Quantifying the electric vehicle charging infrastructure gap in the United Kingdom

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Introduction

The United Kingdom (UK) has seen rapid growth in the electrification of its passenger car market, and the trend is expected to continue. Plug-in electric models represented 3.2% of new passenger car registrations in 2019, and that share has approximately tripled in the first half of 2020.[1] The UK has set a goal of 50%–70% of the new car market being ultra-low emission by 2030[2] to achieve climate, air quality, and energy security ambitions. The government also is considering shifting forward its 100% zero-emission new car sales goal to 2035 from the existing 2040 target.[3] Scotland aims to fully "phase out the need to buy petrol and diesel cars or vans" by 2032.[4]

Achieving the UK's electric vehicle targets will require sustained support, including regulations and taxation policies to spur vehicle investment and deployment. Rapid electric vehicle market expansion also will require a convenient charging infrastructure network. The charging infrastructure will need to expand and adapt as battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs), with backup combustion engines, are introduced more widely. Whereas early adopters can typically rely on

1 "December – EV registrations," Society of Motor Manufacturers and Traders (SMMT), January 7, 2020, https://www.smmt.co.uk/2020/01/december-ev-registrations-3/; "June – EV registrations," SMMT, July 5, 2020, https://www.smmt.co.uk/2020/07/june-ev-registrations-3/

2 Department for Transport, "The Road to Zero," 2018, https://www.gov.uk/government/publications/reducing-emissions-from-road-transport-road-to-zero-strategy

3 Department for Transport, "Open consultation: Consulting on ending the sale of new petrol, diesel and hybrid cars and vans," February 20, 2020, https://www.gov.uk/government/consultations/consulting-on-ending-the-sale-of-new-petrol-diesel-and-hybrid-cars-and-vans/

4 Scottish Government, "Climate Change Plan: Third report on proposals and policies 2018–2032 (RPP3)," 2018, https://www.gov.scot/publications/scottish-governments-climate-change-plan-third-report-proposals-policies-2018/pages/12/

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charging at home,[5] new electric vehicle drivers in the 2020–2030 time frame will increasingly need a variety of charging options.

This paper assesses the electric vehicle charging infrastructure necessary to power electric passenger cars in the UK by 2030. Two plug-in electric vehicle uptake scenarios—50% and 70% of new passenger car sales by 2030—are explored to evaluate the charging infrastructure needed to support the UK's transition to electric. To inform national and local-level charging infrastructure policy, as well as help steer public and private investments, this report quantifies the amount of public, workplace, and rapid charging needed across UK metropolitan and nonmetropolitan areas. The charging assessment reflects best-available market and charging behavior data, expected increases in electric range and charging speed, and the increased need for public charging as the market broadens beyond early adopters. This assessment is based on charging needs for electric passenger cars; additional charging would be needed to support light commercial vans and other vehicle types.

Market characterization of vehicles and charging

In parallel with the growth in the number of electric vehicles on UK roads through 2019, the number of charging points has steadily increased. The following section describes these developments and provides background information on charging infrastructure in the UK, including technical charging specifications, housing stock, and home charging access.

Market overview for electric vehicles and charging infrastructure

Through the end of 2019, approximately 280,000 electric cars had been sold in the UK, and the electric share of new passenger cars was 3.2% in 2019.[6] Electric car shares vary greatly across metropolitan and nonmetropolitan areas,[7] as defined on the European Union's Eurostat Metropolitan Region web page.[8] These metropolitan areas differ from other boundary definitions. Notably the "London metropolitan area" analyzed here is larger than the "greater London area," which does not include outlying areas. New vehicle registration data are considered in this analysis to be nearly synonymous with new vehicle sales as a measure of new electric vehicle uptake. Electric vehicle uptake and charging trends are assessed across the 41 UK metropolitan areas and 11 nonmetropolitan areas in England, Scotland, Wales, and Northern Ireland.

Figure 1 shows electric vehicle uptake across 52 metropolitan and nonmetropolitan areas of the UK in two ways.[9] The left map shows the share of 2019 new passenger car registrations that were electric. The electric vehicle uptake varies from about 1% to greater than 4%. Areas outside of a metropolitan area are denoted with a hatched pattern. On the right, the electric vehicle stock through the end of 2019 is shown normalized on a per-million-inhabitant basis. Vehicle stock gives a measure of the cumulative popularity of electric vehicles since 2010 when modern electric vehicles began to be introduced in the market. The red dots denote a charging location and are shown for context. There are 41 metropolitan areas shown and 11 nonmetropolitan regions delineated by thick dark outlines.

5 Systra, "Plugging the Gap: An Assessment of Future Demand for Britain's Electric Vehicle Public Charging Network Summary of Findings," 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

6 EV-Volumes.com, "EV Data Center, 2020," retrieved from http://www.ev-volumes.com/datacenter/

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

8 Eurostat, "Metropolitan Regions," accessed May 5, 2020, https://ec.europa.eu/eurostat/web/metropolitan-regions/background

9 Dale Hall, Sandra Wappelhorst, Peter Mock, and Nic Lutsey, *European electric vehicle factbook 2019–2020,* (ICCT: Washington, DC, 2020), https://theicct.org/publications/european-electric-vehicle-factbook-20192020

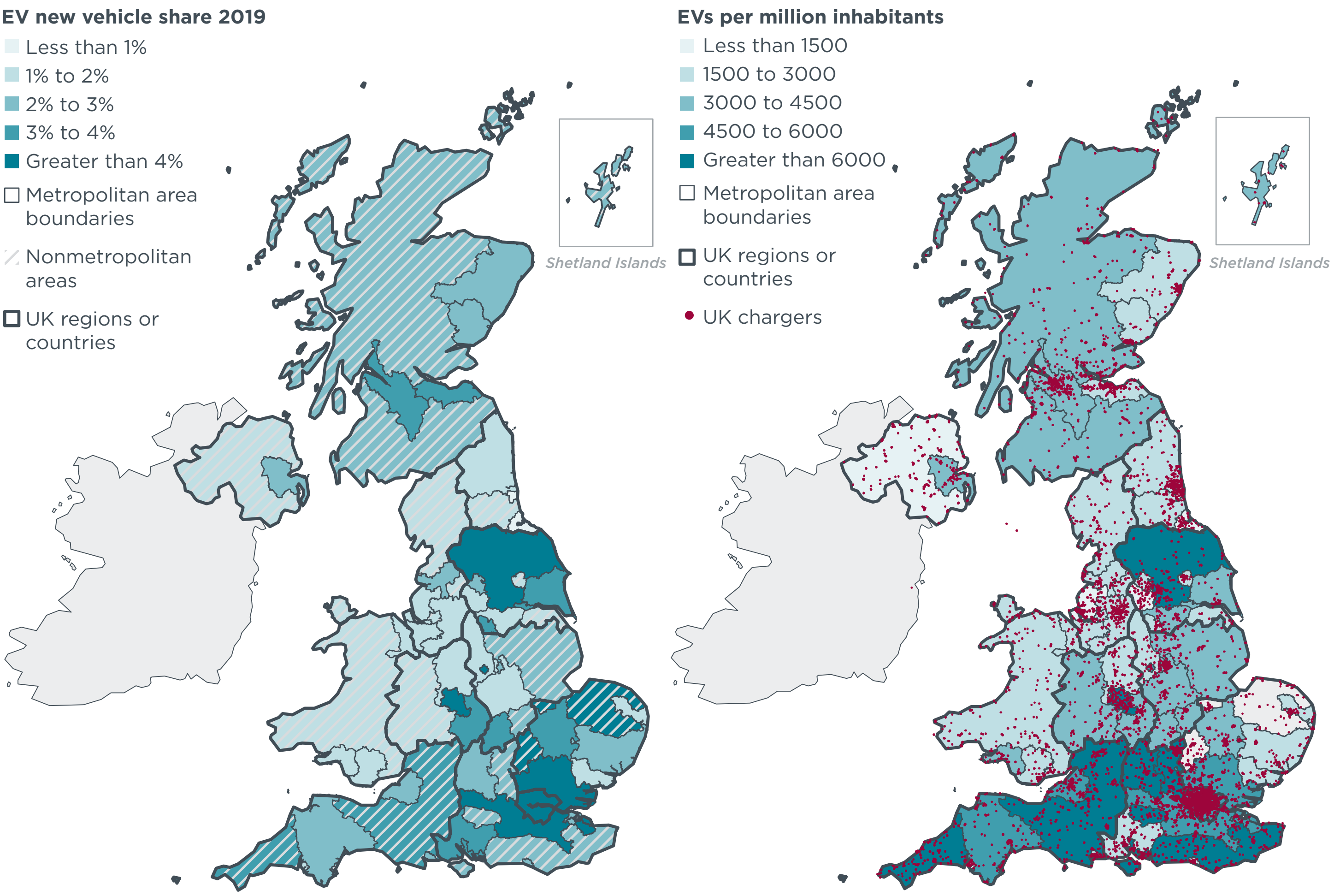

Figure 1. Electric share of new passenger cars in 2019 (left) and cumulative electric cars per million inhabitants overlaid with charging station locations (right).

The maps in Figure 1 show that electric cars per million population in 2019 for metropolitan areas were the highest in Birmingham, Leeds, Oxford, and Portsmouth, each with more than 6,000 electric cars per million inhabitants, compared to the UK average of approximately 4,300. Nonmetropolitan regions of the South East, South West, and East of England also showed relatively high electric vehicle penetration, with more than 6,000 electric vehicles per million inhabitants. Overall, electric vehicle uptake per capita in metropolitan areas was less than in nonmetropolitan areas, with 4,100 versus 4,800 electric cars per million inhabitants.

Table 1 shows the charging terminology used in the analysis related to power level, conventional UK terminology, applicable standards, and current type.[10] This report's terminology for normal (less than or equal to 22 kW) and fast charging (greater than 22 kW) is based on the methods applied across different regions in previous ICCT reports, as described below.

10 Department for Transport, "The Road to Zero" (see note 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

Table 1. Charger terminology, power level, standards, and current type.

Terminology in this report	Typical power level	UK terminology	Standards included in this report	Current type
Normal	Approximately 3 kW	Slow charging	Chargers with Type 2 connectors	Alternating current
	7 kW – 22 kW	Fast charging	Chargers with Type 2 connectors	Alternating current
Fast	43 kW – 99 kW	Rapid charging	Chargers with Type 2, CHAdeMO, CCS, or Tesla connectors	Alternating current and direct current
	Greater than 100 kW	Ultra-rapid charging	Chargers with CHAdeMO, CCS, or Tesla connectors	Direct current

Vehicle charging infrastructure scenarios

This section describes the modeling approach for charging infrastructure scenarios in the UK through 2030. The modeling incorporates charging trends through 2019 and adapts parameters to reflect expected changes in range, vehicle technology, home charging availability, and charging speed. Estimates for the supporting charging infrastructure for given levels of electric vehicle uptake are made for each metropolitan and nonmetropolitan area. The charging infrastructure estimates are made for normal work charging, normal public charging, and fast charging.

Overview of methodology

The electric vehicle charging infrastructure needs for the UK in 2030 follow an analytical framework similar that used in a previous U.S. study.[11] This section provides a summary of the methods with a focus on key data and methodology updates to analyze public and workplace charging needs for the UK market.

Baseline data are based on chargers and vehicle registrations for both electric and conventional passenger cars through 2019. Charger data is from Open Charge Map[12] and the National Chargepoint Registry.[13] The datasets are combined, and duplicates removed. For the fast charging infrastructure, multi-standard fast chargers may have up to three outlets, only one of which can draw electric power at a time. In this charging infrastructure evaluation, a multi-standard charger is counted as one charger. This becomes important when interpreting results or comparing to other studies that use outlets as their basis. For context, the UK at the end of 2019 had an estimated 2.2 outlets per fast charger.

The UK charging infrastructure model used to analyze future charging needs incorporates a series of assumptions through the steps outlined in Figure 2. The blue rectangles represent the model steps, whereas the yellow trapezoids indicate the data and assumptions necessary for each step. Finally, the gray circles explain the steps for what is occurring at each stage. The first step on the top left defines the number of vehicles to serve and the bottom right step is the ultimate estimate of charger infrastructure counts by category needed for the electric vehicle deployment on an annual basis.

11 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

12 Open Charge Map, "The Open Charge Map API," 2019, http://openchargemap.org/site/develop/api

13 Government of the United Kingdom, "National Chargepoint Registry," 2019, https://www.national-charge-point-registry.uk/

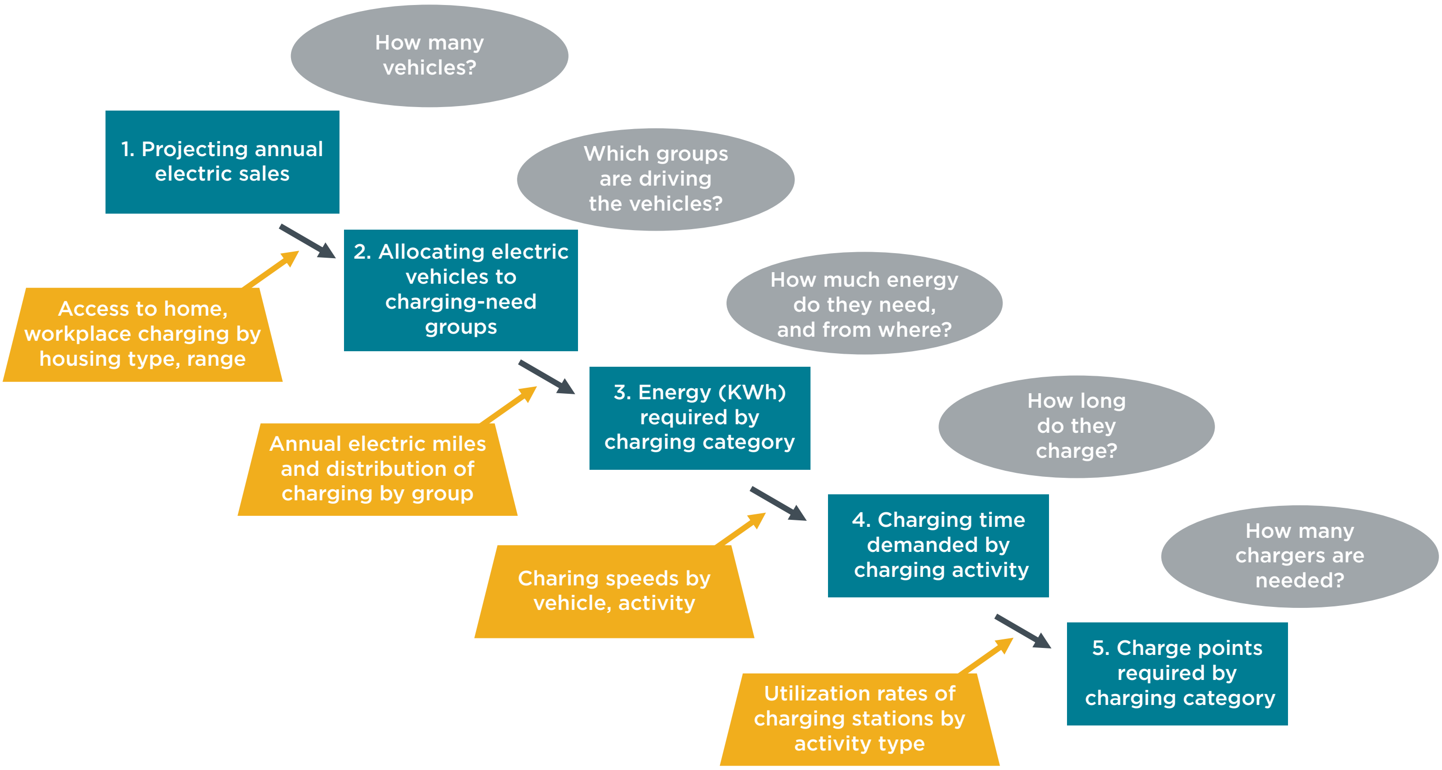

Figure 2. Model to estimate charging infrastructure needs for a given deployment of electric vehicles.

The data inputs shown in the yellow trapezoids are drawn from multiple sources, including commercially available data and other analytical research. Data areas, the variables that depend on these data, and the sources for these data are shown in Table 2.

Table 2. Data sources for key variables.

Data area	Variables	Source
Population	Population by nomenclature of territorial units for statistics (NUTS3) statistical area and future projections	Eurostat [a]
Housing	Number of dwellings in houses and apartments	Eurostat [b]
Metropolitan area definitions	Definition of metropolitan areas in the UK	Eurostat [c]
Electric vehicle registrations by NUTS3 area or local authority	Registrations of new electric vehicles, including battery electric vehicle (BEVs) and plug-in hybrid electric vehicles (PHEVs)	Hall et al., Department for Transport [d]
Existing charging infrastructure	Counts of charging outlets in the UK	Open Charge Map, National Chargepoint Registry [e]
Charging infrastructure relationships	Ratios of electric vehicles to charge point, based on market size and/or electric share	Dodson and Slater, Nicholas et al., Nicholas and Hall, Hall and Lutsey [f]
Charging behavior	Observed charging rates of charging for residential, workplace, public, and fast chargers	Dodson and Slater , UK Government, Electric Nation, Dodson, Systra, Tal et al. [g]
Stock turnover	Retirement of vehicles determining vehicle longevity (assumed 14-year median vehicle life)	Society of Motor Manufacturers and Traders [h]
Vehicle travel	Annual vehicle miles	Department for Transport [i]

[a] Eurostat, "Population on 1 January by Broad Age Group, Sex and NUTS 3 Region," 2019, https://ec.europa.eu/eurostat/web/products-datasets/-/demo_r_pjanaggr3; Eurostat, "Population on 1st January by Age, Sex and Type of Projection," 2019, https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=proj_18np&lang=en, accessed in April 2020 (data have since been updated at https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=proj_19np&lang=en)

[b] Eurostat, "Conventional Dwellings by Occupancy Status, Type of Building and NUTS 3 Region," 2011, https://ec.europa.eu/eurostat/web/products-datasets/-/cens_11dwob_r3

[c] Eurostat, "Metropolitan Regions" (see note 8).

[d] Hall et al., *European electric vehicle factbook 2019–2020* (see note 9); Department for Transport, "UK Vehicle Registrations," accessed May 5, 2020, https://www.gov.uk/government/statistical-data-sets/all-vehicles-veh01

[e] Open Charge Map, "The Open Charge Map API" (see note 12); Government of the United Kingdom, "National Chargepoint Registry" (see note 13).

[f] Tristan Dodson and Shane Slater, "Electric Vehicle Charging Behaviour Study" (Element Energy, 2019), http://www.element-energy.co.uk/wordpress/wp-content/uploads/2019/04/20190329-NG-EV-CHARGING-BEHAVIOUR-STUDY-FINAL-REPORT-V1-EXTERNAL.pdf; Nicholas et al., *Quantifying the Electric Vehicle Charging Infrastructure Gap across U.S. Markets* (see note 11); Michael Nicholas and Dale Hall, *Lessons Learned on Early Electric Vehicle Fast-Charging Deployments*, (ICCT: Washington, D.C., 2018), https://theicct.org/publications/fast-charging-lessons-learned; Dale Hall and Nic Lutsey, *Emerging Best Practices for Electric Vehicle Charging Infrastructure*, (ICCT: Washington, D.C., 2017), https://theicct.org/publications/emerging-best-practices-electric-vehicle-charging-infrastructure

[g] Dodson and Slater, "Electric Vehicle Charging Behaviour Study"; UK Government, "Electric Vehicle Charging Device Statistics," 2019, https://www.gov.uk/government/statistical-data-sets/all-vehicles-veh01; Electric Nation, "Summary of the Findings of the Electric Nation Smart Charging Trial," 2019, http://www.electricnation.org.uk/wp-content/uploads/2019/07/Electric-Nation-Trial-Summary-A4.pdf; Tristan Dodson, "Charger Use Study: Recharge the Future" (Element Energy, 2018), http://www.element-energy.co.uk/wordpress/wp-content/uploads/2019/02/20180921_UKPN-Recharge-the-Future_Charger-Use-Study_FINAL.pdf; Systra, "Plugging the Gap" (see note 5); Gil Tal, Jae Hyun Lee, and Michael Nicholas, "Observed Charging Rates in California" [Research Report UCD-ITS-WP-18-02] (University of California, Davis, 2018), https://itspubs.ucdavis.edu/index.php/research/publications/publication-detail/?pub_id=2993

[h] Society of Motor Manufacturers and Traders, "Average Vehicle Age," accessed May 24, 2020, https://itspubs.ucdavis.edu/publication_detail.php?id=2993

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

Electric vehicle market scenarios

Specifying electric vehicle sales volume over time is the first step in the charging infrastructure estimation model. Our model applies two scenarios of electric vehicle growth, where electric vehicle sales reach 50% (scenario 1) and 70% (scenario 2) of new passenger cars sold by 2030 based on the UK government's similar goals.[14] Scotland aims to phase out petrol car sales by 2032,[15] which suggests scenario 2 is more relevant. This analysis incorporates year-over-year increases in electric vehicle sales to reach those the targets. This charging infrastructure analysis is for passenger cars, so additional charging needs for electric buses, commercial vans, and heavier freight vehicles are excluded.

Electric and conventional vehicle sales are estimated from new vehicle registrations detailed at a local level (NUTS 3 resolution).[16] New vehicle registrations are assumed to remain at 2019 levels through 2030, consistent with demographic changes and broader goals to encourage alternate modes of transportation. The share of annual new registrations that are electric increases by 2030 from approximately 70,000 in 2019 to 1.15 million in scenario 1 and to 1.61 million in scenario 2. The ratio between BEVs and PHEVs of 56% BEVs in 2019 is assumed to rise to 75% BEVs by 2030, reflecting how automakers are expected to shift to BEV production as BEVs approach cost parity with conventional vehicles.

Several vehicle population adjustments are made in the modeling of vehicle sales and stock patterns. Vehicle flows to successive owners over vehicle life are adjusted to match the new vehicle registration data to overall UK-wide vehicle usage patterns. To account for leasing and the subsequent redistribution of vehicles at lease termination, new passenger vehicle registration data are compared to vehicle stock data.[17] The differential in the new registration per capita versus the stock per capita enables the estimation of vehicle flows from areas that tend to register more new vehicles to areas that tend to receive those vehicles secondhand. In 2019, areas for which electric vehicles are relatively more popular are expected to remain so through 2024. From 2025 on, electric vehicle shares of new vehicle sales are assumed to be the same nationwide in order to evaluate consistent charging infrastructure access across UK regions over time. Electric vehicles are assumed to have the same 14-year median lifetime as conventional vehicles.

Figure 3 shows the electric vehicle stock for scenario 1, on the left, and scenario 2 on the right. Cumulative electric vehicle stock for scenario 1, reflecting a 50% electric sales share in 2030, reaches approximately 5.2 million through 2030, and 68% of those electric vehicles are BEVs. Scenario 2, with an electric sales share of 70% in 2030, reaches about 6.7 million total electric vehicles, 69% of which are BEVs, by the end of 2030.

14 Department for Transport, "The Road to Zero" (see note 2).

15 Transport Scotland, "Switched on Scotland Phase Two: An Action Plan For Growth," 2017, https://www.transport.gov.scot/media/39306/switched-on-scotland-phase-2.pdf.

16 Based on Hall et al., *European electric vehicle factbook 2019–2020* (see note 9). The metropolitan regions are defined using nomenclature of territorial units NUTS3 statistical areas to approximate the shape of Functional Urban Areas, which represent urban agglomerations based on commuting patterns. See Eurostat (n.d.), Metropolitan Regions, https://ec.europa.eu/eurostat/web/metropolitan-regions/background

17 Eurostat, "Stock of Vehicles by Category and NUTS 2 Regions," 2018, http://ec.europa.eu/eurostat/product?code=tran_r_vehst&language=en&mode=view.

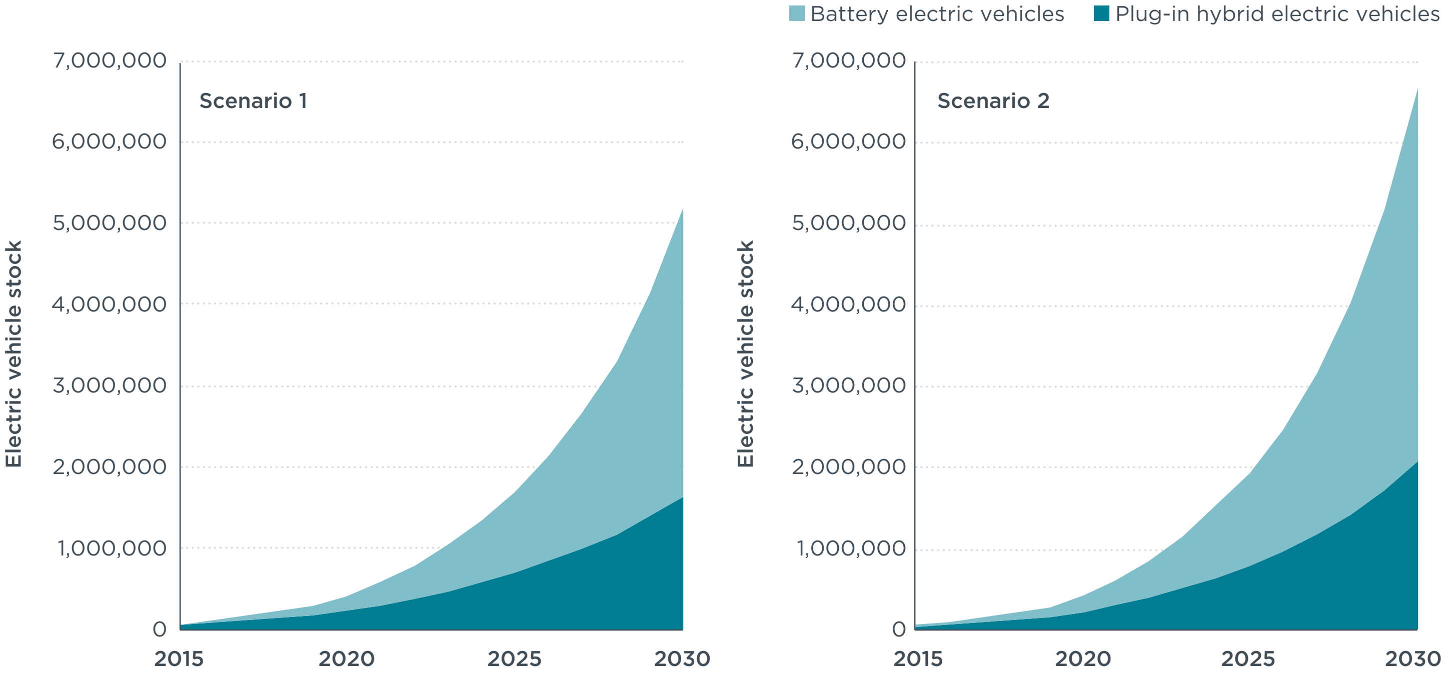

Figure 3. Scenarios for electric vehicle stock in the UK up to 2030, with cumulative electric sales of 50% (left) and 70% (right).

Allocation of electric vehicles to charging need groups

Step two in the model outlined in Figure 2 is to separate the electric vehicle market into groups that exhibit different charging behavior and, therefore, have different charging needs. Three factors—vehicle type (PHEV or BEV), commuting status (commuter or noncommuter), and home charging access (home access, or not)—determine the eight electric vehicle charging need groups. Vehicle type is important because BEVs do not have a backup gasoline engine and their larger batteries allow more charging than PHEVs. Commuting status determines whether work charging is used and affects the overall amount of driving. For 2019, 70% of vehicles are assumed to be driven on a commute, but by 2030 this is reduced to 53% to match trends in the general population.[18]

The definitions for workplace and public charging can be somewhat blurred. Work charging is not defined as a location, but an activity, whereby there is an opportunity for increased electric vehicle charging. Many chargers used while working can be in public parking garages, at retail shops if an employee works in retail, and even curbside charging can be considered work charging if used for work purposes. One study indicated that up to 27% of chargers used while working were available to the general public.[19] We expect this trend to continue in the future as electric vehicle use increases to a wider variety of commuters beyond those with dedicated workplace parking. As a result, a large number of workplace chargers are publicly available, and therefore are interchangeable with public charging. Further, we define public charging as having access generally available to the public, but some can be semiprivate, such as chargers in shopping areas or Tesla chargers.

The type of housing is important for determining if home charging is likely to be available and, therefore, the magnitude of the public and work charging needs. Eurostat defines three UK housing categories: single-dwelling buildings, which are defined as having a private entrance at ground level; two-dwelling structures, which may not have a

18 Dodson and Slater, "Electric Vehicle Charging Behaviour Study" (see Table 2, note f).
19 Tal, Lee, and Nicholas, "Observed Charging Rates in California" (see Table 2, note g).

private ground level entrance; and three or more dwelling buildings, which include a mix of flats and attached houses.[20] The most recent housing census provides comprehensive data on the breakdown of population by the dwelling structure type in the UK by NUTS3 based on data from 2011. Table 3 shows the approximate breakdown of dwellings and population by housing type, conventional and electric vehicle stock by housing type in 2019, and the estimated electric vehicle stock by housing type in 2030. The second row shows the conventional vehicle stock by housing type broken down into the various housing types,[21] which accounts for differences in the number of vehicles per dwelling.[22] As shown, early adopters are more likely to live in single-dwelling buildings, where home charging is typically more available. As the market for electric vehicles grows, a larger percentage of the owners will likely live in more concentrated housing.

Table 3. Housing for the general population in the UK and as evaluated for electric vehicles.

	One-dwelling buildings	Two-dwelling buildings	Three or more dwelling buildings
Percentage of dwellings	23%	30%	46%
Conventional passenger vehicle stock by dwelling type in 2019	28%	33%	38%
Electric passenger vehicle stock by dwelling type in 2019	40%	43%	17%
Electric passenger vehicle stock by dwelling type in 2030	31%	35%	34%

As shown in Table 4, housing type is used to estimate home charging availability using international examples and adjusting for the UK context.[23] This analysis assumes electric vehicle drivers' housing characteristics approach that of general drivers over time and home charging availability by housing type stays constant, meaning that electric vehicles migrate more toward three-or-more-dwelling buildings through 2030. Home charging availability among car owners in this category includes charging installations in dedicated spots and common parking areas serving small housing clusters and large apartment complexes. In Table 4, the availability of home charging by housing type given in the first row is multiplied by the vehicle stock per housing type in 2019 and 2030, from Table 3, to obtain the charging availability by housing type in the respective years.

Table 4. Scenarios for electric vehicle owner housing type and access to home charging.

	EVs in 1-dwelling buildings	EVs in 2-dwelling buildings	EVs in 3-or-more dwelling buildings	Total
Percentage of homes with charging available	92%	83%	65%	—
Percentage of total electric vehicle stock with home charging available in 2019	37%	37%	11%	85%
Percentage of total electric vehicle stock with home charging available in 2030	29%	29%	22%	80%

As shown in Table 4, home charging is available for 85% of electric vehicles in 2019. However, in 2030 that availability has fallen to 80%, showing that over time more electric drivers would not have home charging and would need more charging available away from home. This approach, with 80% of the electric vehicle stock with home charging in 2030, ultimately approaches the general UK National Travel Survey finding that 72%

20 Eurostat, "Conventional Dwellings by Occupancy Status, Type of Building and NUTS 3 Region" (see Table 2, note b).

21 Department for Communities and Local Government, "English Housing Survey: Housing Stock Report 2008," 2010, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/6703/1750754.pdf

22 Ministry of Housing, Communities & Local Government, "English Housing Survey Data on Stock Profile," 2019, https://www.gov.uk/government/statistical-data-sets/stock-profile

23 Tal, Lee, and Nicholas, "Observed Charging Rates in California" (see Table 2, note g).

of car owners in England park overnight on private property or in a garage.[24] However, we note that overnight parking on private property or in a garage does not guarantee access, and the 80% with home charging access includes some mix of overnight charging solutions at semipublic locations in residential areas.

Energy required by charging category

The third step in the model is to determine the total energy that electric vehicles will require and assign the energy demand to home, work, public, and fast chargers. Energy needs for the vehicle stock are apportioned according to breakdowns in Table 5, which are based on a 2019 analysis of EV drivers.[25] It should be noted that the needs are defined by data trends and the trends are influenced by a mix of price and access. There are many possible energy breakdowns to serve the same market and the same number of miles. The three consumer classifications are listed in the first three columns: vehicle type, commuting status, and home charging. The fourth through seventh columns show the percentage of the electric vehicles' energy by charging location comprising home, work, public, and fast charging. The annual kilometers are based on the annual kilometers traveled in the UK and this average is disaggregated by commuting status.[26]

Table 5. Energy breakdown by location of charging.

Vehicle type	Commuting status	Home charging	Home energy	Work energy	Public energy	DCFC energy	Vehicle kilometers traveled per year	Percent vehicle kilometers traveled that are electric	Vehicle kilometers traveled per year that are electric	Percent of electric vehicle stock in 2030
BEV	Commuter	Home	70%	20%	5%	5%	14,500	100%	14,500	32%
BEV	Commuter	No home	0%	45%	30%	25%	14,500	100%	14,500	8%
BEV	Noncommuter	Home	85%	0%	5%	10%	8,200	100%	8,200	23%
BEV	Noncommuter	No home	0%	0%	40%	60%	8,200	100%	8,200	6%
PHEV	Commuter	Home	65%	30%	5%	0%	14,500	70%	10,100	15%
PHEV	Commuter	No home	0%	65%	35%	0%	14,500	40%	5,800	4%
PHEV	Noncommuter	Home	90%	0%	10%	0%	8,200	50%	4,100	10%
PHEV	Noncommuter	No home	0%	0%	100%	0%	8,200	10%	800	3%

BEV = Battery electric vehicle; PHEV = plug-in hybrid electric vehicle; DCFC = direct current fast charger

The kilometers are converted into energy needed based on the assumed efficiency of an average BEV or PHEV at 5.5 and 5.15 kilometers per kilowatt-hour, respectively. New electric vehicle efficiency is assumed to be constant on average, assuming technical efficiency improvements will continue but will be negated by the shift of new electric vehicles to larger vehicle classes over time.

The charging need characteristics of each group represent the average behavior within the group, but individual charging behavior and access to charging vary widely. For example, in the case of workplace charging, not everyone has access to a charger, and sometimes those with access choose to not charge at work due to personal preference, pricing, or congestion. Similarly, all PHEV owners do not consistently plug in each time they have access to charging. Nevertheless, the average charging behaviors of these groups are distinct enough to warrant separate analysis and modeling.

Although the driver charging energy breakdowns are constant through time, the relative proportions of the driver groups are assumed to change over time. The early market is

24 Based on Department for Transport, "National Travel Survey: England 2018," https://www.gov.uk/government/statistical-data-sets/nts09-vehicle-mileage-and-occupancy

25 Dodson and Slater, "Electric Vehicle Charging Behaviour Study" (see Table 2, note f).

26 Based on Department for Transport, "National Travel Survey: England 2018."

assumed to have a higher prevalence of commuters than the later market. As cited in another study, in 2019, the percentage of electric vehicles purchased that are regularly used in commuting was 70%, although just 53% of the general car population is used for commuting.[27] Therefore, we estimate that 53% of electric vehicles will be used for commuting in 2030, in line with the general car population. This reduces the relative need for workplace charging.

Charging hours and charger power

The fourth step in the charging infrastructure model is to determine the number of charging hours needed by charging category. The rate of power draw varies with the capacity of the charger and the ability of a vehicle to accept given power levels. For BEVs, the average rate of power draw for normal chargers is estimated to be 8 kW, and for PHEVs the average is 3.4 kW. The average rate of power draw is affected both by the acceptance rate of the vehicle over the entire charge cycle, which can taper to less than 8 kW at the end of the charge cycle, and the power limitations of the charger, some of which provide only 3.6 kW of power even if the vehicle can accept more. For fast charging, the average rate per charger is assumed to increase annually from 35 kW in 2019 to 80kW in 2030. Even though the maximum charge rate may increase to more than 80kW, power sharing, battery management over an entire charge cycle, and the lower cost of lower power charging suggest that on average, average power will be much lower than the maximum.

Charger utilization and number of chargers

The fifth and final step in the charging infrastructure model shown in Figure 2 is to determine the required number of chargers. Charger output power in kW, as well as the number of hours of active use per day, are used to estimate the daily and annual kWh per charger. The required energy (in kWh) established above for the overall electric vehicle market is divided by this average utilization to determine the number of chargers needed.

As shown in other studies, utilization on public chargers increases as a function of market development.[28] The examination of existing chargers in the UK allows for the estimation of charger utilization, in hours per day, by metropolitan area for normal and fast chargers. As part of the analysis, the average daily utilization in terms of hours of active power draw for normal public charging is estimated by the following equation:

Average daily hours of usage = 0.832 * LN (electric vehicles per million population) - 4.902

This equation was derived from inspection of the UK charger data, and the method is comparable to the approach in studies elsewhere.[29] Electric vehicles in this case include BEVs and PHEVs. Using a natural log (LN) function bounds the utilization at higher electric vehicle penetrations. For example, the average daily hours of usage of a public charger at 6,000 electric vehicles per million population is 2.3 hours. But at 100,000 electric vehicles per million population, the average utilization rises to 4.7 hours, meaning the utilization doubles while the market increases more than 16 times.

This utilization is an average over an entire metropolitan area and across different days of the week and months of the year. Locational, weekly, and seasonal variation results in some chargers being more highly utilized than others across time and geography. The approximate distribution of utilization is estimated by a truncated normal distribution with a standard deviation of 5 hours. As an example of what this equates to in the modeling, when the daily mean is 2.3 hours, 2% of chargers are used 8 hours or more.

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27 Dodson and Slater, “Electric Vehicle Charging Behaviour Study” (see Table 2, note f).

28 Nicholas et al., *Quantifying the Electric Vehicle Charging Infrastructure Gap across U.S. Markets* (see note 11).

29 Ibid.

When the daily utilization is 4.7 hours, 17% of chargers are used 8 hours or more. The implicit assumption is that the average utilization of public chargers will increase along with a growing market. Finally, this usage accounts for only daytime public usage. In the case of curbside or other public charging used for residential charging overnight, the hours of utilization will increase in proportion to the number of public chargers used for overnight charging.

Workplace charging utilization is modeled differently and is set at 6 hours per day of usage regardless of market penetration. Because chargers are not used on weekends, the effective average workplace charger use per day falls to 4.3 hours. Workplace charging usage is constant over time based on the assumption that workplace charging can adapt to an increase in demand in a more controlled manner than publicly available chargers at retail establishments, parking garages, and curbsides.

Fast charging is assumed to follow a trend similar to normal charging, such that average usage in hours increases with market development. In the case of fast charging, the utilization equation includes only BEVs, due to their much more prevalent use of the fast charging infrastructure. The fast charging utilization is separated into two use cases: one for metropolitan areas, which are expected to see higher utilization, and one for nonmetropolitan areas, which are assumed to see generally lower utilization. They are defined by the following two equations:

For metropolitan areas,
Average daily hours of usage = 0.6497 * LN (BEVs per million population) - 4.099

For nonmetropolitan areas,
Average daily hours of usage = 0.483 * LN (BEVs per million population) - 3.021

At a level of 10,000 BEVs per million population, the average estimated hours of power draw for metropolitan and nonmetropolitan areas would be 1.9 and 1.4 hours per day, respectively, and at 100,000 BEVs per million, the hours of power draw would be 3.4 and 2.5 hours. These are averages across the entire year and across a metropolitan region, and many individual chargers would still be expected to have much a higher or lower rate of utilization. Similar to the distribution described above, the mean hours of power draw are assumed to follow a truncated normal distribution with a standard deviation of 5 hours. As an example of what this equates to in the modeling, when the daily mean is 1.9 hours, 12% of chargers are used 4 hours or more per day. When the daily utilization is 3.4 hours, 34% of chargers are used 4 hours or more per day.

The number of chargers in the model is determined using the variables of charger power and utilization defined above. The estimated output per charger in a year is equal to the utilization in hours of power draw, multiplied by charger output (in kW), multiplied by the number of days per year.

Home charging and highway fast chargers are calculated separately from the above calculations for workplace, public normal, and fast charging. Home charging depends on the housing type of vehicle owners, with electric vehicles increasingly sold to households with less home charging availability in the future, as previously noted. Highway fast charger counts rely on outside analyses and are added at a rate of one fast charger for every 1,500 BEVs in metropolitan areas and one fast charger for every 1000 vehicles in nonmetropolitan areas.[30] These highway corridor chargers for long-distance trips are in addition to the local fast chargers described above and are assumed to have power available over 150 kW.

30 Patrick Jochem, Eckhard Szimbac, and Melanie Reuter-Oppermann, "How Many Fast-Charging Stations Do We Need along European Highways?" *Transportation Research Part D: Transport and Environment.,* 2019, (73) 120–29. https://doi.org/10.1016/j.trd.2019.06.005

Summary of data inputs

The inputs for the future scenarios described above are summarized in Table 6. Each of these inputs affects the number of chargers. As indicated, some inputs shift over time from 2019 to 2030, whereas others remain constant over the analysis period.

Table 6. Summary of data inputs and assumptions for the charging infrastructure model.

	2019	2030
Electric vehicle stock	280,000	5,200,000 – scenario 1 6,700,000 – scenario 2
Market share of electric new car registrations	3%	50% – scenario 1 70% – scenario 2
Portion of BEV and PHEV new car registrations	46% BEV, 54% PHEV	75% BEV, 25% PHEV
Dwelling type of electric car owners	One dwelling = 40% Two dwelling =43% Three or more dwelling = 17%	One dwelling = 29% Two dwelling = 33% Three or more dwelling = 38%
Home charging availability by dwelling type	One dwelling = 92% availability Two dwelling = 83% availability Three or more dwelling = 65% availability	
Commuter share of electric new car registrations	70%	53%
BEV average charging acceptance rate for normal	8 kW	
PHEV average charging acceptance rate	3.4 kW	
Workplace charging daily utilization in hours	6 on weekdays, 0 on weekends	
Public charging daily utilization in hours	Average daily hours = 0.832 * LN (EV per million population) – 4.902	
Fast charging daily utilization in hours for metropolitan areas	Average daily hours = 0.650 * LN (BEV per million population) – 4.099	
Fast charging daily utilization in hours for nonmetropolitan areas	Average daily hours = 0.483 * LN (BEV per million population) – 3.021	
Fast charging outlet to charger ratio	2.2:1	—
Fast charging kW acceptance per charger	35 kW	80 kW
BEVs per high power highway fast charger	1,500 in metropolitan areas, 1,000 in nonmetropolitan areas	
Electric vehicle electricity consumption	BEVs 0.182 kWh/km, PHEVs 0.194 kWh/km	
Average vehicle kilometers per year	Commuter 14,500 km, noncommuter 8,200 km	

BEV = Battery electric vehicle; PHEV = plug-in hybrid electric vehicle; DCFC = direct current; LN = natural log

Evolution of charging over time

Because many of the variables shown in Table 6 vary over time, the ratio of electric vehicles per charger changes over time as well. A decrease in the availability of home charging increases the need for other charging, but a corresponding increase in usage per charger decreases the number of chargers needed to serve the same energy demand. Increasing the assumed average charger power (and BEV charge acceptance rate) further decreases the number of chargers needed. The net effect of the various changes is that even though more power is expected to pass through public charging, one charger can support more vehicles in 2030, as estimated and shown in Figure 4.

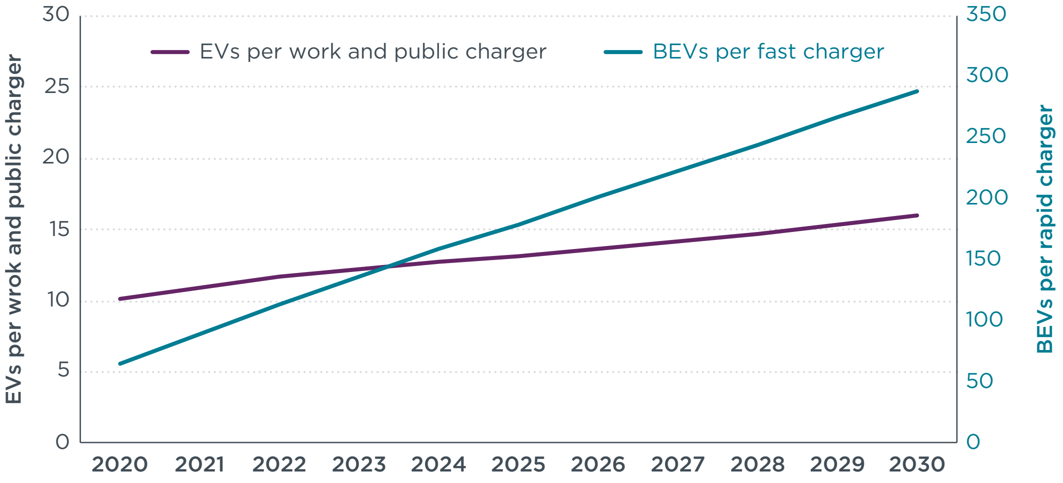

Figure 4. Electric vehicles per workplace and public charger and battery electric vehicles supported per fast charger.

Figure 4 shows that for normal charging at workplace and public locations, the electric vehicles per charger increases from 10 in 2020 to 16 in 2030. For fast charging, the BEVs per charger increases from 66 in 2020 to more than 300 in 2030. As discussed above, this is because of the increased utilization and faster charging on average in future years. The low number of BEVs per fast charger suggests that in early years it is necessary to obtain geographic coverage, but once sufficient coverage is achieved, fewer chargers per BEV are needed to address capacity. These ratios vary by metropolitan area. The higher utilization implies an improving business case for both normal and fast charging between 2020 and 2030.

The energy dispensed by location also changes over time. In 2020, 86% of charging energy is dispensed either at home or at work. By 2030, the portion of electric vehicle charging energy provided by home and work charging declines to 80%. A decline in the fraction of electric vehicle buyers that use their electric cars for commuting by 2030 causes a corresponding shift away from workplace charging. Similarly, access to home charging decreases by 2030, as more electric vehicles are deployed where there is less home charging availability, causing an increase in the need for public charging. Finally, a relative increase in BEVs increases the share of electric vehicle power coming from fast charging.

Results

The charging infrastructure requirements calculated from the model reveal the extent to which workplace, public, and fast charging infrastructure will be needed to support the growing electric vehicle market in the 2025–2030 time frame. Although this research is focused on quantifying how much publicly accessible electric vehicle charging infrastructure is needed, home charging remains the predominant charging type for most drivers. The underlying modeling approach previously described reveals that home charging accounts for more than 90% of total chargers and 60% of all the charging energy needed across the UK through 2030. The results which follow focus on the broader charging infrastructure needs in work, public, and fast charging situations. The results include region-level charging needs, followed by the overall UK results, which are compared to other studies.

Regional results

Based on the detailed electric vehicle and charging infrastructure assessment previously described, chargers needed by type and by region were estimated through 2030.

Figure 5 depicts the electric vehicle charger counts needed in 2025 and 2030 for scenario 1, which assumes 50% electric car sales by 2030, and scenario 2, which assumes 70% electric car sales by 2030, compared to total 2019 charger counts for selected regions. The figure shows charging needs for the seven metropolitan areas and three nonmetropolitan regions with the largest populations, which represent locations with more than two-thirds of projected UK electric car uptake by 2030. Across the 10 areas, as many as 28% (London area) to as few as 5% (Birmingham area) of the 2025 chargers needed had been installed by the end of 2019. Detailed tables for the 2025 and 2030 chargers for each area are shown in the Appendix.

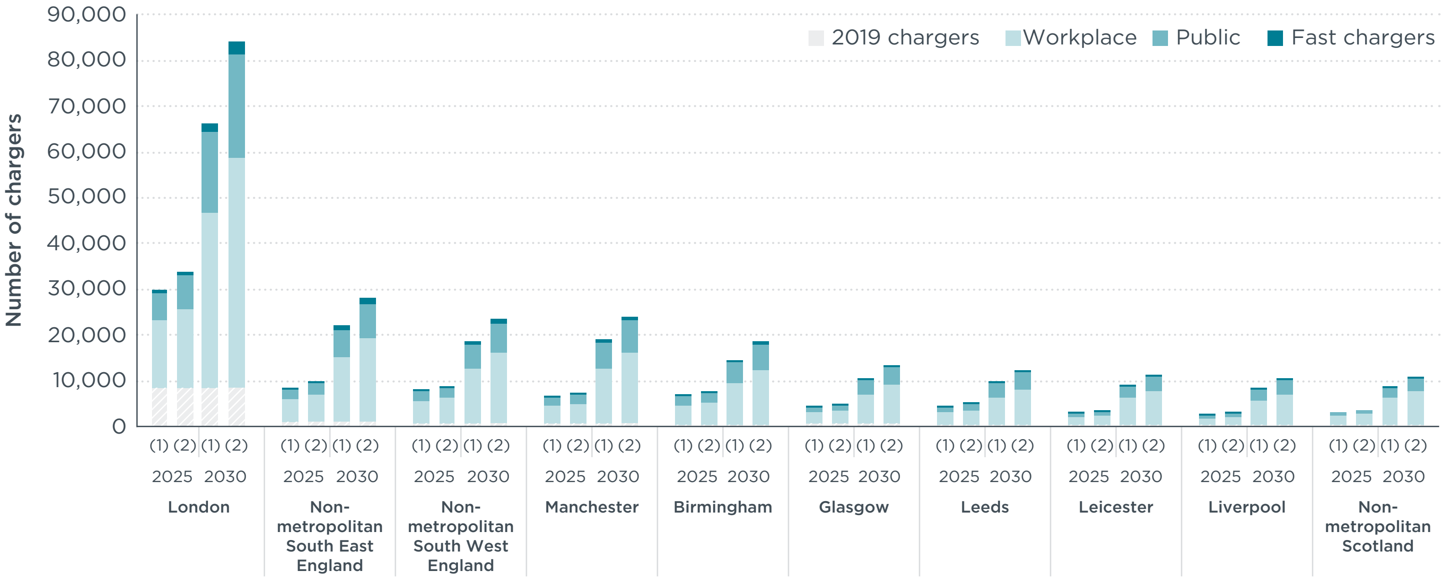

Figure 5. Chargers existing in 2019 versus chargers needed by 2025 and 2030 for selected areas for the UK reaching 50% (scenario 1) and 70% (scenario 2) electric car sales by 2030.

Comparing scenario 2 to scenario 1 indicates that many more chargers will be needed across all regions to support the higher goal of 70% electric car sales—an additional 12% to 15% chargers by 2025, and 25% to 27% more chargers beyond that by 2030. The proportion of work charging is greater than that for public charging due to the large number of vehicles used for commuting, although as we note, much workplace charging will be done at public locations, and the workplace and public definitions are interchangeable for many chargers.

As shown, London in 2019 had between 25% and 28% of the public and workplace charging it needs by 2025, but just 10% to 12% of what it needs by 2030. Nonmetropolitan South East England in 2019 had about 12% to 14% of its 2025 charging needs but only 4% to 5% of its 2030 charging needs. The Birmingham urban area, on the other hand, in 2019 had only 5% of the charging it will need in 2025 and 2% of its 2030 needs. In general, nonmetropolitan areas need fewer chargers per vehicle, primarily because of their greater relative availability of home charging compared to denser urban areas. The findings also indicate that the need for workplace chargers exceeds that of public chargers because of the expected convenience of charging at work.

Figure 6 depicts the charging infrastructure in place in 2019 as a percentage of the chargers needed by 2025 for scenario 2, which is to say 70% electric car sales share by 2030. The national average charging in place in 2019 is 15% of what is needed for 2025, and 6% of what is needed by 2030. As shown in the figure, some areas in 2019 had less than 10% of the needed chargers in 2025, whereas others had more than 25% of the needed chargers. Nonmetropolitan areas are shown with a hatched pattern, and the colors indicate the charging gap as a percentage of charging installed by the end of

2019 that will be needed by 2025. For example, the London metropolitan area had about 8,400 chargers installed in 2019 but 34,000 are needed by 2025, meaning the area was at a 25% level. Darker colors indicate a larger charging gap than lighter colors.

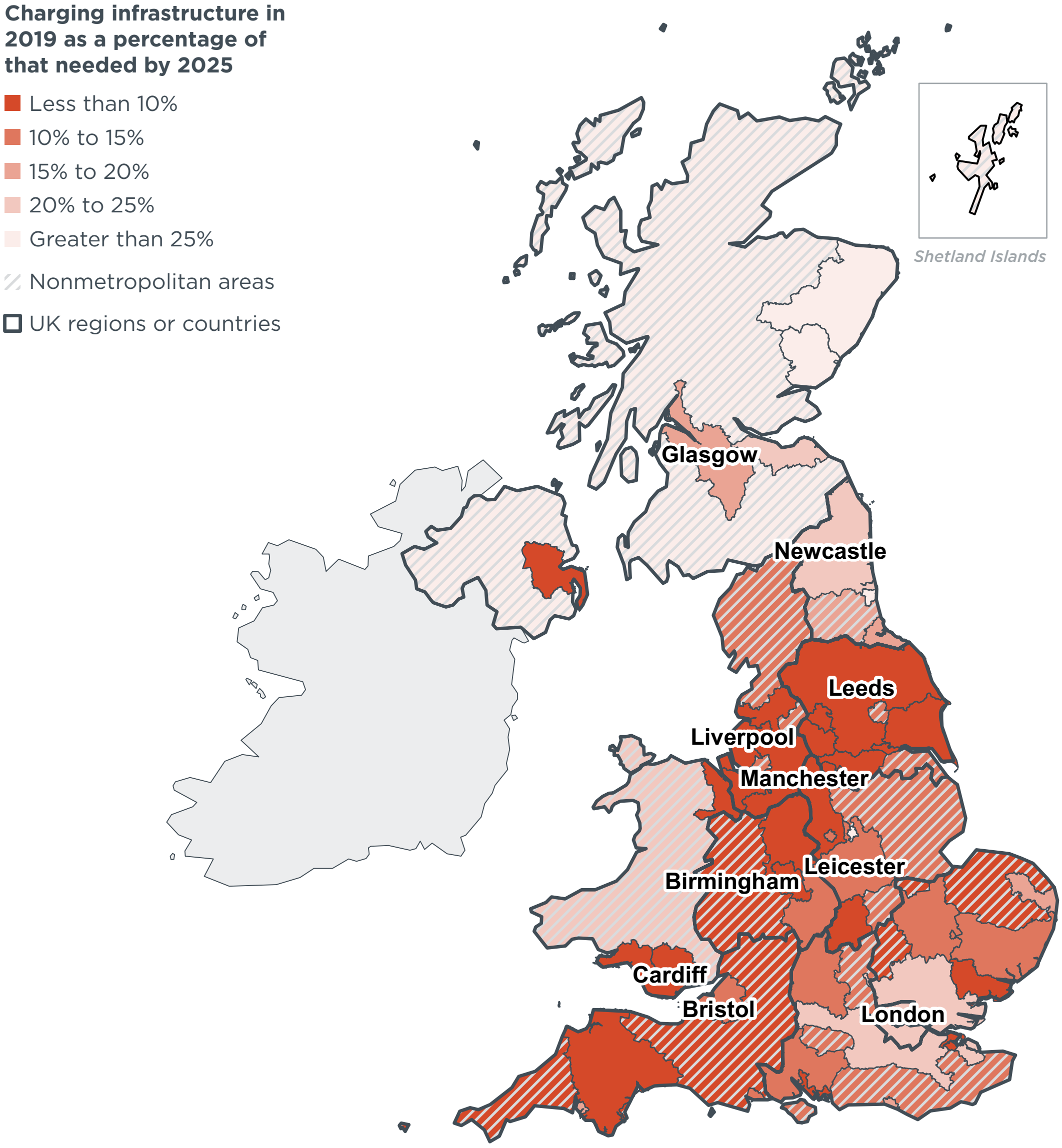

Figure 6. Percentage of charging infrastructure installed as of 2019 relative to what will be needed by 2025 for electric vehicle shares increasing to 70% of new vehicles by 2030.

The Figure 6 map shows several broad trends. In general, areas in England have a larger charging gap than areas in Wales, Scotland, or Northern Ireland. A notable exception is London, which has installed 25% of its 2025 charging infrastructure needs. However, this need is only defined for passenger cars and London will need to install additional charging for ride-hail and commercial vehicles. Among the top 10 metropolitan areas by population, Birmingham shows the greatest gap. In the north, Scotland shows a relatively small charging gap, with Glasgow and the nonmetropolitan areas in Scotland having 16% and 28% of the charging infrastructure needs for 2025 met, respectively.

Overall United Kingdom results

Table 7 summarizes the overall public and workplace charging infrastructure needs in the UK for 2025 and 2030, including overall results for the metropolitan and nonmetropolitan areas and comparisons to chargers installed through 2019. By the end of 2019, the UK had installed 7% of the workplace, public, and fast charging infrastructure it needs in 2030 in scenario 1 and 5% of what it needs in scenario 2. To meet its electric vehicle goals, the overall UK chargers must increase from about 23,000 in 2019 to 134,000 for scenario 1 and to 152,000 for scenario 2 by 2025. To meet the electric vehicle goals through 2030, a total of 338,000 to 426,000 chargers will be needed for scenario 1 and 2, respectively. This means 6 to 7 times more charging is needed in 2025, and 15 to 19 times more charging by 2030, than was installed by the end of 2019. The annual growth rate in charging to reach these targets is from 35% to 37% from 2019–2025 or 28% to 31% from 2019–2030. Excluding the workplace charging from the projected charging needs, for example, to make the results more comparable with other studies that have been done without workplace charging, would greatly reduce the amount of new charging infrastructure needed for 2025 and 2030. As indicated in Figure 5, workplace accounts for more than half the chargers.

Table 7. UK charging infrastructure needed for increasing electric car sales share to 50% or 70% of new vehicles by 2030.

		Scenario 1: 50% electric share in 2030			Scenario 2: 70% electric share in 2030		
	Year	Metropolitan areas	Non-metropolitan areas	UK overall	Metropolitan areas	Non-metropolitan areas	UK overall
Total chargers (public, workplace, fast)	2019	16,836	5,777	22,613	16,836	5,777	22,613
	2025	97,453	36,751	134,204	110,108	41,573	151,681
	2030	243,310	95,112	338,421	306,276	119,722	425,998
Electric vehicle stock	2025	1,205,266	487,158	1,692,424	1,388,461	560,282	1,948,743
	2030	3,681,655	1,515,393	5,197,047	4,750,768	1,950,806	6,701,574
Projected future charging compared to 2019	2025	5.8	6.4	5.9	6.5	7.2	6.7
	2030	14.5	16.5	15.0	18.2	20.7	18.8
2019 as percentage of future chargers needed	2025	17%	16%	17%	15%	14%	15%
	2030	7%	6%	7%	5%	5%	5%
Annual increase in chargers from 2019 to meet 2025 and 2030 needs	2025	34%	36%	35%	37%	39%	37%
	2030	27%	29%	28%	30%	32%	31%

Table 7 allows some limited comparisons with other UK-related charging infrastructure studies. Systra[31] estimates that more than 29,000 chargers will be needed in Great Britain by 2030, which is far fewer chargers than indicated in our analysis. However, the Systra study excludes workplace charging, which is the largest charger type in this study, and assumes that 85% of the 2030 chargers are fast charging; the fast charging share is far less in this study. Another point of reference is the UK's Vision for Rapid Charging,[32] which plans for 2,500 charge points ranging from 150 to 350 kW across England's motorways by 2030 and 6,000 by 2035. This analysis finds that 15,000 to 19,000 fast chargers will be needed by 2030, of which 2,700 to 3,500 are highway fast chargers for scenarios 1 and 2, respectively.

The London Electric Vehicle Infrastructure Delivery plan[33] calculates that for Greater London in 2025, for non-ride-hail vehicles, between 500 and 1,100 fast chargers and between 300 and 3,100 normal chargers are needed. This analysis projects the

31 Systra, "Plugging the Gap" (see note 5).

32 "Government vision for the rapid chargepoint network in England," (14 May, 2020) [UK Government policy paper]. Retrieved from https://www.gov.uk/government/publications/government-vision-for-the-rapid-chargepoint-network-in-england/government-vision-for-the-rapid-chargepoint-network-in-england

33 The Mayor's Electric Vehicle Infrastructure Taskforce, "London Electric Vehicle Infrastructure Delivery Plan" (see note 10).

London metropolitan area will need at least 1,200 fast chargers and 29,000 normal chargers, of which 10,000 are public access (see Appendix). However, the metropolitan area analyzed here has almost twice the number of people as Greater London, due to differing boundaries, and this analysis includes many workplace and semipublic chargers. Accounting for the different size and population, there are likely more fast chargers and fewer normal chargers in London's plan than in this assessment. In reality, normal and fast chargers are, to an extent, interchangeable in proportion to their power difference. Based on an approximate equivalency of six to 10 normal chargers to one fast charger, our results could be quite comparable to London's plan.

Another comparison point is with the pan-European study by Transport & Environment.[34] The scenarios for the number of electric vehicles are similar, but the charger estimates differ slightly. Transport & Environment indicates approximately 500,000 public charge points will be needed in the UK by 2030, whereas our relatively comparable scenario 2 charging infrastructure results are 15% lower. Comparing the findings in a different way, our scenario 2 indicates about 15.7 electric vehicles per charger in 2030, while Transport & Environment specifies 13.8 electric vehicles per charger.

Conclusions

Electric vehicle market growth in the UK through early 2020 has provided great promise for meeting the UK's much more ambitious vehicle electric vehicle transition goals for 2030 and beyond. This research indicates that charging infrastructure will simultaneously be a great challenge and a great opportunity in the upcoming years. The UK has indicated an interest in accelerating its goals to fully phase out combustion vehicles to 2035 and in May 2020 committed £500 million toward building out its charging infrastructure network.[35]

The findings in this research help inform such planning by quantifying the amount and types of charging infrastructure needed to support the UK's electric vehicle transition. Although this research is focused on how much publicly accessible and workplace electric vehicle charging infrastructure is needed, it must be emphasized that home charging accounts for more than 90% of the number of chargers and 60% of all the charging energy needed, and this remains the case through 2030. Beyond the at-home charging, increased public and workplace charging is critical for a comprehensive and convenient charging ecosystem for a growing electric vehicle fleet. We offer three main conclusions.

The UK's ambitious electric vehicle goals will need equally ambitious charging goals. To support 5.2 to 6.7 million cumulative electric vehicles and a 50%–70% electric share of new passenger cars by 2030, an increasingly comprehensive charging network will be needed. We estimate that 341,000 to 430,000 workplace, public, and fast chargers and an approximate 30% annual growth rate in the UK's charging infrastructure will be needed to keep pace with the UK's 2019–2030 electric vehicle growth goals. The London area, in England, and Scotland generally have had relatively strong charger deployment through 2019, putting each on a path toward their 2030 charging needs.

Fast charging deployment has shown strong growth. Our findings indicate that fast charging installed at the end of 2019 represented at least 40% of the UK's 2025 needs and about 20% of its 2030 needs. Scotland has built an especially robust fast charging network through 2019 and sets a leading example for other regions. These developments

34 Transport & Environment, "Recharge EU: How Many Charge Points Will Europe and Its Member States Need in the 2020s," 2020, https://www.transportenvironment.org/publications/recharge-eu-how-many-charge-points-will-eu-countries-need-2030

35 "Government vision for the rapid chargepoint network in England" (see note 32); Department for Transport, "Open consultation: Consulting on ending the sale of new petrol, diesel and hybrid cars and vans" (see note 3).

suggest fast charging infrastructure will need steady deployment of about 18% per year through 2030, which is not as accelerated as the annual growth needed in normal and workplace charging.

More vehicles can be supported per publicly accessible charger in future years. The ratio of electric vehicles (including all-electric and plug-in hybrid) per normal speed charger rises from 10 in 2019 to 16 in 2030. All-electric battery electric vehicles per fast charger increase from 66 to 300. This is the result of the move to more longer-range electric vehicles, faster charging speeds, and higher utilization rates of chargers. These trends can be expected to provide increasing opportunities for improved business cases for charging providers.

This charging infrastructure study points to several areas that are rich for further analysis. Our analysis underscores the need for greater use of normal-speed chargers, which take advantage of where vehicles are naturally parked most often. Further analysis would be warranted on trade-offs between more normal and more rapid charging, specifically related to equipment cost, electricity charging rates for drivers, and driver convenience. This UK analysis provides details on the greatly varying charging needs by region and charger type, but any specific city or region will need to tailor its own charging needs assessments to its own market conditions, electric vehicle transition goals, and broader electric power sector goals, such as enabling more renewable power. Further work could assess how EU- and UK-level stimulus funds and supporting policy could further support the infrastructure growth, as well as how best to allocate charging across disadvantaged communities to support the broader electric mobility transition.

Although charging infrastructure to support the UK's goal to accelerate the transition to zero-emission vehicles is critical, the challenge is broader. Beyond building out the supporting infrastructure, as analyzed here, other actions will also be needed to overcome other barriers. Stronger vehicle emission standards and direct electric vehicle regulations are necessary to ensure industry electric vehicle investment scales up fast enough and an adequate and diverse supply of electric vehicle models is available to the market. Sustained city-level vehicle policies send clear signals to car buyers and the developers of the charging infrastructure network. Sufficient charging infrastructure deployment, with other such reinforcing policies, comprise a comprehensive approach to spur the transition to electric transport.

Appendix

This Appendix provides normal (public and workplace) and fast charging infrastructure results for individual metropolitan areas and nonmetropolitan areas for scenarios 1 and 2.

Table A1. Charging infrastructure needs for electric vehicle scenario 1 (50% electric sales by 2030)

Metropolitan area *(and region or country in italics)*	2019 Normal chargers	2019 Fast chargers	2025 Electric vehicles	2025 Normal chargers	2025 Fast chargers	2030 Electric vehicles	2030 Normal chargers	2030 Fast chargers
London	7,882	501	370,901	29,281	1,239	995,511	64,365	2,501
Manchester	615	91	83,880	6,320	270	298,093	18,350	665
West Midlands urban area	319	57	91,309	6,638	236	250,699	14,181	538
Liverpool	219	47	31,551	2,602	118	112,827	8,121	270
Glasgow	653	116	55,208	4,158	177	176,622	10,404	421
Leeds	314	69	60,965	4,329	162	178,293	9,465	376
Leicester	413	28	45,051	2,919	128	158,354	8,704	316
Newcastle upon Tyne	393	63	20,714	1,638	76	71,895	4,983	171
Bristol	307	49	42,691	2,792	121	138,347	7,369	300
Cardiff	121	15	18,586	1,596	68	64,131	5,148	152
Stoke-on-Trent	164	43	22,303	1,779	69	76,717	5,361	160
Coventry	228	63	26,719	2,110	82	85,427	5,355	186
Edinburgh	408	46	16,710	1,561	64	53,347	3,997	135
Doncaster	67	44	14,158	929	44	41,829	2,483	95
Southampton	199	44	13,426	1,417	44	41,303	3,439	90
Exeter	177	39	29,195	1,878	73	95,144	4,807	188
Belfast	140	12	20,443	1,687	57	67,521	4,797	137
Ipswich	137	27	12,179	1,097	40	40,076	3,133	85
Oxford	249	42	25,875	1,849	70	82,400	4,708	166
Blackburn - Blackpool - Preston	98	23	12,517	1,073	43	40,983	2,996	94
Portsmouth	94	27	20,539	1,676	68	60,222	4,040	153
Cambridge	161	13	13,523	1,168	40	41,564	2,869	86
Kirklees	66	19	8,663	829	33	29,567	2,429	71
Cheshire West and Chester	87	10	11,050	895	35	37,617	2,651	80
Kingston upon Hull	58	7	22,401	1,638	60	72,494	3,773	152
Sheffield	65	10	9,345	768	33	28,710	1,827	72
Middlesbrough	120	15	8,577	723	31	30,832	2,356	70
Bradford	55	15	10,021	830	34	32,274	2,255	76
Swansea	62	14	13,144	963	41	42,942	2,747	93
Aberdeen	215	36	9,808	817	36	32,621	2,282	72
Colchester	61	12	8,291	690	27	27,169	1,981	59
Northampton	53	22	9,968	819	29	31,705	2,057	66
Norwich	84	11	6,570	533	21	21,697	1,613	47
Bournemouth	53	13	5,960	564	19	19,111	1,576	41
Nottingham	186	29	5,049	508	29	15,350	1,330	37
Brighton and Hove	75	-	3,026	378	13	9,770	1,093	25
Medway	16	4	5,051	415	17	14,665	1,210	35
Sunderland	109	20	3,644	321	20	13,017	1,046	31
Dundee	195	56	4,023	438	56	12,356	1,026	56
Plymouth	72	4	3,792	347	15	13,328	1,124	33
Derby	82	8	8,440	617	22	25,124	1,401	52
South East England	*960*	*209*	*124,406*	*8,330*	*471*	*382,448*	*21,304*	*1,086*
South West England	*730*	*124*	*111,540*	*7,655*	*379*	*336,494*	*17,930*	*917*
Scotland	*965*	*278*	*39,567*	*3,241*	*278*	*124,835*	*8,577*	*371*
East Midlands	*397*	*71*	*37,043*	*3,009*	*141*	*118,525*	*8,114*	*329*
East of England	*335*	*39*	*60,849*	*3,705*	*197*	*166,802*	*8,205*	*450*
North West England	*283*	*85*	*21,842*	*1,899*	*99*	*74,077*	*5,583*	*224*
West Midlands	*217*	*71*	*38,052*	*2,549*	*144*	*128,038*	*7,467*	*347*
Wales	*344*	*39*	*18,084*	*1,530*	*79*	*59,131*	*4,736*	*168*
Northern Ireland	*310*	*16*	*13,935*	*1,141*	*63*	*49,503*	*3,651*	*141*
North East England	*152*	*22*	*10,786*	*877*	*52*	*37,296*	*2,724*	*117*
Yorkshire and the Humber	*109*	*21*	*11,055*	*863*	*47*	*38,245*	*2,557*	*113*
All metropolitan areas	15,072	1,764	1,205,266	93,592	3,861	3,681,655	234,853	8,456
All nonmetropolitan areas	*4,802*	*975*	*487,158*	*34,800*	*1,951*	*1,515,393*	*90,848*	*4,264*
United Kingdom total	19,874	2,739	1,692,424	128,392	5,812	5,197,047	325,701	12,720

Table A2. Charging infrastructure needs for electric vehicle scenario 2 (70% electric sales by 2030)

Metropolitan area *(and region or country in italics)*	2019 Normal chargers	2019 Fast chargers	2025 Electric vehicles	2025 Normal chargers	2025 Fast chargers	2030 Electric vehicles	2030 Normal chargers	2030 Fast chargers
London	7,882	501	424,817	32,978	1,381	1,289,308	81,478	3,113
Manchester	615	91	97,468	7,216	303	384,521	23,139	828
West Midlands urban area	319	57	102,958	7,452	263	320,068	17,943	667
Liverpool	219	47	37,178	2,966	133	146,333	10,151	337
Glasgow	653	116	63,740	4,716	199	227,430	13,165	524
Leeds	314	69	69,352	4,878	181	228,229	12,008	466
Leicester	413	28	52,928	3,358	145	205,254	11,032	396
Newcastle upon Tyne	393	63	24,280	1,866	86	93,132	6,239	213
Bristol	307	49	49,429	3,191	137	178,468	9,381	374
Cardiff	121	15	21,773	1,811	77	83,108	6,398	189
Stoke-on-Trent	164	43	26,098	2,020	78	99,315	6,693	200
Coventry	228	63	30,851	2,385	92	110,029	6,731	232
Edinburgh	408	46	19,290	1,754	71	68,709	4,982	167
Doncaster	67	44	16,161	1,053	49	53,758	3,133	117
Southampton	199	44	15,404	1,579	47	53,081	4,251	111
Exeter	177	39	33,822	2,144	83	122,690	6,123	236
Belfast	140	12	23,749	1,907	65	87,209	5,986	172
Ipswich	137	27	14,140	1,234	44	51,754	3,886	106
Oxford	249	42	29,875	2,099	78	106,220	5,952	207
Blackburn - Blackpool - Preston	98	23	14,521	1,212	48	52,916	3,736	117
Portsmouth	94	27	23,400	1,888	76	77,257	5,084	190
Cambridge	161	13	15,515	1,310	44	53,428	3,579	107
Kirklees	66	19	10,119	933	37	38,240	3,012	88
Cheshire West and Chester	87	10	12,905	1,014	40	48,666	3,307	99
Kingston upon Hull	58	7	25,897	1,857	68	93,311	4,797	190
Sheffield	65	10	10,719	864	37	36,894	2,295	88
Middlesbrough	120	15	10,117	823	35	40,007	2,931	88
Bradford	55	15	11,594	938	38	41,644	2,822	95
Swansea	62	14	15,253	1,096	46	55,496	3,452	116
Aberdeen	215	36	11,405	924	36	42,132	2,851	90
Colchester	61	12	9,624	780	30	35,102	2,468	74
Northampton	53	22	11,500	923	32	40,825	2,577	83
Norwich	84	11	7,639	604	24	28,063	2,008	58
Bournemouth	53	13	6,890	633	21	24,650	1,951	51
Nottingham	186	29	5,790	567	29	19,759	1,645	45
Brighton and Hove	75	-	3,503	421	14	12,610	1,339	32
Medway	16	4	5,762	468	19	18,899	1,505	44
Sunderland	109	20	4,294	365	20	16,887	1,299	39
Dundee	195	56	4,614	487	56	15,875	1,268	56
Plymouth	72	4	4,456	393	17	17,282	1,394	41
Derby	82	8	9,629	695	25	32,207	1,772	65
South East England	*960*	*209*	*142,803*	*9,462*	*527*	*491,989*	*26,974*	*1,353*
South West England	*730*	*124*	*127,557*	*8,656*	*427*	*431,869*	*22,732*	*1,144*
Scotland	*965*	*278*	*45,621*	*3,655*	*278*	*160,880*	*10,719*	*461*
East Midlands	*397*	*71*	*42,804*	*3,394*	*159*	*152,831*	*10,130*	*411*
East of England	*335*	*39*	*68,643*	*4,187*	*219*	*213,210*	*10,471*	*561*
North West England	*283*	*85*	*25,493*	*2,147*	*111*	*95,816*	*6,946*	*280*
West Midlands	*217*	*71*	*44,376*	*2,916*	*163*	*165,692*	*9,423*	*435*
Wales	*344*	*39*	*20,997*	*1,727*	*88*	*76,476*	*5,870*	*210*
Northern Ireland	*310*	*16*	*16,403*	*1,295*	*71*	*64,203*	*4,538*	*176*
North East England	*152*	*22*	*12,638*	*997*	*59*	*48,323*	*3,398*	*146*
Yorkshire and the Humber	*109*	*21*	*12,948*	*981*	*53*	*49,517*	*3,202*	*141*
All metropolitan areas	15,072	1,764	1,388,461	105,802	4,306	4,750,768	295,763	10,513
All nonmetropolitan areas	*4,802*	*975*	*560,282*	*39,417*	*2,156*	*1,950,806*	*114,405*	*5,317*
United Kingdom total	19,874	2,739	1,948,743	145,220	6,462	6,701,574	410,168	15,830