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Fulfilling electric vehicle charging infrastructure needs in Greater London and its boroughs

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Executive summary

London has ambitious plans to decarbonize the transportation sector, including setting goals for all new cars and light goods vehicle sales to be zero-emission by 2030, all taxis and private hire vehicles be zero emission capable by 2033, and for a zero-emission zone to take effect in Central London by 2025. Comprehensive charging infrastructure will be critical to meeting these goals and achieving the air quality and climate benefits. While COVID-19 has significantly impacted transportation patterns and government budgets, London remains committed to achieving its climate and air quality targets through green recovery, including by building out an electric vehicle charging infrastructure.

This study outlines targets for charging infrastructure at the borough level up to 2035, complementing the Delivery Plan created by the Mayor's Electric Vehicle Infrastructure Taskforce. Specifically, it estimates the needs for public (residential and destination slow to fast and rapid) and private (home and workplace) charging infrastructure in each of the 32 boroughs and the City of London. The study incorporates local housing, demographic, and transport data to assess the ideal amount and mix of charging types in each borough. In addition, the paper provides case studies with more detailed results and recommendations for three boroughs: Westminster, Lambeth, and Redbridge.

The resulting estimates of public chargers needed in each borough by 2030 are illustrated in Figure ES 1 below. The 2 maps show the projected number of slow to fast chargers (left) and rapid chargers (right), and the share of the estimated 2030 charging of each type that was already in place in June 2020 displayed in shades of blue. In total, powering a projected 947,000 electric vehicles across London in 2030 will require public charging infrastructure to expand to more than 44,000 public chargers, an annual growth rate of over 20% from 2020.

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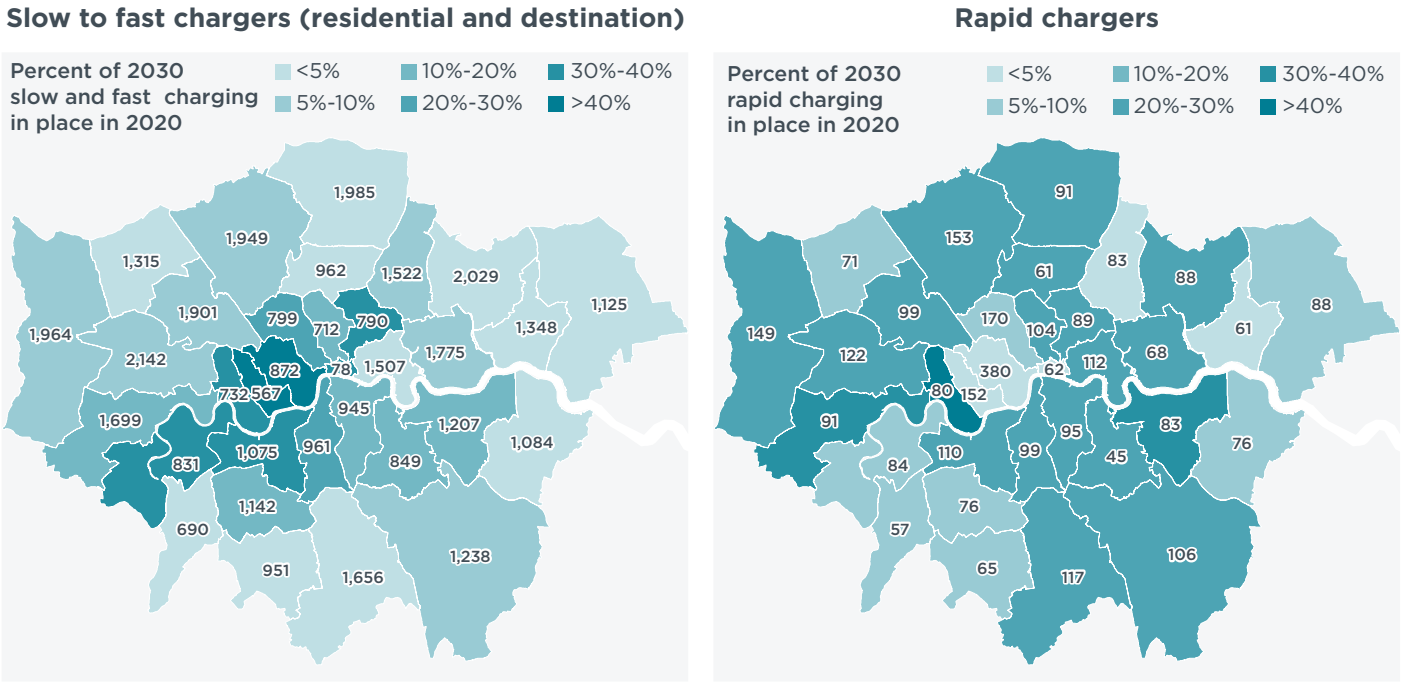

Figure ES 1. Projected public electric vehicle chargers in 2030 by borough (labels) and percentage of 2030 charging needs in place already as of June 2020 (blue shading).

This analysis points to several key findings and recommendations for London and its boroughs.

Overall, London will need many more chargers. Every borough will need at least twice as much public charging by 2030, and most boroughs will need 4 to 20 times as much. Although there will be great demand for both slow to fast and rapid charging across London for the coming decade, the differences in charging patterns shown in Figure ES 1 suggest that constructing more rapid charging may be a priority in inner London boroughs, whereas public residential charging is more needed in outer London boroughs. The required rate of growth also varies: some central boroughs have met up to 70% of their 2025 charging needs, while that figure is below 3% in three outer London boroughs. This study suggests a delay in the rate of charger growth relative to the Delivery Plan, primarily because this study anticipates electric vehicle uptake in private hire vehicles to lag behind the Delivery Plan's expectations.

Shared fleets drive charging need in the near term. Due to the accelerated electrification strategy and the fact that they drive almost six times more than private passenger cars, taxis and private hire vehicles are expected to account for over 70% of charging energy in inner London and 50% in outer London in 2025. Most of this demand comes from rapid charging to serve the daytime pickup and drop-off activity of private hire vehicles in inner London. Over the longer term, the contribution of these fleets declines as electrification of private cars progresses.

Different charging combinations can suit the diverse needs of the boroughs. Charging needs vary widely at the borough level due to diverse housing, demographic, and transportation characteristics. Dense inner London boroughs will require many rapid chargers to serve taxi and private hire vehicle activity, whereas outer London boroughs with higher private car ownership rates will rely more heavily on a mix of public and private residential charging. London and its boroughs can meet these targets by expanding the charging infrastructure programs already in place: installing lamppost chargers, building rapid charging hubs, strengthening building codes, consulting electric utilities, and coordinating with major fleets.

Introduction

Greater London accounts for about one seventh of cumulative passenger electric vehicle sales in the United Kingdom (UK), which is itself the third-largest electric vehicle market in Europe.[1] London therefore presents an immense opportunity to demonstrate how the United Kingdom can transition to electric vehicles, and the region has enacted a broad suite of clean transport policies to accelerate this transition. The Mayor of London is calling for all new car and light goods vehicle sales to be zero-emission by 2030,[2] which will likely require a tenfold increase in the number of electric vehicles by 2025.[3] The supporting actions already underway include transitioning the entire taxi and private hire vehicle (PHV) fleets to zero emission capable and proposals to create zero-emission zones in central London starting in 2025. The Mayor's ambition for London to be a zero-carbon city by 2030 will also dramatically impact London's adoption of electric vehicles.

To support its goals, London has sought to address the availability of charging infrastructure, one of the key barriers to achieving mainstream electric vehicle adoption. While most charging by early adopters is performed at home, this is not an option for more than 40% of London drivers who do not have off-street parking.[4] Additionally, more extensive charging options are needed for high-mileage fleets like taxis, private hire vehicles (PHVs), and delivery vehicles. To overcome this barrier, the Mayor's Office created an Electric Vehicle Infrastructure Taskforce composed of public- and private-sector representatives. The resulting Delivery Plan, published in 2019, lays out how the Taskforce plans to accelerate charging infrastructure deployment through the coordinated efforts of a variety of stakeholders.[5]

This study complements the London Electric Vehicle Infrastructure Delivery Plan, using similar methods and assumptions, but provides granularity into the distribution of chargers at the borough level, extends the time horizon to 2035, rather than 2025, and incorporates new data and market developments from 2018 to 2020. The analysis quantifies the charging infrastructure needs for private home and workplace and public residential, destination, and rapid charging for each of Greater London's 32 boroughs and the City of London. The boroughs fall within two categories, inner London and outer London. The definition of inner and outer London used in this study is presented in Table A1 and Figure A1 in the appendix. Charging needs are estimated for all electric light-duty vehicles, including passenger, taxi, private hire, and light goods vehicles, excluding heavier freight trucks and buses.

This study does not take into account the disruptive impact of the COVID-19 pandemic and subsequent green recovery plans. Across the United Kingdom, new vehicle sales fell by almost 50% during the first half of 2020 compared to the first half of 2019.[6] At the same time, the share of new vehicles that were electric (BEV or PHEV) has risen substantially from 2% to 8%, following a trend seen across Europe. Cities, regions, and countries are implementing "green recovery" packages to simultaneously create jobs and boost the economy while also reducing air pollution and greenhouse gas emissions. London is consulting on its own green new deal to create new jobs and accelerate the

1 Dale Hall, Sandra Wappelhorst, Peter Mock, and Nic Lutsey, *European Electric Vehicle Factbook 2019/2020,* (ICCT: Washington, D.C., 2020), https://theicct.org/publications/european-electric-vehicle-factbook-20192020.

2 The Mayor's Electric Vehicle Infrastructure Taskforce, "London Electric Vehicle Infrastructure Delivery Plan," (London: Mayor of London, June 2019), http://lruc.content.tfl.gov.uk/london-electric-vehicle-infrastructure-taskforce-delivery-plan.pdf.

3 Mayor of London, "Mayor sets out plans for London's electric vehicle future," (17 June 2019), https://www.london.gov.uk/press-releases/mayoral/mayor-sets-out-londons-electric-vehicle-future

4 The Mayor's Electric Vehicle Infrastructure Taskforce, "London Electric Vehicle Infrastructure Delivery Plan"

5 The Mayor's Electric Vehicle Infrastructure Taskforce, "London Electric Vehicle Infrastructure Delivery Plan"

6 Peter Mock and Uwe Tietge, "Market Monitor: European Passenger Car Registrations, January–July 2020," (ICCT, September 2, 2020), https://theicct.org/publications/market-monitor-eu-car-registrations-jan-july-2020.

move to zero emission, including in transport.[7] Additional research will be needed to evaluate how the new priorities of a green recovery, ongoing impacts to government budgets, and new transportation patterns will affect London's transition to electric vehicles and the subsequent need for charging infrastructure.

Background

London's Mayor and Transport for London (TfL) are promoting electric vehicles as a key part of their program to reduce air pollution, a substantial public health issue which claims the lives of thousands of Londoners per year.[8] This section provides a summary of electric vehicle market growth in Greater London through 2019, as well as an overview of the policies that are supporting the transition to electric.

Electric vehicle stock and sales growth

As of the beginning of 2020, more than 32,000 battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) were registered in Greater London, including passenger cars and light goods vehicles (LGVs); this represents about 1.2% of the total vehicles on London's roads.[9] Figure 1 illustrates the growth in electric vehicle stock and the share of London's passenger vehicles that are electric since 2011.

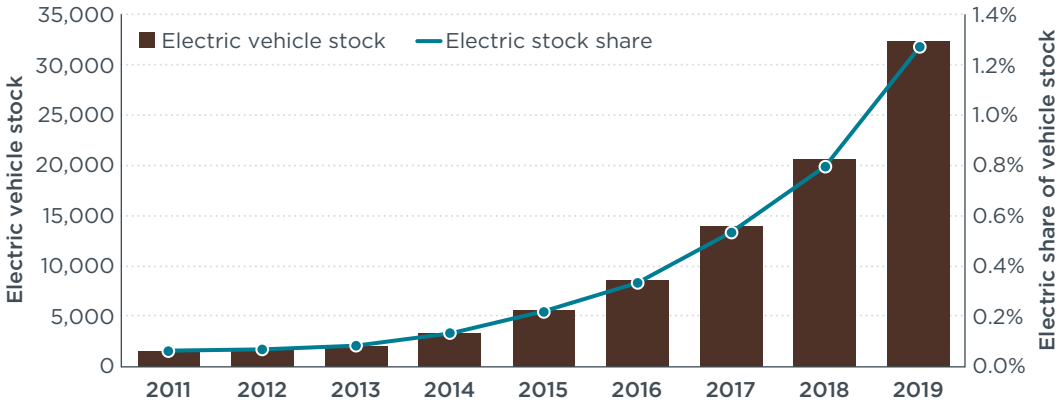

Figure 1. Passenger electric vehicle stock (BEV and PHEV) and share of stock that is electric in London, 2011-2019.

The electric share of new passenger vehicle registrations has been increasing steadily in the past years, reaching more than 5% in 2019 with more than 9,000 new electric vehicles registered.[10] In 2018 and 2019, the electric market was evenly split between BEVs and PHEVs, a shift from the PHEV-heavy market from 2015 to 2017 following changes in tax and incentive structures.

Policies, goals, and actions

The London Environment Strategy in 2018 set out the targets and plans for future electric vehicle growth in London. This includes stating the ambition that all new cars and light goods vehicles be zero emission by 2030, requiring that all licensed taxis and private hire vehicles (PHVs) will be zero emission capable by 2033,[11] and

7 "A green new deal," Greater London Authority, accessed September 15, 2020, https://www.london.gov.uk/coronavirus/londons-recovery-coronavirus-crisis/recovery-context/green-new-deal

8 Joshua Miller, "Health Impacts of Air Pollution from Transportation Sources in London" (ICCT, February 26, 2019), https://theicct.org/publications/fact-sheet-health-impacts-air-pollution-transportation-sources-london.

9 "Vehicles Statistics," GOV.UK, accessed August 4, 2020, https://www.gov.uk/government/collections/vehicles-statistics.

10 Hall et al., "European Electric Vehicle Factbook 2019/2020."

11 Zero emission capable means that the vehicle must emit no more than 50g of CO_2 per km and be capable of being operated with zero exhaust emissions for a minimum range of 10 miles.

proposing to introduce an inner London Zero Emission Zone by 2040 and a London wide Zero Emission Zone by 2050.[12] London and the United Kingdom have instituted a wide variety of programs to meet these targets, including financial incentives, tax benefits, infrastructure programs, and city access benefits for electric vehicles. In fact, a 2018 study found that London had the most promotion actions in place of any city in Europe.[13]

Table 1 summarizes the measures helping to accelerate the electric vehicle transition in London. These benefits are broken into several categories: financial incentives, charging infrastructure incentives, city access benefits, and other incentives.

Table 1. Electric vehicle promotions effective in London.

Type of action	Promotion action	Details
Charging infrastructure	Electric Vehicle Homecharge Scheme (EVHS)	UK government grant which covers up to 75% of the cost of a charge point and its installation, capped at £350 (including VAT).[a]
	Workplace Charging Scheme (WCS)	UK government grant which covers up to 75% of the cost of a charge point and its installation, capped at £350 (including VAT) with a maximum of 40 sockets across all sites for each applicant.[b]
	On-street Residential Charge Point Scheme (ORCS)	UK government grant funding for local authorities to deliver slow-fast (up to 22kWh) on-street residential chargepoints. The funding available is for 75% of the capital costs of procuring and installing the chargepoint and an associated dedicated parking bay, up to a maximum of £6,500.[c]
	Go Ultra Low Cities Scheme (GULCS)	£13m in funding to London boroughs and TfL to deliver residential charge points, car club charge points, rapid charge points, 'Neighbourhoods of the Future' schemes, and other electric vehicle support projects.[d]
Financial incentive	Low-emission vehicles plug-in grant	UK government grant up to £3,000 for cars, £1,500 for motorcycles, £8,000 for light goods vehicles, and £7,500 for taxis.[e]
	Company car tax exemption	Employees using a BEV company car for private purposes are exempted from paying benefit in kind tax, and PHEVs pay reduced rates.[f]
	Vehicle excise tax exemption	BEVs pay no first year or annual vehicle tax; PHEVs pay very low rates.[f]
City access benefits	Congestion charge exemption	Zero emission-capable vehicles exempted from the £15/day Congestion Charge.[g]
	Ultra-low emission zone (ULEZ)	Heavily polluting combustion vehicles must pay additional £12.50/day to enter Central London (expanding to inner London in October 2021).
	Zero-emission zone (ZEZ)	The Mayor, through TfL and the boroughs, and working with Governments, will seek to implement zero emission zones in town centres from 2020 and aim to deliver a zero-emission zone in central London from 2025.
Other	Parking benefits	Some London boroughs (e.g., Westminster, Hackney, Sutton, Waltham Forest) offer free or discounted parking for electric vehicles.
	Scrappage scheme	A targeted van scrappage scheme with an incentive of £9,500 available for scrapping a non-ULEZ compliant van and replacing with a fully electric van.

[a] "Customer Guidance: Electric Vehicle Homecharge Scheme," GOV.UK, accessed August 21, 2020, https://www.gov.uk/government/publications/customer-guidance-electric-vehicle-homecharge-scheme.

[b] "Workplace Charging Scheme Guidance for Applicants, Installers and Manufacturers," GOV.UK, accessed August 21, 2020, https://www.gov.uk/government/publications/workplace-charging-scheme-guidance-for-applicants-installers-and-manufacturers.

[c] "On-Street Residential Chargepoint Scheme guidance for local authorities," GOVE.UK, accessed September 08, 2020, https://www.gov.uk/government/publications/grants-for-local-authorities-to-provide-residential-on-street-chargepoints

[d] "Go Ultra-Low City Scheme," London Councils, accessed September 08, 2020. https://www.londoncouncils.gov.uk/our-key-themes/transport/roads/gulcs

[e] "Low-Emission Vehicles Eligible for a Plug-in Grant," GOV.UK, accessed August 21, 2020, https://www.gov.uk/plug-in-car-van-grants.

[f] "Tax benefits for electric vehicles," Go Ultra Low, accessed August 24, 2020, https://www.goultralow.com/fleets-and-businesses/tax-benefits/.

[g] "Discounts and Exemptions," Transport for London, accessed August 4, 2020, https://www.tfl.gov.uk/modes/driving/congestion-charge/discounts-and-exemptions

12 The Mayor's Electric Vehicle Infrastructure Taskforce, "London Electric Vehicle Infrastructure Delivery Plan"

13 Sandra Wappelhorst, Dale Hall, Mike Nicholas, and Nic Lutsey, *Analyzing policies to grow the electric vehicle market in European cities,* (ICCT: Washington, DC, 2020), https://theicct.org/publications/electric-vehicle-policies-eu-cities.

Road user charging schemes include the Low-Emission Zone (LEZ), Ultra-Low Emission Zone (ULEZ), and proposed Zero-Emission Zones (ZEZ). While the Low-Emission Zone does not apply to private cars, the ULEZ requires a minimum Euro 4 standard for petrol and Euro 6 for diesel. If those standards are not met, a £12.50 fee is paid. The ULEZ is in operation 24 hours a day, 365 days of the year.

Financial benefits are primarily implemented at the national level in the UK. The primary policy is the UK government's plug-in car grant, through which buyers of new electric vehicles can receive a grant of up to £3,000 for cars and £7,500 for taxis. The national government also supports charging infrastructure through a grant covering up to 75%, capped at £350, of the cost of a home charger and its installation; drivers without access to off-street parking can suggest a location near their home for their local authority to provide on-street charging points.[14]

London's electric vehicle activities are only a part of a broader suite of transport policies in London, which include goals to reduce vehicle miles traveled (VMT) and shift trips to more sustainable modes. For example, one of London's key targets is that by 2041, 80% of all Londoners' trips should be made by foot, by cycle, or by public transport.[15] To achieve these targets simultaneously, the share of electric vehicles on the roads must increase rapidly even as the total number of cars decreases.

Charging deployment in Greater London

Table 2 describes the different types of charging infrastructure in place in London, connecting it to the power level, applicable standards, current type and charging category. The UK terminology is used in this paper, with the term "slow to fast" used for AC chargers from 3 kW to 22 kW and "rapid" for chargers above 43 kW.

Table 2. Charger terminology, power level, standards, and current type.

Terminology in the United Kingdom	Terminology in North America	Terminology in this report	Typical power level	Typical standards	Typical charging locations
Slow charging	Level 2	Slow to fast	3 kW – 6 kW (AC)	Chargers with Type 2 connectors	Private home, workplace, and dedicated to car clubs; Public destination and residential
Fast charging			7 kW - 22 kW (AC)	Chargers with Type 2 connectors	
Rapid charging	DC fast	Rapid	43 kW – 99 kW (AC & DC)	Chargers with Type 2, CHAdeMO, Combined Charging System, or Tesla connectors	Rapid chargers for the public, taxis, and PHVs
Ultra-rapid charging			Greater than 100 kW (often 150 kW) (DC)	Chargers with CHAdeMO, CCS, or Tesla connectors	

Note: AC = alternative current, DC = direct current; kW = kilowatt; PHV = private hire vehicles

Mirroring the steady increase of electric vehicles on London's roads, the number of charging points available in London has grown in the past few years. This growth has been enhanced significantly by the investment through the Go Ultra Low Cities Scheme (GULCS), a £13m program funded by the Office for Low Emissions Vehicles (OLEV) and delivered as a partnership between the Greater London Authority (GLA), TfL, and London Councils. The program has allocated over £6.5m funding to London boroughs to deliver 3,000 on-street residential charge points, of which more than 1,700 have been delivered. The program has also contributed to an £18 million program led by TfL to

14 "Suggest a location for an EV charge point," London Councils, accessed September 08, 2020. https://www.londoncouncils.gov.uk/our-key-themes/transport/electric-vehicle-charging/suggest-location-ev-charge-point

15 Greater London Authority, "Mayor's Transport Strategy," (London, March 2018), https://www.london.gov.uk/what-we-do/transport/our-vision-transport/mayors-transport-strategy-2018.

deliver a rapid charging network.[16] Figure 2 below displays the development of public charging infrastructure in London along with the electric vehicle stock as of January 2020 at the borough level. As of June 2020, there were 4,200 slow to fast chargers and 400 rapid chargers in Greater London.[17] The brown shading indicates electric vehicle stock per million population, with darker shading indicating higher uptake. The red circles indicate the concentration of public charging (slow to fast and rapid) within each borough; larger circles indicate that more chargers were in place.

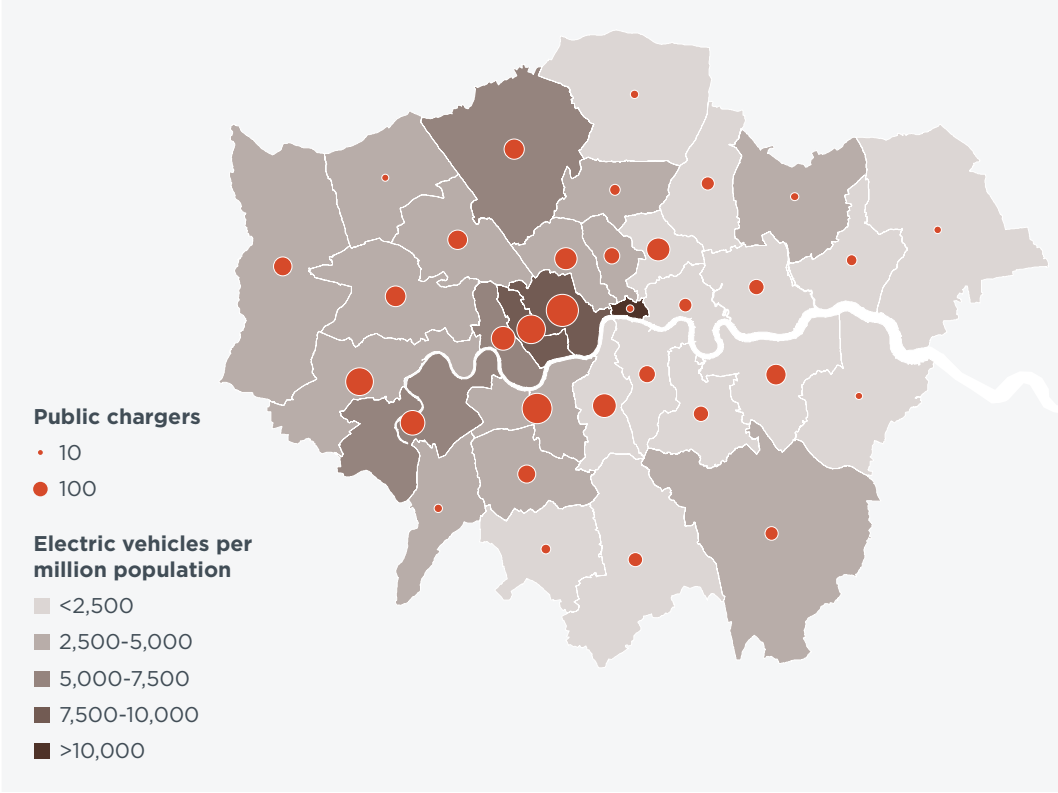

Figure 2. Public charging concentration and electric vehicle uptake in London as of early 2020.

This map allows for several qualitative observations. Electric vehicle charger density tends to align with electric vehicle uptake: both are higher in central and west London. These parts of the city also tend to be wealthier than London as a whole.[18] There are some exceptions, however; some boroughs with low electric vehicle uptake have many chargers in place such as in Greenwich, which can be partially explained by the lower accessibility to off-street parking. The boroughs with the most chargers on an absolute basis are Westminster and Wandsworth in inner London and Hounslow in outer London.

London Electric Vehicle Infrastructure Delivery Plan. Recognizing that planning and delivering electric vehicle infrastructure require coordination between industry, business and the public sector, the Mayor of London gathered industry leaders from 16 organizations and the Deputy Mayor for Environment and Energy to form the Electric Vehicle Infrastructure Taskforce. The Taskforce published a Delivery Plan with recommendations at the Greater London level concerning the growth of London's electric vehicle infrastructure out to 2025; longer-term projections were seen as too uncertain due to rapid changes in the industry.[19] A component of the plan included

16 London Assembly Environment Committee, "Appendix 1: Electric Vehicles," (May 2018), https://www.london.gov.uk/about-us/londonassembly/meetings/documents/s70697/Electric%20Vs%20in%20London.pdf.

17 Zap Map, Charging infrastructure counts, updated June 2020, https://www.zap-map.com.

18 "GLA Household Income Estimates – London Datastore," accessed August 7, 2020. https://data.london.gov.uk/blog/gla-household-income-estimates/.

19 The Mayor's Electric Vehicle Infrastructure Taskforce, "London Electric Vehicle Infrastructure Delivery Plan"

Transport for London's modeling on future charging needs, which considered different scenarios to assess the number of rapid, residential slow to fast, and destination slow to fast chargers. The two main scenarios are high sales, with 35% annual growth in electric vehicle sales share, and low sales, with 10% annual growth. For the high and low sales scenarios, there are three sub-scenarios with emphasis on rapid charging, residential charging, or destination charging. As a result of the six different scenarios, the total number of public chargers needed in 2025 ranges between 23,000 and 54,000. The plan's results are further discussed in context of this analysis below.

Related research

Several other studies have also identified charging needs and supporting measures for London and the United Kingdom more broadly. A 2020 ICCT study assesses the electric vehicle charging infrastructure necessary to power electric passenger cars up to 2030 in the UK, including analysis at the metropolitan area to capture regional commuting and travel patterns.[20] The study evaluated Greater London and the neighboring counties of Hertfordshire, Essex, Surrey, and Kent, which have a 50% greater population than Greater London and includes suburban areas with greater vehicle ownership than the central city. The study found that 4 times the number of rapid chargers and 6 times the number of slow to fast public chargers will be needed in 2030 compared to 2020 in the London metropolitan region.

The House of Commons in the UK investigated charging infrastructure in a briefing paper published in March 2020.[21] In order to support the rising number of electric vehicles on the roads, the report recommends increasing the number of rapid chargers in Great Britain by 150% between 2016 and 2030, and increasing the number of public slow to fast chargers by a factor of ten.

The Committee on Climate Change assessed the future demand for Britain's electric vehicle public charging network up to 2030.[22] The report anticipates 60% of new light duty vehicle sales and 30% of the total vehicle stock being electric by 2030, and recommends the installation of 1,170 rapid chargers by 2030 (up from 460 in 2016) and 27,000 slow to fast public chargers (up from 2,700 in 2016). Due to an expected increase in charging station utilization rate, less reliance on rapid charging, and longer electric vehicle range, only 2.5 times the current number of rapid chargers are recommended to meet the expected increase of electric vehicles in the UK compared to 10 times the number of slow to fast chargers.

Deloitte modelled UK charging infrastructure needs for different electric vehicle uptake scenarios in 2030.[23] The report estimates that the UK will need around 28,000 public chargers by 2030. They advise about 10 electric vehicles per slow to fast charger and point to research indicating between 80 and 1,800 electric vehicles per rapid charger.

Methodology

The core objective of this analysis is to calculate the amount of charging infrastructure required to support future electric vehicle uptake within each of London's boroughs.

20 Michael Nicholas, Nic Lutsey, *Quantifying the electric vehicle charging infrastructure gap in the United Kingdom*, (ICCT: Washington, D.C.., 2020), https://theicct.org/publications/charging-gap-UK-2020.

21 David Hirst, "Electric Vehicles and Infrastructure" (London: House of Commons Library, March 25, 2020), http://researchbriefings.files.parliament.uk/documents/CBP-7480/CBP-7480.pdf.

22 Cenex, Next Green Car, and Systra, "Plugging the gap: An assessment of future demand for Britain's electric vehicle public charging network," (Committee on Climate Change, January 2018), https://www.theccc.org.uk/wp-content/uploads/2018/01/Plugging-the-gap-Assessment-of-future-demand-for-Britains-EV-public-charging-network.pdf.

23 Justine Bornstein and Tom Bain, "Hurry up and... Wait. The Opportunities around Electric Vehicle Charge Points in the UK.," (Deloitte, 2019), https://www2.deloitte.com/content/dam/Deloitte/uk/Documents/energy-resources/deloitte-uk-electric-vechicles-WEB.pdf.

This section describes the key modeling steps used to assess London boroughs' private home, private workplace, public residential, public destination, and public rapid charging needs up to 2035.

This analysis uses the process summarized in Figure 3, applied at the borough level, to model infrastructure needs across Greater London.[24] The blue boxes correspond to the different analytical steps, the yellow trapezoids correspond to the data required, and the grey circles indicate the questions driving the framework. This same framework has been used to assess charging infrastructure needs in other markets, including at the national level in the United States, the United Kingdom, and Germany.[25]

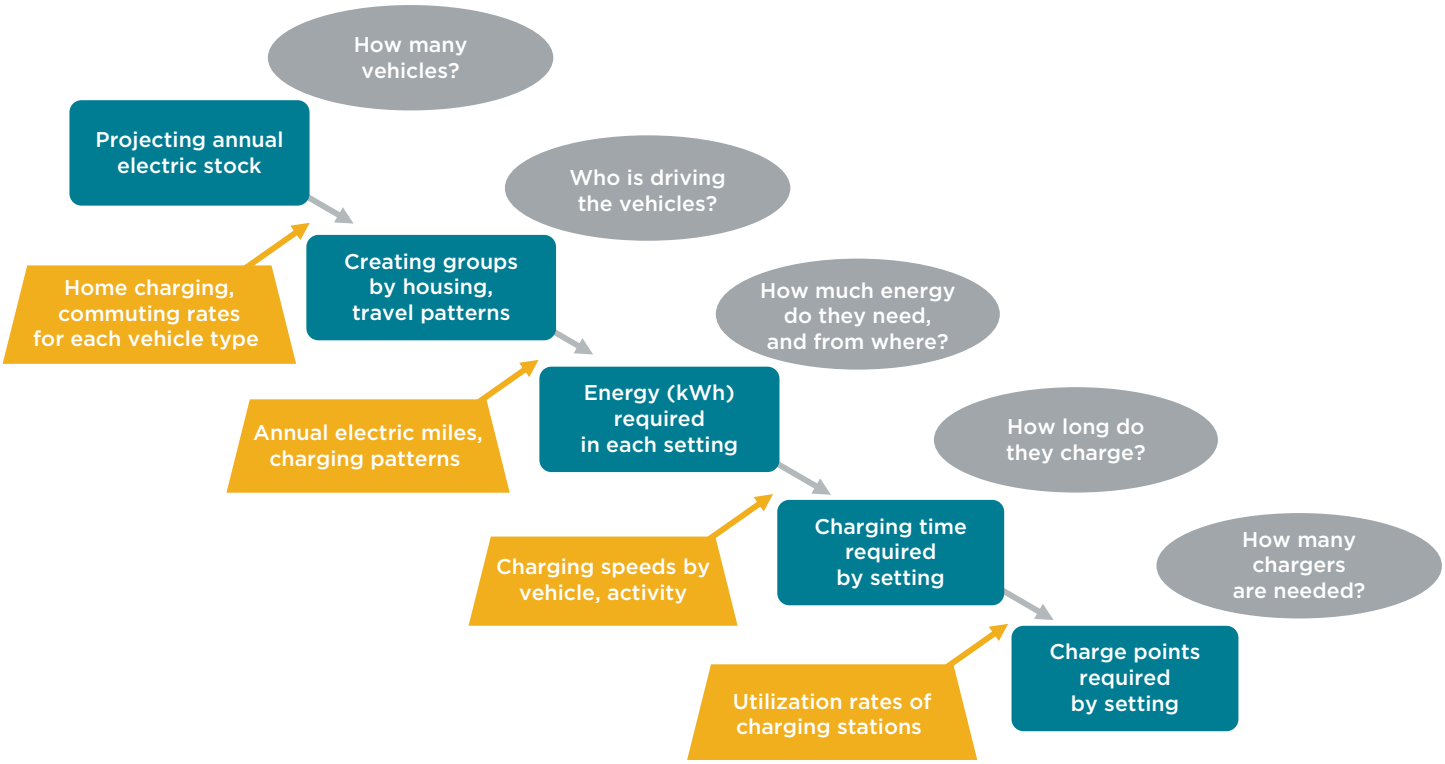

Figure 3. High-level methodology for assessing charging infrastructure needs.

This analysis estimates the need for six categories of chargers: three private – home, workplace, and dedicated to car clubs – and three public – residential-focused AC, destination-focused AC, and rapid. The data outlined in the yellow boxes in Figure 3 are primarily drawn from the London Electric Vehicle Infrastructure Delivery Plan, Transport for London (TfL), London Datastore, the UK Government, and the Office for National Statistics. Public residential and public destination chargers have the same technical specifications and can be sometimes used interchangeably, however here we report them separately to provide guidance as to the fraction of charging that could take place at night in residential areas versus during the day at commercial settings.

The scope of this study includes all light-duty vehicles, including private passenger cars and company cars, taxis and private hire vehicles, light goods vehicles, and car clubs. The analysis excludes medium- and heavy-duty trucks and buses, which are at very early

24 Dale Hall and Nic Lutsey, *Electric vehicle charging guide for cities,* (ICCT: Washington, D.C., 2020), https://theicct.org/publications/city-EV-charging-guide.

25 Michael Nicholas, Dale Hall, and Nic Lutsey, *Quantifying the Electric Vehicle Charging Infrastructure Gap across U.S. Markets,* (Washington, D.C.: International Council on Clean Transportation, January 23, 2019), https://theicct.org/publications/charging-gap-US.; Nicholas and Lutsey, *Quantifying the Electric Vehicle Charging Infrastructure Gap in the United Kingdom,* Mike Nicholas, Sandra Wappelhorst, and Nic Lutsey, *Regional charging infrastructure requirements in Germany through 2030,* (ICCT: Washington, D.C, October 21, 2020), https://theicct.org/publications/regional-charging-infra-germany-oct202.

stages of uptake and do not have well-defined public charging standards. The remainder of this section briefly describes key aspects of our methodology.

Private passenger cars

Electric vehicle uptake up to 2035. This analysis estimates the charging infrastructure required to power future electric vehicle fleet, flowing from assumptions about the number of electric vehicles for each borough up to 2035. We assume that private passenger vehicle sales in London remain flat at 2019 levels from 2020 to 2025 and then decrease by 1% annually from 2025 onwards, up to 2035. This reflects recent sales trends, as car sales have plateaued and even slightly decreased in London since 2016, as well as the Mayor's goals to reduce car dependency in London.[26] The median useful life of electric and combustion-engine vehicles is 12.5 years.

The projected growth in private electric car stock is shown in Figure 4. As shown, the electric vehicle sales share reaches 34% in 2025 and 100% in 2030 in accordance with the Mayor's goal to phase out new combustion vehicle sales by 2030. The share of electric vehicles that are BEVs is projected to rise from 50% in 2018, to 90% BEVs by 2025, and to 100% by 2030. This mirrors the assumptions made in the London EV Infrastructure Delivery Plan and reflects a global industry shift as BEVs become more cost competitive with combustion cars as battery and other component costs fall. The electric passenger and light goods vehicle stock is expected to grow from approximately 40,000 in 2020 to 200,000 by 2025, 800,000 by 2030, and 1.5 million by 2035. This represents 8% of the light-duty vehicles on London's roads in 2025, 30% in 2030, and 57% in 2035.

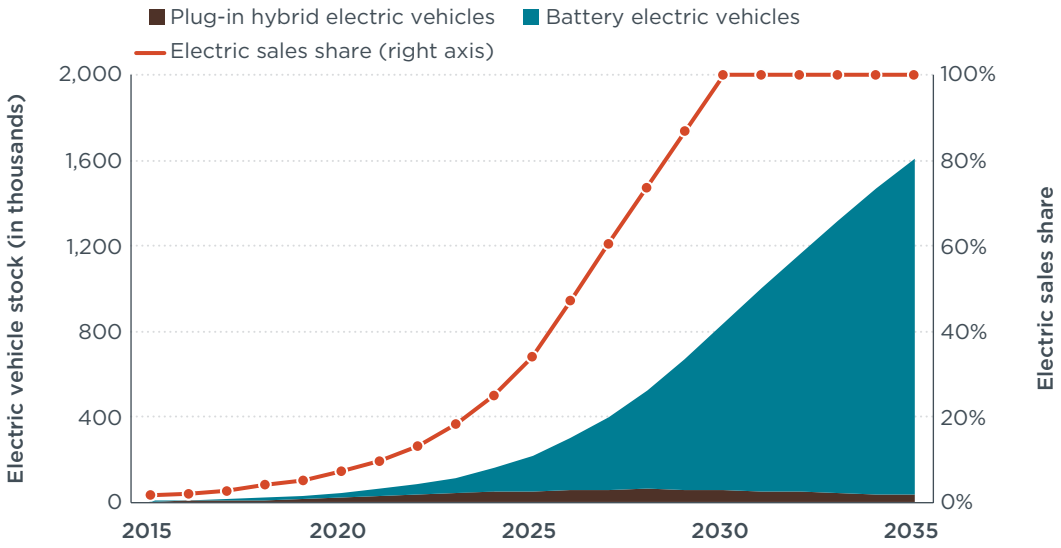

Figure 4. Scenario for electric private passenger and light goods vehicle uptake up to 2035.

As shown in Figure 2, electric vehicle sales up to 2019 have been unevenly distributed by borough. When projecting future sales at the borough level, the model assumes that these will continue in the near-term. In the longer term, as the market becomes more mainstream, electric vehicle sales shares will become more even, eventually reaching 100% by 2030.

Allocation of electric vehicles to charging need groups. The next step involves splitting the electric vehicle stock into groups based on their charging behavior. Three factors are taken into consideration: vehicle type (BEV or PHEV), commuting status, and home charging access. Vehicle type influences the number of electric miles driven per day and

26 Greater London Authority, "Mayor's Transport Strategy."

the efficiency of the car (miles per kilowatt-hour [kWh]). Commuting status is important to determine the number of miles driven and the accessibility to workplace charger. Home charging access influences the magnitude of workplace and public charging needed.

The type of housing is used to assess home charging availability. To account for the shift to mainstream electric vehicle purchases, the share of electric vehicle owners with access to home charging at the London level decreases slightly from 60% in 2020 to 55% in 2030. The number of driving commuters in each borough is based on data from the 2011 Census which provides an origin-destination matrix of driving commuters.[27] Based on data from recent years, the model assumes a 3% reduction of the total number of driving commuters between 2011 and 2018 and then a decrease of 1% per year.

Energy required by charging category. The third modelling step is to determine the daily energy needed to power the vehicle miles for each user group and assign it to the different charging points. We assume that drivers living in the outer boroughs drive twice as much as people living in the inner boroughs as outlined in the 2019 London Travel Demand Survey.[28] Vehicles not used for commuting are assumed to drive 20% less than vehicles used for commuting.[29] The average annual mileage for drivers across London is 5,113 miles in 2020 but decreases slightly over time.[30] The percentage of electric-powered miles driven by PHEVs ranges from 10% to 70% depending on home and workplace charging access.[31] The miles driven are used to calculate energy demand based on an average efficiency of 3.48 miles per kWh for BEVs and 2.34 miles per kWh for PHEVs. The efficiency of new private cars is assumed to be constant over the period of analysis, as improvements in efficiency is negated by a shift towards larger vehicles.

Some charging inevitably takes place outside of a driver's borough of residence, particularly for workplace and public destination charging. Workplace chargers are distributed according to the number of electric vehicle-driving commuters entering each borough per day. Public destination charging takes place across London for different trip purposes: 50% of the charging need is allocated according to the concentration of commercial destinations, 25% is allocated to boroughs based on commuting to workplaces, and 25% remains in the driver's home boroughs.

The proportion of private vehicle owners in the different groups (commuters versus non-commuters, BEV versus PHEVs, and home charging access) changes over time. The early market is assumed to have a higher percentage of electric vehicle owners with access to home charging than the later market, increasing the need for public charging as the mainstream market grows. Similarly, the shift toward BEVs will necessitate more charging (and in particular more fast charging) than in the early market.

Chargers needed based on the utilization rate and charging speed. The final step of the process is to calculate the number of chargers needed to provide the required energy based on the utilization rate and charging speed at different charging locations. Charging speed varies according to vehicle type and setting. At workplace and public slow to fast stations, BEVs charge at 8.7 kW and PHEVs at 5.3 kW. Public rapid charging speed increases from an average of 35 kW in 2020 to 62.5 kW in 2030, reflecting

27 The origin-destination matrix specifies the number of people driving to and from each combination of local authorities. "WU03UK (Location of Usual Residence and Place of Work by Method of Travel to Work) - Nomis - Official Labour Market Statistics," accessed August 12, 2020, https://www.nomisweb.co.uk/census/2011/wu03uk.

28 Mayor of London, "Travel in London Key trends and developments Report Number I," (Transport for London, 2009), https://www.rbkc.gov.uk/pdf/33%20travel%20in%20london%20report-number-1%2005%2009.pdf.

29 Transport for London, "London Travel Demand Survey," (2019), https://tfl.gov.uk/corporate/about-tfl/how-we-work/planning-for-the-future/consultations-and-surveys.

30 Department for Transport, "National Travel Survey: England 2018" (July 2019), https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/823068/national-travel-survey-2018.pdf.

31 Nicholas and Lutsey, *Quantifying the electric vehicle charging infrastructure gap in the United Kingdom.*

increasing deployment of 150-kW chargers and greater charging acceptance speeds in the vehicles as a result of larger batteries and improved technology.[32]

As shown in other studies, utilization of charging stations increases as a function of market development.[33] Table 3 below lists the assumptions around chargers utilization rate (hours of active charging per day) and charging power used in this analysis. Chargers often experience low utilization during the early market but will see higher utilization once the market matures and the network becomes more efficient. We thus assume that the average daily hours of charging increases according to a logarithmic curve until plateauing in 2030 (for DC public rapid chargers), 2033 (for DC rapid chargers dedicated to taxis), or 2035 (for public slow to fast chargers). In contrast, workplace chargers do not increase in utilization.

Table 3. Chargers utilization rate and charging power.

	Charger type	2025	2030	2035
Chargers utilization rate (hours of active power draw/day)	Public residential	3.7	5.3	6
	Public destination	4.2	6.1	7
	Public rapid	5.6	8	8
	Rapid dedicated to taxis	5.1	7.3	8
	Workplace	6 hours per weekday		
Charging speed (kW)	Public residential, public destination, and workplace	8.2	8.7	8.7
	Rapid	49	62.5	76.3

Taxis and private hire vehicles

While following the same general method described in Figure 3, the analysis for electric taxis and private hire vehicles (PHVs) – also known as transportation network companies (TNCs) –requires several modifications. The first step consists of estimating the number of electric vehicles in the fleets for each year, with 100% of PHVs being electric (BEV or PHEV) by 2030 and 100% of taxis being electric by 2033. This meets the London's Mayor goal of having only zero-emission capable taxis and PHVs in 2033.[34] This analysis assumes a faster transition for the PHV fleet (2030 instead of 2033), which is in line with recent electrification commitments from major PHV operators.[35]

The vehicles are then divided into different user groups based on three factors: vehicle type (BEV or PHEV), access to off-street parking (a proxy for home charging availability), and, for PHVs, whether a driver is full-time or part-time. Each of these user groups drive a different number of electric miles per day, the energy for which is provided by a mix of rapid charging, private home charging, and public residential and destination charging. The energy needed is allocated to the different charger categories as described above, although PHV and taxi drivers rely more heavily on rapid and public residential chargers compared to private car drivers. Energy demand in kWh determines the number of chargers needed using the same power and utilization rate as private cars for PHVs and a different utilization rate for taxi-dedicated rapid chargers (as shown in Table 3).

Charging activity for these vehicles is distributed across the London boroughs based on different factors for each charging type. The public residential chargers are allocated

32 Rapid chargers are defined as those that can deliver at least 43kW, but vehicles will not receive the maximum speed over the full charging cycle and there may be a mismatch between charger power and vehicle acceptance rate.

33 Nicholas, Hall, and Lutsey, *Quantifying the Electric Vehicle Charging Infrastructure Gap across U.S. Markets.*

34 The Mayor's Electric Vehicle Infrastructure Taskforce, "London Electric Vehicle Infrastructure Delivery Plan."

35 Uber, "SPARK! Partnering to electrify Europe"," September 8, 2020, https://www.uber.com/us/en/about/reports/spark-partnering-to-electrify-europe/.

according to drivers' borough of residence.[36] The public rapid and public destination chargers are allocated based on the share of weekly pick-ups and drop-offs per borough. This analysis assumes taxis use dedicated rapid chargers not open to the general public, whereas all public slow to fast chargers are shared among all vehicle types.

Light goods vehicles

Light goods vehicles (LGVs) are primarily composed of vans and light trucks used for deliveries, trades, and services. The electric LGV stock is generated through a stock turnover model similar to that of private passenger cars, assuming the same growth in electric vehicles sales shares and the same distribution across boroughs. This vehicle stock is then evenly split in three different categories reflecting different charging behaviors: private-owned delivery vehicles, private-owned service or trade vehicles, and depot-based fleets.

As with other vehicle segments, the distribution of charging activity by borough varies for the different types of chargers. Public residential charging is allocated according to drivers' borough of residence, and depot-based fleets do not use public residential charging. The public rapid and public destination charging activity is assigned based on the percentage of the total population living in each borough as of 2020, which serves as a proxy for the number of delivery and service or trade trips made in each borough. For privately-owned LGVs, we assume the same home charging availability as for the private passenger car model. For depot-based fleets, most of the charging is performed by private chargers at the depot. Those chargers are allocated based on the share of businesses in each borough. Otherwise, LGVs are assumed to use shared public chargers with equivalent charging speeds and utilization rates as private cars.

Car clubs

Car clubs, or car sharing services, can use a number of different charging solutions relying on public or dedicated chargers. We assume car club fleet growth rate at 10% per year up to 2025 based on recent trends to a maximum of 6,210 shared electric cars in 2025, with no growth afterward. As with PHVs, the London car club fleet reaches 100% battery electric vehicles by 2030.

The vehicles are distributed across the London boroughs based on a 2016 ultra-low emission car club study.[37] Charging between trips is assumed to take place at dedicated private slow to fast chargers in the vehicles' "home boroughs." In contrast, public rapid and destination charging is distributed across the city based on different factors. According to the aforementioned survey, cars are used 42% of the time for leisure trips, 30% for personal business, 19% for shopping, and 7% for business. We assume that half of the leisure travel is done outside of London and allocate the remainder of leisure and personal business trips based on the percentage of population in each borough. The share of public charging corresponding to shopping and business trips is allocated based on the percentage of retail stores in each borough.

If electric car-sharing services were to rely on public residential and destination chargers rather than private dedicated chargers, demand from car clubs would require an additional 430 public residential chargers in 2025 (6% of the total number of public residential chargers), up to a maximum of 454 in 2026 (5% of the total public residential charger stock).

36 "Licensing Information," Transport for London, accessed August 4, 2020, https://www.tfl.gov.uk/info-for/taxis-and-private-hire/licensing/licensing-information.

37 WSP Parsons Brickerhoff, "ULEV Car Club Study" (Transport for London, November 2016), http://content.tfl.gov.uk/ulev-car-club-study.pdf.

Charging needs in the London boroughs

The above methodology was used to estimate the amount of electric vehicle charging infrastructure necessary in each London borough to enable electric vehicle growth up to 2035 and compare findings to those in the Delivery Plan. This paper focuses on the high sales, rapid charging emphasis scenario outlined in the Delivery Plan, although comparisons with the low sales, residential, and destination scenarios are provided below. This scenario has been chosen to align with the Mayor's electric vehicle goals and with the path London is taking to develop a rapid charging network in the city. The analysis is presented for the energy demand and the number of chargers needed for 2025, 2030, and 2035, including a breakdown for inner and outer London, and per borough.[38] Projected charger counts for every borough and all six scenarios are provided in the appendix.

Energy demand

Figure 5 presents the total charging energy demand in gigawatt-hours (GWh) per year based on vehicle categories from 2020 to 2035, including charging at public and private stations. Energy demand grows substantially, from an estimated 106 GWh in 2020, to 860 GWh in 2025, and to 2.3 terawatt-hours (TWh) in 2030. Private passenger cars account for over 45% of the 2030 charging demand, followed by private hire vehicles with over 42%, and light goods vehicles with about 8%; the shift toward private cars consuming more energy continues after 2030. However, in the near-term, private hire vehicles account for the majority of the energy demand growth up to about 2026, based on the ambitious targets set by London and the ride-hailing industry.

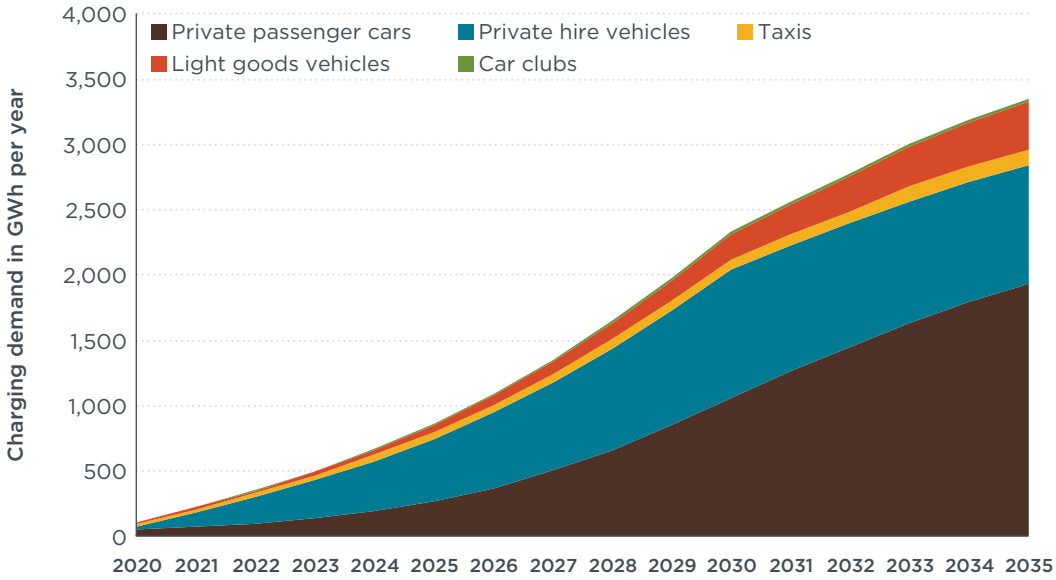

Figure 5. Energy demand in Greater London by vehicle category from 2020 to 2035.

Figure 6 provides a detailed breakdown for the energy demand for the same vehicle segments for inner and outer London in 2025, 2030, and 2035. Overall, inner London will account for 40% of the total charging energy demand in 2025, 34% in 2030, and 29% in 2035. Private hire vehicles account for the majority of the charging energy demand up to 2026. In later years, private passenger cars account for greater shares of energy demand in outer London, but private hire vehicles will still make up higher shares of the charging energy demand in inner London. Taxis typically account for just 2% to 4% of charging

38 The distinction between inner and outer boroughs is made in accordance with the definition provided by the Office for National Statistics and can be found in Annex.

demand in outer London, compared to 5% to 8% in inner London. Light goods vehicles grow from 5% of the charging demand in 2025 to 8% in 2030.

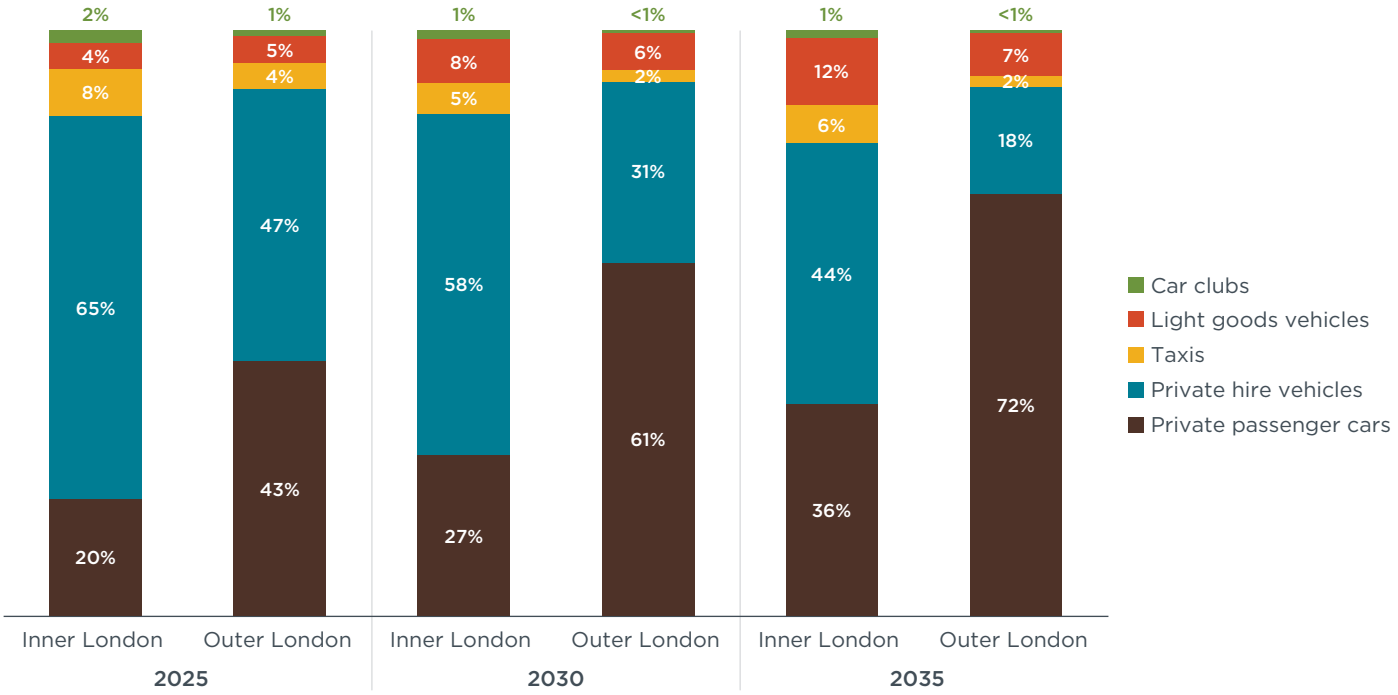

Figure 6. Share of electricity demand at the inner and outer London level for all vehicle categories.

Figure 5 and Figure 6 provide several noteworthy findings. In both inner and outer London, a large share of electricity demand is coming from private hire vehicles, which have the fastest rate of transition to electric vehicles in this analysis. This is especially true for inner London boroughs in early years, with PHVs accounting for 65% of charging electricity demand in 2025. Most of this demand comes from rapid charging to serve the daytime pickup and drop-off activity of PHVs in inner London.

After 2025, the rate of electrification of PHVs slows while the number of electric private vehicles continues to grow. Private car charging energy demand will grow to become the majority of energy demand in outer London, where car ownership is greatest. While in 2025, PHVs will account for over 55% of the total electric vehicle miles traveled (VMT), this goes down to 42% in 2030. The trend is reversed for private passenger cars, which will account for 32% of electric VMT in 2025 up to 47% in 2030. As context, overall VMT by passenger vehicle will decrease slightly by 2030 by 1% per year on average to align with the Mayor's goal of 80% sustainable trips by 2041.

Figure 7 presents the share of electricity demand broken down by charging location for inner and outer London in 2025, 2030, and 2035. Because all vehicle charging activity is accounted for in this analysis, the absolute magnitude of charging demand in London is equivalent to that shown in Figure 5, and the breakdown between inner and outer London is the same as discussed above. In comparison to Figure 6 which shows the share of electricity demand per vehicle type, Figure 7 shows a breakdown of charging by location, which is likely to be more useful for understanding the planning and policy decisions.

Figure 7. Share of electricity demand at the inner and outer London level for all charger types

The figure shows a striking difference between inner and outer London in the composition of charging activity. In inner London, public energy demand will mainly come from rapid chargers—46% public rapid compared to 31% public residential and destination in 2025—but the opposite holds true for outer London. Indeed, 21% of energy will be required by public rapid chargers compared to 37% by public residential and destination in 2025. Public charging requires the biggest share of electricity demand in inner London across all years, whereas energy demand is more evenly split between public and private charging in outer London.

This variation is due to several factors. Drivers in outer London are more likely to have access to private home charging – in 2025, 43% of inner London electric vehicle owners will have access to home charging, compared to 63% in outer London. Therefore, private home chargers will supply more energy than public residential in outer London from 2030 onward, while the opposite is true for inner London. Another important factor is the typical driving patterns of private hire vehicles and taxis. Of the total pick-ups and drop-offs, 57% happen in the inner boroughs, 32% in the outer boroughs, and 10% occur outside of London. In contrast, more drivers live in outer boroughs (55%) than in inner boroughs (30%); taxis see a similar dynamic. Because only 25% of PHV drivers have access to private home charging, most of these high-mileage drivers rely on both rapid charging (mostly in inner London) during the day and public residential charging (mostly in outer London) at night.[39] Consequently, the taxi and PHV fleets will make up the largest share of public charging up to 2030, accounting for about 85% of demand for rapid charging in inner London and 80% of public residential charging in the outer boroughs.

Public charging infrastructure

Figure 8 lays out the charging infrastructure needed throughout the years at the inner and outer London level (bars, left axis) and compares it to the infrastructure already in place as of June 2020 (yellow and blue lines, right axis). The pink bars refer to public residential chargers and the dark red bars to public destination chargers. Similar

39 The Mayor's Electric Vehicle Infrastructure Taskforce, "London Electric Vehicle Infrastructure Delivery Plan."

colors have been chosen since the distinction between public residential and public destination chargers are similar in form and may overlap in practice. As of June 2020, there are 2,699 public slow to fast chargers in place in inner London and 1,989 in place in outer London. Concerning rapid chargers, inner London currently has 192 installed and outer London has 250.[40] Figure 8 shows that overall in London, about 26,800 public chargers will be needed by 2025, 44,200 by 2030, and 54,300 by 2035. Among the 44,200 public chargers needed by 2030, approximately 33% are needed in inner London, 67% are needed in outer London, and about 8% of the total are rapid chargers. In the absence of data on the split between public destination and public residential chargers as of June 2020, the yellow line shows the percentage of all slow to fast charging in place as of 2020.

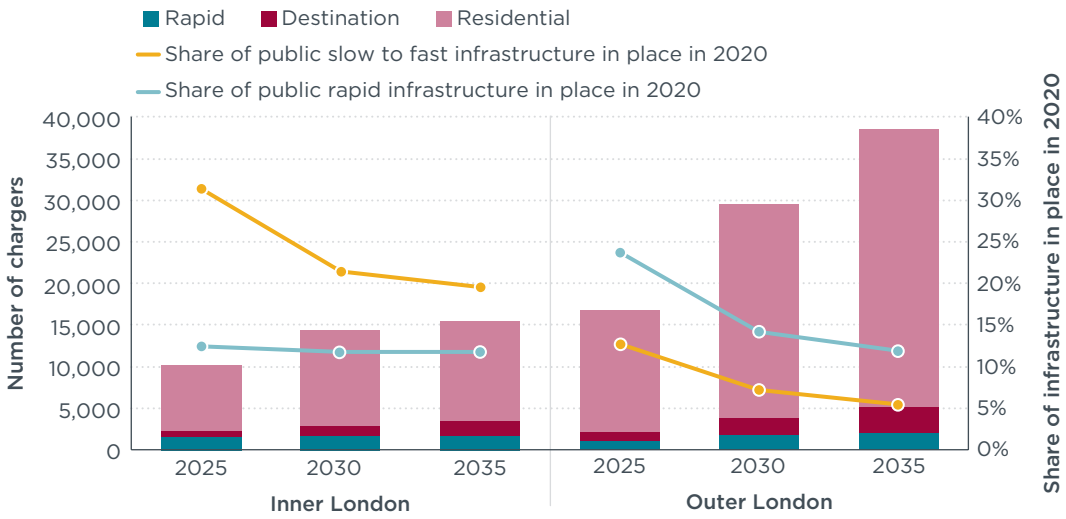

Figure 8. Number of public chargers in London from 2025-2035 with comparison to 2020 development.

Figure 8 shows that inner London boroughs are relatively further ahead than the outer boroughs in terms of public slow to fast charging infrastructure development (yellow line), with a higher share of infrastructure already in place in June 2020. On the other hand, the outer boroughs have made more progress on public rapid infrastructure development (light blue line). Only 13% of the rapid chargers needed in inner London by 2025 are already in place as of June 2020. In comparison, 30% of the rapid chargers needed in outer London in 2025 have already been built (light blue line). We observe a reverse trend for public slow to fast charging, where 38% of the infrastructure needed in 2025 was already achieved in inner London boroughs and only 16% for outer London boroughs. Although there will be great demand for both slow to fast and rapid charging across London in the coming decade, the differences in charging patterns suggest that constructing more rapid charging may be a priority in inner London boroughs, whereas residential charging is more needed in outer London boroughs.

We note that the number of rapid chargers needed reaches its maximum in 2030 for inner London boroughs (except for City of London for which it reaches its maximum in 2027). After this, the increasing number of electric vehicles is balanced by the increase in electric vehicle efficiency, the decrease in miles traveled, as well as the increases in chargers' utilization rate and charging speed.

Ratio of electric vehicles per public charger. The ratio of electric vehicles per public charger is a commonly used metric for evaluating market maturity and planning future installations. In 2020, London as a whole had about 7 electric vehicles per public charger; the ratio was 5 in inner London while for outer London the ratio was closer

40 Zap Map, Charging infrastructure counts.

to 10. This can be explained by the fact that more households have access to home charging in outer London and rely thus less on public chargers. With increasing market maturity, higher utilization rate, and faster vehicle charging speed, this analysis projects the ratio of electric vehicles per regular public charger will grow to 23 in 2030 for the region overall (22 for inner London and 23 for outer London).

A related measure, the BEV per rapid charger ratio, is close to 38 in 2020 across London; the values in inner London and outer London are similar. This number will grow to over 200 in 2030. This is due to the increasing utilization of rapid chargers, the growing prevalence of ultra-rapid chargers, and a shift in the electric vehicle fleet from PHVs and taxis to private cars, which use relatively less rapid charging. The increasing electric vehicle to charger ratios reflects trends observed in other markets as electric vehicle penetration increases, including in Norway, California, and elsewhere in the UK.[41]

Charging needs by borough. Estimates of future charging needs for each of the 32 boroughs and the City of London are illustrated in Figure 9 below. The four maps contain the projected number of slow to fast chargers (top row) and rapid chargers (bottom row) needed within each borough for 2025 (left column) and 2030 (right column). The number of chargers for each borough are indicated with the labels within the map. The maps also indicate the share of the estimated 2025 and 2030 charging of each type that was already in place in June 2020. Darker blue shading indicates that the boroughs have constructed a higher share of the needed charging, with lighter shading illustrating that a smaller share of 2030 needed public charging has been installed. A key to the boroughs is provided in Table A1 in the appendix.

41 Wappelhorst, Hall, Nicholas, and Lutsey, *Analyzing Policies to Grow the Electric Vehicle Market in European Cities.*

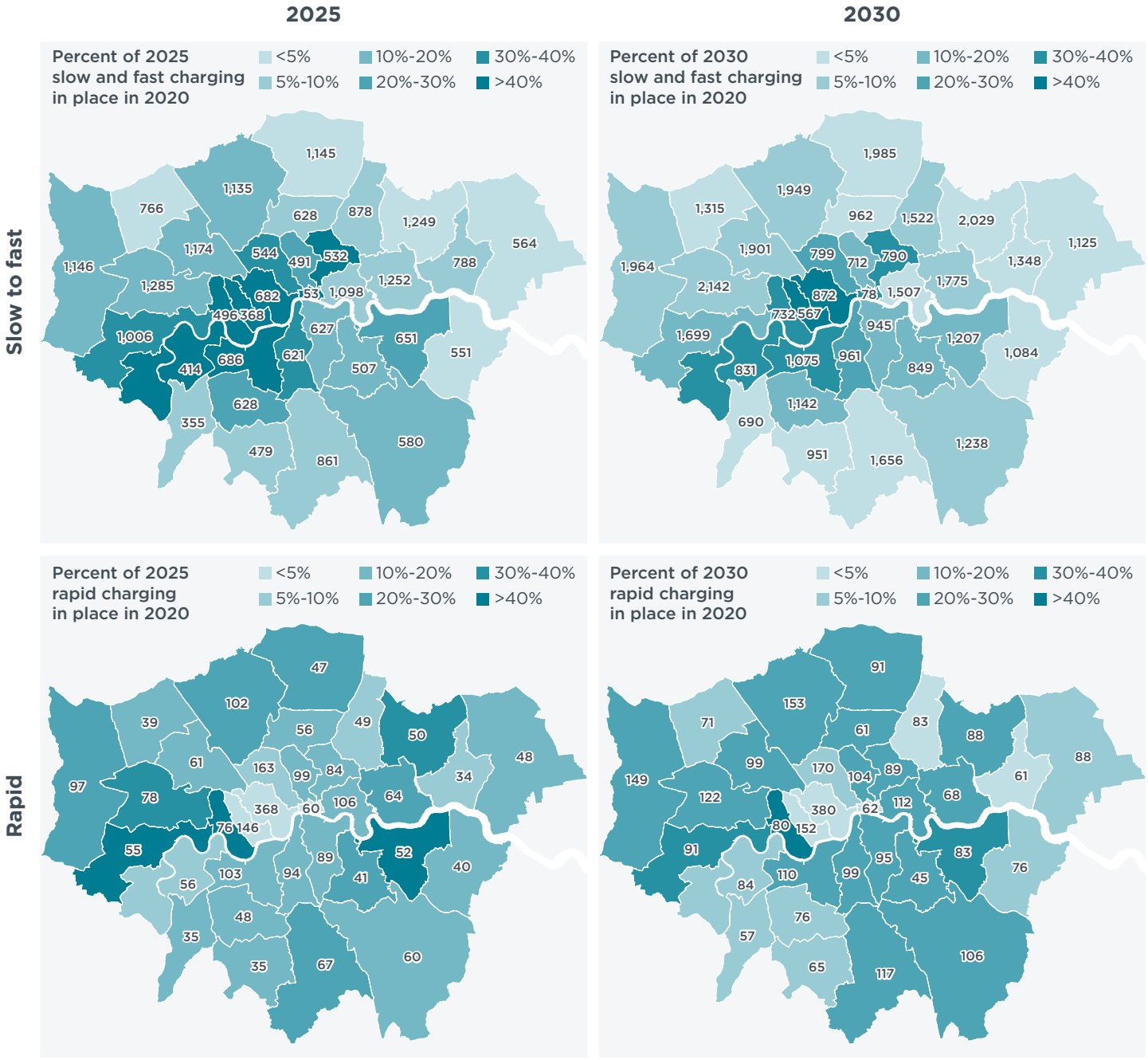

Figure 9. Charging infrastructure needs by borough in 2025 (left) and 2030 (right).

The figure illustrates that many more chargers will be needed throughout London: every borough will need at least twice as much public charging by 2030, and most boroughs will need 4 to 20 times as much. However, the figure also shows some differences across the boroughs. The borough with the greatest need for slow to fast chargers by 2030 is Ealing (2,142), while the greatest need for rapid chargers in 2030 is for Westminster (380). For slow to fast chargers, inner London boroughs generally have a much greater share of their 2025 and 2030 needs already in place compared to the outer London boroughs. Kensington and Chelsea has about 60% of its 2030 slow to fast chargers already in place and 6 other inner London boroughs are above 30%, whereas three outer London boroughs (Enfield, Harrow, and Redbridge) have only 1% of the needed slow to fast chargers built. For rapid chargers, the pattern is less clear, although the 3 central authorities City of London, Westminster, and Kensington and Chelsea all have among the lowest shares of 2030 rapid charging in place. These results, as well as the 2035 charger counts, are also provided in Table A2 in the appendix.

Private charging infrastructure

While the primary focus of this report is on public charging, over which Greater London and its boroughs have a higher degree of control, private charging is responsible for more than a third of charging energy and a greater share of energy for private cars. Private home chargers account for about 90% of the private chargers in London in these results, growing to 100,000 London-wide in 2025, 345,000 in 2030, and 609,000 in 2035. In contrast, private workplace chargers account for 2% of the private chargers, with an estimated 2,000 required across London in 2025, 7,500 in 2030, and 14,000 in 2035. In both cases, charging demand is largely driven by private cars and light goods vehicles rather than PHVs and taxis.

In this analysis, depot-based light goods vehicles mainly charge at dedicated chargers at the depot overnight. While not considered here, there is potential to reduce expenses by sharing chargers between commuters and commercial fleet vehicles. Indeed, while private passenger cars use workplace chargers during the day, those chargers are rarely utilized at night and could thus benefit depot-based fleets. Finally, car clubs could require up to 6,200 private dedicated chargers in 2025 and 9,700 in 2030, although the variety of electric car club business models makes it difficult to forecast charger counts for this application.

As with public charging, private charging patterns show differences between inner and outer London. By 2025, private home chargers in outer London outnumber those in inner London 2 to 1, with the divide growing to 3 to 1 in 2035. Electric car owners in outer London will be 20% more likely to have home charging than in inner London in 2025. A similar disparity exists for workplace charging, reflecting the greater likelihood of using a car to commute to outer London jobs than those in inner London. Car club chargers are likely to be placed near the vehicles, making the placement in the future uncertain. If the distribution of car club vehicles in 2019 continues in the future, however, 80% of car club dedicated chargers would be in inner London, representing 7% of private inner London chargers but only 1% for outer London.

Table A2 in the appendix presents the detailed number of private home, workplace, and car club chargers recommended under the high sales, rapid charging emphasis scenario in 2025, 2030, and 2035 for each of the 32 boroughs and City of London.

Discussion of alternative charging approach

The results featured in this working paper show one pathway to meeting charging needs similar to the "rapid charging emphasis" scenario described in the London Electric Vehicle Infrastructure Delivery Plan. This scenario perpetuates London's mix of infrastructure in place as of 2020, requiring a similar annual growth rate for public rapid and slow to fast charging. The greater emphasis on rapid charging also enables greater flexibility to serve a wider variety of vehicles, including medium and heavy-duty vehicles, in the future.

As demonstrated by the widely varied charging networks in place in the top electric vehicle markets around the world, there are many solutions to satisfy charging demand.[42] This section details one alternative pathway for meeting charging needs for the same electric vehicle growth with an emphasis on public residential chargers, and briefly introduces results from the high sales, destination chargers emphasis and low sales rapid, residential, and destination scenarios. The emphasis on residential chargers is similar to the approach taken in Amsterdam and other cities in the Netherlands, which

42 Dale Hall, Hongyang Cui, and Nic Lutsey, *Electric Vehicle Capitals: Showing the Path to a Mainstream Market,* (Washington, D.C.: International Council on Clean Transportation, November, 2019), https://theicct.org/publications/ev-capitals-of-the-world-2019.

can result in greater convenience for drivers and lower impacts on the electric grid.[43] On the other hand, because a greater number of total installations will be needed, this approach may require more careful planning and coordination between the boroughs, Transport for London, and other stakeholders.

Table 4 below compares the number of public residential, public destination, and rapid chargers in 2025 and 2030 in our primary scenario and the residential emphasis scenario, as well as the chargers in place in mid-2020. The percentage difference in the number of chargers within each category from the primary scenario to the residential emphasis scenario is also provided. Compared to the primary scenario, the greater emphasis on residential charging results in a drastic increase in the number of public residential chargers (43% greater in 2030) and a similarly large decrease in the number of rapid chargers needed (56% fewer in 2030). The number of chargers required in each borough under this alternative scenario is provided in Table A3 of the appendix.

Table 4. Summary of public chargers needed, including range based on alternative scenarios.

	Existing in June 2020	Chargers needed in primary scenario			Chargers needed in residential emphasis *Difference from primary scenario*		
		2025	2030	2035	2025	2030	2035
Public rapid	397	2,602	3,612	4,016	1,335 *-49%*	1,576 *-56%*	1,576 *-61%*
Public destination	3,677 (combined destination and residential)	1,619	3,329	4,898	1,280 *-21%*	3,107 *-7%*	4,793 *-2%*
Public residential		22,621	37,197	45,390	31,120 *+38%*	53,049 *+43%*	65,110 *+43%*
Total	4,074	26,842	44,138	54,304	33,735 *+26%*	57,732 *+31%*	71,479 *+32%*

By comparing these two approaches, one can derive the approximate substitution rate among different types of public chargers. When switching from the rapid emphasis to the residential emphasis, the increase in the number of public regular chargers needed is 7.7 times the decrease in rapid chargers in 2030. This suggests that one rapid charger can provide approximately 7-8 times the charging energy as a public regular charger. The substitution rate implied by this model increases slightly over the time horizon as ultra-rapid charging becomes more common. In reality, a mix of all charging types will be needed, and the most convenient and lowest-cost solution will depend on such factors as vehicle makeup, housing stock, electricity grid conditions, and national government and city level policies. However, this substitution rate may be useful for local governments in comparing different approaches to satisfying charging needs.

Mirroring the approach taken in the Delivery Plan, a high sales scenario with emphasis on destination charging was analyzed. Public destination and residential chargers can sometime be used interchangeably as they have the same technical specifications but mainly differ in terms of placement and typical usage patterns. While residential chargers are primarily used overnight, destination ones are used during the day and for shorter periods of time. The results of this scenario can be found in Table A4 in the appendix. Governments may consider public destination and residential chargers together as a "public slow to fast category" in their implementation strategies.

Low sales scenarios. Even though the high electric vehicle sales growth scenario aligns with London Mayor's ambitious goals, the same analysis was performed with a low sales scenario aiming for 6% electric vehicle sales in 2025, 50% in 2030, and 100% in 2035. This results in roughly 63% fewer electric vehicles on the London roads in 2025, 58%

43 Robert van den Hoed et al., "Emobility: Getting Smart with Data," (Amsterdam: Amsterdam University of Applied Sciences, June 2019), https://pure.hva.nl/ws/files/5796298/HvA_Emob_DIGI.pdf.

fewer in 2030, and 38% fewer in 2035. However, the drop in chargers needed from the high to low scenarios is milder: regardless of the type of charging emphasized, public charger volumes required in the low scenario are about 20% lower in 2025, 28% lower in 2030, and 25% lower in 2035 than in the high scenario. Correspondingly, the ratio of electric vehicles per public charger is greater in the high scenario than in the low.

This discrepancy is primarily because utilization is related to electric vehicle uptake: a greater density of electric vehicles enables more efficient use of the charging network, with each charger supporting more vehicles. This also implies that the infrastructure cost per vehicle is lower when the shift to electric vehicles happens more quickly. As with the high sales scenario, three emphasis scenarios were studied within the low sales scenario: rapid, residential, and destination. The results from these additional scenarios can be found in Table A5, A6, and A7 in the appendix.

Comparison with the London Electric Vehicle Infrastructure Delivery Plan

This work complements the London Electric Vehicle Infrastructure Delivery Plan, published by the Mayor's Electric Vehicle Infrastructure Taskforce in June 2019. It shares much of the underlying methodology as well as many assumptions, including driver charging behavior and electric vehicle uptake. At the same time, this analysis makes several additions, most notably assessing charger need at the borough level and projecting needs up to 2035, and incorporates updated data and some alternative assumptions.

Table 5 provides comparisons for the results of this study versus the Delivery Plan, focusing on 2025 results for the whole of London under the high sales, rapid charging emphasis scenario. A positive value in the second column indicates that this analysis resulted in a higher estimate, whereas a negative value means that the result in the Delivery Plan was higher. A short explanation of the key drivers of the differences is provided.

Table 5. London-wide estimates in this analysis compared to estimates in the Delivery Plan.

Metric	This analysis compared to the Delivery Plan	Explanation
Electric vehicle stock	-3%	Incorporates updated sales data for 2018, 2019, and early 2020 that are slightly lower than Delivery Plan; this results in a slight lag in sales projections compared to the Delivery Plan while still meeting 2030 target.
Total public charging energy demand	-34%	Delayed uptake of PHVs compared to Delivery Plan based on 2020 licensing data; these vehicles represent a disproportionate share of electric VMT and charging energy.
Public residential chargers	-33%	Residential charging for taxis and PHVs based outside of London is not included in this analysis; Delivery Plan assumes all taxis and PHVs reside in London.
Public destination chargers	34%	Estimated utilization and power of chargers is lower in this analysis, based on data from London and other markets. Private cars have higher annual mileage. PHV PHEVs use more public destination chargers rather than rapid chargers in our analysis.
Public rapid chargers	-37%	Result of delayed PHV uptake and other effects above.
Total public chargers	-31%	Result of modeling and combination of effects above.

Overall, the results of this study forecast a requirement for fewer charge points in 2025 than the Delivery Plan. The primary cause is that we anticipate electric vehicle uptake

in private hire vehicles to lag behind the Delivery Plan's expectations, based on recent licensing data from 2018 up to early 2020.[44] Because these vehicles have far higher annual mileage (about 5 times private cars annual mileage), it creates a disproportionate drop in energy and charging demand. However, uptake quickly ramps up after 2025 to reach 100% electric PHV fleet and 100% electric sales for private cars in 2030. In contrast, public destination charging is higher in our scenario than in the Delivery Plan because we assume lower utilization as well as greater annual mileage for private cars, which are the primary users of destination charging. Still, destination slow to fast chargers represent only 6% of public chargers in our results in 2025.

The residential emphasis alternative scenario above can also be compared to the equivalent residential scenario in the Delivery Plan. Similarly, our analysis estimates 33% fewer total public chargers than the Delivery Plan by 2025, with fewer rapid and residential chargers but more destination chargers. Because charging demand will ramp up strongly after 2025, these discrepancies should be interpreted as a slight delay in charging need rather than a signal that less charging will be needed long term.

Case studies for selected boroughs

Boroughs have an important responsibility in charging infrastructure development in London. They control 95% of the road network and have the power to implement policies that favor clean transportation such as discounted or free parking for electric vehicles. Boroughs can also set more stringent emission standards than the London-wide restrictions. Each borough council will be critical in designing and implementing infrastructure plans that account for their unique demographics, geography, and transport patterns. This section provides results and introduces implementation recommendations for three boroughs: Westminster, Lambeth, and Redbridge.

Westminster

Westminster, a central borough home to London landmarks such as Big Ben, Buckingham Palace, and Victoria Station, has pledged to become carbon neutral by 2040. As part of their efforts, the City Council is strongly promoting a transition to electric vehicles. The borough is home to the UK's first "Electric Avenue" which is over half a mile in length and is composed of 24 lamppost charging points. It has also released a detailed electric vehicle Charging Infrastructure Strategy up to 2025.[45] This strategy aims to ensure electric vehicle charging meets the needs of every user, there is charging for every vehicle type, and the infrastructure is well-maintained and remains up-to-date with new technologies. Westminster has an ambition to deliver 1,000 public slow to fast charge points by the end of this fiscal year and aims for 33 rapid chargers by the end of March 2021. Additionally, the borough aims to install at least 200 new chargers every year up to 2025, support electric vehicle car club schemes, display up-to-date information on the location and number of chargers on the council website, and coordinate planning with UK Power Networks.

Westminster has a detailed electric vehicle strategy which recognizes that they will need substantially more charging in the coming years. Figure 10 below outlines the number of public chargers in place in 2020 and the estimated chargers required in 2025, 2030, and 2035 in Westminster. The hashed bars represent the charging already in place as of 2020, while the solid bars indicate additional charging needed to enable projected electric vehicle uptake. As shown in Figure 10, charge points in Westminster would need to increase from 478 in 2020 to 1,391 in 2030 to meet the city's goals. As of June 2020, only 5% of the 2025 rapid chargers are in place in Westminster.

44 "Taxis and Private Hire Vehicle Licensing Information," Transport for London.

45 City of Westminster, "An electric vision for a greener city," (2019), https://committees.westminster.gov.uk/documents/s36600/366_1%20-%20WCC_EV%20Strategy%20Document_web_AW3.pdf.

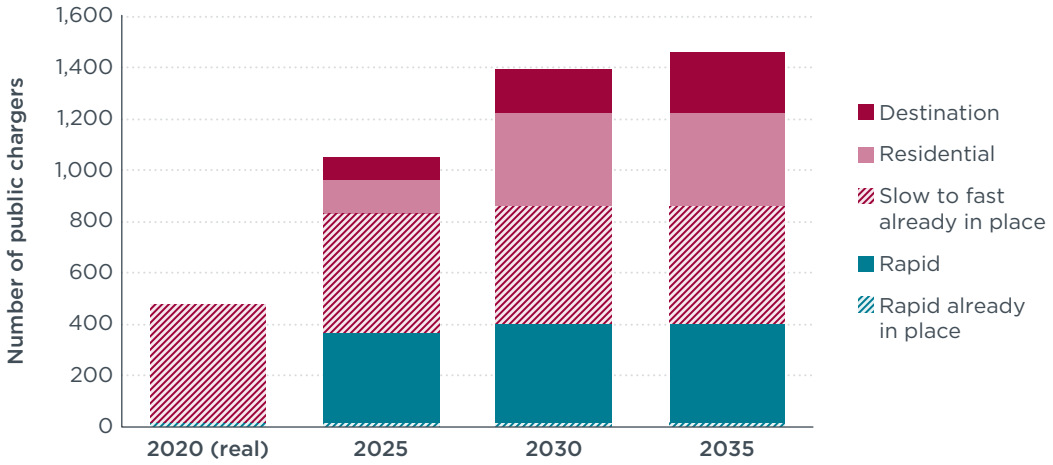

Figure 10. Public charging infrastructure for Westminster up to 2035.

Figure 11 displays the contribution of each vehicle category to the total charging energy demand in 2025 (left) and 2030 (right). Because Westminster has a relatively low car ownership rate but a high number of commuting and commercial visits, most of the borough's charging demand comes from private hire vehicles and taxis. These vehicles will account for 92% of rapid charging activity in Westminster in 2025. Private hire vehicles will account for 56% of overall electricity demand in 2025, and this percentage goes up to about 75% when including taxis.

Figure 11. Breakdown of charging electricity demand by vehicle segment in Westminster in 2025 and 2030.

Because Westminster ranks among the best in public transport, walking, and cycling accessibility among London boroughs, there is less need to develop destination and workplace charging to serve commuters or shoppers coming from other areas. Although Westminster has one of the lowest car ownership rates in London,[46] we estimate that only about 40% of electric vehicle owners in the borough will have access to home charging due to the prevalence of multi-unit dwellings. Public residential charging will therefore be important in the short term, accounting for 13% of electricity demand and the majority of chargers in 2030. However, the Mayor's goal to reduce private car dependency suggests that these will be needed less in the long term if there are fewer cars.

Rapid charging is well suited for Westminster's dense, space-constrained environment and offers a flexible solution for a variety of vehicles: PHVs and taxis, commercial vehicles, and perhaps eventually public transportation and larger commercial vehicles.

46 Transport for London, "How many cars are in London and who owns them," (2012), http://content.tfl.gov.uk/technical-note-12-how-many-cars-are-there-in-london.pdf.

It would be valuable for the Westminster City Council to work with taxis companies and PHVs as well as UK Power Networks to make sure that the appropriate number of rapid chargers are installed at the right locations.

Westminster is home to a large fraction of shared car club vehicles, which could account for 9% of the borough's electric cars in 2025. As they can require a mix of public and private chargers depending on the business model, it will be important to work with the car club operators to locate appropriate sites for private chargers or find ways to integrate these shared vehicles into the public charging network.

Lambeth

The inner London borough of Lambeth is slightly above the London average in terms of electric vehicle uptake in 2019, and the borough has a comprehensive strategy to accelerate this shift. In its Air Quality Action Plan (2017-2022), Lambeth plans to increase the number of hydrogen, electric, hybrid, bio-methane, and cleaner vehicles in the borough's fleet by March 2022.[47] It is also working with car clubs to increase the amount of electric, hydrogen, and ultra-low emission vehicles in their fleet.

Achieving such plans will require an extensive charging network, which Lambeth has already begun to construct. The borough had 18 rapid and 162 public slow to fast chargers in place as of mid-2020, including 121 lamppost column chargers installed by the council. The borough is focused on expanding lamppost column chargers, installing new ultra-rapid charging stations (125 kW and above), and ensuring that taxi drivers and drivers with disabilities have reliable residential charging solutions.

To enable electric vehicle growth in Lambeth, and London more widely, we estimate that many more chargers will be needed. Figure 12 illustrates the number of public chargers in place in 2020 and the estimated chargers required in 2025, 2030, and 2035 in Lambeth. The hashed bars represent the charging already in place as of 2020, while the solid bars indicate additional charging needed to enable projected electric vehicle uptake. As shown, Lambeth chargers would need to increase from 262 in 2020 to 1,079 in 2030 to help meet London's goal.

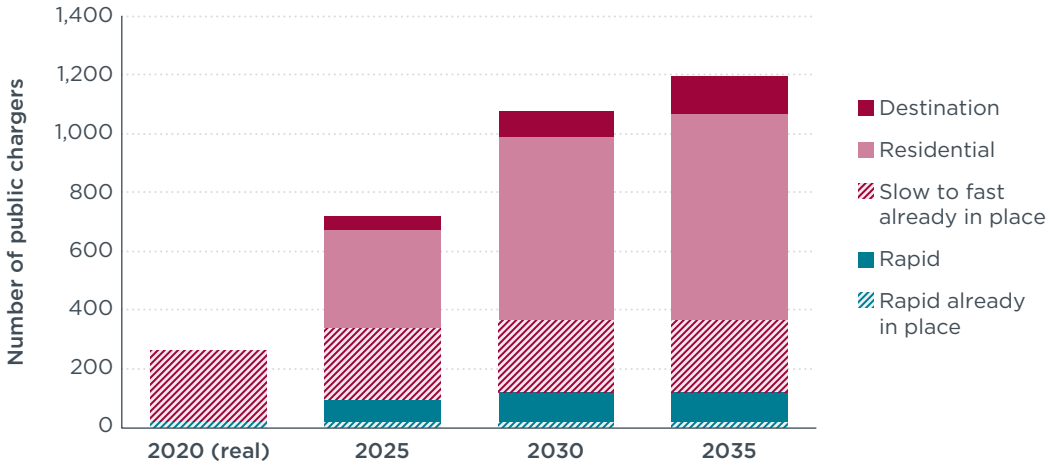

Figure 12. Public charging infrastructure up to 2035 for Lambeth.

This figure illustrates the different near-term and long-term priorities for providing charging in Lambeth. In the near term (up to 2025), rapid charging will be vital, especially in supporting the electrification of PHVs and taxis. Rapid chargers are projected to provide the majority of energy demand for electric vehicles in Lambeth

47 London borough of Lambeth, "Air Quality Action Plan 2017-2022," (June 2016), https://www.lambeth.gov.uk/sites/default/files/pcc-air-quality-action-plan-2017-2022.pdf.

in all years (42% in 2030). In the longer term, however, the focus shifts to residential and destination slow to fast chargers, which more often serve private and light goods vehicles. To reach its estimated 2030 targets, Lambeth would need to expand their public charging by more than fourfold and its rapid charging by more than sixfold.

Figure 13 illustrates the contribution of the different vehicle types to Lambeth's electricity demand in 2025 (left) and in 2030 (right). The figure indicates that private hire vehicles will provide the greatest demand for charging in Lambeth, making up 66% of the electricity demand in 2025 (down to 55% in 2030), followed by private passenger cars (19% in 2025 up to 29% in 2030).

Figure 13. Breakdown of charging electricity demand by vehicle segment in Lambeth in 2025 and 2030.

This distribution suggests that it would be valuable for Lambeth Council to cooperate with private hire vehicle operating companies by providing residential (public or private) charging options for these drivers to reduce the burden on the rapid charging system. As with other boroughs with a high reliance on rapid charging, it will also be important to work with the local distribution network operator to locate these chargers in grid-friendly locations.

Redbridge

Redbridge, a diverse borough in outer northeast London, has an extensive portfolio of infrastructure projects to accelerate its own shift to electric mobility. The borough is constructing several mobility hubs and a community hub with electric car club vehicles, fast charging, and amenities; expanding their lamppost column charging program; and is the first borough to feature wireless charging stations as part of an Innovate UK project. It has committed to have 200 public chargers by 2021, and requires new developments to provide charging for at least 20% of car parking spaces and the remainder to have electricity provision for active charge points to be easily installed.[48] It is also taking action on workplace charging by implementing a Workplace Travel Project which includes electric vehicle chargers and electric car clubs for use by staff and residents.[49]

Although Redbridge lags slightly behind the London average in electric vehicle uptake, this multi-faceted strategy sets the stage for a substantial increase, which will require significantly more charging. Figure 14 displays the number of public chargers in place in 2020 and the estimated chargers required in 2025, 2030, and 2035 in Redbridge. The hashed bars represent the charging already in place as of 2020, while the solid bars indicate additional charging needed to enable projected electric vehicle uptake. As shown, the public charger volume in Redbridge would need to increase from 33 in 2020 to 2,117 in 2030 based on our modeling of London's goals.

48 "Redbridge - Electric Vehicles," London Borough of Redbridge, accessed August 4, 2020, https://www.redbridge.gov.uk/roads-and-pavements/electric-vehicles/.

49 London Borough of Redbridge, "London Borough of Redbridge Third Local Implementation Plan," (June 2019), https://www.redbridge.gov.uk/media/6914/lb-redbridge-local-implementation-plan-june-2019.pdf.

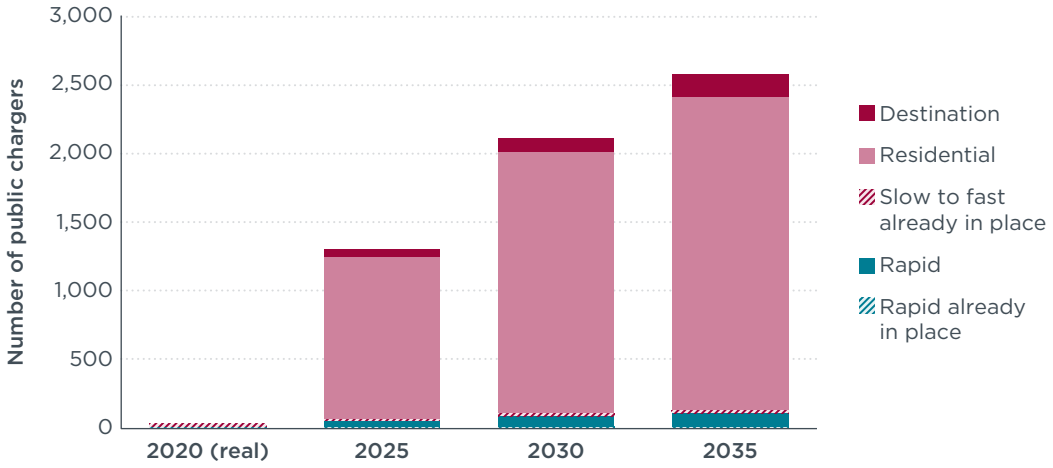

Figure 14. Public charging infrastructure up to 2035 for Redbridge.

According to these projections, Redbridge will require one of the steepest rates of growth among all boroughs to meet the estimated charging needs in 2025 and beyond. The vast majority of this would come in the form of public residential charging to provide reliable home charging for those without off-street parking. Redbridge is home to a high concentration of PHV and taxi drivers, who are expected to make up more than 80% of public residential charging demand in 2025, although this percentage declines later as uptake increases among private cars. In comparison, Redbridge already has about 30% of their 2025 rapid charging needs in place, twice the London average, and planned projects should help to further raise this share. Additional rapid charging may be able to substitute for home charging in the near term as the borough builds its network.

Figure 15 illustrates the contribution of the different vehicle types to the total charging energy demand within Redbridge in 2025 and 2030. As with other parts of outer London, Redbridge has relatively lower access to public transit compared to inner boroughs. Therefore, the long-term electrification of the private car fleet will be a key part of reducing the borough's emissions, and this analysis shows that private cars will eventually represent a large majority of charging demand. Even with an emphasis on rapid charging, the public residential and destination charging infrastructure will need to be widely expanded in order to accommodate the electric vehicle growth in private vehicles, fleets, and light goods vehicles over the following decades.

Figure 15. Breakdown of charging electricity demand by vehicle segment in Redbridge in 2025 and 2030.

Residential chargers account for 91% of public chargers and provide approximately 45% of total charging energy in 2030. The borough is home to a large number of private hire vehicle drivers for whom reliable home charging is especially important. As of mid-2020,

the borough only has less than 1.5% of the estimated public slow to fast charging needed by 2025. The borough is proactively working to address this problem by developing a software tool to ensure that charger locations are optimized in residential areas. Private home charging also plays a large role in Redbridge. This indicates an opportunity for the borough to facilitate the purchase and installation of private home chargers, including helping residents to take advantage of the UK Government's Homecharge scheme.

Conclusions

This working paper assesses charging infrastructure needs in London from 2020 until 2035 to support its zero-emission vehicle goals, including estimates for charging needs in each borough and additional analysis on the boroughs of Westminster, Lambeth, and Redbridge. From this investigation, we draw the following conclusions:

London will need significantly more charge points to sustain its electric vehicle leadership. London is one of the largest electric vehicle markets in the world and has enacted innovative supporting policies to spur uptake. In order to achieve the Mayor's ambitions —including that all new vehicles be zero-emission by 2030—much more charging infrastructure of all kinds will be needed. Powering a forecasted 947,000 electric vehicles across London will require public charging infrastructure to expand to more than 26,800 public chargers by 2025 and 44,000 public chargers by 2030, an annual growth rate of over 20% from 2020. Private chargers at home, at workplaces, and for car clubs will also need to be greatly expanded by a factor of 18 from 2020. This long-term growth can be achieved with coordination and cost sharing among the London and UK governments, the boroughs, fleet and PHV operators, and the power sector.

High-mileage fleets drive charging demand in the near term. Taxis and private hire vehicles drive almost 6 times more than private passenger cars; they are also a priority in London's electrification strategy. All PHVs and taxis are required to be zero-emission capable no later than 2033. Consequently, these fleets account for 55% of electric vehicle miles traveled in London and over 65% of charging energy in inner London in 2025. After 2025, growth in the private electric vehicle market leads to a greater demand for residential and destination-focused public chargers. As London evaluates timelines for the electrification of different parts of the light-duty vehicle fleet, it will be important to update this analysis accordingly and ensure that implementation plans account for the charging patterns and spatial distribution of different vehicle types.

Additional efforts will be needed to ensure equal charging infrastructure access across London. Early electric vehicle growth and the accompanying charging infrastructure development has been uneven. Central London boroughs have experienced greater electric vehicle uptake and deployed more public charging infrastructure than boroughs in outer London, especially compared to those in east and south London. Some central boroughs have met up to 70% of their 2025 charging needs, while that figure is below 3% in three outer London boroughs. To ensure that charging access is not an impediment to the electric vehicle transition for any drivers, including low-income and taxi or PHV drivers, these boroughs will require a greater year-over-year increase in charging infrastructure.

Different charging combinations can suit the diverse needs of the boroughs. Due to their diverse housing, demographic, and transportation characteristics, charging needs vary widely at the borough level. Dense inner London boroughs like Westminster and Lambeth will need many rapid chargers to serve taxi and PHV activity, whereas outer London boroughs with higher private car ownership rates, such as Redbridge, will rely more heavily on a mix of public and private residential charging. Considering that over 30% of charging energy will come from rapid charging in 2030 (and over 40% in inner London), close coordination with power utilities will be needed on installations

and upgrades. Boroughs such as Westminster, Redbridge, and Lambeth have already adopted a robust set of infrastructure programs, such as installing lamppost chargers, creating mobility hubs, and locating grid-friendly rapid chargers. These projects will be important in determining the most cost-effective and user-friendly solutions, enabling all Londoners to experience the benefits of electric vehicles.

This analysis points to several other areas for future research. COVID-19 has dramatically reshaped transport patterns within London and has resulted in lower new vehicle sales in early 2020. This analysis may need to be updated and reconsidered in light of these impacts and proposed green recovery policies. An important next step is also to investigate the location of charging infrastructure within boroughs based on power grid availability, user demand, destinations, and traffic flows. Such studies have been conducted in other cities such as Oslo[50] and are important in maximizing the return on infrastructure investments. Building this charging infrastructure will require significant outlay; financing models and taxation systems will need to be developed to distribute the costs among all levels of government, fleets, and the private sector. Finally, further research is needed to develop implementation strategies and policy guidance models at the London and borough levels to ensure charging growth within the diverse contexts of the 33 local authorities.

London has set the stage for the rapid electrification of its private hire vehicles, taxis, private cars, light goods vehicles, and car clubs with a suite of supportive policies and incentives. Such growth, however, can only occur along with sufficient charging infrastructure, which will need to greatly expand in every borough over the coming decades. Through collaboration with many stakeholders, London and its boroughs can develop a flourishing charging ecosystem for its future zero-emission vehicle fleet, allowing London to remain a leader in sustainable, climate-friendly transport.

50 Bymiljøetaten, Oslo kommune, "Kartlegging av ladebehov i Oslo kommune [Mapping of charging needs in Oslo municipality]," (Oslo, November 28, 2019), https://www.oslo.kommune.no/getfile.php/13354701-1576848117/Tjenester og tilbud/Gate, transport og parkering/Parkering/Kartlegging av ladebehov i Oslo kommune.pdf.

Appendix

This appendix provides additional details on the results of our charging infrastructure modeling at the borough level under our primary scenario (Table A2), high sales residential and destination (Table A3 and Table A4), low sales rapid, residential, and destination (Table A5, Table A6, and Table A7), as well as additional details on the underlying methodology and assumptions (Table A9). Table A8 displays the state of the public charging infrastructure in each borough as of June 2020. Table A1 and Figure A1 provide a key to the inner and outer borough categories used throughout the paper.

Borough key

Table A1. Inner and outer London boroughs, as defined by the Office for National Statistics.

Inner London boroughs	ID on map
Camden	6
City of London[a]	7
Hackney	12
Hammersmith and Fulham	13
Haringey	14
Islington	19
Kensington and Chelsea	20
Lambeth	22
Lewisham	23
Newham	25
Southwark	28
Tower Hamlets	30
Wandsworth	32
Westminster	33

Outer London boroughs	ID on map
Barking and Dagenham	1
Barnet	2
Bexley	3
Brent	4
Bromley	5
Croydon	8
Ealing	9
Enfield	10
Greenwich	11
Harrow	15
Havering	16
Hillingdon	17
Hounslow	18
Kingston upon Thames	21
Merton	24
Redbridge	26
Richmond upon Thames	27
Sutton	29
Waltham Forest	31

[a] City of London is not a borough and is independent from Greater London but is included as a borough-level division for the purposes of this analysis.

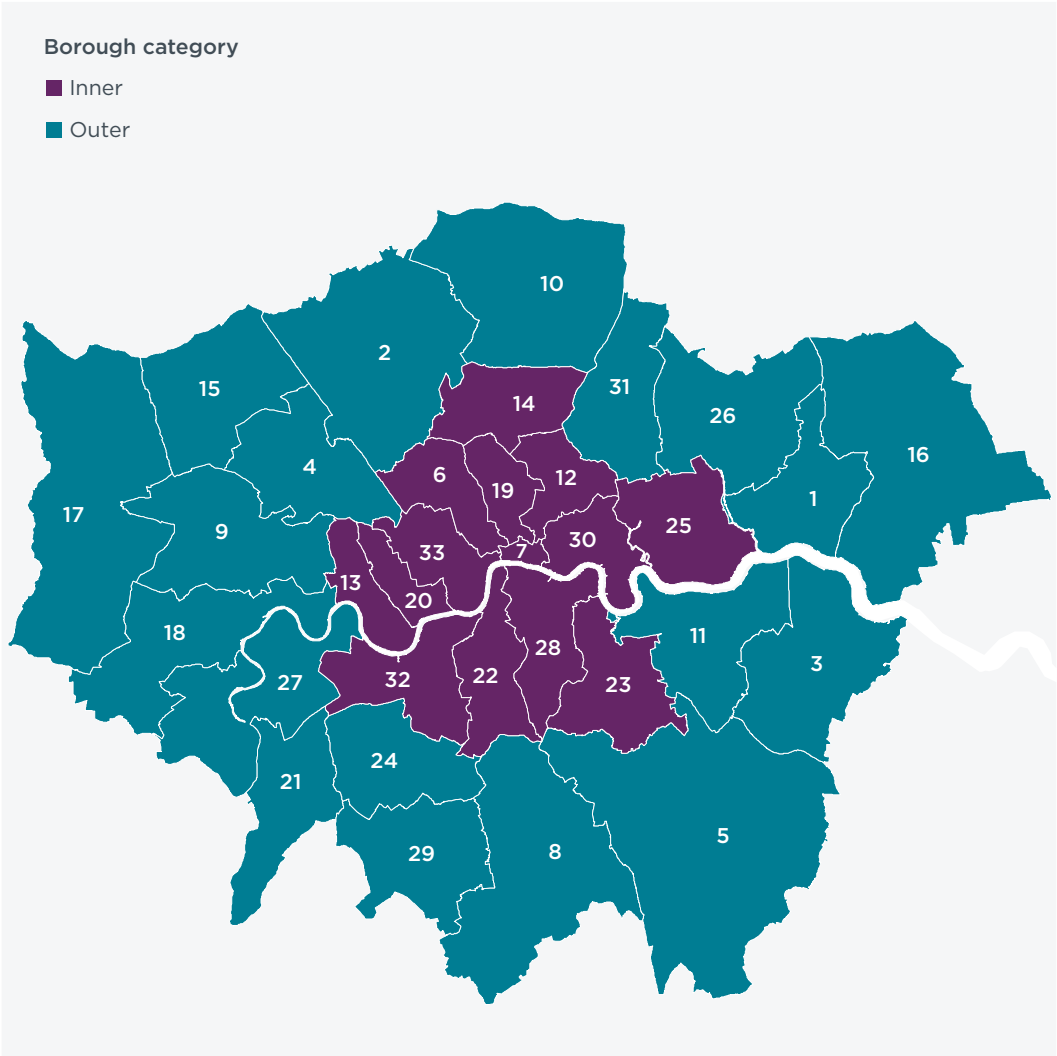

Figure A1. Maps of inner and outer London boroughs.

Detailed results for charging infrastructure projections by borough

Table A2. Number of public and private chargers by borough from 2025 to 2035, primary rapid charging emphasis scenario.

Borough	Public destination chargers			Public rapid chargers			Public residential chargers			Private home chargers			Private workplace chargers			Private car club chargers		
	2025	2030	2035	2025	2030	2035	2025	2030	2035	2025	2030	2035	2025	2030	2035	2025	2030	2035
City of London	19	38	56	60	62	62	34	40	40	269	497	527	42	155	286	107	166	176
Barking and Dagenham	32	70	105	34	61	77	756	1,278	1,572	1,595	6,669	12,712	50	185	342	50	78	82
Barnet	79	154	223	102	153	168	1,056	1,795	2,244	6,999	21,536	35,730	92	338	624	93	144	152
Bexley	44	98	148	40	76	98	507	986	1,441	2,963	13,237	25,904	68	249	459	58	90	95
Brent	57	116	170	61	99	114	1,117	1,785	2,076	3,834	12,769	21,961	73	268	495	78	121	128
Bromley	64	139	209	60	106	133	516	1,099	1,696	4,925	20,225	38,165	91	335	620	78	121	128
Camden	52	102	147	163	170	170	492	697	712	2,693	6,474	9,165	45	165	305	602	934	989
Croydon	67	143	215	67	117	145	794	1,513	2,094	4,585	18,658	34,857	76	281	519	90	140	148
Ealing	71	141	204	78	122	138	1,214	2,001	2,393	5,005	15,620	26,109	90	332	614	79	123	130
Enfield	59	127	190	47	91	120	1,086	1,858	2,397	3,570	14,196	26,461	87	321	594	78	121	128
Greenwich	42	89	132	52	83	99	609	1,118	1,493	2,343	9,137	16,949	60	220	406	68	106	112
Hackney	38	75	109	84	89	89	494	715	746	1,453	4,830	8,410	30	109	201	156	242	256
Hammersmith and Fulham	40	77	110	76	80	80	456	655	679	2,416	5,981	8,667	38	141	260	103	160	170
Haringey	42	84	123	56	61	61	586	878	941	2,227	7,387	12,795	42	154	284	148	230	243
Harrow	44	93	138	39	71	90	722	1,222	1,528	3,718	13,763	24,853	53	195	361	59	91	96
Havering	48	107	164	48	88	112	516	1,018	1,539	3,207	14,489	28,454	74	271	501	61	95	100
Hillingdon	76	159	236	97	149	167	1,070	1,805	2,243	5,817	20,512	36,280	179	663	1,225	72	112	118
Hounslow	56	115	169	55	91	108	950	1,584	1,924	3,584	12,538	22,158	110	407	752	64	99	104
Islington	41	80	115	99	104	104	450	632	656	1,836	4,868	7,440	35	130	239	491	761	806
Kensington and Chelsea	37	72	103	146	152	152	331	495	532	2,288	5,464	7,707	22	81	149	86	132	140
Kingston upon Thames	35	74	109	35	57	69	320	616	870	2,568	9,518	17,252	52	190	352	42	64	68
Lambeth	44	89	129	94	99	99	577	872	949	2,224	7,628	13,442	42	153	282	730	1,133	1,199
Lewisham	40	83	121	41	45	45	467	766	908	2,008	8,322	15,835	43	156	288	168	261	276
Merton	37	78	115	48	76	89	591	1,064	1,387	2,471	9,003	16,175	47	173	319	48	75	79
Newham	48	99	145	64	68	68	1,204	1,676	1,676	2,122	7,800	14,071	57	210	387	196	304	321
Redbridge	50	106	159	50	88	110	1,199	1,923	2,304	3,469	12,819	23,138	57	209	387	71	110	117
Richmond upon Thames	43	85	124	56	84	92	371	746	1,058	3,265	10,772	18,567	48	176	325	47	72	76
Southwark	45	89	129	89	95	95	582	856	916	2,199	7,014	11,942	48	175	323	651	1,009	1,068
Sutton	39	85	128	35	65	84	440	866	1,252	2,554	11,003	21,058	58	214	394	48	75	79
Tower Hamlets	48	97	140	106	112	112	1,050	1,410	1,410	1,969	5,875	9,578	61	226	417	181	281	297
Waltham Forest	47	101	151	49	83	100	831	1,421	1,806	2,073	8,400	15,870	49	178	330	65	101	107
Wandsworth	49	97	141	103	110	110	637	978	1,079	3,215	9,938	16,611	53	193	357	181	281	297
Westminster	86	167	241	368	380	380	596	705	705	3,995	8,278	10,141	66	242	447	1,173	1,820	1,926

Table A3. Number of public and private chargers by borough from 2025 to 2035, high sales residential charging scenario.

Borough	Public destination chargers			Public rapid chargers			Public residential chargers			Private home chargers			Private workplace chargers			Private car club chargers		
	2025	2030	2035	2025	2030	2035	2025	2030	2035	2025	2030	2035	2025	2030	2035	2025	2030	2035
City of London	15	36	55	36	37	37	47	56	56	269	497	527	42	155	286	107	166	176
Barking and Dagenham	25	65	103	14	18	18	1,040	1,837	2,281	1,595	6,669	12,712	50	185	342	50	78	82
Barnet	62	144	218	45	55	55	1,461	2,563	3,216	6,999	21,536	35,730	92	338	624	93	144	152
Bexley	35	91	145	17	22	22	705	1,426	2,098	2,963	13,237	25,904	68	249	459	58	90	95
Brent	45	108	166	27	33	33	1,534	2,547	2,980	3,834	12,769	21,961	73	268	495	78	121	128
Bromley	51	130	205	25	31	31	717	1,580	2,451	4,925	20,225	38,165	91	335	620	78	121	128
Camden	41	95	143	94	98	98	673	974	986	2,693	6,474	9,165	45	165	305	602	934	989
Croydon	53	134	210	29	37	37	1,096	2,178	3,037	4,585	18,658	34,857	76	281	519	90	140	148
Ealing	56	131	200	31	39	39	1,683	2,870	3,447	5,005	15,620	26,109	90	332	614	79	123	130
Enfield	46	118	186	18	23	23	1,499	2,671	3,476	3,570	14,196	26,461	87	321	594	78	121	128
Greenwich	34	83	130	24	29	29	844	1,609	2,163	2,343	9,137	16,949	60	220	406	68	106	112
Hackney	30	70	107	48	50	50	673	1,006	1,051	1,453	4,830	8,410	30	109	201	156	242	256
Hammersmith and Fulham	32	72	108	41	43	43	626	918	943	2,416	5,981	8,667	38	141	260	103	160	170
Haringey	33	79	120	31	32	32	799	1,238	1,329	2,227	7,387	12,795	42	154	284	148	230	243
Harrow	35	87	135	16	20	20	991	1,747	2,202	3,718	13,763	24,853	53	195	361	59	91	96
Havering	38	100	160	21	26	26	719	1,471	2,240	3,207	14,489	28,454	74	271	501	61	95	100
Hillingdon	60	148	231	45	55	55	1,473	2,586	3,240	5,817	20,512	36,280	179	663	1,225	72	112	118
Hounslow	43	107	165	22	28	28	1,313	2,278	2,789	3,584	12,538	22,158	110	407	752	64	99	104
Islington	32	75	113	56	59	59	616	887	915	1,836	4,868	7,440	35	130	239	491	761	806
Kensington and Chelsea	30	67	100	84	87	87	457	691	734	2,288	5,464	7,707	22	81	149	86	132	140
Kingston upon Thames	28	69	107	15	18	18	444	886	1,259	2,568	9,518	17,252	52	190	352	42	64	68
Lambeth	35	83	126	53	56	56	788	1,230	1,339	2,224	7,628	13,442	42	153	282	730	1,133	1,199
Lewisham	32	77	119	21	22	22	639	1,087	1,294	2,008	8,322	15,835	43	156	288	168	261	276
Merton	30	73	113	22	26	26	817	1,526	2,001	2,471	9,003	16,175	47	173	319	48	75	79
Newham	38	92	142	35	37	37	1,632	2,362	2,362	2,122	7,800	14,071	57	210	387	196	304	321
Redbridge	40	99	155	20	26	26	1,645	2,747	3,317	3,469	12,819	23,138	57	209	387	71	110	117
Richmond upon Thames	34	80	122	25	31	31	520	1,074	1,527	3,265	10,772	18,567	48	176	325	47	72	76
Southwark	35	83	126	51	53	53	794	1,204	1,289	2,199	7,014	11,942	48	175	323	651	1,009	1,068
Sutton	30	79	125	15	19	19	611	1,253	1,829	2,554	11,003	21,058	58	214	394	48	75	79
Tower Hamlets	38	90	137	60	63	63	1,426	1,981	1,981	1,969	5,875	9,578	61	226	417	181	281	297
Waltham Forest	37	94	147	23	28	28	1,146	2,039	2,611	2,073	8,400	15,870	49	178	330	65	101	107
Wandsworth	39	91	138	57	60	60	871	1,376	1,516	3,215	9,938	16,611	53	193	357	181	281	297
Westminster	68	157	236	214	221	221	821	976	976	3,995	8,278	10,141	66	242	447	1,173	1,820	1,926

Table A4. Number of public and private chargers by borough from 2025 to 2035, high sales destination charging scenario.

Borough	Public destination chargers			Public rapid chargers			Public residential chargers			Private home chargers			Private workplace chargers			Private car club chargers		
	2025	2030	2035	2025	2030	2035	2025	2030	2035	2025	2030	2035	2025	2030	2035	2025	2030	2035
City of London	102	192	260	32	33	33	40	47	47	269	497	527	42	155	286	107	166	176
Barking and Dagenham	105	260	401	14	19	19	975	1,623	1,903	1,595	6,669	12,712	50	185	342	50	78	82
Barnet	266	580	837	45	59	59	1,322	2,217	2,663	6,999	21,536	35,730	92	338	624	93	144	152
Bexley	135	341	531	17	26	29	645	1,201	1,685	2,963	13,237	25,904	68	249	459	58	90	95
Brent	186	429	638	26	35	35	1,429	2,273	2,530	3,834	12,769	21,961	73	268	495	78	121	128
Bromley	197	482	743	26	38	41	641	1,306	1,945	4,925	20,225	38,165	91	335	620	78	121	128
Camden	275	511	672	82	85	85	618	885	885	2,693	6,474	9,165	45	165	305	602	934	989
Croydon	211	512	785	29	42	43	1,005	1,859	2,455	4,585	18,658	34,857	76	281	519	90	140	148
Ealing	234	528	776	31	41	41	1,525	2,494	2,864	5,005	15,620	26,109	90	332	614	79	123	130
Enfield	177	447	699	18	27	30	1,399	2,338	2,882	3,570	14,196	26,461	87	321	594	78	121	128
Greenwich	143	336	506	22	29	29	768	1,373	1,756	2,343	9,137	16,949	60	220	406	68	106	112
Hackney	169	340	461	42	44	44	639	932	941	1,453	4,830	8,410	30	109	201	156	242	256
Hammersmith and Fulham	168	337	459	36	38	38	569	825	833	2,416	5,981	8,667	38	141	260	103	160	170
Haringey	154	335	480	28	29	29	753	1,133	1,171	2,227	7,387	12,795	42	154	284	148	230	243
Harrow	132	320	490	17	25	27	924	1,541	1,839	3,718	13,763	24,853	53	195	361	59	91	96
Havering	152	381	590	21	31	34	658	1,234	1,796	3,207	14,489	28,454	74	271	501	61	95	100
Hillingdon	264	601	887	44	59	59	1,365	2,271	2,698	5,817	20,512	36,280	179	663	1,225	72	112	118
Hounslow	177	419	632	22	30	31	1,208	1,992	2,316	3,584	12,538	22,158	110	407	752	64	99	104
Islington	190	371	499	50	52	52	573	812	822	1,836	4,868	7,440	35	130	239	491	761	806
Kensington and Chelsea	224	399	505	74	76	76	401	601	632	2,288	5,464	7,707	22	81	149	86	132	140
Kingston upon Thames	110	260	394	15	21	22	400	745	1,012	2,568	9,518	17,252	52	190	352	42	64	68
Lambeth	192	391	537	46	49	49	743	1,124	1,178	2,224	7,628	13,442	42	153	282	730	1,133	1,199
Lewisham	133	307	456	19	20	20	600	972	1,104	2,008	8,322	15,835	43	156	288	168	261	276
Merton	128	296	443	21	27	27	745	1,311	1,636	2,471	9,003	16,175	47	173	319	48	75	79
Newham	174	387	562	30	32	32	1,585	2,248	2,248	2,122	7,800	14,071	57	210	387	196	304	321
Redbridge	158	385	589	20	29	30	1,552	2,462	2,819	3,469	12,819	23,138	57	209	387	71	110	117
Richmond upon Thames	147	326	473	25	32	32	446	876	1,206	3,265	10,772	18,567	48	176	325	47	72	76
Southwark	190	387	533	44	46	46	748	1,105	1,144	2,199	7,014	11,942	48	175	323	651	1,009	1,068
Sutton	118	297	462	15	22	24	557	1,056	1,462	2,554	11,003	21,058	58	214	394	48	75	79
Tower Hamlets	216	435	593	53	56	56	1,381	1,897	1,897	1,969	5,875	9,578	61	226	417	181	281	297
Waltham Forest	156	378	575	21	28	28	1,068	1,787	2,171	2,073	8,400	15,870	49	178	330	65	101	107
Wandsworth	214	432	588	50	52	52	807	1,240	1,320	3,215	9,938	16,611	53	193	357	181	281	297
Westminster	542	948	1,215	188	194	194	724	858	858	3,995	8,278	10,141	66	242	447	1,173	1,820	1,926

Table A5. Number of public and private chargers by borough from 2025 to 2035, low sales rapid charging scenario.

Borough	Public destination chargers			Public rapid chargers			Public residential chargers			Private home chargers			Private workplace chargers			Private car club chargers		
	2025	2030	2035	2025	2030	2035	2025	2030	2035	2025	2030	2035	2025	2030	2035	2025	2030	2035
City of London	8	17	35	61	62	62	21	24	24	111	202	336	15	64	178	107	166	176
Barking and Dagenham	15	31	66	26	40	53	656	970	1,215	807	3,230	8,118	18	77	213	50	78	82
Barnet	35	68	140	82	110	124	819	1,242	1,693	3,111	9,670	22,421	33	140	389	93	144	152
Bexley	20	43	93	30	49	67	405	656	1,051	1,319	5,991	16,196	24	103	286	58	90	95
Brent	26	52	107	48	68	82	948	1,363	1,634	1,860	6,080	13,996	26	111	308	78	121	128
Bromley	29	62	131	46	69	92	378	674	1,205	2,055	8,881	23,611	33	139	386	78	121	128
Camden	24	46	92	160	165	165	391	526	578	1,177	2,833	5,830	16	69	190	602	934	989
Croydon	30	64	135	53	79	102	638	1,036	1,543	2,024	8,438	21,693	27	117	323	90	140	148
Ealing	32	62	128	59	83	99	959	1,425	1,821	2,287	7,158	16,523	32	138	382	79	123	130
Enfield	26	56	120	34	56	80	926	1,372	1,839	1,748	6,734	16,745	31	134	370	78	121	128
Greenwich	19	40	83	42	58	71	483	765	1,100	1,057	4,167	10,640	21	91	253	68	106	112
Hackney	18	34	69	81	84	84	437	588	623	679	2,247	5,373	11	45	125	156	242	256
Hammersmith and Fulham	18	34	70	71	74	74	353	481	541	1,037	2,593	5,508	14	59	162	103	160	170
Haringey	20	38	78	51	54	54	506	699	767	1,010	3,376	8,103	15	64	177	148	230	243
Harrow	20	41	87	28	45	61	610	908	1,179	1,741	6,407	15,668	19	81	225	59	91	96
Havering	21	48	103	38	59	78	411	667	1,120	1,426	6,545	17,759	26	113	312	61	95	100
Hillingdon	33	70	147	82	110	125	892	1,328	1,727	2,696	9,496	22,867	64	275	762	72	112	118
Hounslow	25	50	106	42	60	76	785	1,163	1,476	1,686	5,858	14,047	39	169	468	64	99	104
Islington	19	36	73	96	100	100	374	496	542	821	2,179	4,759	13	54	149	491	761	806
Kensington and Chelsea	17	32	65	143	148	148	227	324	401	952	2,300	4,863	8	34	93	86	132	140
Kingston upon Thames	16	33	68	27	39	49	243	400	633	1,100	4,214	10,718	19	79	219	42	64	68
Lambeth	21	40	82	89	93	93	499	692	771	1,004	3,479	8,501	15	64	176	730	1,133	1,199
Lewisham	19	38	77	35	37	37	400	581	709	879	3,755	9,919	15	65	179	168	261	276
Merton	17	35	72	39	54	65	468	735	1,030	1,118	4,115	10,156	17	72	199	48	75	79
Newham	23	45	92	58	61	61	1,134	1,491	1,491	1,151	3,960	9,146	21	87	241	196	304	321
Redbridge	23	47	100	38	57	75	1,050	1,496	1,826	1,778	6,260	14,794	21	87	241	71	110	117
Richmond upon Thames	19	38	78	46	61	69	242	435	740	1,347	4,641	11,492	17	73	202	47	72	76
Southwark	21	40	82	85	89	89	502	683	752	997	3,196	7,577	17	73	201	651	1,009	1,068
Sutton	17	38	80	26	42	58	351	578	913	1,127	4,970	13,104	21	89	246	48	75	79
Tower Hamlets	22	44	89	103	107	107	981	1,263	1,263	1,041	2,977	6,306	22	94	260	181	281	297
Waltham Forest	22	45	95	40	57	71	706	1,049	1,382	1,020	4,001	10,094	18	74	205	65	101	107
Wandsworth	23	44	89	97	102	102	523	737	854	1,402	4,415	10,455	19	80	222	181	281	297
Westminster	38	74	151	365	376	376	417	469	469	1,682	3,463	6,461	24	101	279	1,173	1,820	1,926

Table A6. Number of public and private chargers by borough from 2025 to 2035, low sales residential charging scenario.

Borough	Public destination chargers			Public rapid chargers			Public residential chargers			Private home chargers			Private workplace chargers			Private car club chargers		
	2025	2030	2035	2025	2030	2035	2025	2030	2035	2025	2030	2035	2025	2030	2035	2025	2030	2035
City of London	6	16	35	37	38	38	29	32	32	111	202	336	15	64	178	107	166	176
Barking and Dagenham	11	29	65	14	16	16	899	1,378	1,752	807	3,230	8,118	18	77	213	50	78	82
Barnet	26	63	138	45	52	52	1,125	1,759	2,418	3,111	9,670	22,421	33	140	389	93	144	152
Bexley	15	40	92	17	20	20	558	938	1,524	1,319	5,991	16,196	24	103	286	58	90	95
Brent	19	48	105	26	31	31	1,297	1,928	2,335	1,860	6,080	13,996	26	111	308	78	121	128
Bromley	22	57	129	24	28	28	521	961	1,738	2,055	8,881	23,611	33	139	386	78	121	128
Camden	18	43	91	96	99	99	534	735	802	1,177	2,833	5,830	16	69	190	602	934	989
Croydon	23	59	133	29	34	34	876	1,475	2,229	2,024	8,438	21,693	27	117	323	90	140	148
Ealing	24	58	126	31	36	36	1,318	2,022	2,611	2,287	7,158	16,523	32	138	382	79	123	130
Enfield	20	52	118	17	20	20	1,271	1,951	2,652	1,748	6,734	16,745	31	134	370	78	121	128
Greenwich	15	37	82	24	26	26	664	1,089	1,587	1,057	4,167	10,640	21	91	253	68	106	112
Hackney	14	32	68	48	50	50	597	826	877	679	2,247	5,373	11	45	125	156	242	256
Hammersmith and Fulham	14	32	69	42	44	44	483	673	752	1,037	2,593	5,508	14	59	162	103	160	170
Haringey	15	36	77	31	32	32	691	982	1,081	1,010	3,376	8,103	15	64	177	148	230	243
Harrow	15	39	86	15	18	18	836	1,286	1,691	1,741	6,407	15,668	19	81	225	59	91	96
Havering	16	44	101	21	24	24	568	954	1,624	1,426	6,545	17,759	26	113	312	61	95	100
Hillingdon	24	65	145	46	53	53	1,223	1,884	2,483	2,696	9,496	22,867	64	275	762	72	112	118
Hounslow	18	47	104	22	26	26	1,077	1,653	2,127	1,686	5,858	14,047	39	169	468	64	99	104
Islington	14	34	72	57	60	60	513	695	756	821	2,179	4,759	13	54	149	491	761	806
Kensington and Chelsea	13	30	64	86	89	89	312	452	554	952	2,300	4,863	8	34	93	86	132	140
Kingston upon Thames	12	30	67	15	17	17	334	570	913	1,100	4,214	10,718	19	79	219	42	64	68
Lambeth	16	38	80	54	56	56	682	972	1,085	1,004	3,479	8,501	15	64	176	730	1,133	1,199
Lewisham	15	35	76	20	21	21	546	819	1,007	879	3,755	9,919	15	65	179	168	261	276
Merton	13	32	71	22	24	24	643	1,043	1,479	1,118	4,115	10,156	17	72	199	48	75	79
Newham	17	42	90	35	36	36	1,545	2,094	2,094	1,151	3,960	9,146	21	87	241	196	304	321
Redbridge	17	44	98	20	24	24	1,438	2,118	2,615	1,778	6,260	14,794	21	87	241	71	110	117
Richmond upon Thames	14	35	77	26	30	30	335	621	1,066	1,347	4,641	11,492	17	73	202	47	72	76
Southwark	16	38	80	51	53	53	686	958	1,056	997	3,196	7,577	17	73	201	651	1,009	1,068
Sutton	13	35	79	15	17	17	483	827	1,328	1,127	4,970	13,104	21	89	246	48	75	79
Tower Hamlets	17	41	88	61	64	64	1,337	1,771	1,771	1,041	2,977	6,306	22	94	260	181	281	297
Waltham Forest	16	42	93	23	25	25	970	1,490	1,987	1,020	4,001	10,094	18	74	205	65	101	107
Wandsworth	17	41	88	58	60	60	714	1,035	1,199	1,402	4,415	10,455	19	80	222	181	281	297
Westminster	29	69	149	219	226	226	571	649	649	1,682	3,463	6,461	24	101	279	1,173	1,820	1,926

Table A7. Number of public and private chargers by borough from 2025 to 2035, low sales destination charging scenario.

Borough	Public destination chargers			Public rapid chargers			Public residential chargers			Private home chargers			Private workplace chargers			Private car club chargers		
	2025	2030	2035	2025	2030	2035	2025	2030	2035	2025	2030	2035	2025	2030	2035	2025	2030	2035
City of London	71	118	186	33	34	34	26	30	30	111	202	336	15	64	178	107	166	176
Barking and Dagenham	52	126	261	13	16	16	876	1,288	1,516	807	3,230	8,118	18	77	213	50	78	82
Barnet	144	297	556	41	50	50	1,077	1,618	2,065	3,111	9,670	22,421	33	140	389	93	144	152
Bexley	66	164	344	16	20	22	539	843	1,262	1,319	5,991	16,196	24	103	286	58	90	95
Brent	95	212	418	24	29	29	1,260	1,816	2,051	1,860	6,080	13,996	26	111	308	78	121	128
Bromley	97	232	483	23	30	32	496	846	1,413	2,055	8,881	23,611	33	139	386	78	121	128
Camden	193	320	482	83	86	86	514	700	736	1,177	2,833	5,830	16	69	190	602	934	989
Croydon	107	251	513	27	34	35	845	1,341	1,858	2,024	8,438	21,693	27	117	323	90	140	148
Ealing	118	259	507	29	35	35	1,262	1,868	2,243	2,287	7,158	16,523	32	138	382	79	123	130
Enfield	82	210	450	16	21	23	1,237	1,811	2,277	1,748	6,734	16,745	31	134	370	78	121	128
Greenwich	76	169	332	21	25	25	638	991	1,331	1,057	4,167	10,640	21	91	253	68	106	112
Hackney	111	201	321	42	44	44	585	796	809	679	2,247	5,373	11	45	125	156	242	256
Hammersmith and Fulham	103	190	315	36	38	38	462	637	684	1,037	2,593	5,508	14	59	162	103	160	170
Haringey	87	178	321	27	28	28	674	939	983	1,010	3,376	8,103	15	64	177	148	230	243
Harrow	64	153	318	14	19	20	812	1,201	1,461	1,741	6,407	15,668	19	81	225	59	91	96
Havering	77	186	384	19	25	26	548	854	1,343	1,426	6,545	17,759	26	113	312	61	95	100
Hillingdon	142	307	587	42	51	51	1,185	1,754	2,137	2,696	9,496	22,867	64	275	762	72	112	118
Hounslow	87	202	411	20	25	25	1,040	1,535	1,830	1,686	5,858	14,047	39	169	468	64	99	104
Islington	126	222	350	50	52	52	497	665	698	821	2,179	4,759	13	54	149	491	761	806
Kensington and Chelsea	164	262	371	75	78	78	292	417	490	952	2,300	4,863	8	34	93	86	132	140
Kingston upon Thames	55	127	258	14	17	17	319	512	755	1,100	4,214	10,718	19	79	219	42	64	68
Lambeth	124	227	372	47	49	49	666	929	985	1,004	3,479	8,501	15	64	176	730	1,133	1,199
Lewisham	70	154	300	18	19	19	532	771	889	879	3,755	9,919	15	65	179	168	261	276
Merton	68	150	292	20	23	23	618	955	1,249	1,118	4,115	10,156	17	72	199	48	75	79
Newham	99	204	375	30	31	31	1,527	2,048	2,048	1,151	3,960	9,146	21	87	241	196	304	321
Redbridge	79	186	383	18	23	24	1,405	2,000	2,301	1,778	6,260	14,794	21	87	241	71	110	117
Richmond upon Thames	79	167	314	23	28	28	310	540	861	1,347	4,641	11,492	17	73	202	47	72	76
Southwark	121	223	368	44	46	46	669	918	966	997	3,196	7,577	17	73	201	651	1,009	1,068
Sutton	58	143	300	14	18	19	465	744	1,095	1,127	4,970	13,104	21	89	246	48	75	79
Tower Hamlets	141	256	412	54	56	56	1,319	1,738	1,738	1,041	2,977	6,306	22	94	260	181	281	297
Waltham Forest	80	186	376	20	24	24	943	1,385	1,712	1,020	4,001	10,094	18	74	205	65	101	107
Wandsworth	137	250	407	50	52	52	692	980	1,077	1,402	4,415	10,455	19	80	222	181	281	297
Westminster	403	627	899	191	197	197	536	610	610	1,682	3,463	6,461	24	101	279	1,173	1,820	1,926

Table A8. Charging infrastructure in place as of June 2020.

Borough	Public slow to fast chargers	Public rapid chargers
City of London	26	1
Barking and Dagenham	56	2
Barnet	171	25
Bexley	23	6
Brent	172	10
Bromley	72	12
Camden	217	13
Croydon	73	20
Ealing	163	30
Enfield	22	13
Greenwich	161	29
Hackney	241	10
Hammersmith and Fulham	235	33
Haringey	45	11
Harrow	18	6
Havering	20	6
Hillingdon	137	20
Hounslow	320	31
Islington	102	18
Kensington and Chelsea	358	6
Kingston upon Thames	26	4
Lambeth	244	18
Lewisham	92	11
Merton	146	6
Newham	90	15
Redbridge	17	16
Richmond upon Thames	272	5
Southwark	117	14
Sutton	41	6
Tower Hamlets	71	12
Waltham Forest	79	3
Wandsworth	401	12
Westminster	460	18

Note: Data from Zap Map (Charging infrastructure counts, updated June 2020), https://www.zap-map.com

Private passenger car model

Table A9. Main data inputs and assumptions at the London level for the private passenger car model.

		2020	2025	2030	2035
EV stock	High sales	41,674	201,919	760,264	1,412,335
	Low sales	36,205	75,177	316,019	876,058
Market share electric new car registrations	High sales	7.1%	34.0%	100.0%	100.0%
	Low sales	3.8%	6.1%	50.0%	100.0%
Ratio BEV among all new EV registration		60%	90%	100%	100%
BEV efficiency (mi/kWh)		3.48			
PHEV efficiency (mi/kWh)		2.34			
Share of EV owners with access to home charging		60%	58%	55%	52%
Dwelling type of electric car buyers	Detached house	23.8%	18.7%	13.7%	8.7%
	Semi-attached and Bungalows	17.5%	16.8%	16.2%	15.5%
	Terraced and converted and purposed built flats/ maisonettes	58.6%	64.0%	69.4%	74.8%
Home charging availability by dwelling type	Detached house	92.7%			
	Semi-attached and Bungalows	79.3%			
	Terraced and converted and purposed built flats/ maisonettes	39.0%			
Number of EVs sharing a private charging point		1.36			
% of EV owners who commute by car	Average inner London	22%	17%	12%	7%
	Average outer London	36%	31%	26%	21%
% change in EV owners who commute by car		- 1 % per year			
Average daily miles (mi/day)	Commuter inner London	10.55	9.53	8.62	7.79
	Non-commuter inner London	8.44	7.63	6.89	6.23
	Commuter outer London	20.25	19.26	18.32	17.42
	Non-commuter outer London	16.88	16.05	15.26	14.51
Decrease in miles driven per day	Inner London	-2% per year			
	Outer London	-1% per year			