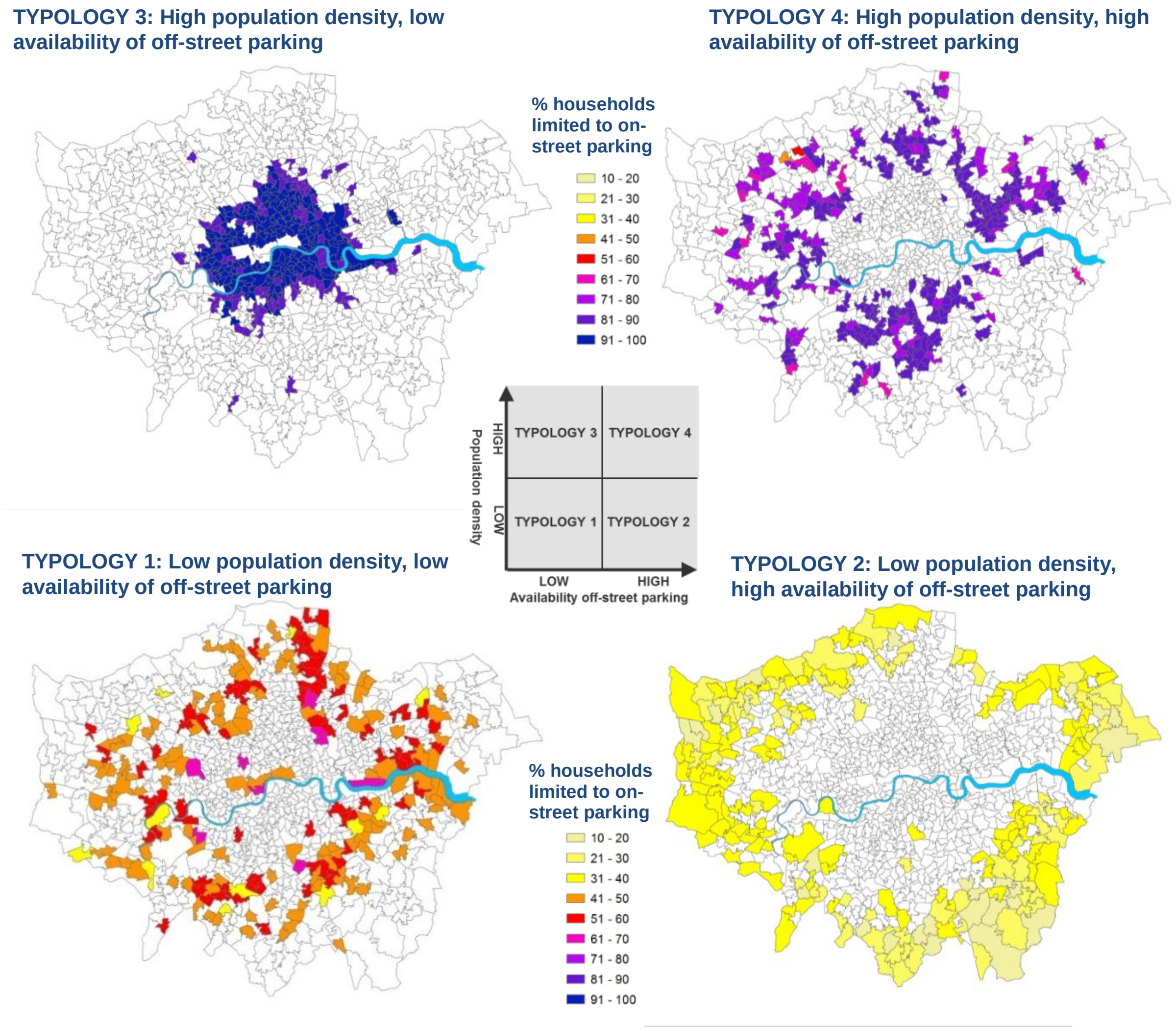


Figure 50 Area typologies

[44] Low population density being defined as under 65 people per hectares, low availability of off-street parking being bottom 50% of MSOAs

5.2 Overview of Impacts

5.2.1 Impacts to consider

The impacts for EV charging in London within the four MSOA typologies are discussed in this section for the key factors listed below:

Grid Impacts

Key considerations:

- Maximum power demand from EVs (calculated based on assumptions shown in Section 3; profiles based on aggregated demand profiles from real world trials).
- Power capacity of the local electricity network
- With additional load from EVs, whether there is spare capacity in the network and if not then what interventions are required

The approach for calculating the power demand figures shown in the typology tables was to assume a maximum power value per household to calculate the overall power capacity per MSOA, then compare this with the forecast EV power demand per MSOA discussed in Section 3 to identify the extent to which the MSOA is under or over capacity[45]. A Red, Amber, Green rating was then applied using the criteria shown in Table 11 below.

- It should be noted that within the scope of this study, it has not been possible to determine the actual levels of installed capacity and spare capacity for the entire network as this would require a much more detailed assessment on individual locations (as the dynamic nature of electricity demand and capacity means it is not possible to map out capacity across the whole network). In addition, our approach to determining the spatial extent of EV demand is limited to MSOAs therefore this would not necessarily identify demand clusters (such as depots adopting several EVs) which would place increased power loading on the network. Heavy duty vehicles such as buses and trucks are also excluded from the scope of this study and are more likely to trigger network reinforcement need. It is important that the grid impacts of additional load from light duty EV uptake is not viewed in isolation, with additional load from domestic, non-domestic and other transport modes included when assessing the need for enhancement works, including sub-stations.

The following table was developed by UKPN and outlines the impacts EV charging will have on the grid as well as possible mitigation measures that can be implemented, with their associated costs.

[45] This covers only residential charging for light vehicles. It does not address rapid charging networks. The grid impact criteria is based on the ratio of peak EV power demand and household power demand, where household demand is defined as 2kW x number of households

Table 11 Criteria for determining grid impacts

Ratio: EV power demand to power capacity	RAG rating	Description/ Mitigation	Mitigation cost	Mitigation timescales
0-10%	**Green**	It is anticipated that the existing spare capacity in the local network would cope with this additional load without the need for any enhancement works.	£ 0	n/a
10-20%	**Amber**	It is anticipated that there may be some requirement for low level enhancement works based on this level of load increase. Examples of this may include redistribution of loads between different feeders or substations or reinforcement of individual feeders.	£1,000 to £50,000	1 to 4 months
>20%	**Red**	It is anticipated that there will be some requirement for medium to high level enhancement works based on this level of load increase. Examples of this may include upgrade of secondary or, in extreme cases, primary substations.	£50,000 to 1,000,000+	4 to 18 months+

Summary of key impacts:

- In general, it is anticipated that the existing spare capacity in the local network will cope with the additional load from the overnight charging requirements of light duty EV uptake in 2020 & 2025 without the need for any significant enhancement works, however this will vary on a local basis depending on existing capacity

Parking Impacts

Key considerations:

- Ability to restrict access to EV users, especially local EV users
- Increase in parking stress
- Parking revenue loss
- Enforcement of designated EV bays
- Increase burden on boroughs of creating Traffic Management Orders and enforcing EV bays

Designated on-street EV bays could take one of several forms:

- EV only bay at all times
- EV only bay at particular times of the day
- EV only bay when recharging only
- EV only bays and Permit Holder restrictions

The bays would be suitable for all charging types shown in Figure 47, perhaps apart from domestic charging facilities which, unlike the other types, are only temporary on-street charging facilities. For domestic charging facilities, if an EV did not charge for an extended period then the bay would remain unoccupied, reducing capacity in what may be an area of high parking demand.

This will reduce the parking capacity for non-EV vehicles which some will have issues with, especially if the EV bays are not utilised to the same degree as the other bays. Therefore, it will be important to ensure that the utilisation of EV bays is maximised in areas of London with high parking demand. Interoperable charging booking systems, and technology to inform drivers of available spaces in networks to which they subscribe or which are pay per use, could help to ensure that EV bays are more frequently occupied. Systems following this concept are now starting to be used in various European cities; for example, users of the open access EV scheme Autolib in Paris can reserve parking spaces in advance.

At present there are a diverse mix of permits and subsidies that relate to EV parking. Access to an EV users' primary source of charging is the key consideration, which is most cases will be close to where they live. In Controlled Parking Zones (CPZ), residents are often restricted to parking within their immediate CPZ which, to provide context, in broad terms are consistent in size with MSOAs. However, with Local Charging facilities, EV user may need to charge up to 10 minutes' walk away, which may be outside their CPZ. So boroughs may need to take a more flexible approach to allowing EVs to access a wider catchment of charging facilities. This is particularly important if booking systems are used, where greater choice is needed to increase utilisation.

Within CPZs, it is easier to limit access to privately funded (i.e. by residents) but otherwise publicly accessible charging facilities to residents within that permit zone, although in most areas the restrictions do not apply overnight, so in principle non-residents could park up and charge within these bays.

Table 6 shows that in the Baseline scenario for 2025, there will be approximately 60,000 EVs that require some form of on-street charging facility, which roughly equates to 1,800 EVs per borough. In areas with parking restrictions then, over a 10 year period, this potentially means that 180 designated EV bays will need to be introduced and then enforced by boroughs every year. This would significantly increase the burden for local authorities. Depending on how a charging network is operated, by whom, the tariffs that are applied and the rate of occupancy of the bays, the overall parking revenue for an area could reduce with the introduction of EV bays. Unless EV users paid a higher charge than that for a normal CPZ permit, then an alternative source of funding may need to be identified in order to offset the loss in revenue and to pay for increased borough administration fees.

Summary of key impacts:

- Issues related to designating spaces for EVs in order to provide the assurance that users will be able to access charging facilities when and where they need them
- Increase in parking stress, and associated issues with neighbouring non-EV owners householders
- EV users may need to charge up to 10 minutes' walk away, which may be outside their CPZ, an area for which they do not have a permit and therefore cannot charge in during certain periods
- Depending on how a charging network is operated, by whom, the tariffs that are applied and the rate of occupancy of the bays, the overall parking revenue for an area could reduce with the introduction of EV bays

Streetscape

Key considerations:

- Visual intrusion from charging facilities installed in large numbers in residential streets
- Reduced effective footway width from charging facilities
- Potential footway access issues from secured matting used to protect trailing cables for domestic charging
- An increase in utilities works and associated disruption and degrading of footway surfaces

With street furniture connections and remote (rapid) charging solutions (which have fewer streetscape issues as in this model they are more likely to be located off-carriageway) taking a larger share of the charging mix in 2025, and given that the identified issues are only likely to be acute with the worst-case scenarios, then it is considered that in general the streetscape issues will be relatively minimal.

In practice, especially with the Local Charging Parallel Networks, there are likely to be clusters of charging facilities. Careful consideration would need to be given to their location in order ensure that the visual intrusion on premises in the immediate vicinity are not overly detrimental.

Whilst not likely to be a significant issue, the placement of charge points (posts) on the footway, which will be common to the Source London and Parallel Network facilities, will need be made such that the minimum acceptable footway width is maintained (normally a width of 2m is required).

Summary of key impacts:

- Safety issues due to reduction and degradation of footway space
- Potential for reduction of footway space creating conflict between residents

5.2.2 Assessment of Impacts

These impacts are primarily informed by information which is contained in this report and which includes:

- EV demand figures calculated in Chapter 2
- Charging requirements calculated in Chapter 3
- Typology determinants: level of off-street parking and population density
- Charging categories (e.g. residential) and charging solutions (e.g. domestic charging) summarized in Figure 47
- Projected mix of on-street residential charging solutions shown in Figure 48
- Charging solutions rated by key factors for suitability/feasibility shown in Table 10

The impacts relate to the charging categories and range of charging solutions that are shown in Figure 47. Destination charging was not included as locations cannot be mapped and the overall contribution to charging is expected to be small, as discussed in 3.1.3. Off-street charging was considered in the grid impacts assessment only, as it will not affect the other impacts.

Figure 51 provides a high level assessment of the severity of impact for the factors listed above. The assessment is based on multiple factors (i.e. cost of installation and existing policies) as well as professional judgement from the project team. A discussion of the impacts and mitigating measures is provided below.

This assessment is examined in more detail in Sections 5.5 - 5.8.

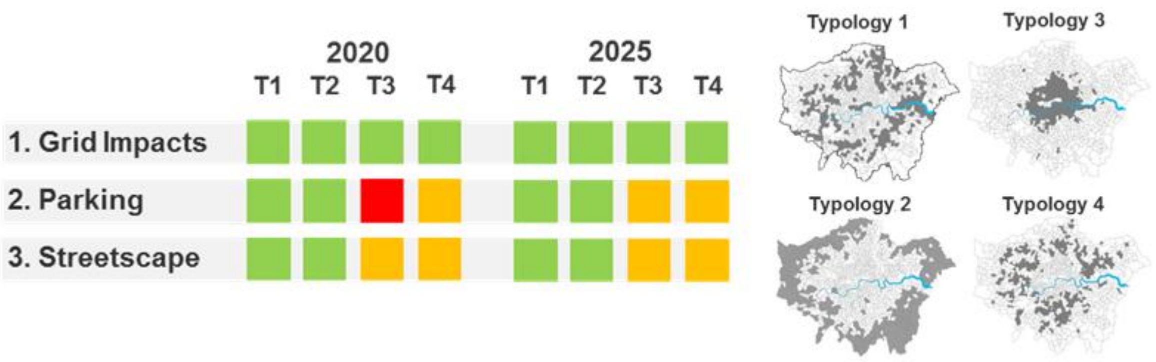


Figure 51 High level assessment of impacts of EV charging in London

As shown in Figure 51, the assessed grid impacts are low in 2020 and 2025, due to the focus on slow charging: rapid charging networks were not included in the assessment.

The parking impacts in 2025 are reduced compared to 2020, as it is assumed that new vehicle and charging technologies will enter the market, bringing reduced charging times, greater numbers of vehicles accommodated at each charging point, and possible advancements in parking management. These developments will be required to maximise utilisation of charging points and accommodate demand for on-street EV charging, and related demand for parking. In addition, outstanding issues regarding the practicalities of designating bays are likely to be resolved in these timeframes. By 2025 it is also expected that policy and planning with be adapted to accommodate the growth in use of EVs and make it easier to implement new charging schemes. However, it should be noted that if these assumed improvements do not occur then the impacts may in fact increase in severity as the number of EVs increases.

5.3 Key Considerations for Local Authorities

Each of these impacts is linked to various other factors which must be considered both in terms of their contribution towards the impacts, and also in terms of their role in preventing and alleviating some of the impacts. Below is a general overview of these factors; further consideration is included in the impact assessments for each Typology.

Charge Point/ Network Operation

Key considerations:

- Inter-operability and consistency of different charging types that may be managed by different operators
- Availability of charging facilities
- Degree of consistency of pricing and cost transparency
- Compatibility of connectors for different charging types and vehicles types
- Charging safety
- Managing demand in areas of workplace and residential charging

The on-street charging networks in place at the moment mostly only include the Source London network and a Parallel Network on certain residential streets in the City of Westminster. Nevertheless, interoperability is very likely to become more of an issue as more network providers enter the market. Already there are some issues with drivers needing to have more than one access device or card for chargers operating for different schemes that cross the capital's border and for charging on journeys beyond London.

However, as early experiences of establishing a London-wide charging network showed, there are inherent issues and increased complexity with multi-operator and multi-network charging for reasons which may include:

- Increased administrative burden for local authorities to liaise with different organisations as an on-going concern regarding implementation and maintenance of charging facilities
- Confusion for current or prospective EV owners as to which charging facilities they can access and the means by which they can get authorisation to charge (e.g. type of access card)
- If/how subscription and electricity costs are paid by EV users to operators/boroughs
- Standards to which operators must adhere regarding installation and maintenance of the charging facilities and levels of service to boroughs and the EV users

As the use of electricity has so far been free and as there are relatively few operators, there has not been the need to seriously consider interoperability between networks. However, as payment for electricity (through a subscription) or the service through pay per use (non-subscription) becomes commonplace within the next few years it is incumbent on network operators and any authority or organisation that commissions a network operator to consider the implications regarding consistency and inter-operability of the networks[46].

Summary of key impacts:

- Wide range of charging facilities, which has serious implications for inter-operability and consistency of operation
- Increased complexity with multi-operator and multi-network charging:
  - Increased administrative burden for local authorities to liaise with different organisations as an on-going concern regarding implementation and maintenance of charging facilities
  - Possible confusion for current or prospective EV owners as to which charging facilities they can access and the means by which they can get authorisation to charge (e.g. type of access card)
  - Uncertainty regarding if/how subscription and electricity costs are paid by EV users to operators/boroughs
  - Standards to which operators must adhere regarding installation and maintenance of the charging facilities and levels of service to boroughs and the EV users
- Range of different connectors has the potential to become more of an issue in future as the range of charging facilities increases, complicated by the fact that new EVs are rapidly entering the market, including EV vans and taxis
- High proportion of Domestic Charging (with trailing cables) may present a problem regarding safety
- High proportion of Domestic Charging (with trailing cables) may present a problem in that it will be difficult to ensure that a space will be available to park outside an EV owner's house
- With the introduction of EV parking bays there will be an increased administrative burden on boroughs to create the necessary Traffic Management Orders and to enforce these parking areas

[46] The introduction of tariffs has started on the Source London network in September 2016, see https://www.sourcelondon.net/#prices

Technical Feasibility

Key considerations:

- Ability to retro-fit charging solutions onto the footway/into street furniture
- Legal position regarding domestic charging with trailing cables

Slow, fast and rapid charge points are now all available technologies from a range of commercial suppliers and have, to varying degrees, been installed in some form in London for several years - albeit rapid charge points are a later addition. Based on the assumption that future Source London and Parallel Network charging facilities are most likely to take the form of charge points (posts), or in some cases wall mounted points, then almost all of the Immediate, Local and Remote Charging facilities described in Figure 45 (page 38) are proven technology in terms of their technical feasibility.

The only charging type for which there is less technological certainty is for street furniture connections. As described earlier, the main emerging solution in this category is for lamp columns to be retro-fitted with a charging connection, to which an intelligent (metered) charging cable is plugged into. However, whilst this system is being installed in certain cities on the continent there are uncertainties regarding certain technical factors which may render it less suitable for use in London.

The main factors are: location of lamp columns; 'Single Switchability'; and lamp column dimensions.

- To avoid trailing cables, the lamp columns need to be located at the front of the footway. However, a certain proportion is located at the back of the footway but there are no records held by boroughs regarding the actual numbers. It will vary from street to street, and borough to borough and from observations could be in the region of 30% or more across London.
- 'Single Switchability' refers to the situation where in some cases lamp columns are powered through a parallel connection to the main grid, which is centrally controlled and only powered up over-night when the lights are in use. Therefore, modifications would need to be made to ensure that EVs could be charged through lamp columns at all times.
- Lamp columns need to have a certain diameter to be able to contain the required connection. It is considered that the majority of lamp columns would be of sufficient width to accept the connection.
- In addition to retro-fitting the lamp column which is relatively low cost (~£500), the lamp column could be replaced with one which has a pre-installed connector. This would add additional cost (~£1000) which may be acceptable to some boroughs, however many have Private Finance Initiative (PFI) contracts to replace all of their lamp columns over a short period, which will have implications on the feasibility of using socket connections within their borough.

There is the also the issue of connector compatibility but this has already been covered in the section on Charge Point/Network Operation impacts.

The high level impact assessment in Figure 51 shows that the impact for Typology 3 and 4 remains the same from 2020 to 2025 largely due to the potential lingering issues regarding the legality of trailing cables for domestic chargers which will be more acute for these areas due to the high number of EVs that will need to be charged on-street. As previously discussed, trailing cables may be required to meet demand for on-street charging before alternative solutions become commercially available, but are not seen as a long term solution.

It is anticipated that the uncertainties regarding street furniture connections are likely to have been addressed by 2020 and certainly by 2025. This supports our estimation that this low cost solution could constitute 30% of the projected mix of charging solutions in 2020, and 35% in 2025, subject to these uncertainties being addressed which should be prioritised.

Summary of key impacts:

- Street Furniture Connections are predicted to make up 30% & 35% of the mix of charging facilities in 2020 and 2025 respectively. However, there are major uncertainties regarding certain factors which may render this solution less suitable for use in London than on the continent (where it is currently being used in certain cities)
- Issues with connector compatibility resulting from multiple charging facilities (impact also covered in Charge Point/ Network Operation Impacts)

Commercial Viability

Key considerations:

- Implementation cost for charging facilities
- Cost to operate and maintain the network, and extent of liability for boroughs
- Subscription/ pay per use costs to user
- Demand cost elasticity
- Charge point utilisation during the day and evening
- Scalability of charging types
- Extent of adoption of demand responsive versus planning-led approach to introducing charging facilities
- Extent of new development, where installation costs will be less

The cost of implementation of any EV charging infrastructure can be viewed in three parts, equipment, installation (including earthworks) and connection. Within this the equipment can be regarded as a relatively fixed cost once a supplier has been chosen. The equipment costs for charging facilities vary significantly, with the lowest cost option being commercial charging using a trailing cable (virtually no cost), then street furniture connections (~£1k) up to the highest cost charging facilities which are rapid charge points (~£50k each). Earthworks and connection costs are more difficult to predict, with costs varying significantly depending on conflicts with sub-surface services and ease of electricity connection.

Operating costs for EV charging includes: standing charges related to provision of electricity; cost of electricity dispensed to vehicles; cost of electricity to operate equipment; communication costs to network operator and network function for data handling, call centre and routine maintenance (including cleaning and annual safety checks). The majority of these services are likely to be outsourced to an EV charging network provider.

The introduction of payment for charging is inevitable after the initial period of “free electricity” to incentivise drivers. The issue is how to determine a charging rate that makes commercial sense. To do that it must begin to cover some of the many costs outlined above, not just the cost of electricity, but at the same time not disincentive drivers. The tariff which is levied on EV users will clearly have an impact on demand but much more so for EV drivers who have alternative charging sources, and particularly for drivers of plug-in hybrid EVs who may have more flexibility in where and when they charge their vehicles.

In the case of the Westminster parallel network model, the costs of installation are spread between the applicants, with a requirement that there must be a minimum of three applicants who live close to one another. However, with applicants contributing to capital costs (through a 3 year contract), as demand rises this may become an issue as it is not possible within current parking regulations to prevent further EVs from using these charging facilities.

As discussed earlier, a key attraction of the street furniture connection model is the greatly reduced capital costs, by relying on mobile metering technology which effectively provides the user access to the electricity grid in the same way a mobile phone provides access to the telecommunications grid. Like a mobile phone, users could choose a contract to match their needs with the supplier of their choice.

In new development, charging facilities can be installed as part of the highway construction, which will significantly reduce cost. It will be easier to provide spare capacity through ‘passive charging’, which provides the connections to which charge facilities can be made as demand increases. Therefore, subject to demand for EVs, which may be constrained by planning policy (as discussed earlier), then installation and operation of charging facilities in new development may be a commercial attractive proposition.

A fundamental issue that applies to Domestic Charging but is more important for charging facilities which will be open to other EV users is whether, in order to restrict usage/parking to EV users, it will be necessarily and feasible to formally designate a space which only EVs can use, at least during certain hours of the day. This is possible using current parking regulations but it would increase the burden on boroughs to create the necessary Traffic Management Orders and to enforce these parking areas. This subject is discussed further below in the Parking Impacts section.

Summary of key impacts:

- From increased EV demand, EV users are likely to have to pay for electricity used and pay higher tariffs for parking/charging in general. This means the demand-cost elasticity will become more sensitive, therefore needs to be carefully managed to not disincentivise prospective EV buyers
- Commercial operators will understandably want to concentrate their resources on those locations that have a high usage rate (typically in Typologies 3 and 4). This may mean that those in areas with lower numbers of EVs requiring on-street charging may find it more difficult to access charging facilities
- Scalability is an important consideration and certain charging facilities provide greater flexibility to respond to demand than others, particularly Street Furniture Connections
- Commercial risk will be influenced by whether a demand responsive or planning-led approach is adopted. Different charging types and different areas of London will be more suitable for one type than the other. The planning-led option will be more suitable for the high density areas where there is less off-street parking. In practice, in most areas there will be a combination of these approaches
- With the mobile metering functionality of the Street Furniture Connection model, like a mobile phone, users could choose a contract to match their needs with the supplier of their choice
- Subject to demand for EVs in new development (possibly limited by planning policy), the operation of charging facilities in new development may be a commercial attractive proposition as facilities will be built-in to the infrastructure resulting in lower capital costs and greater flexibility in responding to demand through passive charging facilities

Planning and Consultation

Key considerations:

- Policy required for planning-led and demand responsive charging facilities
- Requirement for public consultation for introduction of charging facilities
- Agreement between stakeholders for introduction of charging facilities
- Agreement between stakeholders for introduction of new technology and networks

In Figure 51, Typologies 3 & 4 have been given a red rating and Typologies 1 and 2 an amber rating. The use of a red rating is due to two primary reasons, the first of which relates to the uncertainty which may exist regarding planning policy for reacting to applicant requests for charge points as well as the extent to which a planning–led approach should be adopted.

The second reason relates to political acceptability. There is a risk that the bays would be perceived as being effectively for private use by individuals, which in an area of high parking stress would be controversial, and potentially seen as elitist. The Westminster model's approach overcomes this to an extent by requiring that each point be shared by at least three users. In practice this is likely to be more than adequate for the users, for whom charging twice a week is likely to provide them all the charge they need for the short average trip lengths common to central London. Then the remainder of the time they must find a residents' parking space like everyone else.

In addition to the need to formally advertise Traffic Management Orders for the EV bays, which was discussed earlier, depending on local sensitivities, it may also be necessary to consult more informally with residents if it is felt there may be potential issues associated with, for example, reduced parking capacity, streetscape impacts, safety hazards from charging or use of EV spaces by non-residents.

In addition to the factors above, the minimum amber rating given reflects the fact that there may be a lack of appetite amongst boroughs to forge a new series of agreements with providers and operators, given resource constraints and with the legacy left from the challenges associated with the introduction of Source London.

Additional consultation would be required to trial and roll-out new technology such as the street furniture connections, for which there are several fundamental questions regarding their feasibility and scalability for use in London. As discussed earlier, this will vary significantly within and between different boroughs.

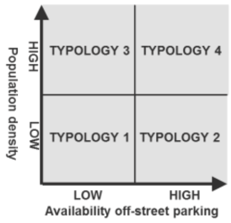
Summary of key impacts:

- With increased EV uptake the current issue becomes much more acute regarding the need for policy for reacting to applicant requests for charge points as well as the extent to which a planning–led approach should be adopted
- Issues related to political acceptability of introducing bays at the request of a single household. This may be less of an issue with a minimum number of households of say three being required before a charging facility will be considered
- It may also be necessary to consult more informally with residents if it is felt there may be potential issues associated with, for example, reduced parking capacity, streetscape impacts, safety hazards from charging or use of EV spaces by non-residents
- Potential lack of appetite amongst boroughs to forge a new series of agreements with providers and operators

5.4 Residential, depot and workplace charging needs and impacts per typology

As described earlier, areas of London have been categorised according to the key determinants which influence charging solutions, which are population density and provision of off-street parking. The MSOAs in London have been assigned to one of four Typologies, which are:

- **Typology 1**: Low population density, low availability of off-street parking
- **Typology 2**: Low population density, high availability of off-street parking
- **Typology 3**: High population density, low availability of off-street parking
- **Typology 4**: High population density, high availability of off-street parking



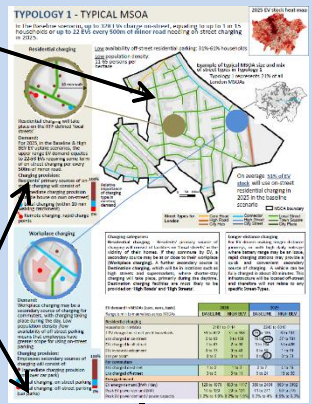
For Typologies 3 and 4, which cover inner London, there may be a relatively high EV uptake within areas where there is low car ownership. However, for each Typology (including Typology 3, which has the most constraints to parking and streetscapes), the analysis only considers the uptake of EVs in place of cars that would be used in any case, under a baseline increase in car sales (in line with national projections). The recommendations and policy changes do not encourage uptake in driving from those who currently walk, cycle or take public transportation. As Typology 3 MSOAs will most likely have a high Public Transport Accessibility Level (PTAL) score, it is expected for the level of car use to remain low.

The following sections contain summary results for each of these typologies, which help to put the EV uptake forecasts into perspective and assists in understanding the impacts that are described later.

Interpreting the results for the illustrative MSOA:

The typology sheets show examples of a typical MSOA that is located within the four areas of London covered by the typologies. The MSOA example gives an indication of how the areas may look using the Street Type classification.

An indication is given regarding the relative importance of the different types of charging provision (immediate, local or remote) in meeting the EV demand for on-street charging in residential and workplace locations for these typologies.



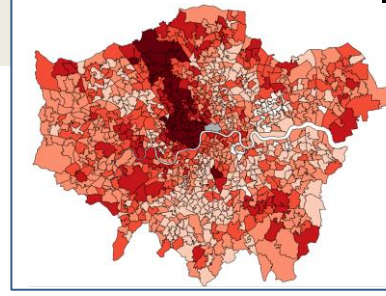
The sheets include a table which identifies all the key figures that relate to EV demand and Energy demand. Some of these are highlighted in the text below the MSOA diagram. For the rows related to residential and workplace charging, "EV" includes cars, vans and taxis.

The ranges shown in each column are the highest and lowest figures seen in the MSOAs represented by the typology. So for those boroughs that fall into Typology 1 may see between 5 to 158 EVs charged on-street by 2020. Where they fall in that range will depend on the factors explained in the chapters related to EV uptake.

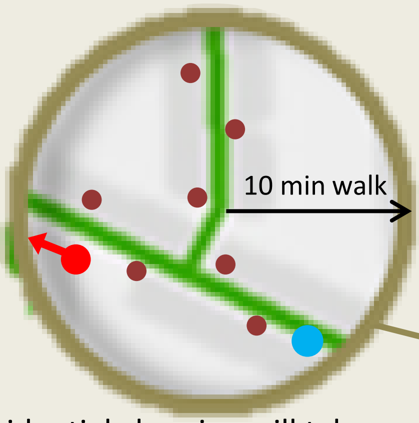
5.5 TYPOLOGY 1 - TYPICAL MSOA

In the Baseline scenario, **up to 328 EVs charge on-street**, equating to up to 1 in 15 households or **up to 22 EVs every 500m of minor road** needing on-street charging in 2025.

2025 EV stock heat map



Residential charging

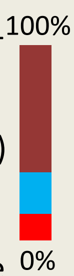


Residential charging will take place on the RTF-defined '**local streets**'.

Demand:
For 2025, in the Baseline & High BEV EV uptake scenarios, the upper range EV demand equates to **22-53 EVs** requiring some form of on-street charging **per every 500m** of minor road.

Charging provision:
Residents' primary sources of on-street charging will consist of:

- Immediate charging provision (outside house on own on-street)
- Local charging (within 10 min walking catchment)
- Remote charging: rapid charge points



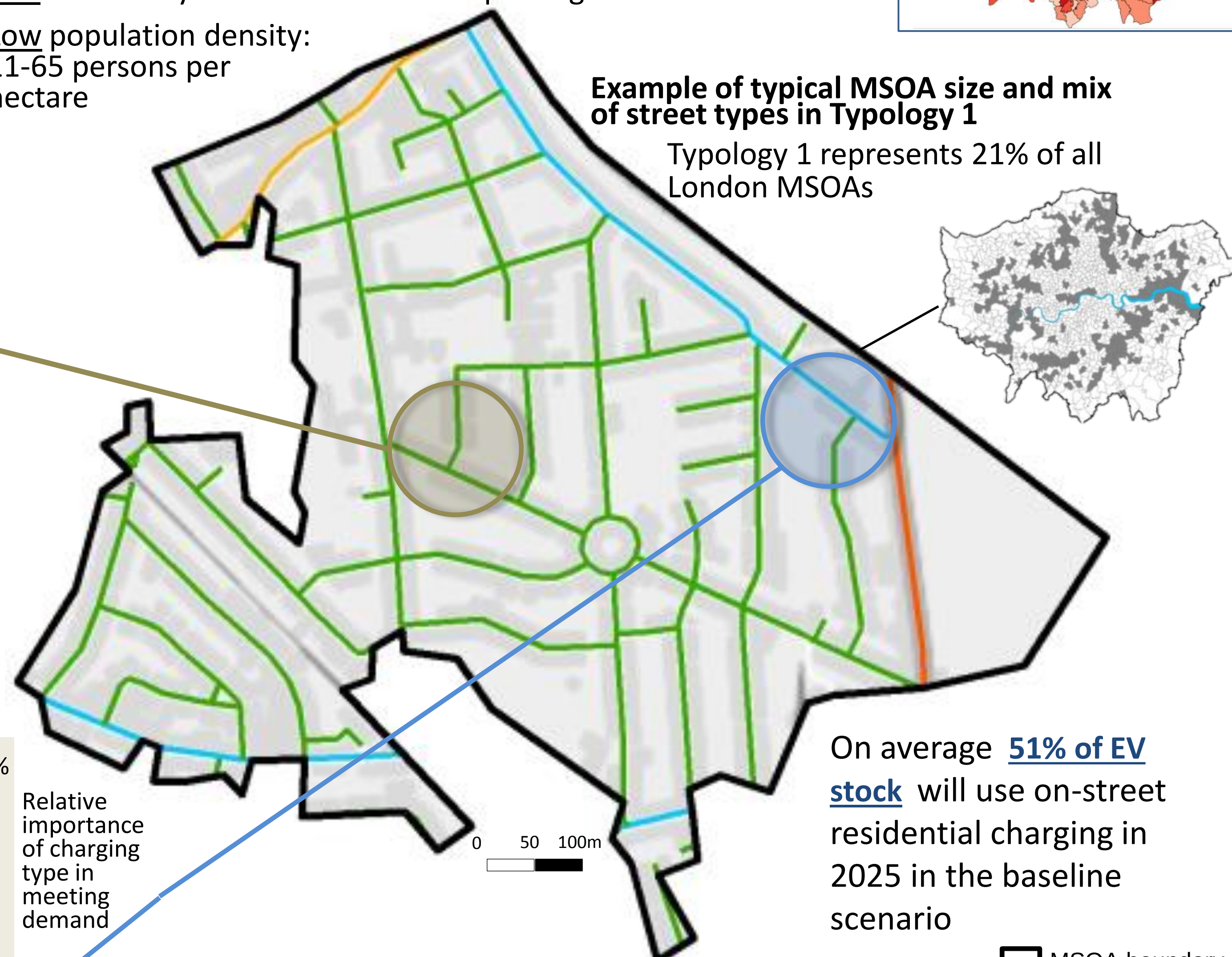
Relative importance of charging type in meeting demand

Low availability off-street residential parking: 31%-61% households

Low population density: 11-65 persons per hectare

Example of typical MSOA size and mix of street types in Typology 1

Typology 1 represents 21% of all London MSOAs

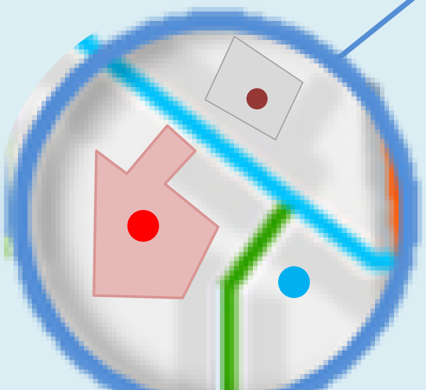


On average **51% of EV stock** will use on-street residential charging in 2025 in the baseline scenario

Street Types for London

- Core Road
- High Road
- City Hub
- Connector
- High Street
- City Street
- Local Street
- Town Square
- City Place

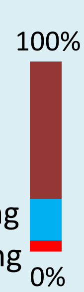
Workplace charging



Demand:
Workplace charging may be a secondary source of charging for commuters, with charging taking place during the day. Low population density /low availability of off-street parking means that employees have greater scope for using on-street parking.

Charging provision:
Employees secondary sources of charging will consist of:

- Immediate charging provision (employer car park)
- Local charging: on-street parking
- Local charging: off-street parking (car parks)



Charging categories:
Residential charging - Residents' primary source of charging will consist of facilities on '**Local streets**' in the vicinity of their homes. If they commute by EV, a secondary source may be at or close to their workplace (**Workplace charging).** A further secondary source is **Destination charging,** which will be in locations such as high streets and supermarkets, where shorter-stay charging will take place, primarily during the daytime. Destination charging facilities are most likely to be provided on '**High Roads**' and '**High Streets**'.

Longer-distance charging
For EV drivers making longer distance journeys, or with high daily mileage where battery range may be an issue, rapid charging stations may provide a quick and convenient secondary source of charging. A vehicle can be fully charged in about 30 minutes. This infrastructure will be located off-street and therefore will not relate to any specific Street-Types.

EV demand in MSOAs [cars, vans, taxis] Range is min to max values across MSOAs, mean in brackets	2020		2025	
	BASELINE	HIGH BEV	BASELINE	HIGH BEV
Residential charging				
Households in MSOAs	2181 to 6114 (3461)		2245 to 8010 (3620)	
1 EV charged on-street per X households	59 to 622 (210)	31 to 358 (122)	15 to 185 (64)	6 to 101 (32)
EVs charged in on-street	5 to 69 (20)	9 to 158 (35)	18 to 328 (71)	37 to 781 (148)
EVs charged in off-street	1 to 63 (16)	2 to 90 (27)	3 to 184 (52)	5 to 426 (105)
EVs in new development	0 to 33 (2)	0 to 48 (4)	0 to 50 (5)	1 to 89 (10)
EVs per 500m	0 to 5 (1)	0 to 11 (2)	0 to 22 (4)	0 to 53 (8)
For commuters				
EVs charged on-street	1 to 2 (1)	1 to 3 (2)	2 to 7 (4)	4 to 16 (9)
EVs charged off-street	3 to 5 (4)	5 to 11 (7)	9 to 24 (14)	19 to 55 (31)
Energy demand				
EV energy demand (kWh / day)	128 to 1076 (364)	183 to 1117 (434)	380 to 2401 (941)	560 to 3092 (1421)
Peak EV power demand (kW)	14 to 120 (40)	20 to 124 (47)	41 to 271 (104)	60 to 346 (156)
Peak EV power demand / power capacity	0.2% to 1.8% (0.6%)	0.2% to 1.9% (0.7%)	0.3% to 4% (1.5%)	0.5% to 5.3% (2.2%)

5.5.1 Typology 1 Impacts & Considerations

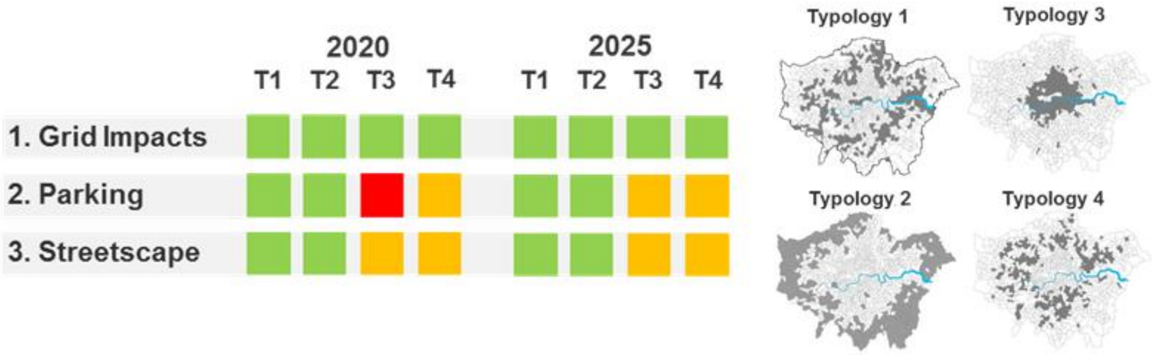


Figure 52 High level assessment of impacts of EV charging in London

Electricity Demand on the Grid

The grid impacts for all typologies have been given a Green rating in 2020 and 2025. This is based on the fact that the ratio of EV power demand to power capacity shown in the typology tables is below 10%. Therefore, within the next 10 years it is not anticipated that mitigating measures will be necessary when considering light duty EV uptake in isolation.

Electricity demand on the grid for Typology 1 is low. This is because even in the High BEV scenario in 2025 there will a maximum of 781 EVs charged on-street, 426 charged off-street and 89 charged in new developments overnight in an MSOA. As a result the maximum peak EV power demand is 5.3% of the power capacity.

It is anticipated that no mitigating measures will be required by 2025 due to the additional load of light duty EV uptake alone. Refer to the London Energy Plan for identification of where enhancement works and mitigation measures are required.

Parking Pressure

In the baseline scenario for 2025 it is estimated there will be a maximum of 328 EVs charging on-street. This will result in 22 EVs per 500m of minor road on average, with over 23m space separating each charge point. Therefore, for Typology 1, it is not anticipated for there to be substantial parking pressures. The current systems in place should be enough to meet demand for EV parking spaces.

The challenge residents in Typology 1 may face is ensuring the commercial viability of dedicated EV parking bays with charge points. Commercial operators will want to concentrate their resources on locations with a high usage rate. This may mean that those in areas with lower numbers of EVs charging on street (i.e. Typology 1) may find it more difficult to access charging facilities.

To mitigate this, an interoperable booking system could be introduced to help maximize utilisation and make charging networks more commercially viable. This should work because in Typology 1, as shown in the demand table, there is likely to be a relatively dense network of charging facilities. As Figure 48 shows, in 2020 the charging mix is likely to consist of street furniture connections (30%), such as lamp columns, Source London charge points (15%), Domestic Charge Points (15%), Remote (rapid) Charging (20%), and Parallel Networks (20%).

This wide range of charging facilities has serious implications on inter-operability and consistency of operation which will need to be carefully considered over the next few years. It is expected that many of these issues will have been addressed by 2025 which is why in the summary of impacts (Figure 49), the severity of impact has been reduced.

Streetscape/Street Clutter

The key considerations for streetscape and possible street clutter are the visual intrusion from charging facilities installed in large numbers on residential streets. In the High BEV scenario by 2025, Typology 1 MSOAs may see up to 781 EVs charging on-street, with the potential to see an EV charge point every 23 meters. This could lead to significant streetscape impacts in these MSOAs.

As some of these charge points could involve trailing cables across the footway for domestic charging it could lead to potential footway access issues, and secured matting spread across the pavement. This matting would mean an increase in utilities works and associated disruption and degrading of footway surfaces. In order to avoid conflict local authorities should look to install charge points that have minimal impact to the footway and streetscape. This means the split shown in the pie charts in Figure 48 will shift slightly. The number of domestic charge points would be reduced and other types, like parallel networks and street furniture, would be increased.

With street furniture connections and remote (rapid) charging solutions (which have fewer streetscape issues) taking a larger share of the charging mix in 2025, and given that the identified issues are only likely to be acute with the scenario of highest EV uptake, then it is considered that in general the streetscape issues will be relatively minimal.

In practice, especially with the Local Charging Parallel Networks, there are likely to be clusters of charging facilities. Careful consideration would need to be given to their location in order ensure that the visual intrusion on premises in the immediate vicinity are not overly detrimental.

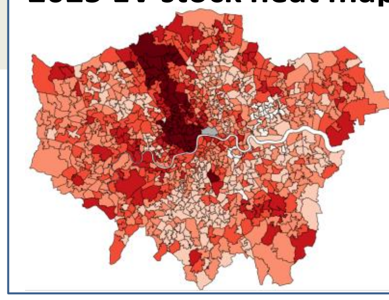
Whilst not likely to be a significant issue, the placement of charge points (posts) on the footway, which will be common to the Source London and Parallel Network facilities, will need be made such that the minimum acceptable footway width is maintained (normally a width of 2m is required).

Some of the EV uptake will be accommodated by new developments. For the MSOAs in Typology 1 there is expected to be 50 EVs in new developments in the 2025 Baseline Scenario and 89 in the 2025 High BEV Scenario. For these EVs the infrastructure will be built into the streetscape and conflict with residents over use of space will be minimised.

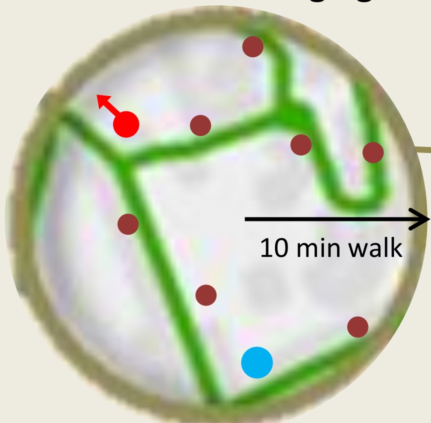
5.6 TYPOLOGY 2 - TYPICAL MSOA

In the Baseline scenario, **up to 167 EVs charge on-street**, equating to up to 1 in 20 households or **up to 14 EVs every 500m of minor road** needing on-street charging in 2025.

2025 EV stock heat map



Residential charging



Residential charging will take place on the RTF-defined '**local streets**'.

Demand:
For 2025, in the Baseline & High BEV EV uptake scenarios, the upper range EV demand equates to **14-31 EVs** requiring some form of on-street charging **per** every **500m** of minor road.

Charging provision:
Residents' primary sources of on-street charging will consist of:

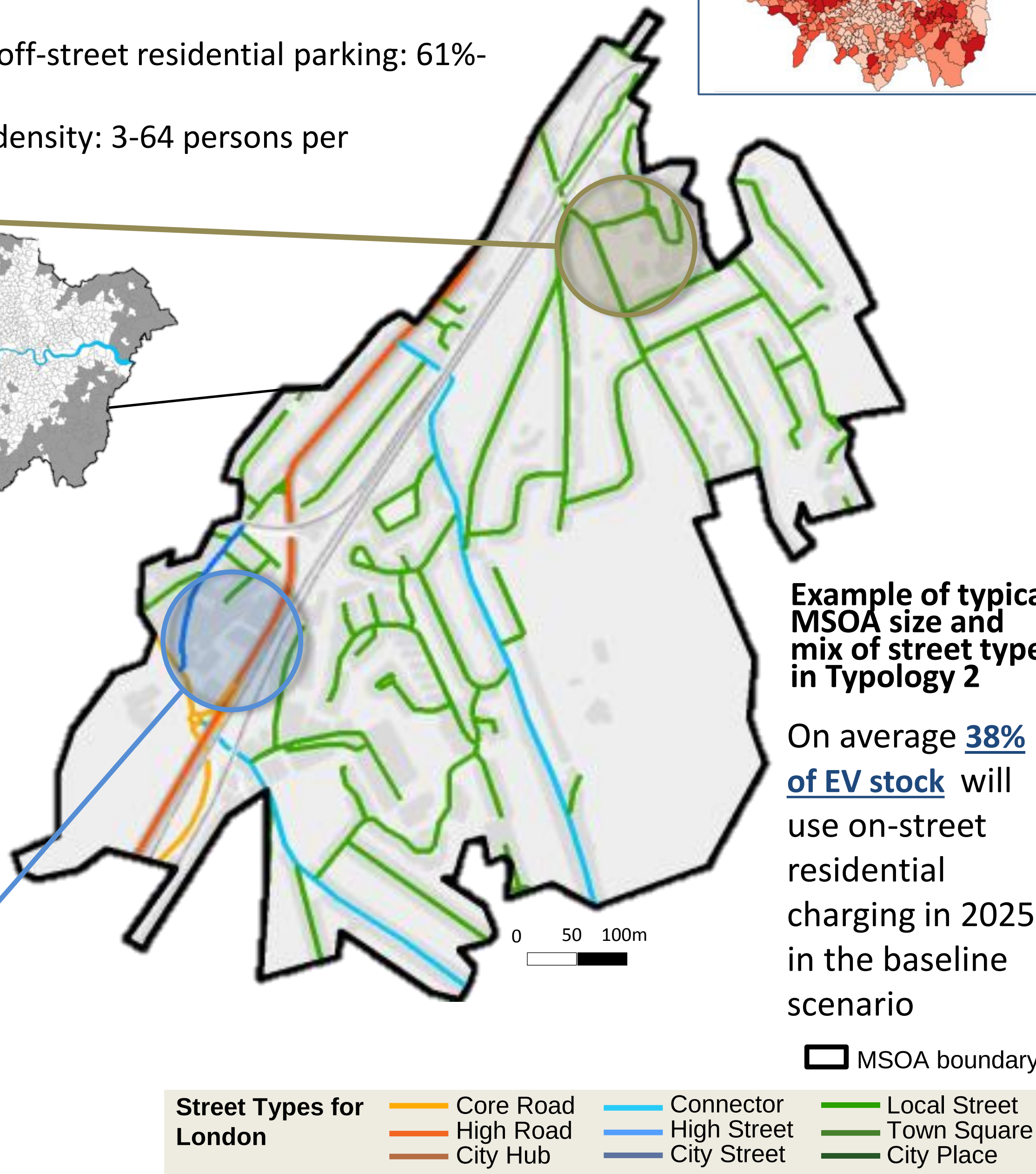
- Immediate charging provision (outside house on own on-street)
- Local charging (within 10 min walking catchment)
- Remote charging: rapid charge points

High availability off-street residential parking: 61%-87% households

Low population density: 3-64 persons per hectare

Typology 2 represents 21% of all London MSOAs

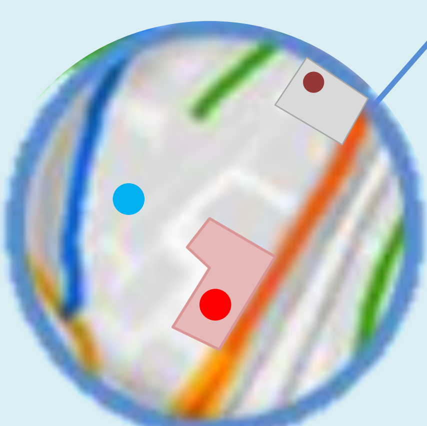
Relative importance of charging type in meeting demand



Example of typical MSOA size and mix of street types in Typology 2

On average **38% of EV stock** will use on-street residential charging in 2025 in the baseline scenario

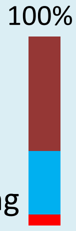
Workplace charging



Demand:
Workplace charging may be a secondary source of charging for commuters, with charging taking place during the day. Low population density /low availability of off-street parking means that employees have greater scope for using on-street parking.

Charging provision:
Employees secondary sources of charging will consist of:

- Immediate charging provision (employer car park)
- Local charging: on-street parking
- Local charging: off-street parking (car parks)



Charging categories:
Residential charging - Residents' primary source of charging will consist of facilities on '**local streets**' in the vicinity of their homes. If they commute by EV, a secondary source may be at or close to their workplace (**Workplace charging).** A further secondary source is **Destination charging,** which will be in locations such as high streets and supermarkets, where shorter-stay charging will take place, primarily during the daytime. Destination charging facilities are most likely to be provided on '**High Roads**' and '**High Streets**'.

Longer-distance charging
For EV drivers making longer distance journeys, or with high daily mileage where battery range may be an issue, rapid charging stations may provide a quick and convenient secondary source of charging. A vehicle can be fully charged in about 30 minutes. This infrastructure will be located off-street and therefore will not relate to any specific Street-Types.

EV demand in MSOAs [cars, vans, taxis] Range is min to max values across MSOAs, mean in brackets	2020 BASELINE	2020 HIGH BEV	2025 BASELINE	2025 HIGH BEV
Residential charging				
Households in MSOAs	2145 to 6899 (3424)		2187 to 8706 (3556)	
1 EV charged on-street per X households	63 to 777 (264)	39 to 497 (155)	20 to 246 (80)	9 to 134 (41)
EVs charged in on-street	4 to 50 (16)	7 to 83 (28)	15 to 167 (55)	31 to 384 (113)
EVs charged in off-street	2 to 63 (23)	3 to 86 (38)	5 to 179 (74)	9 to 404 (148)
EVs in new development	0 to 15 (2)	0 to 33 (3)	0 to 37 (4)	1 to 86 (9)
EVs per 500m	0 to 4 (1)	0 to 7 (1)	0 to 14 (2)	0 to 31 (5)
For commuters				
EVs charged on-street	1 to 2 (1)	1 to 3 (2)	2 to 7 (4)	5 to 15 (9)
EVs charged off-street	3 to 5 (3)	5 to 10 (7)	10 to 21 (14)	20 to 47 (30)
Energy demand				
EV energy demand (kWh / day)	131 to 1268 (456)	182 to 1354 (525)	408 to 2685 (1092)	710 to 3408 (1560)
Peak EV power demand (kW)	14 to 139 (50)	19 to 148 (57)	44 to 296 (120)	76 to 379 (171)
Peak EV power demand / power capacity	0.2% to 2.2% (0.8%)	0.3% to 2.2% (0.9%)	0.6% to 4.3% (1.8%)	1% to 5.5% (2.6%)

5.6.1 Typology 2 Impacts & Considerations

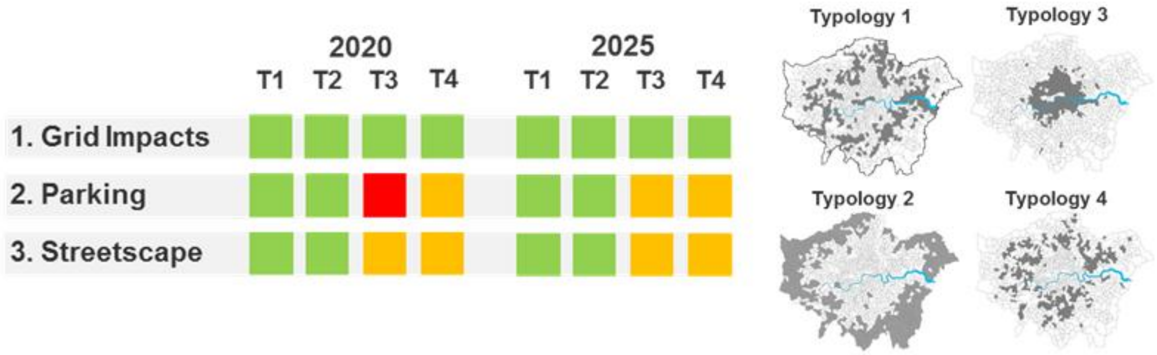


Figure 53 High level assessment of impacts of EV charging in London

Electricity Demand on the Grid

The grid impacts for all typologies have been given a Green rating in 2020 and 2025. This is based on the fact that the ratio of EV power demand to power capacity shown in the typology tables is below 10%. Therefore, within the next 10 years it is not anticipated that mitigating measures will be necessary when considering light duty EV uptake in isolation.

The maximum value for Typology 2 MSOAs is 5.5% of the power capacity, which applies in the High BEV scenario in 2025. It is anticipated that no mitigating measures, resulting from the additional load of light duty EV uptake alone, will be required by 2025. Refer to the London Energy Plan for identification of where enhancement works and mitigation measures are required.

Parking Pressure

Typology 2 has a low population density and a high availability of off-street parking, and therefore more EV owners will use domestic, off-street, charge points compared to MSOAs in higher population density areas. There are not expected to be any major parking issues generated by installing EV charge points and designated EV parking bays.

In the Baseline scenario for 2025 it is estimated there will be a maximum of 167 EVs charging on-street. This equates to 14 EVs every 500m of minor road needing on-street charging. That means there could be up to 35m of minor road between each charge point.

Similarly to Typology 1, the challenge for EV parking and charge points will be commercial viability. In Typology 2, where demand will be more dispersed, then a demand-led approach may be more commercially attractive. However, the demand-led approach may necessitate multiple requests from applicants, who would need to live or work in close proximity to one another, which may be an issue in areas with lower population density such as Typology 2. In responding to multi-applicant demand, it will be easier to ensure sufficient utilisation.

In residential streets, as most EV users will charge at the same time at night there will need to be sufficient supply of charging facilities to meet this demand. In Typology 2, these facilities will get minimal use during the day and this may impact on the commercial viability of all but the Domestic Charging types.

A fundamental issue that applies to Domestic Charging but is more important for charging facilities which will be open to other EV users is whether, in order to restrict usage/parking to EV users, it will be necessarily and feasible to formally designate a space which only EVs can use, at least during certain hours of the day. This is possible using current parking regulations but it would increase the burden on boroughs to create the necessary Traffic Management Orders and to enforce these parking areas.

Streetscape/Street Clutter

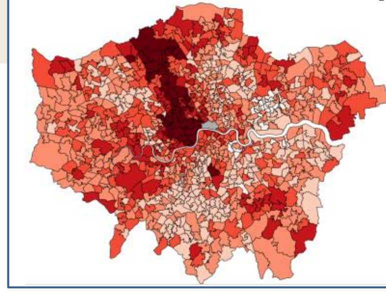
The key considerations for streetscape and possible street clutter are the visual intrusion from charging facilities installed in large numbers on residential streets. It is expected that even in the High BEV scenario Typology 2 will see only 31 EVs charging per 500m of minor road, which could cause some visual intrusions or footway degradation. Local authorities should still pursue investigations into the viability of retrofitting street furniture (i.e. lamp columns) into charge points to minimise any potential conflict over footway space amongst residents.

With the lower number of charge points the impact to the streetscape and infrastructure will be minimal. As the number of EV users continues to grow the impact to the pavement, footway and streets should be monitored, but at this time this is not a major concern for Typology 2 MSOAs.

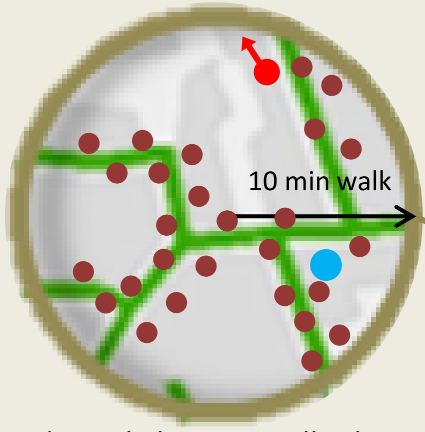
5.7 TYPOLOGY 3 - TYPICAL MSOA

In the Baseline scenario, **up to 335 EVs charging on-street**, equating to up to 1 in 12 households or **up to 30 EVs every 500m of minor road** needing on-street charging in 2025.

2025 EV stock heat map



Residential charging

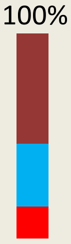


Residential charging will take place on the RTF-defined '**local streets**'.

Demand:
For 2025, in the Baseline & High BEV EV uptake scenarios, the upper range EV demand equates to **30-70 EVs** requiring some form of on-street charging **per** every **500m** of minor road.

Charging provision:
Residents' primary sources of on-street charging will consist of:

- Immediate charging provision (outside house on own on-street)
- Local charging (within 10 min walking catchment)
- Remote charging: rapid charge points

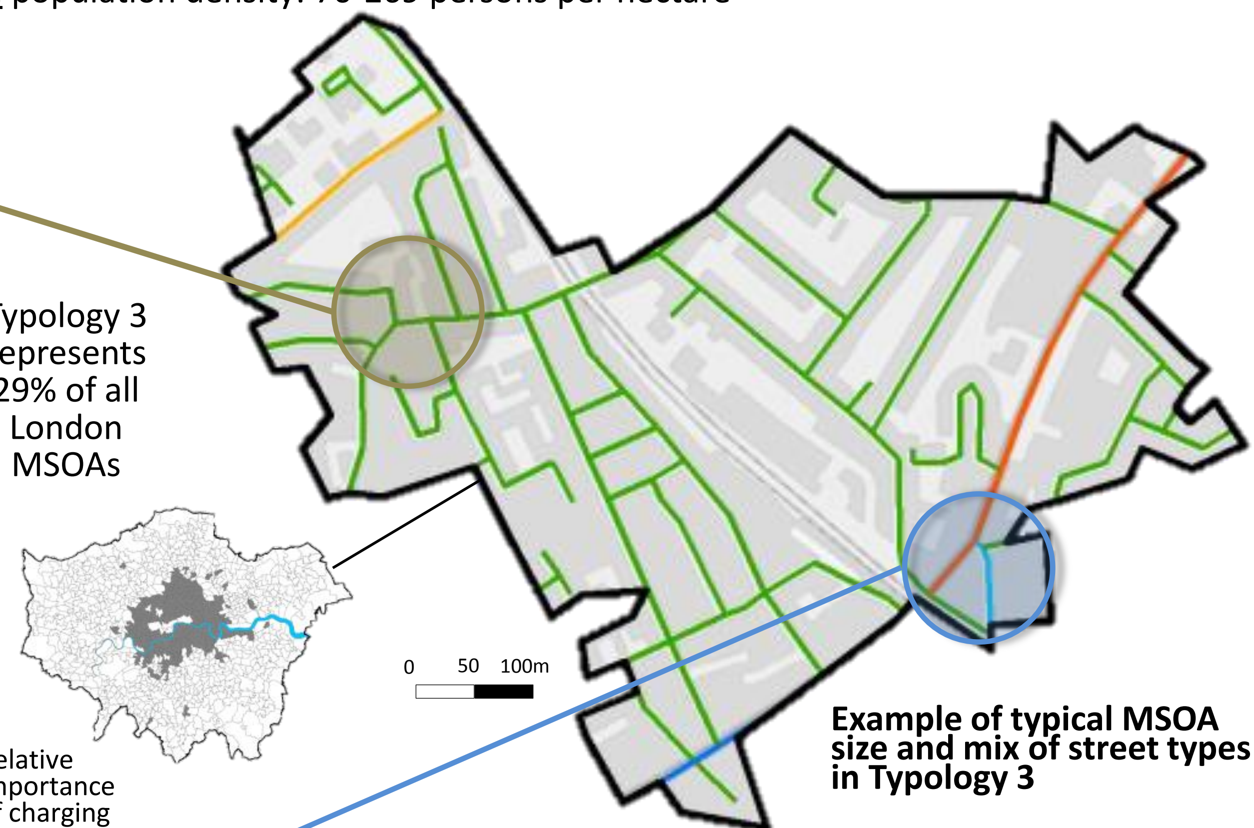


Relative importance of charging type in meeting demand

<u>Low</u> availability off-street residential parking: 5%-13% households

<u>High</u> population density: 70-269 persons per hectare

Typology 3 represents 29% of all London MSOAs

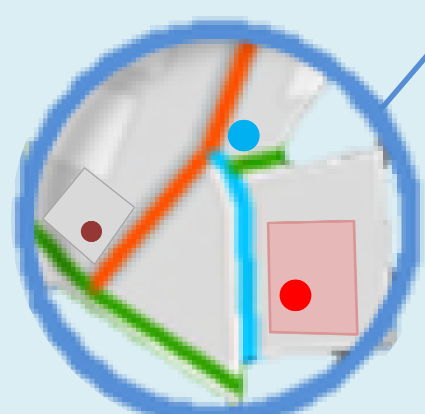


Example of typical MSOA size and mix of street types in Typology 3

On average <u>**78% of EV stock**</u> will use on-street residential charging in 2025 in the baseline scenario

Street Types for London: Core Road, High Road, City Hub, Connector, High Street, City Street, Local Street, Town Square, City Place

Workplace charging



Demand:
Workplace charging may be a secondary source of charging for commuters, with charging taking place during the day. Low population density /low availability of off-street parking means that employees have greater scope for using on-street parking.

Charging provision:
Employees secondary sources of charging will consist of:

- Immediate charging provision (employer car park)
- Local charging: on-street parking
- Local charging: off-street parking (car parks)

Charging categories:
Residential charging - Residents' primary source of charging will consist of facilities on '**local streets**' in the vicinity of their homes. If they commute by EV, a secondary source may be at or close to their workplace (**Workplace charging).** A further secondary source is **Destination charging,** which will be in locations such as high streets and supermarkets, where shorter-stay charging will take place, primarily during the daytime. Destination charging facilities are most likely to be provided on '**High Roads**' and '**High Streets**'.

Longer-distance charging
For EV drivers making longer distance journeys, or with high daily mileage where battery range may be an issue, rapid charging stations may provide a quick and convenient secondary source of charging. A vehicle can be fully charged in about 30 minutes. This infrastructure will be located off-street and therefore will not relate to any specific Street-Types.

EV demand in MSOAs [cars, vans, taxis] Range is min to max values across MSOAs, mean in brackets	**2020**		**2025**	
	BASELINE	**HIGH BEV**	**BASELINE**	**HIGH BEV**
Residential charging				
Households in MSOAs	2310 to 10507 (3977)		2364 to 14303 (4259)	
1 EV charged on-street per X households	50 to 1073 (174)	23 to 570 (93)	12 to 318 (49)	5 to 170 (23)
EVs charged in on-street	4 to 69 (28)	7 to 160 (56)	16 to 335 (114)	31 to 806 (253)
EVs charged in off-street	1 to 43 (4)	1 to 85 (9)	3 to 171 (17)	6 to 379 (38)
EVs in new development	0 to 26 (3)	0 to 49 (6)	0 to 46 (7)	1 to 100 (16)
EVs per 500m	0 to 7 (2)	0 to 15 (4)	0 to 30 (7)	0 to 70 (16)
For commuters				
EVs charged on-street	0 to 1 (1)	1 to 3 (2)	2 to 6 (3)	4 to 15 (7)
EVs charged off-street	3 to 6 (4)	5 to 12 (8)	11 to 24 (16)	24 to 55 (35)
Energy demand				
EV energy demand (kWh / day)	96 to 550 (246)	130 to 630 (334)	285 to 1274 (704)	449 to 2422 (1201)
Peak EV power demand (kW)	11 to 60 (27)	14 to 68 (36)	31 to 140 (76)	48 to 257 (129)
Peak EV power demand / power capacity	0.1% to 0.8% (0.3%)	0.2% to 0.9% (0.5%)	0.2% to 1.8% (0.9%)	0.3% to 3.7% (1.5%)

5.7.1 Typology 3 Impacts & Considerations

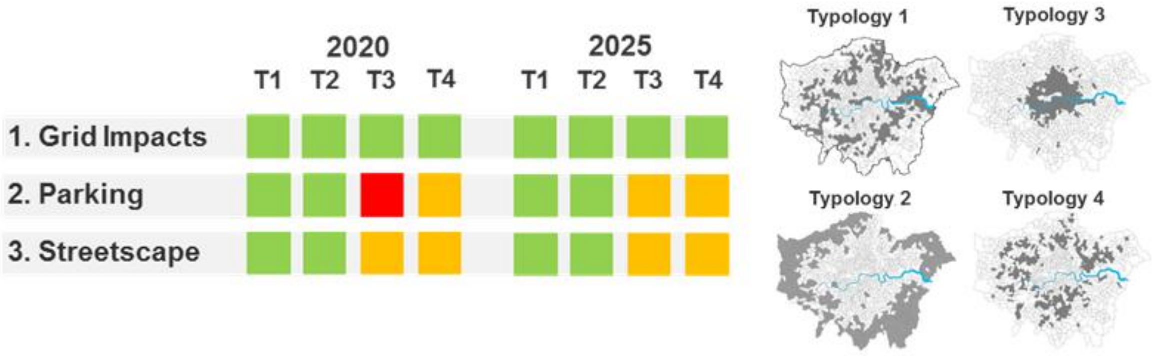


Figure 54 High level assessment of impacts of EV charging in London

Electricity Demand on the Grid

The grid impacts for all typologies have been given a Green rating in 2020 and 2025. This is based on the fact that the ratio of EV power demand to power capacity shown in the typology tables is below 10%. Therefore, within the next 10 years it is not anticipated that mitigating measures will be necessary when considering light duty EV uptake in isolation.

In the 2025 Baseline Scenario, Typology 3 MSOAs are estimated to have up to 506 EVs charging on and off street. With 335 EVs charging on-street, this equates to 30 EVs every 500m of minor road. That will result in a peak EV power demand of 3.7% of the power capacity. Therefore it is not expected that the EV charge points will have a significant impact on the grid.

It is anticipated that no mitigating measures, due to the additional load of light duty EV uptake alone, will be required by 2025. Refer to the London Energy Plan for identification of where enhancement works and mitigation measures are required.

Parking Pressure

The impacts of parking are more significant in Typology 3, compared to the other typologies. This is due to the fact that the demand for parking is high due to the high population density, and there are many more parking restrictions in place. In Typology 3 there is a near blanket coverage of Controlled Parking Zones on residential streets. With the introduction of EV charging facilities, as discussed earlier, it may be necessary to designate spaces for EVs in order to provide the assurance that users will be able to access charging facilities when and where they need them.

When the network is viewed from a commercial viability perspective, the location of charge points becomes more important. Commercial operators will understandably want to concentrate their resources on those locations that have a high usage rate which will occur in MSOAs, such as Typology 3, particularly where there is higher demand during the day as well as overnight. The potential booking systems described earlier in the Charge Point/Network Operation section will help to ensure that utilisation is maximised. With an effective maintenance system in place, downtime will be minimised which will also increase commercial gains.

Scalability is an important consideration and certain charging facilities provide greater flexibility to respond to demand than others. This is particularly the case with street furniture connections. For Typology 3 a combination of demand responsive and planning-led approach is likely to be the best way to accommodate growth in demand for charge points along with the parking restricted, high density areas.

There are also issues with Domestic Charging regarding availability, in that it will be more difficult than other charging types to guarantee that a space will be available to park outside an EV owner's house. This is heavily subject to parking demand and capacity. In residential streets, as most EV users will charge at the same time at night there will need to be sufficient supply of charging facilities to meet this demand.

It may be necessary in future to introduce booking systems, so that a user can be assured that they can charge at the time and for the duration they require. This could help to reduce any conflict between residents over use of parking spaces.

Streetscape/Street Clutter

Typology 3 has been given an amber rating for streetscape impacts. This is because of the higher quantity and frequency of charging facilities on residential streets in these parts of London. In terms of safety, the high proportion of Domestic Charging (with trailing cables likely to be needed as a short-term solution) may present a problem.

The worst-case is that with the High BEV scenario for Typology 3 there will be 70 charging facilities every 500m, or one every 7 metres. With the mix of on-street residential charging solutions shown in Figure 48 Expected mix of solutions for on-street residential charging in 2020 and 2025 (note that remote rapid chargers will be located off-carriageway), this would mean there is secured matting laid across the footway every 25 metres and a parallel network charge point about every 30 metres. This eventuality would create significant impacts for the streetscape.

With street furniture connections and remote (rapid) charging solutions (which have fewer streetscape issues) taking a larger share of the charging mix in 2025 and given that the identified issues are only likely to be acute with the worst-case scenarios then it is considered that in general the streetscape issues will be relatively minimal.

In practice, especially with the Local Charging Parallel Networks, there are likely to be clusters of charging facilities. Careful consideration would need to be given to their location in order ensure that the visual intrusion on premises in the immediate vicinity are not overly detrimental.

Whilst not likely to be a significant issue, the placement of charge points (posts) on the footway, which will be common to the Source London and Parallel Network facilities, will need be made such that the minimum acceptable footway width is maintained (normally a width of 2m is required).

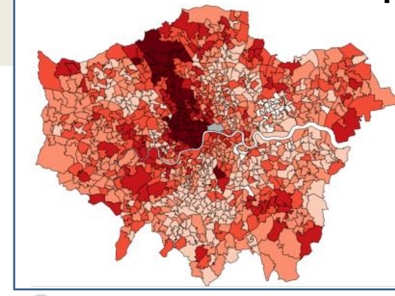
In order to mitigate conflicts over use of footways, charge points with minimal impact to the streetscape should be implemented. Domestic charge points that involve trailing cables across the pavement should be avoided. These densely populated areas will see higher footfall than Typologies 1 and 2 and the trailing cables are more likely to cause conflict.

London Boroughs that fall with the Typology 3 MSOAs should focus on parallel network charge points and investing in converting viable street furniture (i.e. street lamps) into charge points. These will have the least impact to the streetscape and will minimise conflict over space.

5.8 TYPOLOGY 4 - TYPICAL MSOA

In the Baseline scenario, **up to 168 EVs charging on-street**, equating to up to 1 in 19 households or **up to 11 EVs every 500m of minor road** needing on-street charging in 2025.

2025 EV stock heat map



Residential charging

Residential charging will take place on the RTF-defined '**local streets**'.

Demand:
For 2025, in the Baseline & High BEV EV uptake scenarios, the upper range EV demand equates to **11-26 EVs** requiring some form of on-street charging **per** every **500m** of minor road.

Charging provision:
Residents' primary sources of on-street charging will consist of:

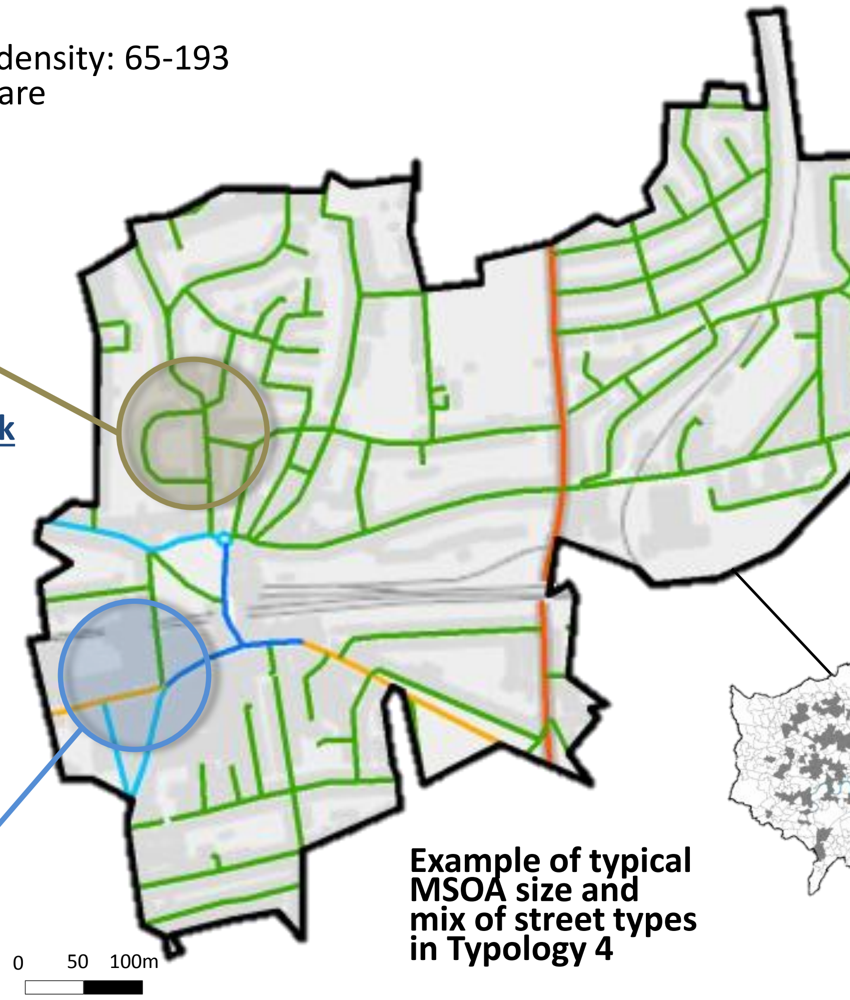
- Immediate charging provision (outside house on own on-street)
- Local charging (within 10 min walking catchment)
- Remote charging: rapid charge points

Relative importance of charging type in meeting demand

High Availability off-street residential parking: 13%-51% households

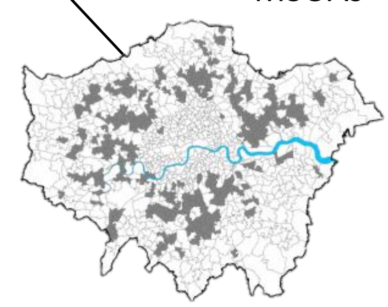
High Population density: 65-193 persons per hectare

On average **54% of EV stock** will use on-street residential charging in 2025 in the baseline scenario



Example of typical MSOA size and mix of street types in Typology 4

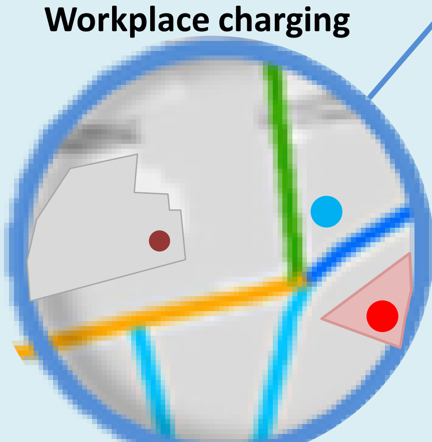
Typology 4 represents 29% of all London MSOAs



MSOA boundary

Street Types for London: Core Road, High Road, City Hub, Connector, High Street, City Street, Local Street, Town Square, City Place

Workplace charging



Demand:
Workplace charging may be a secondary source of charging for commuters, with charging taking place during the day. Low population density /low availability of off-street parking means that employees have greater scope for using on-street parking.

Charging provision:
Employees secondary sources of charging will consist of:

- Immediate charging provision (employer car park)
- Local charging: on-street parking
- Local charging: off-street parking (car parks)

Charging categories:
Residential charging - Residents' primary source of charging will consist of facilities on '**local streets**' in the vicinity of their homes. If they commute by EV, a secondary source may be at or close to their workplace (**Workplace charging**). A further secondary source is **Destination charging,** which will be in locations such as high streets and supermarkets, where shorter-stay charging will take place, primarily during the daytime. Destination charging facilities are most likely to be provided on '**High Roads**' and '**High Streets**'.

Longer-distance charging
For EV drivers making longer distance journeys, or with high daily mileage where battery range may be an issue, rapid charging stations may provide a quick and convenient secondary source of charging. A vehicle can be fully charged in about 30 minutes. This infrastructure will be located off-street and therefore will not relate to any specific Street-Types.

EV demand in MSOAs [cars, vans, taxis] Range is min to max values across MSOAs, mean in brackets	2020		2025	
	BASELINE	HIGH BEV	BASELINE	HIGH BEV
Residential charging				
Households in MSOAs	2186 to 6540 (3416)		2207 to 7016 (3565)	
1 EV charged on-street per X households	82 to 511 (211)	37 to 280 (120)	19 to 148 (63)	8 to 96 (31)
EVs charged in on-street	5 to 43 (18)	10 to 80 (34)	19 to 168 (68)	42 to 384 (143)
EVs charged in off-street	1 to 54 (12)	2 to 91 (22)	3 to 178 (41)	7 to 386 (85)
EVs in new development	0 to 16 (2)	0 to 33 (3)	1 to 34 (4)	1 to 78 (9)
EVs per 500m	0 to 3 (1)	0 to 6 (2)	0 to 11 (3)	1 to 26 (7)
For commuters				
EVs charged on-street	1 to 2 (1)	1 to 3 (2)	2 to 7 (4)	4 to 15 (9)
EVs charged off-street	3 to 5 (3)	5 to 11 (7)	10 to 22 (14)	21 to 49 (30)
Energy demand				
EV energy demand (kWh / day)	109 to 1166 (273)	168 to 1199 (332)	357 to 2524 (740)	597 to 3096 (1143)
Peak EV power demand (kW)	12 to 129 (30)	18 to 132 (36)	38 to 283 (82)	65 to 348 (126)
Peak EV power demand / power capacity	0.2% to 2% (0.5%)	0.2% to 2.1% (0.5%)	0.4% to 4.3% (1.2%)	0.7% to 5.3% (1.8%)

5.8.1 Typology 4 Impacts & Considerations

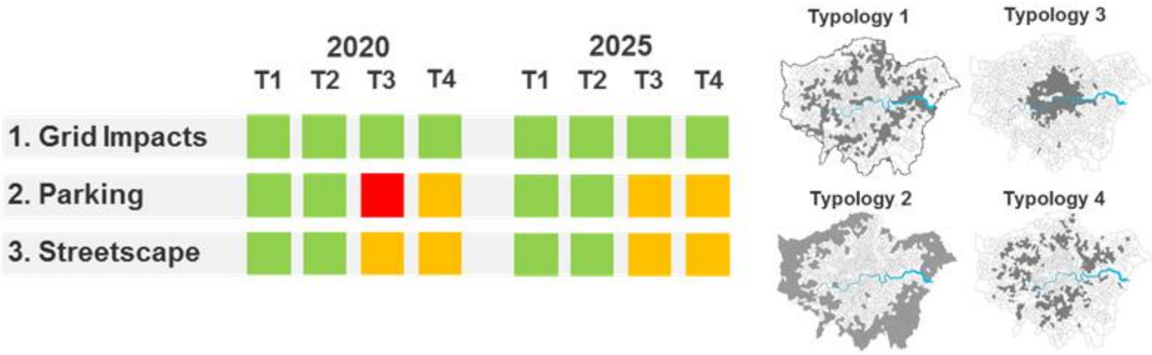


Figure 55 High level assessment of impacts of EV charging in London

Electricity Demand on the Grid

The grid impacts for all typologies have been given a Green rating in 2020 and 2025. This is based on the fact that the ratio of EV power demand to power capacity shown in the typology tables is below 10%. Therefore, within the next 10 years it is not anticipated that mitigating measures will be necessary when considering light duty EV uptake in isolation.

In the 2025 High BEV scenario there are potentially 848 EVs that will need to charge during the night. For on-street parking that could mean a vehicle every 19 meters. With these figures the highest peak EV power demand for Typology 4 MSOAs would be ca. 5% of the power capacity. The existing spare capacity in the network should accommodate this.

As a result, it is anticipated that no mitigating measures, due to the additional load of light duty EV uptake alone, will be required by 2025. Refer to the London Energy Plan for identification of where enhancement works and mitigation measures are required.

Parking Pressure

MSOAs in Typology 4 will see parking impacts. They will not be a significant as those in Typology 3, but the demand for parking is already high and there are more restrictions in place than in Typologies 1 and 2, so there will be parking pressures.

With the introduction of EV charging facilities it may be necessary to designate spaces for EVs in order to provide the assurance that users will be able to access charging facilities when and where they need them, designated on-street EV bays could be:

- EV only bay at all times
- EV only bay at particular times of the day
- EV only bay when recharging only
- EV only bays and Permit Holder restrictions

As MSOAs in Typology 4 have a high availability of off-street parking, and therefore less pressure on existing on-street parking, all of these options should be viable. However these MSOAs also have a high population density so if a mixture of these types of bays is implemented it would be beneficial to focus more on the types of parking bays that allow shared use between EVs and non-EVs. Any increases in the number of EV only bays will reduce the parking capacity for non-EV vehicles. To maximize utilization and minimize conflict, it may be necessary in future to introduce booking systems, so that a user can be assured that they can charge at the time and for the duration they require. This is a technology to inform drivers of available spaces in networks to which they subscribe or which are pay per and will help ensure that EV bays are more frequently occupied.

With the parking bays that are designated for EVs, local authorities must also consider the types of charging technology that are used. In residential streets, as most EV users will charge at the same time at night there will need to be sufficient supply of Domestic charging facilities to meet this demand. In terms of safety, as these MSOAs are densely populated, the high proportion of on-street Domestic Charging (with trailing cables) may present a problem. There are also issues with Domestic Charging regarding availability, in that it will be more difficult than other charging types to guarantee that a space will be available to park outside an EV owner's house. This is heavily subject to parking demand and capacity, which will be less of a problem in Typology 4, but must still be taken into consideration.

From a policy and planning perspective, trailing cables present an issue. The high level impact assessment in Figure 55 shows that the impact for Typology 4 remains the same from 2020 to 2025, largely due to the potential lingering issues regarding the legality of trailing cables for domestic chargers. This will be more acute for these areas due to the high number of EVs that will need to be charged on-street.

Streetscape/Street Clutter

Typology 4 has been given an amber rating for streetscape impacts. This is because of the higher quantity and frequency of charging facilities on residential streets in these parts of London. London Boroughs that fall with the Typology 4 MSOAs should focus on parallel network charge points and investing in converting viable street furniture (i.e. street lamps) into charge points. These will have the least impact to the streetscape and will minimise conflict over space.

In the High BEV scenario, by 2025, there may be 26 EVs for every 500 meters of minor road, which equates to 1 EV charging every 19 meters. Some of those may be domestic charge points with secure matting. These could contribute to visual intrusion, and create potential footway access issues. In addition, Typology 4 MSOAs have a high population density, which means there will be high footfall traffic on the streets. Therefore, in order to minimise conflict over footway space, charge points with minimal impact to the streetscape should be implemented. Domestic charge points that involve trailing cables across the pavement should be avoided.

Street furniture connections and remote (rapid) charging solutions (which have fewer streetscape issues) are expected to take a larger share of the charging mix in 2025 and, given that the identified issues are only likely to be acute with the worst-case scenarios, then it is considered that in general the streetscape issues will be relatively minimal.

In practice, especially with the Local Charging Parallel Networks, there are likely to be clusters of charging facilities. Careful consideration would need to be given to their location in order ensure that the visual intrusion on premises in the immediate vicinity are not overly detrimental.

Whilst not likely to be a significant issue, the placement of charge points (posts) on the footway, which will be common to the Source London and Parallel Network facilities, will need be made such that the minimum acceptable footway width is maintained (normally a width of 2m is required).

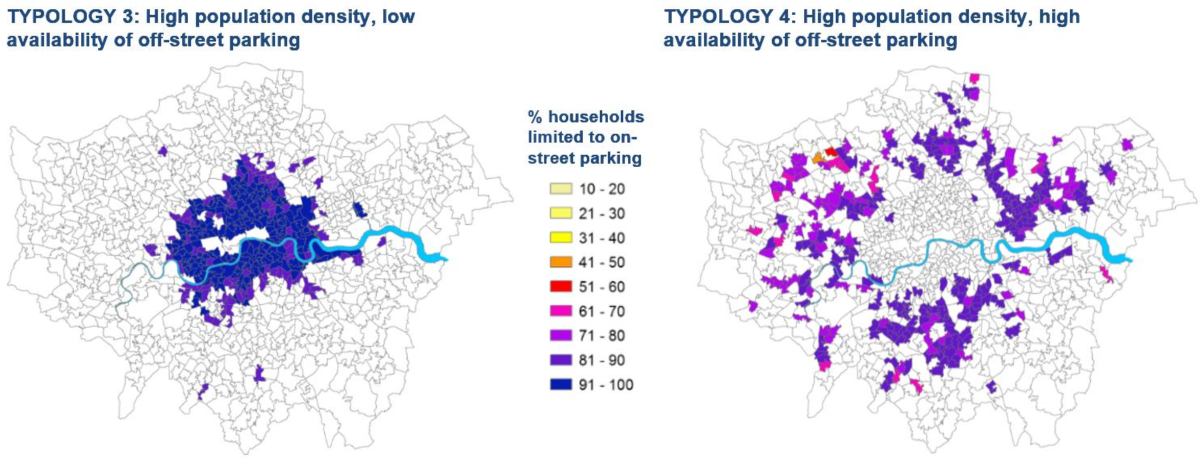
Regardless of the type of charge point installed, consideration must also be given to existing utilities. An increase in utilities works and associated disruption would result in degrading of footway surfaces and an increased cost.

5.9 Summary

The text below refers to how the EV demand varies across the typologies. As a reminder, for each Typology (including Typology 3, which has the most constraints to parking and streetscapes), the analysis only considers the uptake of EVs in place of cars that would be used in any case, under a baseline increase in car sales (in line with national projections). The recommendations and policy changes do not encourage uptake in driving from those who currently walk, cycle or take public transportation. As Typology 3 MSOAs will most likely have a high Public Transport Accessibility Level (PTAL) score, it is expected for the level of car use to remain low.

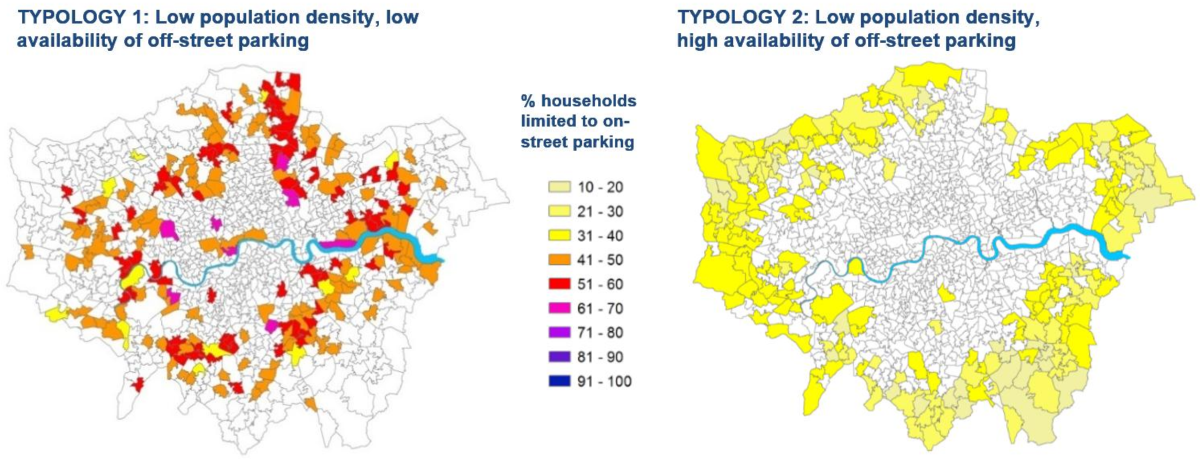
Residential charging

Inner London mainly comprises MSOAs of Typologies 3 and 4:



- Typology 3 covers large parts of central and inner London. It has the highest population density and lowest availability of off-street parking, significantly lower than Typology 4.
- These characteristics result in high levels of reliance on on-street charging for EV stock in both of the inner London typologies in 2025, particularly in Typology 3, where on average 78% of EV stock will need to be charged on-street. In Typology 4, where there is a high population density but more residents have access to off-street parking, on average 54% of EVs will need to be charged on-street.
- Car use/ownership in Typology 3 is the lowest of the four typologies, owing to the high levels of public transport accessibility and low provision of parking. However owing the very low availability of off-street parking, the number of EVs charging on-street per 500m (30-70 for Typology 3) is the highest of all the Typologies and roughly twice the number in Typology 4 (11-26).

Outer London mainly comprises MSOAs of Typologies 1 & 2:



- Both Typology 1 and Typology 2 have low population density, but Typology 2 (found around the outskirts of Greater London) has significantly higher availability of off-street parking. Typology 1 has lower availability of off-street parking than Typology 2, but still higher than the inner London typologies.
- As would be expected from these characteristics, in the outer London Typologies a lower proportion of EV stock will rely on on-street charging in 2025: 38% in Typology 2 and 51% in Typology 1.
- In terms of the numbers of EVs relying on on-street charging, there are predicted to be fewer EVs charging on-street in Typology 2 (max. 384 compared to max. 781 for Typology 1) and fewer per 500m of minor road (max. 31 compared to max. 53 for Typology 1).

The table below summarises some EV uptake metrics, for 2025 results in the baseline scenario, across the four typologies.

Table 12 Metrics of EV uptake for different MSOA typologies (Baseline scenario, 2025)

Typology	Average % EV stock needing on-street charging	Maximum no. of EVs per MSOA	1 EV charged on-street per X households (maximum)	X EVs per 500m of minor road (maximum)
1 – Low population density, low availability off-street parking	51%	375	15	22
2 – Low pop. density, high availability off-street parking	38%	264	20	14
3 – High pop. density, low availability off-street parking	78%	376	12	30
4 – High pop. density, high availability off-street parking	54%	318	19	11

Workplace charging

There is minimal variation between typologies for workplace charging demand. The proportion of EV (car, van) commuters that will park on-street or off-street (as shown in Table 7, in section 4.3.1) does not vary significantly across inner and outer London and in general the figures are low compared to residential charging. This can be seen by comparing Typologies 3 and 4 ("inner London") with Typologies 1 and 2 ("outer London").

New development

The share of EVs that will be in new developments has been determined using the ratio of new housing stock to existing housing stock in 2020 and 2025, as predicted by the GLA London Housing Projections. Estimates of the on-street and off-street parking share for residential and workplace charging, and the subsequent impact analysis, do not take into account the fact that many new developments will have reduced car parking provision (both on-street and off-street), as dictated by borough development planning policy. The standards for planning policy will vary by borough and by location (e.g. according to Public Transport Accessibility Level). The share of EVs in new developments can be used to consider how the demand for on-street charging and associated impacts might vary. Heavy restrictions on parking in these areas, as new development in London is generally concentrated in areas of good public transport accessibility with more stringent parking standards, could limit car use/ownership in general. This could result in lower numbers of EVs, compared to the scenarios used here, or it could exacerbate the impacts of EV uptake relating to parking, planning and space. Alternatively, new developments could come with built-in EV charge-point compatibility in some areas, which could alleviate some of the barriers to EV uptake and charging and result in a higher proportion of EV uptake in relation to conventional cars, compared to that predicted in existing residential areas.

As the typology tables show, the estimated number of EVs in new development does not vary significantly across the typologies. Typology 3 has the highest demand, with a maximum in the High BEV scenario for 2025 of 100 EVs per MSOA (includes on-street and off-street charging) which is just a fraction of the total on-street and off-street demand in existing streets (806+379 = 1185 EVs). The lowest demand is in Typology 4 where there are 78EVs per MSOA in new development, compared to 770 EVs (384+386) in existing streets.

5.10 Delivery of EV charging in London

As the previous sections have outlined, there are multiple components, issues and mitigation factors to consider when planning for the delivery of EV charging and infrastructure. Street type, density, population and housing type are all factors which play a crucial part in determining what type of charging is appropriate, and as these vary significantly across London there is not a once size fits all model which can be applied. Therefore, it is important for all stakeholders involved in the delivery of EV infrastructure, particularly commercial operators and London boroughs, to understand the range of choices available, and their respective benefits or drawbacks if charging facilities/networks are implemented in isolation or in combination in specific locations.

Delivery responsibilities and actions will need to be defined in detail for each part of the planning, implementation and operational process, but clearly, as the delivery of the infrastructure on the highway will largely be the responsibility of boroughs then they will need to be the driving force in ensuring that the demand of future EV drivers is met.

Timely and effective collaboration and consultation between delivery and operation stakeholders will be critical to ensure that there is the required interoperability and consistency between charging facilities and networks. This is essential in being able to give the public the required confidence that they will be able to access suitable charging facilities where and when they need them, and at an acceptable cost.

It is important that the step-change required in the delivery of EV infrastructure over the next 10 years, to meet the expected level of uptake identified as part of this study, is not achieved at the expense of non-EV owning households, as many of these are likely to be lower income households (with a lower density of new car buyers). Parking capacity and streetscape impacts are the main considerations here. Where possible, it will be vital to provide flexibility in the use of parking spaces between EVs and other vehicles and to maximise the utilisation levels of EV bays. Consolidation of EV network communications and access through a single, interoperable interface will help EV users understand their charging and payment options, which bays they are permitted to access and during which hours, and can provide real-time information on when they are available. Minimising the down-time of EV bays will also increase utilisation; therefore it will be important to have effective maintenance processes in place.

Whilst boroughs will be the main delivery agents for the EV infrastructure, other parties will play an important role in informing and facilitating the growth of London's charging networks. To create a consistent and effective system will require the development of policy and standards regarding the approach and adoption of demand-led or planning-led charging facilities. The ability to designate and enforce EV bays, and access domestic charge points from the street may require new policy and/or legislative changes (local and/or national). The impacts this may have on neighbouring households will also need consideration.

Certain charging types will be a more attractive and commercially viable proposition in certain areas of London. Their implementation may be financed privately and their operation sustained through subscription and/or pay per use methods. In other areas, however, a more resourceful approach may be required, which relies, at least in the shorter-term, on a certain level of financial support from public sources. The increased burden that will fall on boroughs to liaise with operators and administer certain elements of the process (e.g. creation of Traffic Management Orders) needs to be factored into the commercial model.

There are a myriad of actions and interventions that will be required to deliver the charging infrastructure. However, there are some that should be afforded a higher priority than others to negate the biggest risk to delivery: a disconnected network which London residents cannot use easily and that does not have the flexibility to adapt to future growth and innovation. Certainty of access to charging facilities, technological feasibility/suitability of certain charging types and network operation/interoperability are the key impacts that require more immediate mitigation.

As discussed, this will require policy/standards and, ideally, a common interface for operation of all charging facilities in London. This may incorporate communication functionality such as in-car, on-line and app-based real-time information on EV charging facilities as well as an integrated, interoperable booking system. To address some fundamental uncertainties regarding the technological feasibility of charging types such as street furniture connections may require trials and liaison with technology providers.

6 Conclusions

In this study, the predicted uptake of electric cars, vans, taxis and powered-two-wheelers in London was distributed across London at MSOA level, according to where they are likely to be based, and where they will charge, in 2020 and in 2025. Based on these projections, distributions of the energy and power demand from EV charging in 2020 and 2025 were mapped, as was the share of EVs charging on and off street in each MSOA.

The potential demand for different charging infrastructure solutions, and the impacts of charging were assessed for London as a whole and according to different MSOA typologies, reflecting the case in inner and outer London and between areas with different parking provisions. The assessment of impacts and issues for these typologies provides a basis for Local Authorities to consider the planning and policy implications of increasing EV uptake over the next 10 years.

6.1 Mapping future electric vehicle uptake

The predicted distribution of EVs in 2020 and 2025, under an ambitious policy-led uptake scenario, is shown in Figure 56. There are likely to be several hotspots for EV uptake across London, with higher levels of ownership to be observed in outer London, as well as in areas of high income in inner London.

6.2 Charging infrastructure requirements and options

There are multiple impacts, considerations and potential mitigations to account for when planning for the delivery of EV charging infrastructure in London. Street type, population density and housing type are all factors which play a crucial part in determining what type of charging is appropriate on-street, and as these vary significantly across London there will be a variety of solutions. New developments will present the opportunity to embed the provision of charging facilities – whether parking is provided or not – and typically offer access to the lowest installation cost of charging solutions.

This study quantified the level of EV uptake in MSOAs across London and categorised the MSOAs into one of four typologies which informed the assessment of impacts and interventions regarding the provision of charging infrastructure. The most acute impacts are likely to be experienced in Typology 3 MSOAs (in inner London), where in the High BEV scenario for 2025, it is estimated that in a particular MSOA there will be up to 806 EVs charging on-street: requiring one charging facility every 7 metres. The higher level of on-street parking, and the associated impacts on parking pressure and streetscape (compared to areas on the outskirts of London), are largely due to the high population density and existing parking constraints, which are likely to become more severe as the population continues to increase.

It is important that the step-change required in the delivery of EV infrastructure over the next 10 years is not achieved at the expense of non-EV owning households, as many of these are likely to be lower income households (with a lower density of new car buyers). Parking capacity and streetscape impacts are the main cause for concern. Energy and power demand from EVs is forecast to be relatively low by 2025 and as such is unlikely to be an issue - although rapid charging has not been included in the energy modelling and could lead to concentrated areas of demand in higher EV demand areas.

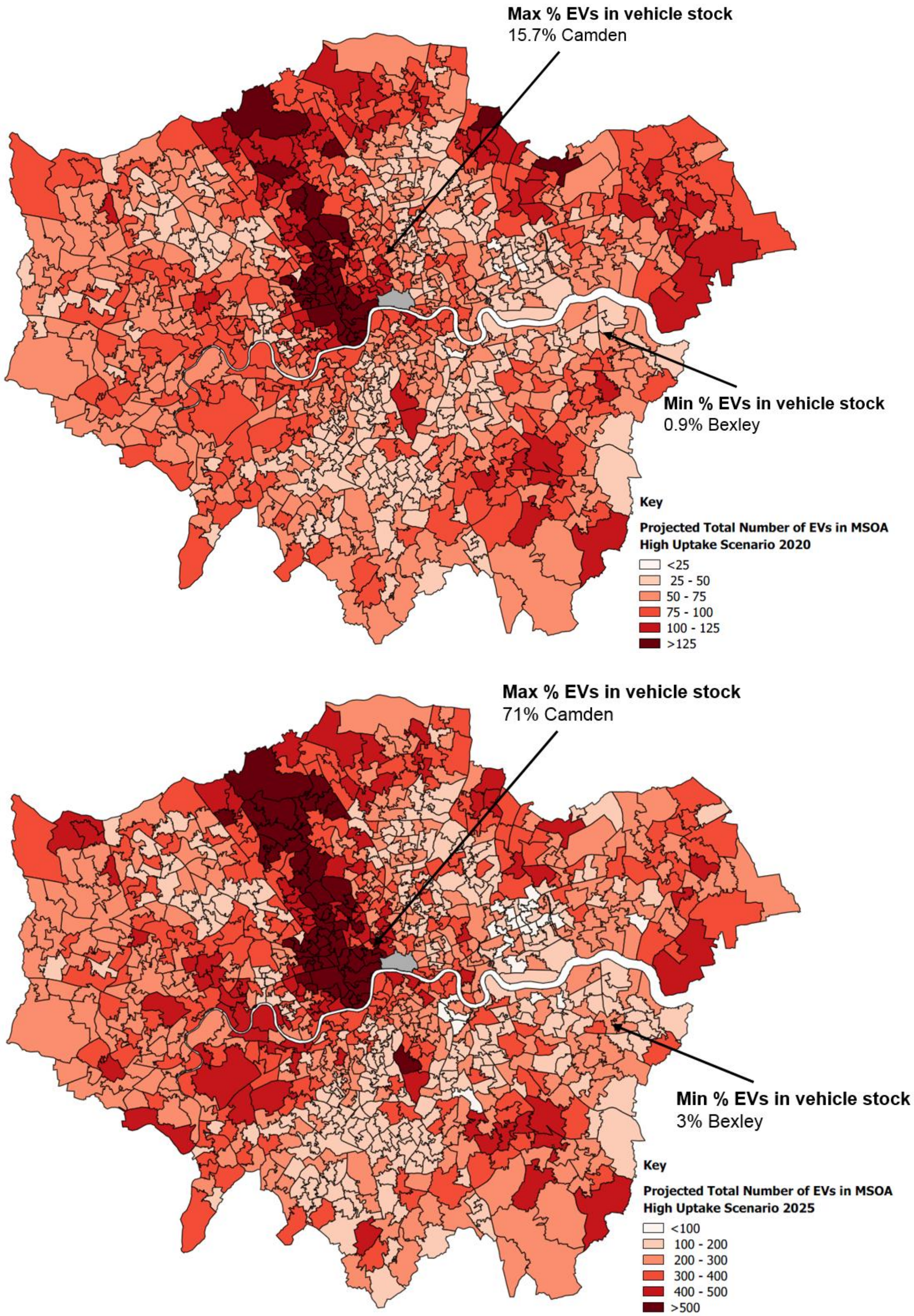


Figure 56 Distribution of EV stock in 2020 (top) and 2025 (bottom) – cars, vans, taxis and P2Ws (High BEV scenario)

Recommendations regarding the key interventions and mitigating measures that are required are described as follows:

For Boroughs and Local Authorities:

- **To maximise the utilisation levels of EV bays and thereby reduce parking stress, it is recommended that there should be flexibility in the use of parking spaces between EVs and other vehicles.**
- **To create a consistent and effective system will require the development of policy and standards regarding the approach and adoption of demand-led or planning-led charging facilities.**
- **New policy and/or legislative changes may be required to designate and enforce EV bays, as well as access domestic charge points from the street.**
- **Fundamental uncertainties regarding the technological and commercial feasibility of charging types such as street furniture connections need to be addressed, for example by trials and liaison with technology providers and DNOs.**
- **Minimising the down-time of charge points will increase utilisation; therefore it will be important to ensure that effective maintenance processes are in place (e.g. through procurement contracts).**
- **Certain charging types will be a more attractive and commercially viable proposition in certain areas of London. Their implementation may be financed privately and their operation sustained through subscription and/or pay per use methods. In other areas, however, at least in the short-term, a certain level of financial support from public sources may be required to install and operate charge points.**
- **Timely and effective collaboration between delivery and operation stakeholders will be critical to ensure that there is the required interoperability and consistency between charging facilities and networks. This is essential in giving the public the required confidence that they will be able to access suitable charging facilities where and when they need them, and at an acceptable cost.**

For Infrastructure providers:

- **Consolidation of charging network communications and access through a single, interoperable interface will help EV users understand their charging and payment options, which bays they are permitted to access and during which hours, and can provide real-time information on when they are available. An integrated booking system could help to reduce parking pressures once the concentration of EVs increases[47].**
- **Minimising the down-time of charge points will increase utilisation; therefore it will be important to have effective maintenance processes in place.**
- **The increased burden that will fall on boroughs to liaise with operators and administer certain elements of the process (e.g. creation of Traffic Management Orders) needs to be**

[47] Rapid charging network study, Element Energy for TfL, 2015

factored into the commercial model.

Of the myriad actions and interventions that will be required to deliver the charging infrastructure, some should be afforded a higher priority than others to negate the biggest risk to delivery: a disconnected network which London residents cannot use easily and that does not have the flexibility to adapt to future growth and innovation.

The key impacts which require more immediate mitigation are certainty of access to charging facilities, technological feasibility/suitability of certain charging types and network operation/interoperability. This will require the development of policy/standards.

Delivery responsibilities and actions will need to be defined in detail for each part of the planning, implementation and operational process, but clearly, as the delivery of the infrastructure on the highway will largely be the responsibility of boroughs, they will need to be the driving force in ensuring that the demand of future EV drivers is met.

Data availability and caveats on local results

In the development of this study, it became apparent that some metrics key to the planning of EV uptake and related infrastructure were not readily accessible (and were therefore estimated for this study). As far as possible, boroughs s should work on accessing this data and/or putting frameworks for access in place, for the following:

- Numbers of vehicles parking on-street and off-street while at home,
- Numbers of vehicles parking on-street and off-street while at work during the day,
- Number of vehicles parked at work at night and locations of depots – this inventory should extend beyond cars and vans, as the impact of heavy duty electric vehicles will be more severe, in terms of grid impact.

It was found that power demand from light duty vehicles would not represent a significant extra demand compared to the (increasing) base demand. However, demand specifically from future rapid charge points for light vehicles was not mapped, and could change this finding in places.

Boroughs can influence the local EV uptake through local incentives, as observed already in several LAs and accounted for in the modelling. Boroughs s intending to introduce new measures should therefore consider the possibility that their uptake might be greater than forecasted in the report.

Conversely, uptake might be lower where measures are taken to lower car use. No modal shift was explicitly accounted for in this study, i.e. the London car ownership heat map is assumed to stay the same.

7 Appendix

Figure 57 Boundaries of London MSOAs and Local Authorities

7.1 Appendix related to vehicle sales projections and electricity use projections

Table 13 Projections of London vehicle sales (all propulsion types)

		2015	2020	2025
CARS	Total sales	160,000	161,120	167,565
VANS	Total sales	18,028	18,184	18,893
TAXIS	Total sales	1,360	1,360	1,360
P2Ws	Total sales	13,825	14,029	14,544

Table 14 Projections of EV sales and sales share to 2050 – ranges represent Baseline and High BEV scenarios

		2015	2020	2025	2030	2040	2050
CARS	BEV sales share	0.5%	1.2%-3.5%	5.6%-12.6%	10.8%-21.6%	10.3%-37.4%	10.0%-50%
	PHEV sales share	0.5%	1.8%-5.4%	7.5%-17.5%	15.0%-30%	41.4%-9.4%	75.0%-0%
	Plug-in sales	1,600	4,785 - 14,356	21,867 - 50,347	44,226-88,452	92,115-83,264	157,293 -92,525
VANS	BEV sales share	1.0%	10.0%	20.0%-30%	42.0%-55%	60.0%-65%	70.0%
	PHEV sales share	0.5%	5.0%	10.0%-22%	20.0%-35%	15.0%	0.0%
	Plug-in sales	270	2,728	5,668 – 9,824	11,984-17,396	15,062-16,066	14,614
TAXIS	BEV sales share	0%	0%	0%	3%	21%	27%
	PHEV sales share	0%	100%	100%	97%	79%	73%
	Plug-in sales	0%	1,360	1,360	1,360	1,360	1,360
P2Ws	BEV sales share	1.9%	5%	20%	45%	80%	80%
	Plug-in sales	259	701	2,909	6,699	12.306	12,859

Table 15 Assumptions for charging rates to 2050, by charging location

		2015	2020	2025	2030	2040	2050
Residential/depot based charging	Share of vehicles charging at 3kW	100%	50%	50%	50%	50%	50%
	Share of vehicles charging at 7kW	0%	50%	50%	50%	50%	50%
Workplace based charging	Share of vehicles charging at 3kW	100%	100%	0%	0%	0%	0%
	Share of vehicles charging at 7kW	0%	0%	100%	100%	100%	100%

Table 16 Assumptions used to calculate daily energy demand from EVs

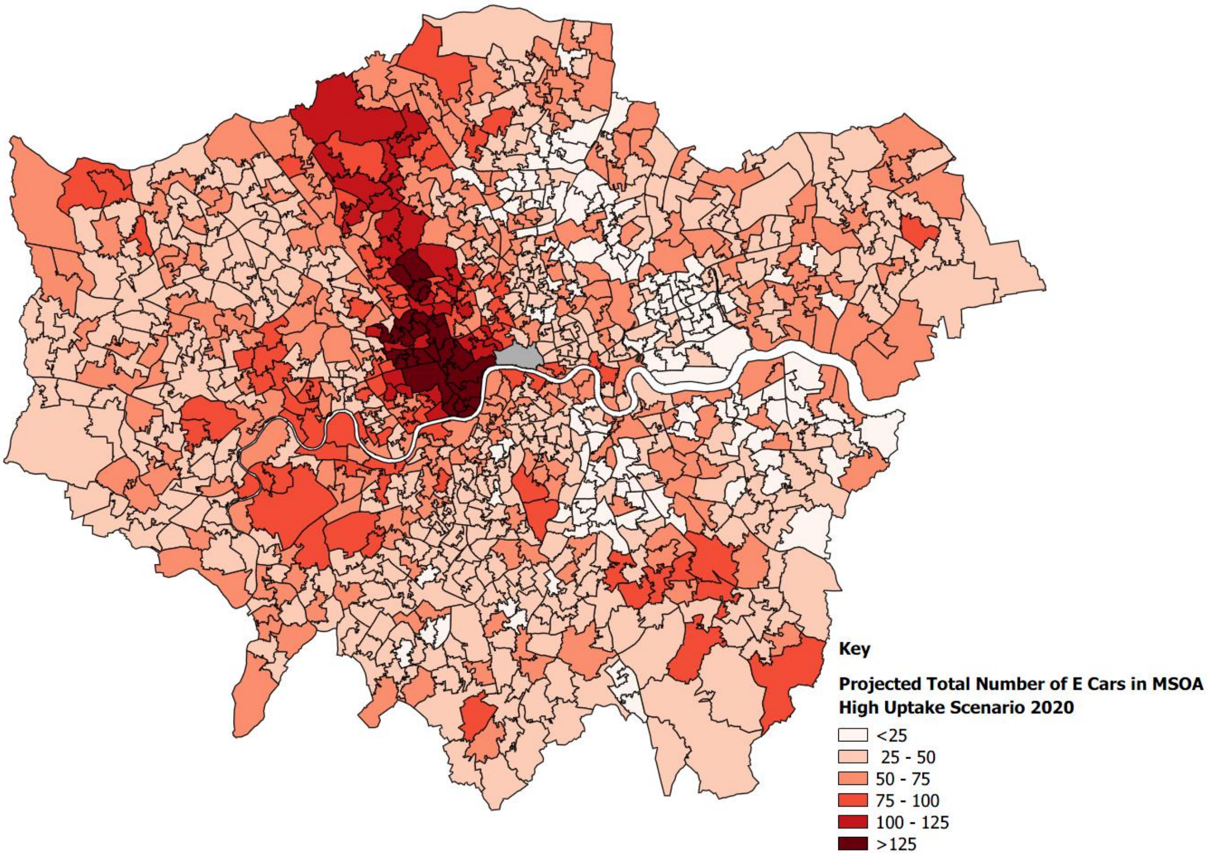
		Cars	Vans	Taxis	P2Ws
Mileage (km/year)	2015-2025	6,900	20,580	57,550	5,500
Share of electric miles (PHEVs)	2015	49.0%	59.0%	49.0%	
	2020	49.0%	59.0%	49.0%	
	2025	50.0%	62.0%	50.0%	
Battery capacity (kWh)	2015	20	22	20	(Not limiting)
	2020	22	25	22	(Not limiting)
	2025	30	35	30	(Not limiting)
Efficiency – BEVs winter use (kWh/km)	2015	0.19	0.34	0.19	0.12
	2020	0.18	0.33	0.18	0.12
	2025	0.18	0.32	0.18	0.12
Efficiency – PHEVs winter use (kWh/km)	2015	0.24	0.33	0.24	
	2020	0.23	0.32	0.23	
	2025	0.22	0.31	0.22	

Table 17 Daily energy demand from EVs (winter day)

		Cars	Vans	Taxis	P2Ws
BEV daily energy demand (winter) - kWh	2020	3.86	20.67	32.24	1.99
	2025	3.72	19.90	31.09	1.93
PHEV daily energy demand (winter) - kWh	2020	2.38	11.88	19.83	
	2025	2.33	12.07	19.40	

Table 18 Calibration factors used to predict EV sales distribution

Borough	Calibration Factor
Barking and Dagenham	0.15
Barnet	0.82
Bexley	0.13
Brent	0.28
Bromley	0.31
Camden	0.70
City and County of the City of London	0.34
City of Westminster	1.00
Croydon	0.12
Ealing	0.32
Enfield	0.20
Greenwich	0.13
Hackney	0.12
Hammersmith and Fulham	0.20
Haringey	0.15
Harrow	0.24
Havering	0.26
Hillingdon	0.23
Hounslow	0.32
Islington	0.22
Kensington and Chelsea	0.56
Kingston upon Thames	0.24
Lambeth	0.10
Lewisham	0.02
Merton	0.23
Newham	0.00
Redbridge	0.26
Richmond upon Thames	0.35
Southwark	0.18
Sutton	0.18
Tower Hamlets	0.10
Waltham Forest	0.13
Wandsworth	0.23



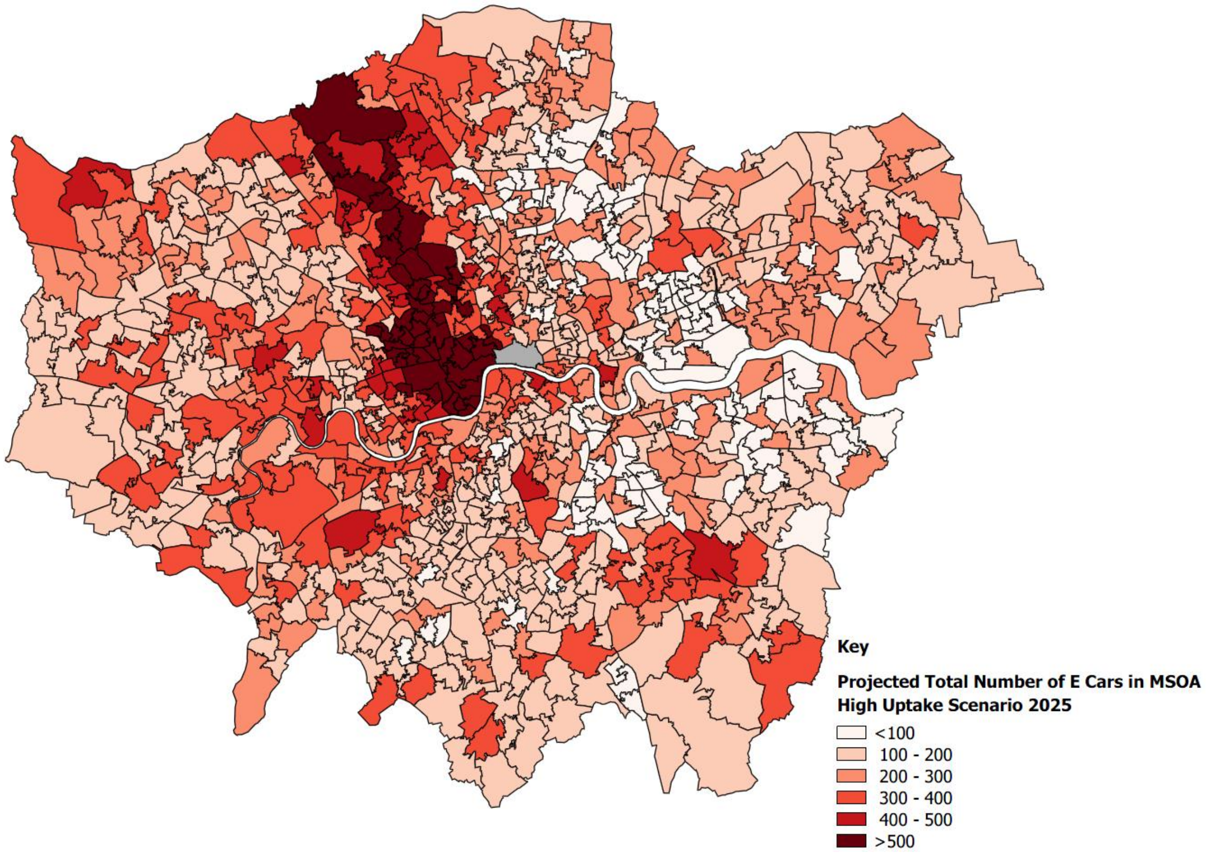
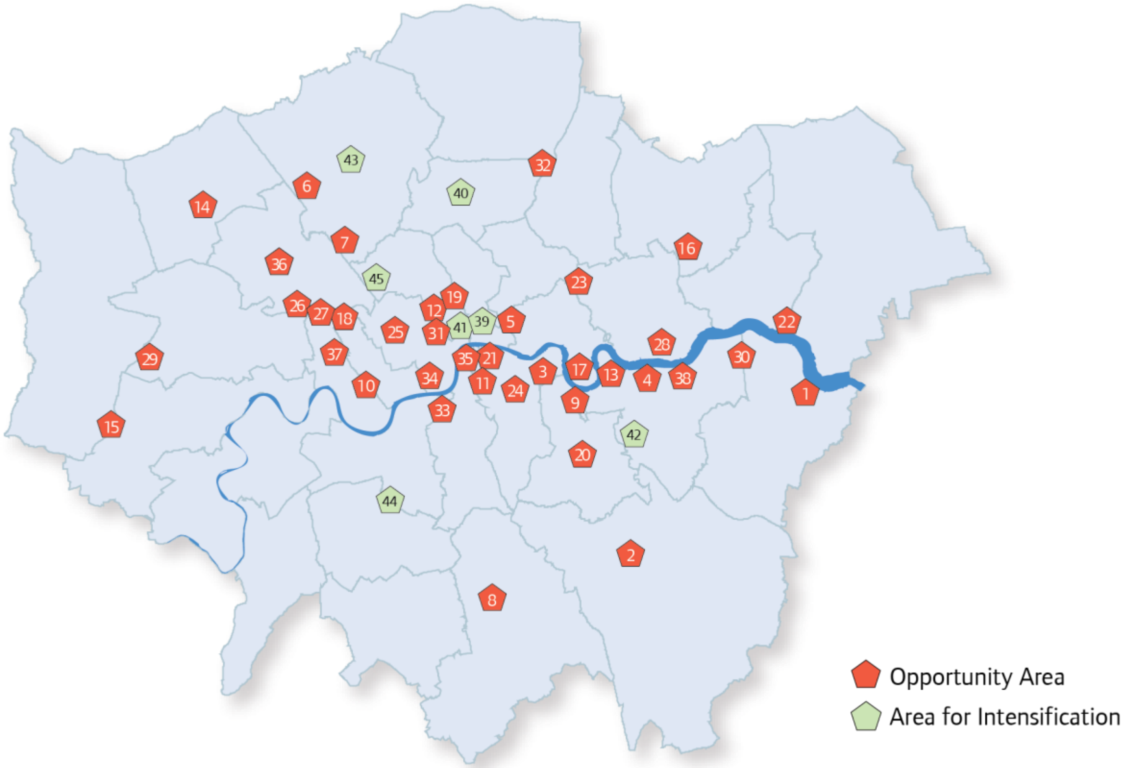


Figure 58 Predicted stock distribution of electric cars in 2020 (top) and 2025 (bottom) (High BEV Scenario used as an illustration – similar distribution under Baseline scenario)

7.2 Appendix related to housing and parking provision



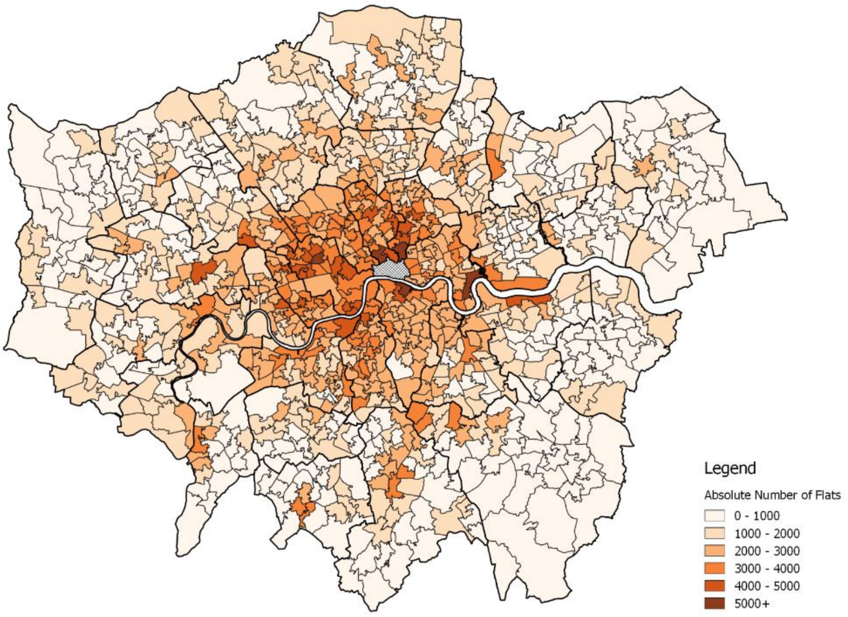
Opportunity Areas

1 Bexley Riverside
2 Bromley
3 Canada Water
4 Charlton Riverside
5 City Fringe/Tech City
6 Colindale/Burnt Oak
7 Cricklewood/Brent Cross
8 Croydon
9 Deptford Creek/Greenwich Riverside
10 Earls Court & West Kensington
11 Elephant & Castle
12 Euston
13 Greenwich Peninsula
14 Harrow & Wealdstone
15 Heathrow
16 Ilford
17 Isle of Dogs
18 Kensal Canalside
19 King's Cross - St Pancras
20 Lewisham, Catford & New Cross
21 London Bridge, Borough & Bankside
22 London Riverside
23 Lower Lee Valley (including Stratford)
24 Old Kent Road
25 Paddington
26 Park Royal
27 Old Oak Common
28 Royal Docks and Beckton Waterfront
29 Southall
30 Thamesmead & Abbey Wood
31 Tottenham Court Road
32 Upper Lee Valley
33 Vauxhall, Nine Elms & Battersea
34 Victoria
35 Waterloo
36 Wembley
37 White City
38 Woolwich

Areas for Intensification

39 Farringdon/Smithfield
40 Haringey Heartlands/Wood Green
41 Holborn
42 Kidbrooke
43 Mill Hill East
44 South Wimbledon/Colliers Wood
45 West Hampstead Interchange

Figure 59 Opportunity areas map. Source: the London Plan, GLA



MSOA	Number of Flats
Southwark 003	5,733
Hackney 027	5,507
Westminster 009	5,430
Tower Hamlets 028	5,293
Islington 022	5,268
Wandsworth 002	4,906
Westminster 005	4,884
Hackney 025	4,683
Westminster 017	4,648
Westminster 014	4,634
Islington 011	4,502
Westminster 011	4,413
Westminster 013	4,395
Lambeth 004	4,370
Westminster 021	4,368
Westminster 022	4,339
Brent 031	4,304
Westminster 016	4,279
Westminster 024	4,279
Islington 023	4,257
Westminster 007	4,208
Greenwich 004	4,165
Hackney 021	4,157
Hammersmith & Fulham 012	4,156
Ealing 020	4,137
Southwark 006	4,134
Westminster 003	4,103
Kensington and Chelsea 013	4,089
Islington 014	4,086
Kensington & Chelsea 004	4,072
Hackney 016	4,047

Figure 60 Absolute number of flats per MSOA in 2013. Source: GLA housing data

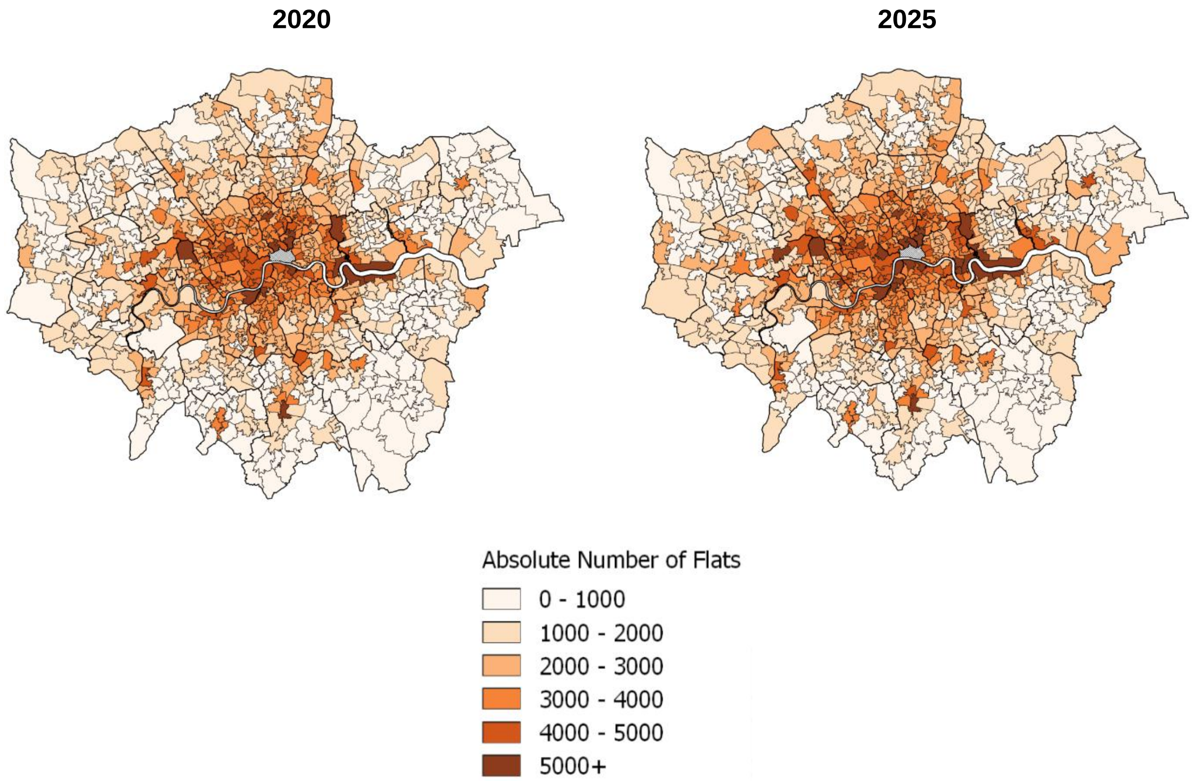


Figure 61 Absolute number of flats per MSOA in 2020 and 2025. Source: GLA housing data

Figure 62 and Figure 63 show the number of households relying on on-street parking. These are estimations derived from projections of population density: for each level of population density, a share of off-street parking is attributed to detached houses, semi-detached houses, flats etc., as shown in Table 19**Error! Reference source not found.** below. These assumptions are based on the statistics presented in *Spaced Out – Perspectives on Parking Policy*, RAC Foundation, 2012. The Borough level results were compared with the numbers published in the *London's Electric Vehicle Infrastructure Strategy (2009)* report and show a good fit.

Table 19 Assumed percentage of off-street parking in London

	Population density (pph: persons per hectare)		
Housing type	**Low (20-45 pph)**	**Medium (45-65 pph)**	**High (65+ pph)**
Detached	95%	95%	75%
Semi-detached	90%	85%	65%
Terrace	45%	35%	5%
Purpose built flats	50%	35%	5%
Non-purpose built flats	45%	35%	10%

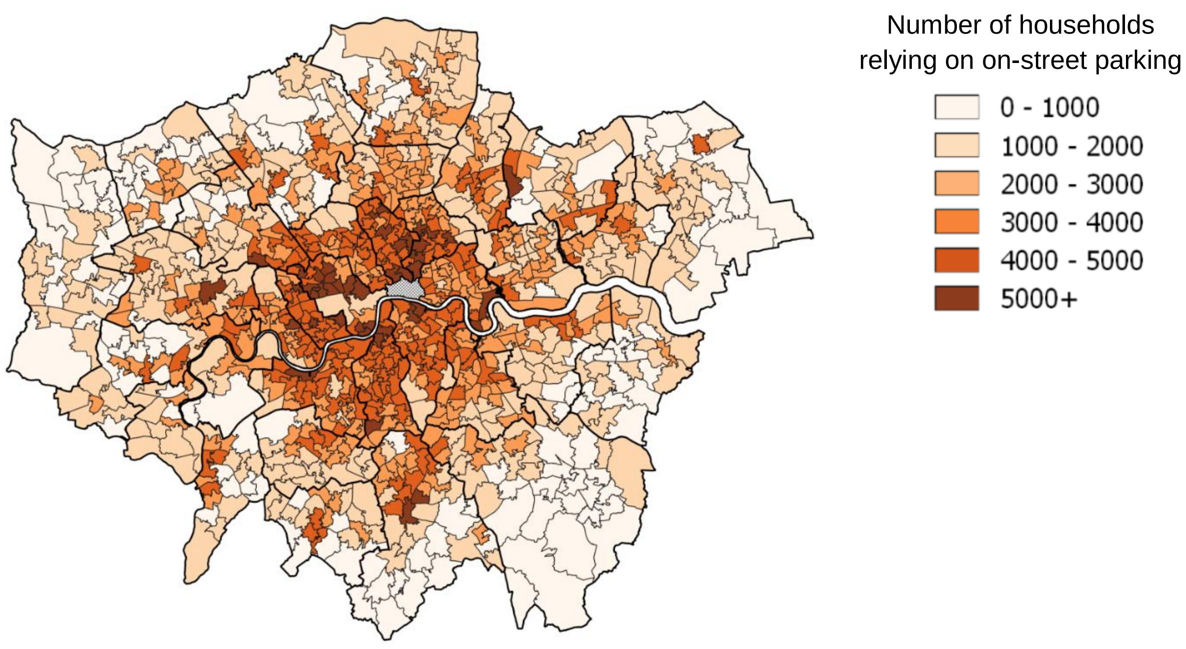


Figure 62 Absolute number of households that rely on on-street parking in 2013. Source: authors' projection based on GLA housing data and rules as described in Table 19

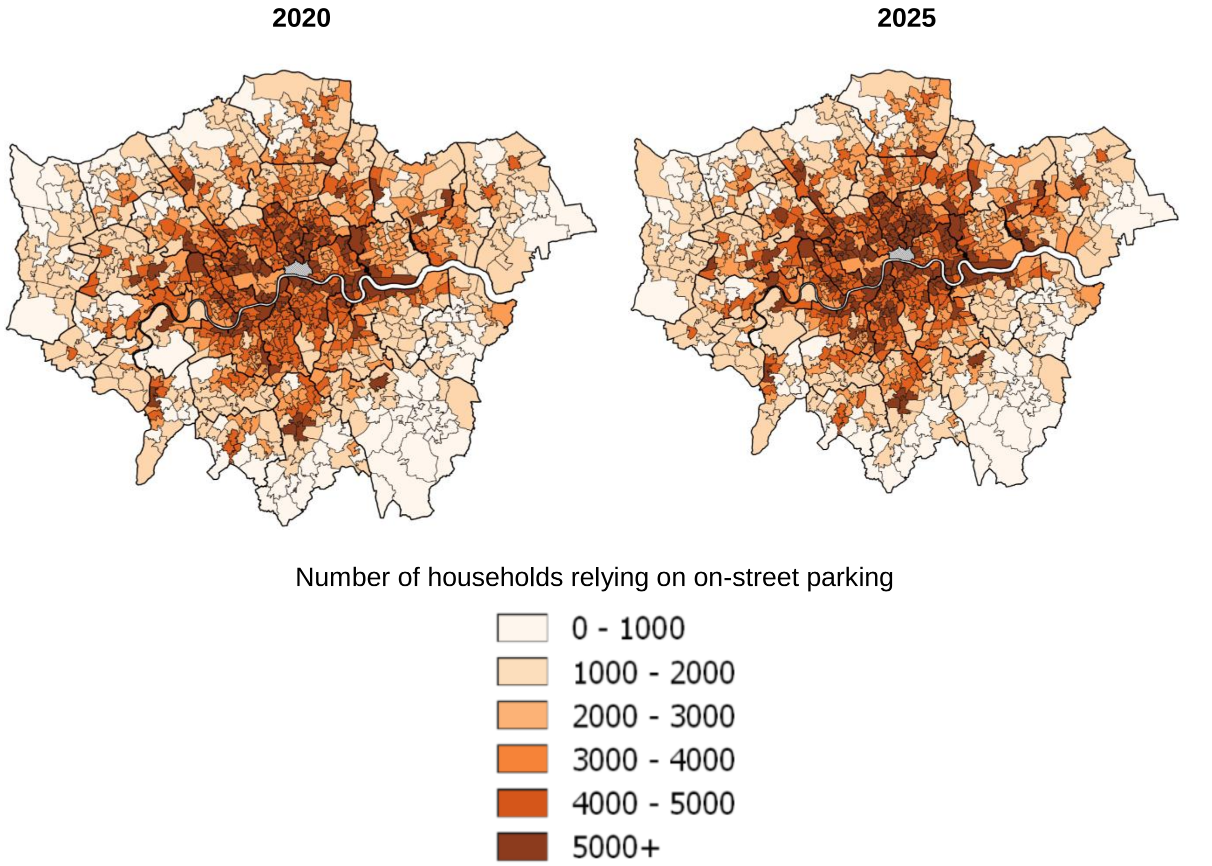


Figure 63 Absolute number of households that rely on on-street parking in 2020 and 2025. Source: authors' projection based on GLA housing data and rules as described in Table 19