

A Greener Future: Electric Vehicles & Charging Infrastructure in the United Kingdom

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Abstract—This paper presents a literary review of the charging infrastructure together with the electric vehicle uptake in the UK. The literature review covers the UK Governments legal binding commitments, current policies for improving EV uptake and accelerating the charging infrastructure in the UK. Industry position and government papers were reviewed which highlight the key challenges faced. The current charging infrastructure in the UK is presented together with future requirement for charging points. Modelling the future number of chargepoints is highly uncertain. The technological and commercial climate for charging infrastructure is developing at a rapid pace and it is not clear what will be the optimal mix between the high and low powered chargers.

Keywords—electric vehicle (EV), charging infrastructure, charging points,

I. INTRODUCTION

The United Kingdom (UK) is party to The Paris Agreement (PA) [1] which has the main ambition to improve the global response to the threat of climate change by keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius. The PA requires all Parties (countries) to design and implement a strategy through “nationally determined contributions” (NDCs).

In December 2020, the UK communicated its NDC which commits to reducing economy-wide greenhouse gas emissions by at least 68% by 2030, compared to 1990 levels. The Department for Business, Energy and Industrial Strategy (BEIS) is responsible for the strategic oversight of the UK’s international climate and energy policy, and for the UK Government’s domestic climate and energy policy. [2]

The legally binding Climate Change Act 2008 [3] sets a framework for the UK to reduce emissions. The Climate Change Act introduced carbon budgets for the UK, which cap emissions over successive five-year periods and must be set 12 years in advance. The first six carbon budgets cover the period from 2008-37. The Act also established the Climate Change Committee (CCC) – the independent statutory body that advises the UK Government on climate change mitigation and adaptation, including emissions reduction targets [2]

Delivering the PA will require increased ambition from all sectors of the economy. All sectors will need to reduce their

emissions to zero. Road transport emissions have risen over the last two decades and currently produce 16% of total global CO₂ emissions, predominantly from passenger (car) transport. Accelerated decarbonisation of the passenger transport fleet (e.g., cars) is particularly important for achieving the global emission reductions required this decade for the Paris Agreement. [4]. In the UK, transport is now the highest emitting sector of the UK economy, accounting for 22% of total greenhouse gas (GHG) emissions. Cars comprise 13% of the UK’s GHG emissions, vans 4% and HGVs 4%. [5]

II. EV CONTRIBUTION TO A GREENER FUTURE

The full transition to electric vehicles (EVs) will be one of the most important actions to achieve the UK’s Net Zero target. The CCC has called for all new light-duty vehicles to be fully battery-electric vehicles by 2032. To reach Net Zero, all vehicles – including heavy-goods vehicles (HGVs) – must be fossil fuel free by 2050. [6]. In response, the UK Government has published “The zero-emission vehicle (ZEV) mandate” which sets out the percentage of new zero emission cars and vans manufacturers will be required to produce each year up to 2030. 80% of new cars and 70% of new vans sold will be zero emission by 2030, increasing to 100% by 2035. [7]

To achieve the ambitious plan for 100% of new zero emission cars and vans sales by 2035, an integrated approach is required for all key aspects of the transition from fossil fuels vehicles. The UK Government approach is set out in the “Transitioning to zero emission cars and vans: 2035 delivery plan” [8]. This delivery plans sets out the key actions needed:

1. Phasing out sales of new petrol and diesel cars and vans (see Zero-emission vehicle mandate [7])
2. Increasing uptake of zero emission vehicles
3. Accelerating infrastructure rollout
4. Relying the UK’s energy system
5. Greening vehicle lifecycles (i.e. low carbon electricity generation, battery recycling)
6. Review of supply chains for new manufacturing processes for EVs and associated equipment
7. Research & Development (i.e. battery, vehicle and charging infrastructure technologies)

All the above actions have a close interrelationship and a successful outcome for the transition to zero emission

vehicles will require all actions to be met. This paper focuses on item 3 - Accelerating the infrastructure rollout. However, for this to be a positive outcome, it is totally dependent upon:

- 2 – Increasing the uptake of ZEVs
- 4 - Readyng the UK’s energy system

As battery prices continue to reduce and the production of ZEVs increases, the upfront cost of ZEVs will continue to fall. It is considered across the motor industry that purchase prices of ZEV’s will become cheaper than fossil fuel vehicles prior to 2030 [4]. The increase in the uptake of ZEVs directly leads to a proportional increase in the electrical demand from the grid. The Climate Change Committee’s Sixth Carbon Budget suggests that electric cars and vans could increase total electricity demand by approximately 65-100TWh in 2050, compared to the total electricity demand of 600-900TWh in 2050. In comparison, the total electricity demand for 2021 was in the region of 300TWh [8]. The EV charging infrastructure will require significant capacity from electrical generation, transmission, and distribution, which in turn will have cost implications to ensure the electricity network can manage the demand. Smart charging and vehicle-to-grid (V2G) and vehicle-to-everything (V2X) offer consumers flexibility and the ability to charge at time of lowest cost, or even sell back energy to the grid. Smart charging allows EVs to be charged when it is most efficient for the balance of supply and demand across the electricity system. This means shifting charging to periods of lower overall demand for electricity. Smart charging and V2G technology would reduce the need for grid upgrades but will not eliminate it.

III. EV INFRASTRUCTURE – CURRENT POSITION IN THE UK

Charging devices in the UK are now categorized into four power categories:

- 1. Slow: 3 kilowatts (kW) – 7kW
- 2. Fast: 8kW to 49kW
- 3. Rapid: 50kW to 149kW
- 4. Ultra-rapid: 150kW and above

The current charging options are either private or public charging, each have several options:

Private charging (ranges typically Slow – Fast)

- 1. Residential off-street (home charging)
- 2. Workplace Charging
- 3. Depot

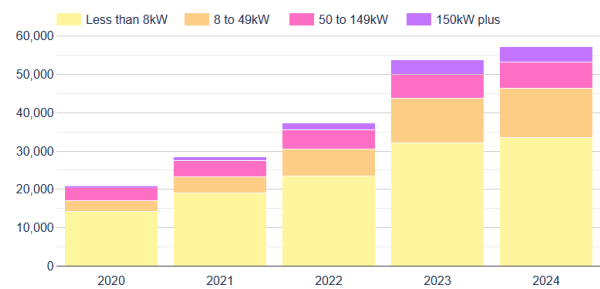
Public charging (ranges from Slow to Ultra-rapid)

- 1. Residential on-street (lamp-post chargers, free-standing chargers)
- 2. On-route Rapid and ultra-rapid charging (e.g., Motorway service stations)
- 3. Residential charging hubs
- 4. Destination Charging (gyms, supermarkets, shopping centres, train stations).

As at 30 September 2023, there were approximately 34 million cars on UK roads, of which approximately 33 million were conventional petrol and diesel cars and on UK roads [9].

The fossil fuels cars are supported by 66,000 fuel pumps [10] at around 8,400 locations around the UK [11]. In comparison, The number of zero emission electric vehicles (fully electric) on the UK roads at 30 September 2023 of 863,643 [9]. These are supported by 53,677 public electric vehicle charging devices installed in the UK as at 1 January 2024, of which 10,118 had 50kW of power or above (19% of all charging devices) and 31,910 had a power rating of 3kW up to 8kW (59% of all charging devices) [12].

Figure 1 depicts the level of public chargepoints in the UK for the last 4 years and for the 2 months to 28 February 2024 and represents a significant increase year-on-year since 2020 [13]. Today, a driver is never more than twenty-five miles away from a rapid charge device anywhere along England’s motorways and major roads [8].



Data representative of Zapmap database (www.zap-map.com) 28th February 2024.

Newly defined power rating bandings for 2024 are slow (3-7kW), fast (8-49kW), rapid (50-149kW) and ultra-rapid (150kW+)

Figure 1 – UK Public Charging Points as at 28 February 2024 [13]

However, whilst the total number of public chargepoints is increasing in real terms, it is not keeping pace with the number of EVs on the road and certainly not with the projected number to be on the road in future. The ratio of cars to public chargepoints across the UK has increased significantly from 2019 to 2022, (Table 1) primarily due to the uptake of EV’s is outweighing the installation of public charging points. Furthermore, there is an uneven geographical distribution of charging devices within the UK, it is not being equitably distributed across regions and socioeconomic groups. (figure.2). In particular, rural areas could be left behind, primarily due to lack of investment as the business models for these areas (low utilisation of charging devices) are especially challenging.

TABLE 1: RATIO OF EV’S TO PUBLIC CHARGEPOINTS IN THE UK [14]

Year	Ratio of EV’s to public chargepoints
2019	33:1
2020	51:1
2021	75:1
2022	95:1

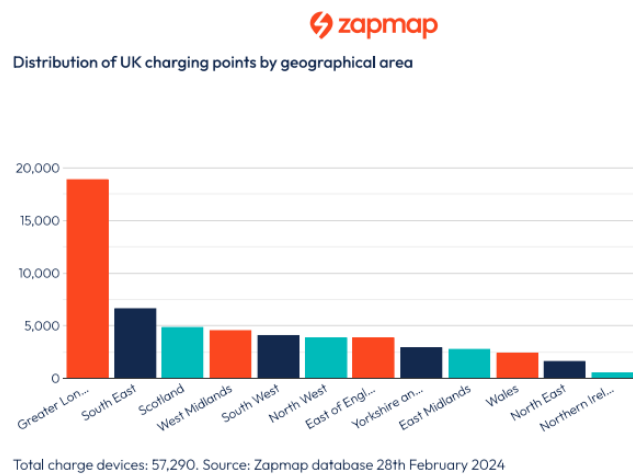


Figure 2 – UK Public Charging Points as at 28 February 2024 – geographical view [13]

IV. KEY CHALLENGES WITH ACCELERATING THE INFRASTRUCTURE ROLLOUT

The zero-emission vehicle (ZEV) mandate sets out that 100% of new cars and vans sold in the UK will be zero emission by 2035. [7]. Looking at ZEV cars alone, scenarios show that ownership could equate to 11 – 13 million by 2030, 20 – 25 million by 2035 and 26 – 35 million by 2040 [5], which is significantly higher than figures estimated on the UK roads at 30 September 2023 of 863,643 [9]. The key barriers to increasing the uptake of ZEVs, and correspondingly meeting the ZEV mandate and the UK's legally binding commitments under the Climate Change Act 2008 are:

- Upfront cost of purchasing an EV
- Current lack of EV Charging Infrastructure

Car users like the convenience of their existing driving (refuelling) and parking habits [15]. Insufficient access to reliable charging is one of the main barriers to drivers considering a purchase of an EV together with the limited range of ZEVs and the challenges of charging away from home. Any future EV Charging Infrastructure will need to provide solutions as close as possible to existing driving and parking habits to achieve a large EV uptake. The UK Government's vision is that EV charging should be cheaper and more convenient than refuelling at a petrol station.

Most UK motorists have access to off-street parking, correspondingly, charging is primarily completed at home, where the costs are cheaper. However, not everyone has access to off-street parking, 34% of UK households do not have off-street parking and need to charge on-street or elsewhere. [6]. The UK Government's EV Infrastructure Strategy [10] focuses on the public charging devices for two main purposes:

1. To enable long distance journeys (high powered chargers on the strategic road network), and
2. To support those without off-street parking (local on-street charging).

EV users face several challenges with the current EV charging infrastructure and provide a barrier to EV uptake. First and foremost, the pace of the EV charging Infrastructure is too slow. This is evidenced by the deterioration of the ratio of cars to public charges from 2019 to 2022. The public charging infrastructure often lets down EV users with poor reliability, opaque or excessive charging, complex access involving numerous apps together with a lack of customer service [10]. Furthermore, difficulty in locating charging points that are in operation. Over and above EV user challenges, there are significant issues with connecting new charge points to the electricity system can be very slow, primarily due to planning issues and cost implications where grid capacity and/or distribution equipment needs to be upgraded.

In response to these challenges, the UK Government has introduced the Public Charge Point Regulations 2023 on 2 November 2023 and come into force on 24 November 2023. These regulations deal with many of the issues currently facing EV drivers and mandate the following:

1. **Contactless payment:** for chargepoints of 8kW and above, must have ability to pay by contactless payment
2. **Payment Roaming:** pay for charging using a payment service provided by a third party roaming provider
3. **Reliability:** for chargepoints of 50kW and above, they should reflect average reliability of 99% of the time during a calendar year
4. **Helpline:** Provision of a staffed telephone helpline available free of charge for 24 hours a day
5. **Data:** chargepoint providers to open up their data, so drivers can easily find an available chargepoint that meets their needs. It will open up data for apps, online maps, and in-vehicle software, making it easier for drivers to locate chargepoints, providing data on charging speeds and to determine whether they are working and available for use.
6. **Pricing Transparency:** Display price in pence per kilowatt hour

A further challenge with accelerating the EV charging infrastructure is the collaboration required across a large number of stakeholders (figure.3), all of which will need to play their part to achieve a successful transition to meet the ZEV mandate.

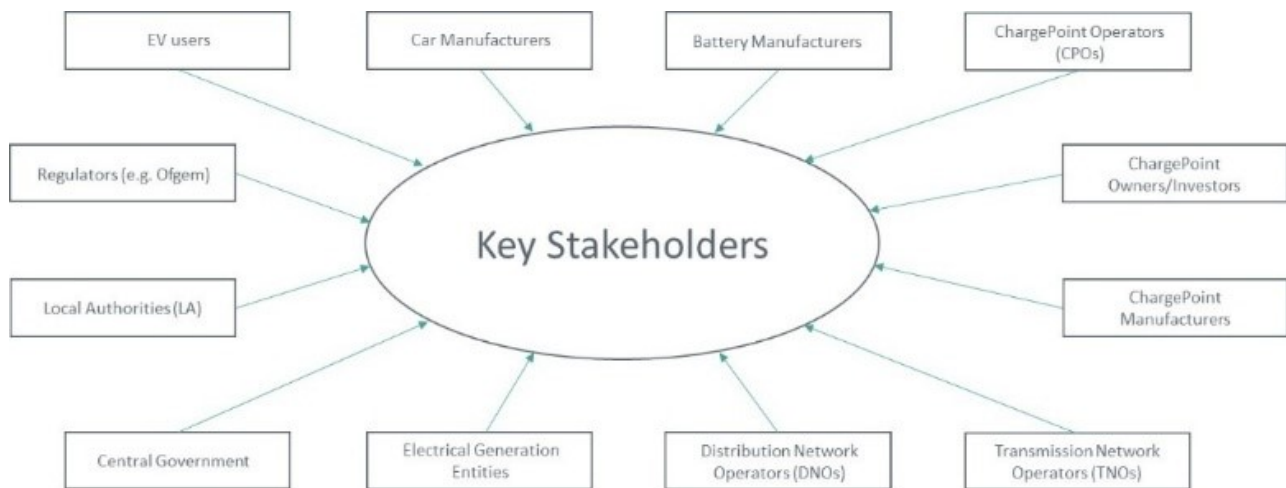


Figure 3 – Key stakeholders EV charging infrastructure.

Car and Battery Manufacturers, together with the supply chain, will need to ensure an adequate supply of EVs are available to meet the sales requirements under the ZEV mandate. Chargepoint Manufacturers, Electrical Generating entities, DNOs, TNOs and Ofgem need to work together with Central and Local Government to ensure the UK's electrical system will meet electrical demand requirements in a timely and cost-effective manner. Local Authorities, ChargePoint Operators (CPOs), ChargePoint Owners/Investors to ensure the installation of EV Charging Points is ahead of the EV uptake curve. Above all, Central Government will need to set appropriate policies and the legal structure to facilitate the uptake of EVs and the acceleration of the EV Charging Infrastructure to ensure it meets the motoring needs.

This could lead to EVs being charged from 20% to 90% in the space of less than 10 minutes, which in turn could change the equation for the future EV Charging Infrastructure requirements in the UK. Whilst this may be the end state, the EV Charging Infrastructure needs to be ahead of the curve for EV cars on the road to give the public confidence in the public charging network.

Modelling based estimations for the UK charging points required by 2030 have been completed by several bodies, as set out in Table 2. Estimates vary significantly, with different analytical approaches taken and assumptions made in relation to future vehicle and charging infrastructure technology, EV uptake, driving and charging behaviours.

V. FUTURE REQUIREMENT FOR EV CHARGING INFRASTRUCTURE IN THE UK

Estimations for future charge points is highly uncertain. There are a large number of variables, e.g. developments in vehicle efficiencies, battery technology, charging technology together with forecasting distances travelled, average annual mileage, traffic flows, all of which will influence the outcome. Furthermore, a key element will be the charging preferences and behaviour (behavioural consideration of "range anxiety"), particularly for those without off-street parking, and how these solutions will be used in practice, which in turn will determine variables such as number of charges required.

The technological and commercial climate for charging infrastructure is developing at a rapid pace and it is not clear what will be the optimal mix between the high and low powered chargers. Technological advancements in charging technology could lead to 500kW+ chargers, combined with battery technology and power electronics improvements such that on-board car technology will allow EVs to accept these power levels.

TABLE 2: ESTIMATES OF PUBLIC CHARGERS REQUIRED BY 2030

Body who performed estimate	Estimate of public chargers required by 2030
Transport & Environment (T&E) [16]	370,000 – 500,000
Committee on Climate Change (CCC) [5]	140,000 – 270,000 by 2030 250,000 – 460,000 by 2040
HM Government – Taking charge – the electric vehicle infrastructure strategy [10]	300,000 public charge points as a minimum in the UK but there could potentially be more than double that number (range between 280,000 – 720,000)
International Council on Clean Transportation (ICCT) [17]	340,000 – 430,000

The Society of Motor Manufacturers and Traders Limited (SMMT) – 3 scenarios by 2030 [18]	(1) On-street residential as the dominant model – 2.33 million (rapid/ultra rapid: 40,000) (2) Forecourt/hub/motorway as the dominant model – 689,000 (rapid/ultra rapid: 147,000) (3) Workplace destination as the dominant model – 938,000 (rapid/ultra rapid: 82,000)
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The T&E in-house model estimates future charging demand on the public charging network and then examining the charging capacity of different charger types to calculate the number of charging points of different types required. The ICCT model also analyses future charging needs but determines this by projecting annual electric sales, allocating EVs to charging need groups then energy required per charging category following which estimate charging time demanded by charging activity to derive the charging points required. The HM Government model utilises a top-down approach, based on a calculation of the future energy requirements of EVs which takes into account a number of factors, including EV uptake, where vehicles are licensed (rural v urban), access to off street parking, battery efficiency, average miles travelled, charging preferences, energy supplied per charging event. The ICCT model is similar to the T&E in-house model and is based on projected annual EV uptake, allocating EVs to charging need groups which in turn provides and energy demand and charging time demand by charging activity that results in the estimated charge points required.

VI. CONCLUSION

This paper summarized a literature review of the EV uptake and charging infrastructure in the United Kingdom. The United Kingdom is legally bound to reduce greenhouse gas emissions. The full transition to EVs will be one of the most important actions to achieve the UK's Net Zero target. The UK Government has set out a policy that all requires sales of all vehicles to be net zero at the tailpipe by 2035. There are significant challenges with meeting this plan, namely, increasing the uptake of ZEVs, current lack of EV charging infrastructure and readying the UK's energy system, in particular, capacity issues. A further challenge with accelerating the EV charging infrastructure is the collaboration required across a large number of stakeholders involved, ranging from government to manufacturers. The total number of public chargepoints in the United Kingdom is increasing in real terms, however, it is not keeping pace with the number of EVs on the road and certainly not with the projected number to be on the road in future. Modelling the future need, type, and number of chargepoints is highly uncertain. The technological and commercial climate for charging infrastructure is developing at a rapid pace and it is

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