SMMT
DRIVING THE
MOTOR INDUSTRY

Delivering consumer-centric charging infrastructure for zero emission mobility

Position Paper

THE SOCIETY OF
MOTOR MANUFACTURERS
AND TRADERS LIMITED

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EXECUTIVE SUMMARY

The automotive industry shares government's Net Zero vision and is fully committed to zero emission motoring. These are evidenced by the very significant investments that have resulted, and are continuing to result, in a rapidly increasing number of plug-in models introduced and an exponentially growing plug-in vehicle market. Plug-in vehicles accounted for a record-breaking more than one in six UK car registrations in 2021, while battery electric vehicle (BEV) registrations rose to an all-time high of one in nine, with more registered than in 2016-2020 combined.

Our outlook is positive, as we believe the new plug-in car market will continue to grow at an exponential rate, resulting in a car parc comprising 9.3 million plug-ins by 2030 (27.0%) and 18.4 million by 2035 (54.8%), of which 6.9 million (20.1%) and 15.3 million (45.6%) respectively are BEVs. However, this outlook is contingent on the key assumption that charging infrastructure is no longer a barrier to mass market uptake. Unlocking the full environmental and socioeconomic benefits of this transition requires collaboration involving industry, government and key sectors such as fleets, infrastructure and energy.

Government, local authorities and the charging infrastructure sector deserve credit for the more than 3,000% growth in public charging infrastructure since the first chargepoints were installed in 2011. However, every single reputable study or consumer survey have invariably and consistently shown that the inadequacy of infrastructure provision is still a concern for many consumers and is a main barrier to mass uptake. Range anxiety has now been replaced by charging anxiety. Although most current plug-in vehicle users charge at home, public chargepoints remain critical for consumer confidence and are heavily relied upon by many commercial and grey fleets as well as the one-third of British households that do not have off-street parking.

As plug-in vehicle registrations surged, public charging infrastructure expansion has failed to keep pace. Plug-in cars on the road had grown a phenomenal 280.3% between 2019 and 2021, but slow/fast public chargepoints grew by just 69.8% in the same period. While BEVs in the car parc grew by a staggering 586.8%, rapid/ultra-rapid charger stock grew by 82.3%. We should be proud that the UK is a leader in the rapid/ultra-rapid charger segment, with its 32 BEVs per charger ratio well ahead of most major markets apart from China (11:1), South Korea (12:1) and Japan (17:1). However, our plug-in cars per slow/fast public charger ratio has deteriorated from 11:1 to 16:1, which compares unfavourably to the ratios in South Korea (3:1), the Netherlands (5:1), China (9:1), France (10:1) and Belgium (13:1).

With government's 2030 and 2035 end-of-sale deadlines in place and binding targets for zero emission vehicle sales expected from 2024, the UK automotive industry is required to make a more significant and advanced commitment than just about any other major car or van market. Yet there is a glaring lack of an equivalent mandate with binding targets for delivering a commensurate nationwide network of chargepoints that is fit for purpose for the mass market transition and that matches consumer needs.

Left entirely to market forces, the rollout of chargepoints will naturally prioritise commercial rather than consumer interests, focussing predominantly on the more profitable types of chargers and high-utilisation locations. As a result, while the problem may not be a **lack** of chargepoints, the provision of public chargers risks becoming increasingly **inadequate**, **inequitable** and **disproportionate** as plug-in vehicle uptake accelerates. The lack of regulation in the charging infrastructure market, meanwhile, has resulted in poor **consumer experience**, as both the Competition and Markets Authority and government have discovered. Charging should really be as easy and uneventful as refuelling.

Industry is determined to work with government and all stakeholders to jointly deliver an ambitious transition to zero emission mobility that has consumers at the heart of it and is accessible and affordable for all. Consumer-centricity must be based on three fundamental principles: **adequacy**, **experience** and **equity**. In this paper we set out the UK automotive industry's views on the key measures required to deliver consumer-centric charging infrastructure that is pivotal to a successful transition. Involving the three inextricable and mutually reinforcing elements of **binding targets**, **proportionate regulation** and **enabling support**, these measures are summarised in the following **seven-point plan**.

1. Embed consumer-centricity in policy and a national plan on charging infrastructure

Consumer-centricity means putting **consumer interests first** in every aspect of charging infrastructure development and expansion, including policy-making, and should be based on three key principles:

- **Adequacy:** There must ultimately be at least adequate charging infrastructure to enable motorists to find an available and working public charger on demand. This means there needs to be a binding commitment and a coordinated plan to significantly uplift the number of public chargers of the right types in the right places.

- **Experience:** The consumer experience of charging a plug-in vehicle must be as easy as, if not easier than, refuelling. There must be regulation on a minimum standard of reliability, ease of payment, pricing transparency, information provision, accessibility and security.

- **Equity:** No socioeconomic groups or communities, particularly those in rural areas or reliant on on-street residential charging, should be disadvantaged or left behind. Public charging must also be affordable so that consumers are not "penalised" in the pocket for not having a private driveway and access to a dedicated home charger.

2. Develop and implement a nationally coordinated but locally delivered infrastructure plan

Government's forthcoming EV Infrastructure Strategy is a step in the right direction. However, for maximum effectiveness and impact, the strategy must be accompanied by a **nationally coordinated but locally delivered infrastructure plan** that is delivery orientated. The plan must include:

- A focus on ensuring there is a national network of public chargers of **the right types in the right places,** serving the right needs and achieving as high utilisation as possible. This should be delivered by **mapping** out actual and anticipated consumer charging needs and gaps in provision through the help and involvement of all key stakeholders.

- A comparable **metric** to appropriately assess and track charging infrastructure adequacy over time, and thus signal if additional investment or policy measures are required. This metric should be based on a cars-to-charger ratio, as this provides a more accurate picture of chargepoint **density** and the potential **pressure** on public charging infrastructure based on the expected number of vehicles at a given location. The ratios that should be tracked are **plug-in cars per slow/fast public chargepoint** and **BEVs per rapid/ultra-rapid public chargepoint**.

- Minimum requirements in public chargepoint planning, commissioning and delivery, along with an associated parking space, that meet the needs of **light commercial vehicles**, which have a larger footprint and different form factor compared to cars.

3. Invest significantly to uplift all types of charging infrastructure, particularly public chargers, ahead of need

Government and the infrastructure sector should commit to bold and ambitious investments in expanding the rollout of all types of charging infrastructure, ensuring everyone has a **universal "right to charge"**. Government should build on the success of its current £1.3 billion infrastructure package that will be further strengthened by a share of a new commitment of £620 million. While the largest proportion of public funds has been allocated to future-proofing electricity grid capacity at motorway service areas and major A-roads, increased support is needed in other areas such as:

- Significantly uplifting the number of public chargers **ahead of need**, focussing particularly on creating investable propositions and de-risking private investment in segments where there is genuine market failure, such as certain on-street and rural chargepoints.

- Extending funding support for both **home and workplace charging** through the Electric Vehicle Homecharge Scheme and the Workplace Charging Scheme into the second half of this decade. Home charging will remain the backbone of plug-in vehicle charging for those with access to a dedicated private home charger.

- Reforming the **VAT regime for public charging** by applying the lowest rate (i.e. 5%) across the board for electricity used for charging regardless of where the vehicle is charged. Consumers should not be "penalised" in the pocket for not having a private driveway or garage.

4. Set binding targets to ensure adequate public chargepoint provision and social equity

As a condition of the ZEV mandate that will be introduced in 2024, government should also put in place a **charging infrastructure mandate** by setting **binding targets** of public chargepoint provision on a **graduated basis**, commensurate with expected plug-ins on the road over time driven by the ZEV mandate and predicated on robust modelling that is periodically reviewed. These targets, which set out government commitment and call-to-action to achieve a specific goal by a specific time, should focus primarily on the type of chargepoints that are less likely to follow an organic growth path. Binding targets should not be viewed negatively. If reasonable and well designed, like the gigabit broadband target, they reflect positively on government's zero emission mobility ambitions, hold government to account and provide long-term signals and direction for public-private investment. We suggest the following binding targets:

- **Ratio of plug-in vehicles per fast (7-22kW) public charger in each of the economic regions**, set appropriately and reasonably based on the unique characteristics and consumer needs in each region and reviewed annually for relevance. This target, like carbon budgets, should be **binding on government itself**, who should assume overall accountability but delegate responsibilities, by way of a statutory duty for planning and delivery oversight, to local authorities, whose combined performance influences the ratio of the region.

- **Minimum number of rapid/ultra-rapid (50-350kW) public chargers per forecourt/hub/motorway service area**, depending on the size of the site and expected traffic throughput, and reviewed every two years. This target should be **binding on CPOs**. Compared to fast public chargers, it is not expected that there will be material underprovision of rapid and ultra-rapid chargers, as these are the relatively more profitable chargers in a CPO's portfolio.

5. Enact proportionate regulation to deliver the best outcomes for consumer experience and expansion of provision

We welcome the various announcements so far in which government has set out its intention to regulate to deliver the best outcomes for consumers. We firmly believe it is now important that government follows through and goes further by enacting regulation on the following:

- Setting **minimum standards of consumer experience**. These should include:
  - All public chargepoints, not just rapid and ultra-rapid chargers, must offer ad-hoc access and payment via contactless debit/credit card and network roaming.
  - A mandated minimum reliability rate of 99%, measured per operator per annum.
  - All public chargepoints must make available the "must have" static and dynamic (real-time) information set out in government's consumer experience consultation.
  - For pricing transparency, all CPOs should charge for the electricity they provide in p/kWh.

- Creating a fit-for-purpose regulatory body, Office of Charging (Ofcharge), to monitor the market, including for price levels and affordability, and enforce the regulated minimum standards.

- Reforming building regulations to mandate chargepoints to be installed in new residential and non-residential buildings, and existing ones undergoing major renovation.

- Introducing a statutory duty on the part of local authorities to **plan for** and **oversee the delivery** of chargepoints on a proportionate and graduated basis.

- Requiring a minimum number of chargepoints in non-residential car parks on a graduated basis.

- Banning long-term exclusive arrangements at motorway service areas.

6. Provide adequate enabling support to incentivise and facilitate delivery of charging infrastructure

The infrastructure sector and local authorities must be supported in delivering charging infrastructure through a raft of measures that should work **in combination**. These support measures are aimed at **de-risking** private investment and creating **investable propositions** to address genuine market failures and plugging recognised **resource gaps** at the local authority level. These measures include:

- **Mixed high-low utilisation blocks for long-term tenders**. Public chargepoint tenders issued by local authorities should be long-term and require both urban and rural, as well on-street and off-street, coverage, thus resulting in successful bidders operating high-utilisation urban and off-street chargers that offset potential losses from low-utilisation rural and on-street chargers.

- **Modified contracts for difference**. Akin to price guarantees, government should set a fair expected annual revenue (strike price) for normal operations, along with stringent service level agreements and other conditions, in specifically targeted low-utilisation, or commercially unattractive, blocks and cover the shortfall in the CPO's verified annual revenues until the market is deemed to have matured.

- **Anticipatory demand-led approach through an online portal**. In areas with insufficient chargepoints, local residents intending to purchase or lease a plug-in vehicle within the next six months should be able to log requests for a chargepoint online. The local authority is then obliged to ensure a chargepoint is installed in the location of need within six months.

- **Adequately supporting and resourcing local authorities**. Statutory duty placed on local authorities to plan for and oversee the delivery of public chargers must be accompanied by greater levels of support in the form of resource funding, not just the existing capital funding. The proposed Ofcharge should be given an additional role as a dedicated national body that assists local authorities with all matters pertaining to charging infrastructure planning and implementation. It should be the custodian of a uniform national guidance, including streamlined planning permission processes and standardised procurement templates.

7. Ensure electricity networks are future-proofed and fit for purpose for zero emission mobility

We welcome and support the use of smart charging and Vehicle-to-Grid (V2G) as demand side response mechanisms to help delay the need for costly electricity network reinforcements. However, smart charging must not be regarded as a panacea for network capacity constraints or an ersatz substitute for much needed network reinforcements. We believe the following measures are necessary:

- Government and Ofgem must put in place frameworks that enable Distribution Network Operators to commit to well justified **anticipatory investments** in local networks that are most constrained and in strategic locations to future-proof charging for heavy duty vehicles.

- Load limitation must be limited to the **boundary of the home only**, and not exercising control beyond the meter. It must not single out the plug-in vehicle as the only “appliance” that is being targeted for the purpose of load balancing and grid protection.

- Regulatory frameworks must encourage the development of **flexibility services and markets** that incentivise consumers to participate in smart charging and V2G.

- In order to ensure the electricity used to power and produce zero emission vehicles by 2035 is as green as the new cars and vans themselves, government must mandate **100% grid decarbonisation by 2035** and legislate for a **binding target of 90% of electricity to be generated from renewables** under normal operation by 2035. This mandate must be supported by increased investment in renewable electricity generation capacity and innovative reforms to electricity markets.

CHAPTER 1
THE VISION OF ZERO EMISSION MOBILITY

Industry vision and commitment

In November 2020, the UK Prime Minister announced government's decision to end the sale of new petrol and diesel cars and vans by 2030, and that all new cars and vans will be fully zero tailpipe emission from 2035.[1] The UK was the first major economy to legislate to end its contribution to climate change. By law the UK's emissions must be net zero by 2050.[2] In line with this, government envisages almost every car and van on the parc to be zero emission by 2050. These were followed by an October 2021 announcement that government will impose a zero emission vehicle mandate on vehicle manufacturers from 2024.[3]

The automotive industry shares government's ambition and is fully committed to zero emission motoring. A key pillar of the automotive industry's long-term vision is the increasing electrification of vehicles that leads ultimately to zero tailpipe emissions and a future of greener and more sustainable mobility. In line with industry's commitment to zero emission motoring, we aspire for the UK to be both a leading market and location of choice for the design, development and manufacture of electrified vehicles. UK automotive is committed to delivering on the country's triple bottom line, supporting **people** (with 864,000 skilled jobs across the country), **prosperity** (accounting for £326 billion turnover, £58 billion value added and 10% of UK exported goods) and the **planet** (with a proven track record of reducing CO_2 emissions over the past 20 years).

However, this is a multi-year transition, not an overnight sprint. This transition has gathered pace in the last few years, as evidenced by various vehicle manufacturers' ambitious commitment to electrify their product ranges. For example, a number of manufacturers have announced their brands will be fully electric between 2025 and 2030.[4] Thanks to huge investments by vehicle manufacturers, a rapidly increasing number of electrified models are now available on the UK market, and more are expected to follow in the coming months and years. About a third of the models currently available on the market are electrified, one in four a plug-in or fuel cell vehicle and one in ten a zero emission vehicle (ZEV).

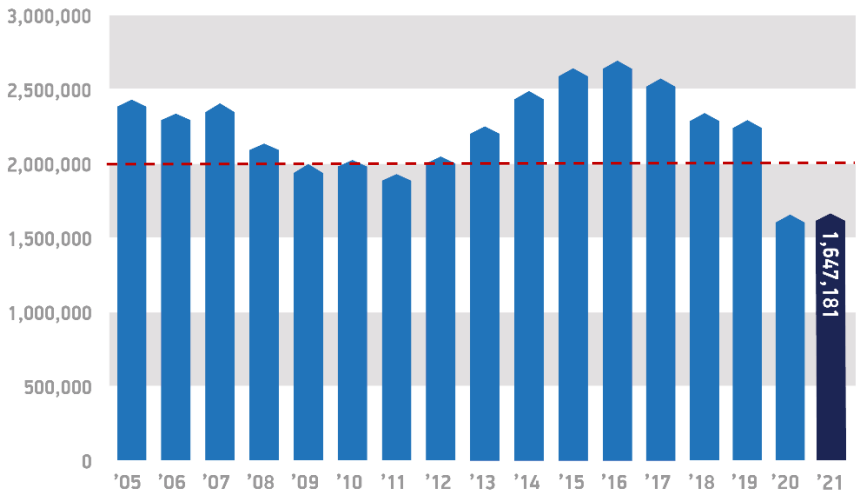
We expect this to grow exponentially, with more new battery electric vehicle (BEV) models to be launched than internal combustion engine (ICE) ones. A study suggests there will be over 300 models in the market in Europe by 2025,[5] while another predicts about 450 new plug-in models will be launched

[1] HM Government press release, "Government takes historic step towards net-zero with end of sale of new petrol and diesel cars by 2030", 18 November 2020, available at https://www.gov.uk/government/news/government-takes-historic-step-towards-net-zero-with-end-of-sale-of-new-petrol-and-diesel-cars-by-2030.
[2] HM Government press release, "UK becomes first major economy to pass net zero emissions law", 27 June 2019, available at https://www.gov.uk/government/news/uk-becomes-first-major-economy-to-pass-net-zero-emissions-law.
[3] HM Government (2021), Net Zero Strategy: Build Back Greener, available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1033990/net-zero-strategy-beis.pdf.
[4] For a list of vehicle manufacturer commitments, see for example, SMMT (2021), 2021 UK Automotive Sustainability Report, available at https://www.smmt.co.uk/wp-content/uploads/sites/2/SMMT-Sustainability-Report-2021.pdf; HM Government (2021), Transitioning to zero emission cars and vans: 2035 delivery plan, available at https://www.gov.uk/government/publications/transitioning-to-zero-emission-cars-and-vans-2035-delivery-plan; International Energy Agency (2021), Global EV Outlook 2021, available at https://www.iea.org/reports/global-ev-outlook-2021; and Deloitte Insights, available at https://www2.deloitte.com/us/en/insights/focus/future-of-mobility/electric-vehicle-trends-2030.html.
[5] Transport & Environment (2019), Electric surge: Carmakers' electric car plans across Europe 2019-2025, available at https://www.transportenvironment.org/sites/te/files/publications/2019_07_TE_electric_cars_report_final.pdf.

globally by 2022.[6] Data from the International Energy Agency suggests there were already 368 plug-in models available globally by the end of 2020.[7] These figures are impressive given the first mass market BEV model, the Nissan LEAF, was only introduced just under a decade ago.

With government's 2030 and 2035 end-of-sale deadlines in place, the UK automotive industry is required to make a more significant and advanced commitment than just about any other major car or van market. While vehicle manufacturers continue to accelerate the introduction of more zero emission models, the pace of consumer adoption between now and 2035 is beyond industry's control. UK automotive aspires to maintain a healthy overall new car and van market even when the sale of non-ZEVs is phased out from 2035. As Figure 1 shows, for most of the last two decades UK new car registrations were at least two million units annually. A strong new car and van market is critical to the health of the overall economy, jobs, government revenues through taxes, the volume and strength of the used car market, the delivery of goods and services, and the personal mobility of millions of people.

Figure 1: Annual UK new car registrations, 2005-2021.



Source: SMMT car registration data.

To realise this vision, industry is committed to continue investing heavily to bring an ever increasing number of plug-in models to the UK market. Industry had invested £54 billion in 2019 alone to produce plug-in vehicles and batteries in Europe,[8] while government's own estimates suggest industry will invest an estimated £230 billion in the next five to ten years.[9] Globally, vehicle manufacturers are expected to invest an estimated $515 billion over the same period.[10]

[6] McKinsey & Company (2020), McKinsey Electric Vehicle Index: Europe cushions a global plunge in EV sales, 17 July, available at https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/mckinsey-electric-vehicle-index-europe-cushions-a-global-plunge-in-ev-sales.
[7] International Energy Agency (2021), Global EV Outlook 2021, available at https://www.iea.org/reports/global-ev-outlook-2021.
[8] Transport & Environment (2020), Can electric cars beat the COVID crunch?, available at https://www.transportenvironment.org/sites/te/files/publications/2020_05_Can_electric_cars_beat_the_COVID_crunch.pdf.
[9] HM Government (2021), Transitioning to zero emission cars and vans: 2035 delivery plan, available at https://www.gov.uk/government/publications/transitioning-to-zero-emission-cars-and-vans-2035-delivery-plan.
[10] Lienert, P. and Bellon, T. (2021), "Exclusive: Global carmakers now target $515 billion for EVs, batteries", Reuters, 10 November, available at https://www.reuters.com/business/autos-transportation/exclusive-global-carmakers-now-target-515-billion-evs-batteries-2021-11-10/.

However, the automotive industry cannot deliver on this transition alone. Unlocking the full environmental, economic and social benefits of this transition requires close collaboration with government and key adjacent sectors such as fleets, infrastructure and energy. Industry is determined to work with government and all stakeholders to deliver an electric revolution that is accessible and affordable for all.

State of the market and future outlook

In order to ensure the success of government's ambitious policy to end the sale of non-zero emission cars and vans by 2035, there must be significant uplift in plug-in vehicle uptake, especially of the zero emission variety. As Table 1 shows, plug-in vehicle market share for passenger cars in 2019 was still languishing at just 3.2%, up from 2.5% in 2018. Although registrations of BEVs were up 144.0%, they still equated to just a 1.6% market share. Thanks to manufacturer investments in recent years that resulted in a surge of new models coming to the UK market, plug-in vehicle uptake since then has been very positive, with market share reaching 10.7% (6.6% BEVs and 4.1% PHEVs) in 2020 despite a depressed overall market due to the Covid-19 pandemic. This represented a 185.9% and 91.2% rise in BEV and plug-in hybrid electric vehicle (PHEV) registrations respectively from the previous year, or a 140.4% increase in plug-in registrations overall.

More impressively, these records were recently broken when the uptrend in plug-in vehicle registrations continued throughout 2021. Market share for plug-in vehicles rose to an all-time high of 18.5% despite an overall market that remained sluggish due to the continuing impact of the pandemic. BEV registrations grew 76.4% from the previous year, while PHEV registrations increased by 70.6%, giving BEVs and PHEVs a record market share of 11.6% and 7.0% respectively.

Table 1: Registrations and market share of plug-in vehicles (passenger cars), 2017-2021.

	2021		2020		2019		2018		2017	
	Registrations	Market share	Registrations	Market share	Registrations	Market share	Registrations	Market share	Registrations	Market share
BEVs	190,727	11.6%	108,205	6.6%	37,850	1.6%	15,510	0.7%	13,632	0.5%
PHEVs	114,554	7.0%	66,877	4.1%	34,984	1.5%	44,437	1.9%	35,585	1.4%
Total plug-ins	305,281	**18.5%**	175,082	**10.7%**	72,834	**3.2%**	59,947	**2.5%**	49,217	**1.9%**
All cars	1,647,181	100%	1,631,064	100%	2,311,140	100%	2,367,147	100%	2,540,617	100%

N.B. FCEV registrations are not shown as they are currently negligible.

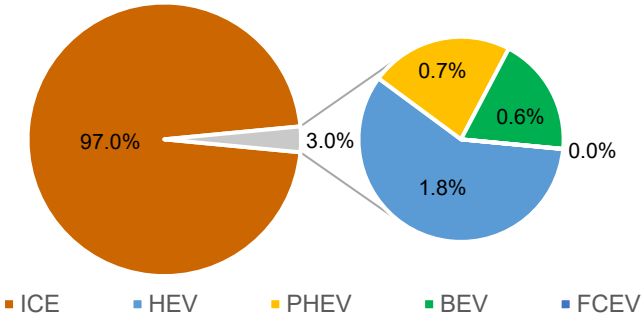
Source: SMMT car registration data.

Plug-in van registrations also achieved phenomenal growth in 2021, as 12,759 units were registered, representing a 142.3% growth from 2020, which itself recorded a 64.4% growth from the year before. However, the market for plug-in vans, which is only just developing, is several years behind plug-in cars, as plug-in vans made up only 3.6% of the total van market in 2021.

The recent surge in plug-in vehicle registrations will take time to filter through to the motor parc. While getting to a parc that is virtually zero emission by 2050 is not impossible, current figures underline the scale of the challenge. Latest available data shows that of the 35,082,800 cars in the UK parc as of 31 December 2020, only 438,595 (1.3%) were plug-in vehicles. At 199,085 units, BEVs made up only 0.6% of the parc (Figure 2).

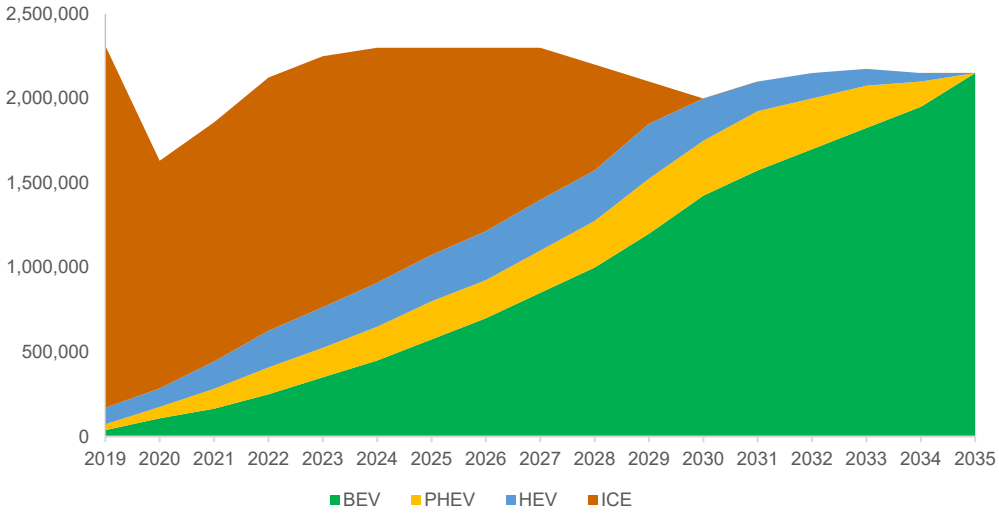
Our long-term new car market outlook is optimistic (Figure 3).[11] We believe plug-in vehicle market share will reach 34.8% (25.0% BEVs and 9.8% PHEVs) by 2025 and 87.5% (71.3% BEVs and 16.2% PHEVs) by 2030, when new petrol and diesel vehicles are no longer allowed on the market. We anticipate annual new BEV registrations could reach one million cars by 2028. The new car market will of course be made up of entirely ZEVs from 2035, by when our outlook suggests it could remain at a healthy 2.15 million units. As only a very small number of these are likely to be fuel cell electric vehicles (FCEVs), these are subsumed under BEVs in our analysis.

Figure 2: UK car parc by fuel type, 2020.



Source: SMMT motor parc data.

Figure 3: Long-term new car market outlook to 2035.



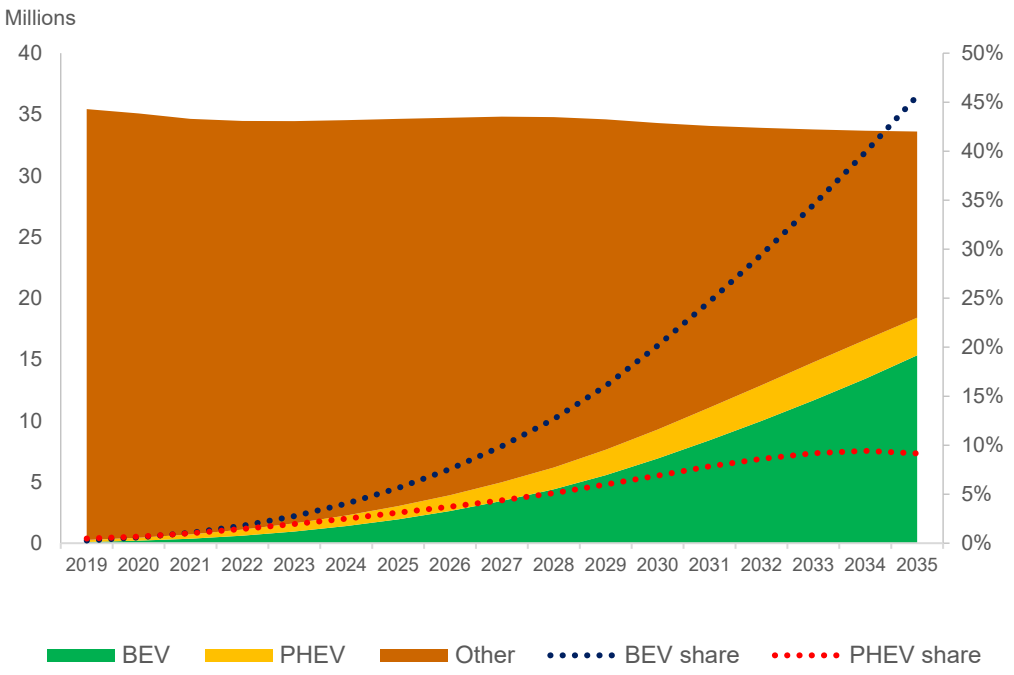
Source: SMMT analysis.

[11] Based on our "central" scenario in SMMT (2021), New car market and parc outlook to 2035, by powertrain, available at https://www.smmt.co.uk/2021/06/smmt-new-car-market-and-parc-outlook-to-2035-by-powertrain/. The potential impact of a ZEV mandate had not been accounted for at the time of publication.

However, this outlook is **highly contingent** on supportive government policy and infrastructure provision.[12] A key assumption in our outlook is that there will be adequate provision of on-demand charging infrastructure ahead of need, such that infrastructure is no longer a barrier to mass market uptake. The positive impact of this and a supportive fiscal regime on market demand should then lead to unconstrained vehicle allocation to the UK market. The UK competes with other major markets for vehicle allocation and is not alone in aspiring to drive a massive uplift in plug-in vehicle uptake. Just like any rational business, vehicle manufacturers allocate more products to markets where they sell best. Creating the right demand conditions is therefore critical to ensuring the UK is at the front of the allocation queue. This means encouraging consumers to switch to plug-in vehicles with attractive incentives, the provision of adequate charging infrastructure and the assurance that the energy networks are fit for purpose to support escalated plug-in vehicle uptake.

Based on the same market outlook and current vehicle survival rates, our analysis suggests there are likely to be around 6.9 million BEVs in the car parc by 2030 (20.1% of the car parc) and approximately 15.3 million by 2035 (45.6%). Total plug-in vehicles in the car parc should reach 9.3 million by 2030 (27.0%) and 18.4 million by 2035 (54.8%) (Figure 4).

Figure 4: Long-term car parc outlook to 2035.



Source: SMMT analysis.

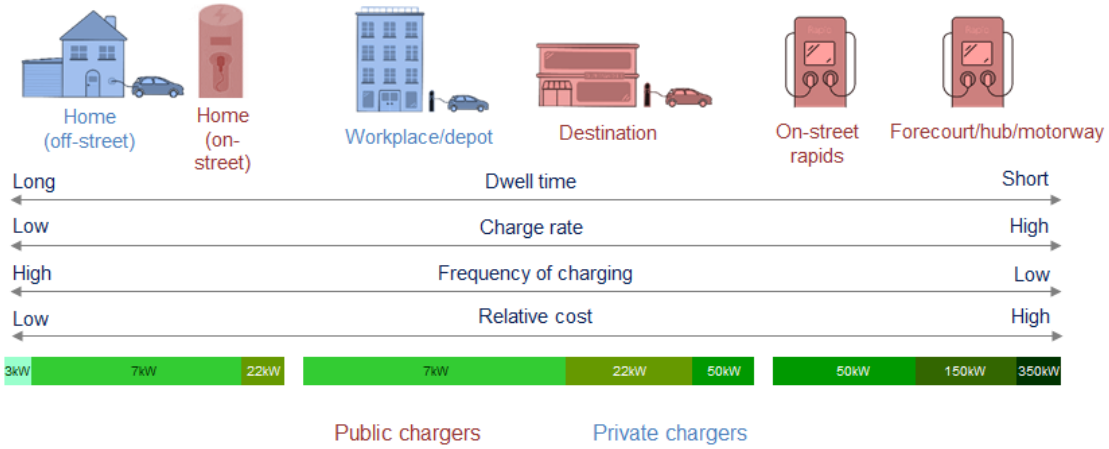
[12] SMMT (2021), New car market and parc outlook to 2035, by powertrain, available at https://www.smmt.co.uk/2021/06/smmt-new-car-market-and-parc-outlook-to-2035-by-powertrain/.

CHAPTER 2
THE STATE OF CHARGING INFRASTRUCTURE

Types of chargepoint

For the purposes of this paper, we set out our view of the different types of charging infrastructure in Figure 5 and below.

Figure 5: Types of charging infrastructure



Private chargepoints

- Dedicated **home chargers**, often, but not exclusively, in the form of a wall box installed on a private driveway/garage in dwellings with off-street parking. By 2035, we expect most of these to be 7kW chargers, although there could also be a small number of 11kW and 22kW chargers. This is the cheapest form of charging, as the cost depends on the consumer's domestic electricity tariff, which is subject to just 5% VAT, and attractive dynamic tariffs based on time of use may also be available.

- **Workplace/depot chargers**, which are usually not open to the general public but are for the exclusive use of employees, business visitors and back-to-base fleets. We expect most workplace chargers to be 7kW given the relatively long dwell times, although there will also be some 22kW chargers. Depending on the needs, size and expected downtime of the fleet, depot chargers for cars and vans could be 7kW, 11kW, 22kW or 50kW. It is up to employers to decide whether to make these chargers available for use free of charge, recoup the cost of electricity used, or outsource the installation, commercial operation and maintenance to a chargepoint operator (CPO).

Public chargepoints

- **On-street residential chargers** that serve the needs of local residents without off-street parking, or those with off-street parking but for various reasons are not able to install dedicated

private home chargers (e.g. flats, communal garages). Most of these are stand-alone units, although there are also variations such as lamp post chargers and retractable units in the ground. We expect most of these to be 7kW chargers given the long dwell times. However, there could also be some 5.5kW chargers (mainly on lamp posts) and a small number of 22kW chargers. Operated by either CPOs or local authorities, these chargers are relatively more expensive to use than home chargers but cheaper than rapid and ultra-rapid chargers.

- **On-street chargers**, which provide opportunity charging while the vehicle is parked. Dwell times when the vehicle is parked are relatively shorter than in dedicated car parks. While some of these are still 7kW chargers, we expect most of these in the future to be 50kW rapid chargers, which will be used mainly, but not exclusively, by commercial vehicles, taxis and private hire vehicles. Rapid chargers offer the convenience of a very quick charge, hence normally cost more to use than standard 7-22kW chargers.[13]

- **Destination chargers**, which could be found in places such as dedicated private and public car parks (including Park and Ride), supermarkets, retail parks, shopping centres, entertainment venues, restaurants, hotels, and recreational and touristic places. Depending on the expected dwell times, these could be 7kW, 11kW, 22kW or 50kW chargers. It is up to the property owners, landlords or car park operators to decide whether to make these chargers available for use free of charge, recoup only the cost of electricity used, or outsource the installation, commercial operation and maintenance to a chargepoint operator (CPO).

- **Forecourt/hub/motorway charging**, which serves mainly transient traffic with short dwell times. As such, we expect these chargers to be 50kW, 150kW and 350kW. Most of these locations are also co-located with cafes, restaurants and retail outlets. Forecourts and hubs, which aim to replicate as closely as possible the convenience and brevity of a refuelling event for petrol or diesel vehicles today, are likely to be located in urban and extra-urban conurbations as well as near major roads. Some charging hubs could also be located in residential areas. Chargepoints at motorway service areas are mostly for en-route charging. Consumers expect to pay a premium for the speed and convenience of these chargers.

For further information on how chargepoints in the UK are defined, as well as how the nomenclature differs to that used in Europe, see Appendix A.

Commendable progress – the UK has come a long way

Government support has driven much of the early progress in building and expanding charging infrastructure in the past decade. This has resulted in considerable improvement in both private and public charging infrastructure deployment. We commend government for its current £1.3 billion package to accelerate the rollout of charging infrastructure, comprising:[14]

- A £950 million Rapid Charging Fund to future-proof electricity grid capacity at service areas on motorways and major A-roads,
- £275 million to extend support for charge point installation at homes, workplaces and on-street,

[13] An exception to this is the ChargePlace Scotland network, where most public chargepoints are still free to use subject to a small membership fee.
[14] HM Government (2021), Transitioning to zero emission cars and vans: 2035 delivery plan, available at https://www.gov.uk/government/publications/transitioning-to-zero-emission-cars-and-vans-2035-delivery-plan.

- £20 million for the On-Street Residential Charging Scheme in 2021-22, and
- £90 million for the Local EV Infrastructure Fund to support the rollout of larger on-street charging schemes and rapid hubs in England.

In addition to this package, there is also the £200 million Charging Infrastructure Investment Fund, although this is not grant funding.[15] This package was recently strengthened by a new government commitment of £620 million, which will be divided between funding public charging in residential areas and targeted plug-in vehicle grants.[16] These are further strengthened by a £300 million down payment by Ofgem for new investment in electricity network infrastructure aimed at supporting 1,800 new ultra-rapid chargepoints at motorway service areas as part of its Green Recovery programme.[17]

Home and workplace charging

Government funding has been instrumental in driving the installation of home and workplace chargepoints. Since the beginning of the Electric Vehicle Homecharge Scheme (EVHS) in September 2014 and the Workplace Charging Scheme (WCS) in late 2016, a total of £96 million has been spent supporting the installations of these mostly private chargepoints. As of 1 October 2021, the EVHS had funded a total of 189,815 domestic chargepoint installations, with a total grant value of £88,107,323, whereas the WCS had funded the installation of 19,054 sockets worth £7,930,714.[18]

The EVHS provides grant funding of up to 75% of the cost (or a maximum of £350) of installing chargepoints at domestic properties. In Scotland a similar grant of up to £300 is available through the Energy Saving Trust. The South East accounted for the lion's share (19%) of the total chargepoints installed under the scheme, whereas Northern Ireland had the lowest share of installations (1.7%). Government acknowledges the uneven geographical distribution of EVHS uptake was due to a combination of access to a plug-in vehicle, access to off-street parking, leasehold or tenancy properties, car ownership, rurality and household affluence. The WCS is a voucher-based scheme that covers up to 75% of the cost (or a maximum of £350) of each socket for eligible businesses, charities and public sector organisations. Each organisation is now eligible to apply for funding for up to 40 sockets, an increase from 20 sockets previously. Mirroring EVHS uptake, the South East has the most socket installations (14.4%) under the scheme, whereas Northern Ireland has the least (2.1%).

Given the important role the EVHS has played in supporting the installation of home chargepoints, it is disappointing that government has decided that single unit properties such as bungalows, detached, semi-detached or terraced housing will no longer be eligible for the scheme from April 2022.[19] While it is right that the scheme will widen its support for leaseholders, renters and those living in flats, supporting single unit properties to install home chargers is crucial if home charging in all types of dwellings is to become the backbone of plug-in vehicle charging. However, government's decision to

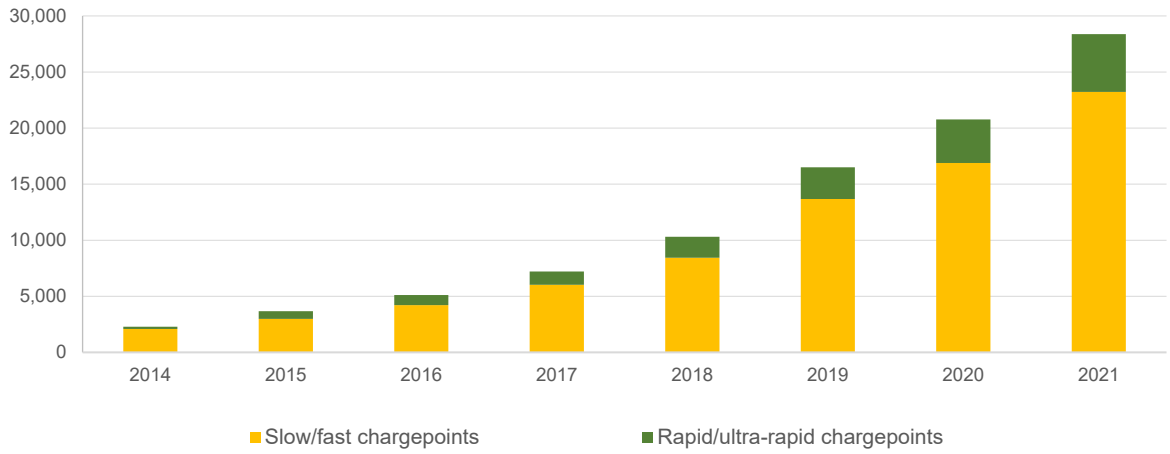
[15] HM Treasury and Infrastructure and Projects Authority (2018), Policy paper: Charging Infrastructure Investment Fund, available at https://www.gov.uk/government/publications/charging-infrastructure-investment-fund.
[16] HM Treasury (2021), Autumn Budget and Spending Review 2021, available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1029974/Budget_AB2021_Web_Accessible.pdf.
[17] Ofgem press release, "Ofgem delivers £300 million down payment to rewire Britain", 24 May 2021, available at https://www.ofgem.gov.uk/publications/ofgem-delivers-ps300-million-down-payment-rewire-britain.
[18] Department for Transport (2021), Electric vehicle charging device grant scheme statistics: October, available at https://www.gov.uk/government/statistics/electric-vehicle-charging-device-grant-scheme-statistics-october-2021/electric-vehicle-charging-device-grant-scheme-statistics-october-2021.
[19] Department for Transport (2021), Support for small businesses, landlords and leaseholders: government charges up the electric vehicle revolution with £50 million boost, available at https://www.gov.uk/government/news/support-for-small-businesses-landlords-and-leaseholders-government-charges-up-the-electric-vehicle-revolution-with-50-million-boost; and Office for Zero Emission Vehicles (2021), Grant schemes for electric vehicle charging infrastructure, available at https://www.gov.uk/government/collections/government-grants-for-low-emission-vehicles#history.

widen the WCS to provide more support for SMEs, small accommodation businesses and charities is laudable.

Public charging

The UK has come a long way since the first public chargepoints were installed under the Plug-in Places scheme back in 2011. From just 1,537 connectors at the end of 2011, we now have a total 48,770 connectors on 29,019 devices, the majority of which (16,337 devices) are 7-22kW fast chargers.[20] Government, local authorities and the charging infrastructure sector deserve credit for this 3,073% increase in public charging infrastructure in just over a decade. Since January 2020, motorists are never more than 25 miles away from a rapid chargepoint along England's Strategic Road Network (SRN).[21] For a UK definition of the types of chargers, see Appendix A.

Figure 6: Growth of public chargepoints in the UK, 2014-2021.



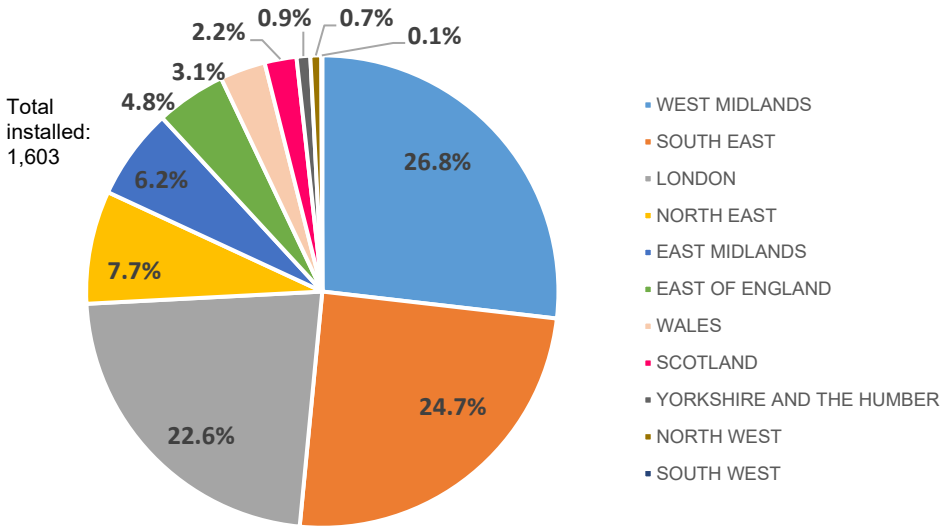
Source: SMMT analysis of data from Department for Transport (2022), Electric vehicle charging device statistics: January, available at https://www.gov.uk/government/statistics/electric-vehicle-charging-device-statistics-january-2022.

On-street residential charging

Since its commencement in 2017, government's On-Street Residential Chargepoint Scheme (ORCS), which pays 75% of the capital costs (up to £13,000) of procuring and installing on-street chargepoints in residential areas, has played an important role in supporting local authorities to roll out charging infrastructure for residents without private off-street parking. The ORCS, though initially undersubscribed, has now funded the installation of 1,603 public chargepoints with grant funding totalling £5,236,664 across 57 councils. However, as Figure 7 shows, take-up of the scheme has been dominated by local authorities in the West Midlands and the South East and councils in London.

[20] Public chargepoint statistics from ZapMap, available at https://www.zap-map.com/statistics/, correct as of 25 January 2022.
[21] Department for Business, Energy and Industrial Strategy, Department for Transport, and Office for Low Emission Vehicles (2020), Policy paper: Government vision for the rapid chargepoint network in England, available at https://www.gov.uk/government/publications/government-vision-for-the-rapid-chargepoint-network-in-england/government-vision-for-the-rapid-chargepoint-network-in-england.

Figure 7: Completed public chargepoint installations funded by the OZEV On-Street Residential Chargepoint Scheme.*



* As of 1 October 2021.

Source: SMMT analysis of data from Department for Transport (2021), Electric vehicle charging device grant scheme statistics: October, available at https://www.gov.uk/government/statistics/electric-vehicle-charging-device-grant-scheme-statistics-october-2021.

Other charging innovations

In addition to the more conventional forms of charging described above, several innovative ways to charge plug-in vehicles have spawned in recent years. Peer-to-peer and community charging, where households rent out their private home chargers to other plug-in vehicle users, have the potential to turn many private chargers into semi-public ones, thus complementing the existing networks of public chargers and further unlocking the ability of consumers without off-street parking to charge their vehicles. Portable charges, some of which are suitcase-sized, are the equivalent of jerry can for petrol and diesel vehicles. Depending on the size of the portable battery, these can provide an extra 15-20 miles of range and help users avoid being caught short before the nearest available chargepoint can reached.[22]

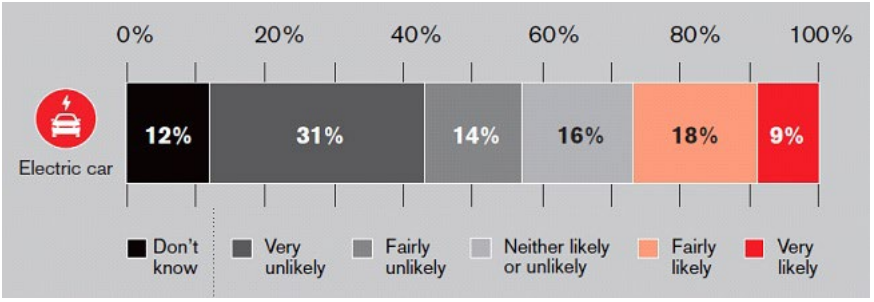
The encouraging growth of the public charging network in the last decade, coupled with some hitherto below average utilisation rates at certain public chargepoints and the fact that most current plug-in vehicle users charge at home, may have given the impression that there is more than adequate public charging infrastructure in the UK. It has also been claimed that range anxiety and charging anxiety are merely a perception issue, given that up to 94% of all daily car journeys are no more than 25 miles,[23] which is well within the range of every plug-in vehicle today, including PHEVs.

[22] Examples of peer-to-peer or community charging include, but are not limited to, JustPark EV and Co Charger, while ZipCharge Go is an example of a portable charger.
[23] Department for Transport (2018), The Road to Zero, available at https://www.gov.uk/government/publications/reducing-emissions-from-road-transport-road-to-zero-strategy.

Despite commendable progress charging infrastructure is still a barrier to uptake

Despite the very encouraging recent surge in plug-in vehicle uptake and our optimistic outlook that suggests the uptrend will continue well into 2022 and beyond, findings from recent consumer studies suggest a rather different perspective. Government's own commissioned survey suggests only 14% of consumers say the next car they plan to buy or lease will be a BEV, while only 15% say they are more likely to buy or lease a BEV as their next car as a direct result of government's end-of-sale policy.[24] Another study reveals exactly the same disappointing finding, that only 9% of UK consumers prefer a BEV as their next car.[25] A recent survey by Transport Focus, the independent watchdog for transport users, reveals that only 27% of drivers are likely to purchase a BEV in the next five years, while 45% are unlikely to do so (Figure 8). Such findings are worrying not just for the success of the transition to a zero emission new car and van market by 2035, but also for the potential delays in realising the environmental benefits that come with zero emission mobility.

Figure 8: Likelihood to purchase a battery electric car in the next five years.



Source: Courtesy of Transport Focus (2021), Going electric: the drivers' view, available at https://www.transportfocus.org.uk/gd/publication/going-electric-the-drivers-view/.

However, rather than dismissing consumer sentiments as "irrational", or worse still disputing the validity of the many studies that reveal the same findings, it is more important to understand the underpinning factors behind such consumer sentiments. Listening to consumers, **particularly those we are trying to convert to become plug-in vehicle users**, has never been more important. Every single reputable study or consumer survey in recent years have invariably and consistently shown that the inadequacy of charging infrastructure is still a concern for many consumers and is a main barrier to uptake. For example:

[24] Department for Transport and Ipsos MORI (2021), Transport and Technology: Public Attitudes Tracker – Wave 7 summary report, available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1028241/dft-transport-and-transport-technology-public-attitudes-tracker-wave-7-summary-report.odt.
[25] Deloitte (2021), Deloitte Global Automotive Consumer Study 2021, available at https://www2.deloitte.com/content/dam/Deloitte/global/Documents/Consumer-Business/gx-automotive-consumer-study-emea-countries.pdf.

- An SMMT-commissioned survey shows the biggest factors holding consumers back from switching to BEVs after affordability are the lack of local chargepoints (44%) and the fear of being caught short on longer journeys (38%) (Figure 9).

- Government's own commissioned study shows an overwhelming 75% of the public consider insufficient charging infrastructure as a disadvantage of BEVs, more than any other drawbacks including affordability (Figure 10).

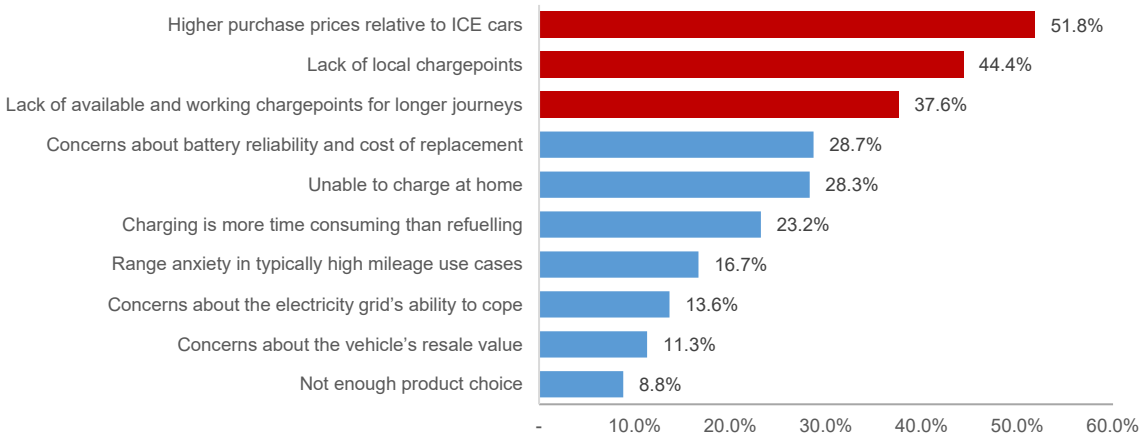
- Access to charging away from home and access to charging near home are two of the top four barriers according to a recent study by consumer organisation Which?. The study found that an overwhelming majority of consumers (88%) believe ensuring there is easy access to public charging infrastructure is the most helpful measure to support plug-in vehicle ownership.[26]

- These same concerns are evident in a recent survey by the watchdog Transport Focus, which shows affordability (46%), charging infrastructure (44%) and range anxiety (42%) are by far the top reasons drivers say they are unlikely to purchase a BEV within the next five years.[27]

- The AA Driver Poll in March 2021 reveals 75% of respondents said easy access to home charging would give them more confidence in owning a BEV, while 73% cited the ability to access any chargepoint irrespective of the operator.[28]

- A recent study of global automotive consumers shows charging infrastructure is consistently ranked by consumers across major markets, including the UK, as one of the top two barriers to uptake (Table 2).

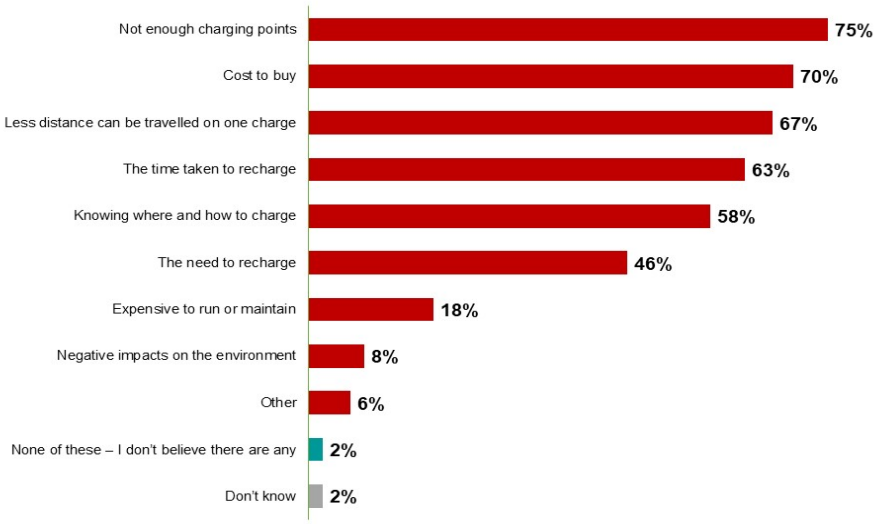
Figure 9: Key factors holding consumers back from buying electric vehicles.



Source: Savanta ComRes survey for SMMT between 21-24 August 2020.

[26] Which? (2021), Supporting consumers in the transition to net zero, available at https://www.which.co.uk/policy/sustainability/8178/supporting-consumers-in-the-transition-to-net-zero.
[27] Transport Focus (2021), Going electric: the drivers' view, available at https://www.transportfocus.org.uk/gd/publication/going-electric-the-drivers-view/.
[28] The AA (2021), The AA Yonder Driver Poll, March, summary available at https://www.theaa.com/about-us/public-affairs/aa-yonder-driver-poll-summaries-2021#march2021.

Figure 10: Disadvantages of electric vehicles.



Source: Department for Transport and Ipsos MORI (2021), Transport and Technology: Public Attitudes Tracker – Wave 7 summary report, available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1028241/dft-transport-and-transport-technology-public-attitudes-tracker-wave-7-summary-report.odt.

Table 2: Barriers to uptake of battery electric vehicles in selected major markets.

Concern	Austria	Belgium	France	Germany	Italy	Spain	Turkey	UK	South Africa
Driving range	32%	27%	28%	28%	27%	23%	22%	27%	15%
Lack of charging infrastructure	19%	19%	21%	22%	29%	31%	31%	25%	37%
Cost/price premium	18%	28%	26%	16%	13%	19%	9%	22%	16%
Time required to charge	10%	12%	14%	13%	15%	15%	18%	11%	14%
Safety concerns	15%	8%	7%	12%	10%	10%	11%	8%	14%
Lack of choice	2%	3%	2%	5%	5%	2%	9%	6%	3%
Other	4%	3%	2%	4%	1%	0%	0%	1%	1%

Source: Courtesy of Deloitte (2021), Deloitte Global Automotive Consumer Study 2021, available at https://www2.deloitte.com/content/dam/Deloitte/global/Documents/Consumer-Business/gx-automotive-consumer-study-emea-countries.pdf.

The findings from these recent studies are hardly new revelations. If anything, they corroborate the findings from earlier studies commissioned by other stakeholders and prove that concerns about charging infrastructure have not dissipated. For example, in a 2019 study backed by an oil major, 40% of respondents cited charging infrastructure as a barrier, second only to vehicle purchase cost (47%).[29] Similarly, another 2019 survey commissioned by a major motor insurer shows 56% of respondents will buy a plug-in vehicle if the price is right, but 74% are concerned about charging.[30] 84% of respondents in a survey by The AA in 2018 said the right plug-in vehicle at the right price was the key to achieving

[29] SYSTRA (2019), On the Move: Navigating the Future of Road Transport, available at https://www.systra.co.uk/IMG/pdf/on_the_move_web.pdf.
[30] YouGov (2019), Car Master survey conducted for Aviva, March, available at https://www.aviva.co.uk/content/dam/aviva-public/gb/pdfs/personal/insurance/motor/car/articles/yougov-car-master.pdf.

government's policy ambitions.[31] A study found that a rapid charger every 20 miles on England's SRN would provide the required confidence to consumers;[32] there is currently a rapid charger every 25 miles on the SRN.[33] Critics may dismiss the findings of any one study as possibly containing statistical errors, but it would be imprudent to ignore the same findings shown in every single reputable study over several years.

Home charging is the backbone, but public charging infrastructure matters

Owing to its convenience and the fact that most cars are usually parked at home overnight, we expect home charging to be the backbone of plug-in vehicle charging, provided consumers have access to a dedicated private home charger. Consumers who could charge at home will most likely do so and use other types of charging (e.g. destination, workplace, motorway) for topping up or a recharge while on longer journeys. However, consumers who could not charge at home will have to rely on some form of public (e.g. on-street residential, destination, workplace, hubs/forecourts) or workplace charging for their regular charging events.

Although most current plug-in vehicle users charge at home, public chargepoints remain critical for consumer confidence. An RAC Foundation report shows that even though 80% of current plug-in vehicle owners have access to home charging, 93% use the public charging network.[34] This is corroborated by a recent survey of plug-in vehicle drivers by the Electric Vehicle Association England that found even among drivers with off-street parking over 90% still rely on public chargepoints from time to time.[35]

There is also a substantial proportion of the population that do not have access to off-street parking such that they could avail themselves of the convenience of charging on their private driveway. The English Housing Survey reveals that 67.1% of dwellings have a garage or off-street parking, 31.4% have only on-street parking and 1.6% have no parking at all.[36] These figures are supported by a recent RAC Foundation study that shows 65% of Britain's 27.6 million households have, or could have, enough off-street parking to accommodate at least one car or van, although this figure drops to just 44% in London.[37] The one-third of British households without off-street parking rely heavily on on-street residential chargepoints and/or other chargepoints, including at the workplace and destinations.

However, even among the two-thirds of UK dwellings that have off-street parking, we estimate about 20% are not able to have a dedicated private home charger due to various reasons, including wiring

[31] The AA (2018), AA-Populus Driver Poll, August, summary available at https://www.theaa.com/about-us/public-affairs/aa-populus-driver-poll-summaries-2018#aug2018.
[32] Transport Research Laboratory (2019), CVEI - D5.2 Consumer Uptake Trial Report, available at https://trl.co.uk/reports/cvei-d52-consumer-uptake-trial-report.
[33] Department for Business, Energy and Industrial Strategy, Department for Transport, and Office for Low Emission Vehicles (2020), Policy paper: Government vision for the rapid chargepoint network in England, available at https://www.gov.uk/government/publications/government-vision-for-the-rapid-chargepoint-network-in-england/government-vision-for-the-rapid-chargepoint-network-in-england.
[34] Dermott, H. (2017), Ultra Low Emission Vehicle Infrastructure: What Can Be Done, RAC Foundation, available at http://www.racfoundation.org/assets/rac_foundation/content/downloadables/Ultra_Low_Emission_Vehicle_Infrastructure_Harold_Dermott_September_2017.pdf.
[35] Electric Vehicle Association England (2021), Improving Drivers' Confidence in Public EV Charging, available at https://www.evaengland.org.uk/wp-content/uploads/2021/04/EVA-England-Consumer-Charging-Survey-Report.pdf.
[36] Department for Levelling Up, Housing and Communities and Ministry of Housing, Communities and Local Government (2021), Statistical data set: English Housing Survey data on amenities, services and local environments, DA2201: parking and mains gas – dwellings, available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1000179/DA2201_Parking_and_mains_gas_-_dwellings.ods.
[37] Nagler, E. (2021), Standing Still, RAC Foundation, available at https://www.racfoundation.org/wp-content/uploads/standing-still-Nagler-June-2021.pdf.

challenges, communal garages and shared parking for multi-unit dwellings (e.g. flats). This means overall about 47% of the 28.7 million dwellings in the UK are not able to have a dedicated private home charger.

Apart from back-to-base fleets, many commercial vehicle, taxi and private hire drivers, as well as car sharing schemes, also rely heavily on public charging.[38] For example, 93% of EV drivers for one private hire firm said rapid charging through the public network was not an easy process, while 37% said that it could take them over 30 minutes to locate a rapid charger.[39] A popular car club, meanwhile, believes London will need an eight-fold increase in rapid chargers by 2025.[40]

Measuring public charging infrastructure adequacy

Government's own data suggests the national distribution of public chargepoints is far from even.[41] However, we do not think reporting the number of public chargepoints per 100,000 population, which is government's preferred metric,[42] is necessarily the right yardstick for assessing charging infrastructure adequacy. Not every person in the population owns a plug-in vehicle, or any vehicle for that matter. Furthermore, population per se do not need chargers; plug-in vehicles do.

We think a more useful metric to measure public charging infrastructure adequacy is the number of **plug-in cars per public charger**. A cars-to-charger ratio denotes the number of plug-in cars sharing a public chargepoint were all plug-in cars to use public charging infrastructure at the same time. This gives an idea of chargepoint **density** and the potential **pressure** on public charging infrastructure at a given location. It also implies the potential difficulty of finding a public chargepoint on demand, or an alternative chargepoint when one is in use.

When assessing cars-to-charger ratios, it is also necessary to further distinguish between the relevance of the type of public chargepoints to the type of plug-in vehicles. Both BEVs and PHEVs could use one or more types of slow/fast (3-22kW) chargers,[43] but rapid/ultra-rapid chargers (50-350kW) are used mainly by BEVs.[44] We do not accept any suggestion that PHEVs should not be charged at public chargepoints on the basis that they have an internal combustion engine and therefore could supposedly use private chargers only. All types of plug-in vehicles must be entitled to equal access to all public chargepoints, as PHEVs are also charged using slow/fast public chargers. Excluding PHEVs from the right to use public chargepoints is tantamount to considering PHEV users second class motorists and will do nothing to encourage them to plug in and drive in electric mode as often as possible.

As such, we suggest a more meaningful ratio-based metric should capture the following:

- Plug-in cars per slow/fast public chargepoint
- BEVs per rapid/ultra-rapid public chargepoint

[38] British Vehicle Rental and Leasing Association (2021), "BVRLA presents to Parliamentarians on EV charging", 20 April, available at https://www.bvrla.co.uk/resource/bvrla-presents-to-parliamentarians-on-ev-charging.html.
[39] Roberts, G. (2021), "Addison Lee calls for urgent investment in EV charging network", FleetNews, 10 December, available at https://www.fleetnews.co.uk/news/latest-fleet-news/electric-fleet-news/2021/12/09/addison-lee-calls-for-urgent-investment-public-ev-charging-network.
[40] Zipcar (2021), The Road to Electrification: Zipcar Sustainability Report, available at https://www.zipcar.com/en-gb/press/sustainability-report.
[41] Department for Transport (2021), Electric vehicle charging device statistics: October, available at https://www.gov.uk/government/statistics/electric-vehicle-charging-device-statistics-october-2021.
[42] Government analysis assesses the distribution of public chargepoints by local authority in terms total devices and devices per 100,000 population, see for example http://maps.dft.gov.uk/ev-charging-map/.
[43] Although the actual charging rate may depend on the on-board charger. Most plug-in hybrids typically use 3-11kW chargers.
[44] With the exception of a very small number of plug-in hybrid models, usually in the premium or luxury segments, that have a relatively large battery (by plug-in hybrid standards) capable of supporting 50kW charging.

However, we also retain in some parts of this paper a general ratio of plug-in cars per public chargepoint (i.e. without distinguishing between chargepoint types) solely for the purpose of providing an overall perspective. As alluded to above, this ratio is less meaningful as it assumes PHEVs are also normally charged at rapid/ultra-rapid chargepoints, which is not the case.

Infrastructure expansion failing to keep pace with vehicle uptake

Thanks to huge investments by industry in the past five years that led to the introduction of an increasing number of plug-in models on the UK market, there has been an upsurge in plug-in vehicle registrations since the beginning of 2020, as evidenced by the figures in Table 1. Plug-in vehicles accounted for a record-breaking more than one in six UK car registrations in 2021, while BEV registrations rose to an all-time high of one in nine, with more registered than in 2016-2020 combined. The growth in public charging infrastructure, however, has not kept pace with the phenomenal growth in the plug-in vehicle market. With 6,324 new slow/fast public chargepoints installed in the whole of 2021, compared with 305,281 new plug-in car registrations in the same year, just one new charger is being installed for every 48 new plug-in cars.[45]

Indeed, the disparity in growth rates between the plug-in car parc and public chargepoints in the past two years is evident (Table 3). Plug-in cars on the road had grown a phenomenal 280.3% between 2019 and 2021, but slow/fast public chargepoints grew by just 69.8% in the same period. While BEVs in the car parc grew by a staggering 586.8% in the same period, rapid/ultra-rapid charger stock grew by only 82.3%.

Table 3: Growth rates of the plug-in car and BEV parc and public chargepoints, 2019-2021.

	All plug-ins in the parc	BEVs in the parc	All public chargers	Slow/fast public chargers	Rapid/ultra-rapid public chargers
North East	244.7%	305.7%	29.7%	15.7%	113.0%
North West	802.1%	892.8%	41.0%	36.1%	60.8%
Yorkshire and The Humber	324.4%	926.8%	83.6%	74.7%	112.6%
East Midlands	209.4%	392.4%	79.8%	72.3%	108.4%
West Midlands	99.6%	543.2%	107.4%	113.7%	91.9%
East of England	156.4%	320.1%	85.8%	78.3%	117.3%
London	253.4%	412.1%	91.8%	92.2%	87.5%
South East	332.7%	699.4%	69.3%	71.2%	62.7%
South West	337.1%	858.3%	55.0%	49.1%	79.4%
Wales	248.5%	393.1%	85.4%	77.9%	138.0%
Scotland	298.8%	475.6%	46.5%	43.4%	56.8%
Northern Ireland	239.3%	393.7%	16.9%	17.0%	15.8%
United Kingdom	**280.3%**	**586.8%**	**71.9%**	**69.8%**	**82.3%**

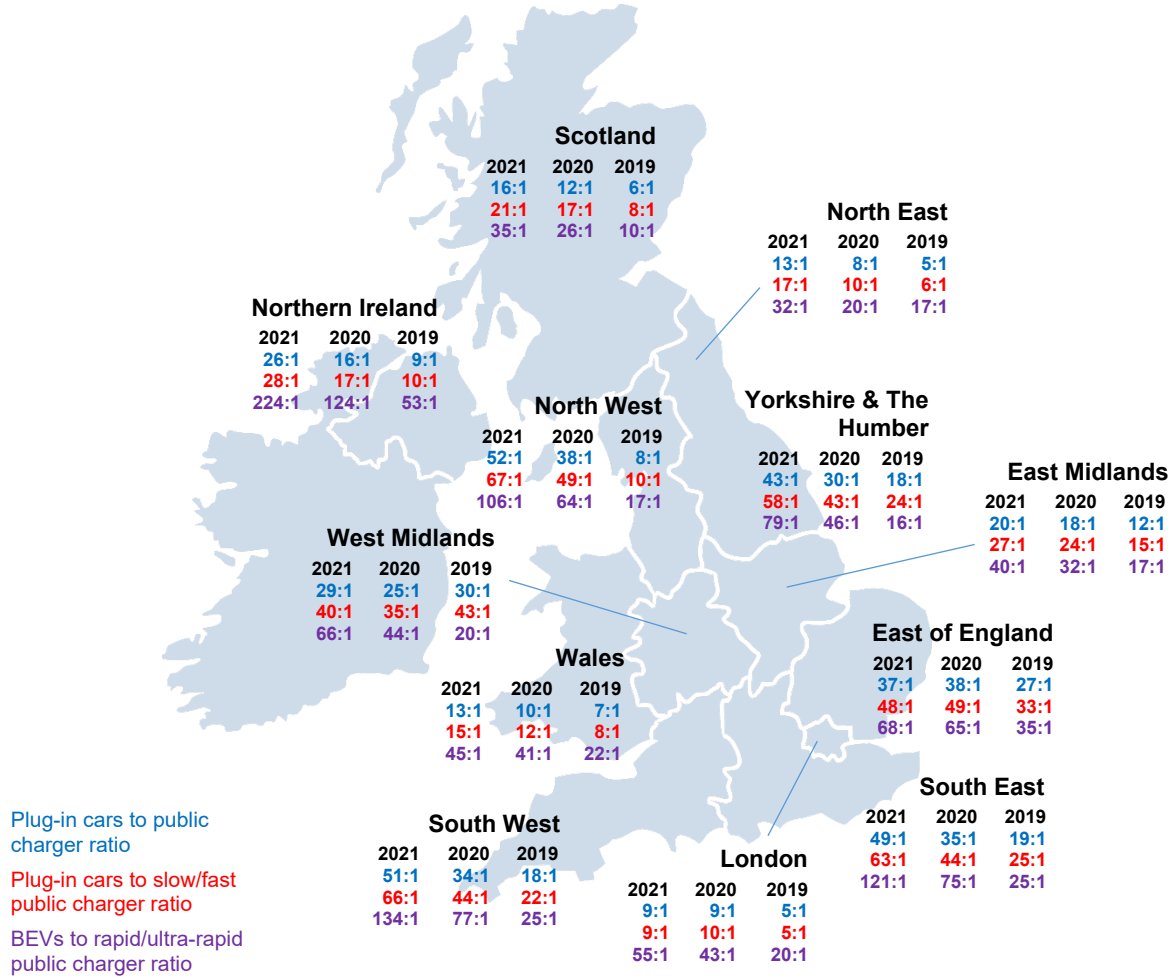
Source: SMMT analysis of data from Department for Transport (2022), Electric vehicle charging device statistics: January, available at https://www.gov.uk/government/statistics/electric-vehicle-charging-device-statistics-january-2022; and SMMT registration and parc data.

[45] Registration figures from SMMT car registration data. Public chargepoint figures from Department for Transport (2022), Electric vehicle charging device statistics: January, available at https://www.gov.uk/government/statistics/electric-vehicle-charging-device-statistics-january-2022.

Regional comparisons

By using SMMT car parc data, we can obtain a clearer picture of the national distribution of all plug-in cars on the road and public chargepoints. Our analysis is broken down by the 12 economic regions of the UK, as a more detailed analysis by local authorities or postcode areas will be less meaningful given cars registered in a local area may not be owned, used, parked or charged in the same area. Our analysis shows that it is clear there are regional disparities in cars-to-charger ratios (Figure 11), thus further corroborating the postcode lottery claims. On the whole, London, the North East, Wales and Scotland have the highest density of public chargepoints relative to plug-in cars.

Figure 11: Cars to public chargepoint ratio, by type of cars* and chargepoints, 2019-2021.**



* Denotes cars in the parc.
** Based on full year figures. Car parc data for 2021 is provisional.

Source: SMMT analysis of data from Department for Transport (2022), Electric vehicle charging device statistics: January, available at https://www.gov.uk/government/statistics/electric-vehicle-charging-device-statistics-january-2022; and SMMT registration and parc data.

Further scrutiny shows that in terms of **plug-in cars per slow/fast public chargerpoint**, the ratio in each of the past two years had deteriorated in every region of the UK apart from London, the West Midlands and the East of England. While the ratios in London and the East of England had improved marginally in 2021 compared to the year before, the ratio in the West Midlands had improved in 2020 compared to 2019 before deteriorating last year. Despite this, the West Midlands is the only region where the ratio in 2021 was still better than two years before. This can be explained by the growth rates of the plug-in car parc and public chargepoints between 2019 and 2021 (Table 3). The West Midlands was the only region where public charger stock grew faster (113.7%) than the plug-in cars on the road (99.6%).

Between 2019 and 2021, the deterioration of the ratio was worst in the North West, where a slow/fast public chargepoint went from being shared among ten to as many as 67 plug-in cars. This region is the starkest proof yet of public charging infrastructure expansion failing to keep pace with plug-in vehicle uptake – plug-in vehicle parc grew 802.1% in the two-year period, whereas slow/fast public chargers grew by only a relatively meagre 36.1% in the same period. By contrast, plug-in car users in London, where every slow/fast public charger is shared among only nine plug-in cars, benefit from greater provision of public charging infrastructure compared to drivers in other regions. It is unsurprising that a recent study by consumer organisation Which? found that Londoners (66%) felt most comfortable switching to a plug-in vehicle.[46]

Should rapid/ultra-rapid chargers be concentrated only in motorway service areas (MSAs), measuring BEVs on the road per rapid/ultra-rapid charger in a given region would be largely meaningless, as traffic at MSAs are transient and potentially cross-region. However, as the trend of rapid/ultra-rapid charger deployment is increasingly expanding to local hubs and forecourts, which in the future may replicate the fuel forecourt model serving local residents, the **BEVs-to-rapid/ultra-rapid charger** ratio may provide an indication of future pressures. While it is normal for these ratios to be substantially higher than plug-in cars-to-slow/fast charger ratios due to the much shorter dwell times and higher vehicle throughput per charger, the problem with deteriorating ratios seems most acute in the North West, the South West, Yorkshire and The Humber, Northern Ireland and the South East. With the exception of Northern Ireland, which suffered from disappointingly low growth in rapid/ultra-rapid charger stock (15.8% between 2019 and 2021), the other four regions saw an upsurge in BEVs on the road that far outpaced rapid/ultra-rapid charger growth.

National comparisons

The UK has among the highest number of public chargepoints in Europe in absolute terms. However, in terms of slow/fast public chargers, there is faster deterioration in cars-to-charger ratio vis-à-vis other major plug-in vehicle markets as a result of infrastructure expansion failing to keep pace with the surge in plug-in vehicle uptake. In terms of rapid/ultra-rapid public chargers, although there is likewise deterioration in cars-to-charger ratio, the UK's ratio is still far better than those in many other major markets (Table 4).

The UK's plug-in cars-to-slow/fast public charger ratio has increased from 11:1 to 16:1. While the ratio has also understandably deteriorated in most countries due to higher plug-in car uptake, relatively faster growth in slow/fast public chargepoints means the deterioration has been substantially smaller than the UK's. The Netherlands, which has a very sizeable proportion of dwellings without off-street or dedicated parking, has an enviable ratio of five plug-in cars per slow/fast public charger, while in France it is 10:1.

[46] Which? (2021), Supporting consumers in the transition to net zero, available at https://www.which.co.uk/policy/sustainability/8178/supporting-consumers-in-the-transition-to-net-zero.

Remarkably, the ratios in South Korea (3:1), China (9:1) and the USA (22:1) have actually improved slightly. The deteriorating ratio in Norway in recent years had not impeded plug-in vehicle uptake because, in contrast to some other major European markets, most Norwegian dwellings have off-street parking.

The UK performs better vis-à-vis other major countries in the rapid/ultra-rapid charger segment, with 32 BEVs per charger, behind only China (11:1), South Korea (12:1) and Japan (17:1). Despite a deteriorating ratio, the UK remains the best in Europe, although countries like the Netherlands and France have actually improved their respective ratios. However, BEV users in Norway are increasingly experiencing frustratingly long queues at public rapid/ultra-rapid charging stations.[47]

Table 4: Plug-in vehicle parc, public chargepoints and cars to public chargepoint ratio in selected major countries.

	EVs in the parc				Slow/fast public chargers				Rapid/ultra-rapid public chargers			
	2020		2019		Number of chargers		Plug-in cars to charger ratio		Number of chargers		BEVs to charger ratio	
	BEVs	Plug-ins total	BEVs	Plug-ins total	2020	2019	2020	2019	2020	2019	2020	2019
South Korea	119,691	136,550	88,362	96,712	54,383	37,396	2.51	2.59	9,805	7,396	12.21	11.95
Netherlands	182,481	291,133	107,536	203,421	63,586	49,324	4.58	4.12	2,047	829	89.15	129.72
China	3,512,477	4,508,668	2,581,186	3,349,086	498,000	301,238	9.05	11.12	309,000	214,670	11.37	12.02
France	281,603	416,210	166,809	226,829	42,000	27,661	9.91	8.20	4,045	2,040	69.62	81.77
Belgium	31,692	104,399	18,660	59,901	8,006	6,070	13.04	9.87	476	359	66.58	51.98
Japan	136,700	293,081	122,100	263,781	21,916	22,536	13.37	11.70	7,939	7,858	17.22	15.54
UK	**199,085**	**438,595**	**92,913**	**237,248**	**27,222**	**22,359**	**16.11**	**10.61**	**6,248**	**4,735**	**31.86**	**19.62**
Germany	330,780	633,424	136,617	238,792	37,213	34,203	17.02	6.98	7,456	5,088	44.36	26.85
USA	1,138,654	1,778,086	882,281	1,450,017	82,263	64,265	21.61	22.56	16,718	13,093	68.11	67.39
Norway	339,105	484,674	222,617	328,639	11,677	10,337	41.51	31.79	5,299	3,970	63.99	56.07

N.B. Slow/fast chargers (3-22kW in UK definition) are referred to as slow chargers by IEA in its report. Rapid/ultra-rapid chargers (≥43kW in UK definition) are referred to as fast chargers by IEA. EV parc and charger figures collected by IEA may differ from official figures published by the government of respective countries.

Source: SMMT analysis of data from International Energy Agency (2021), Global EV Outlook 2021, available at https://www.iea.org/reports/global-ev-outlook-2021.

[47] As admitted by As presented by Christina Bu, Secretary General of the Norwegian EV Association, at the JUICE Conference & Exhibition in London, 8 November 2019; and Schmidt, B. (2019), "Norway approaches 250,000 EVs while drivers queue to use fast chargers", The Driven, 30 July, available at https://thedriven.io/2019/07/30/norway-approaches-250000-evs-while-drivers-queue-to-use-fast-chargers/, and Ulven, E. and Sutterud, T. (2021), "Norway's electric car drive belies national reliance on fossil fuels", The Guardian, 9 January, available at https://www.theguardian.com/business/2021/jan/09/norways-electric-car-drive-belies-national-reliance-on-fossil-fuels.

CHAPTER 3
CONSUMER-CENTRICITY IN CHARGING INFRASTRUCTURE EXPANSION

From range anxiety to charging anxiety

Until recently, range anxiety had always been the top barrier to wider BEV uptake. For example, one 2018 study discovered that most affordable BEVs in the B- and C-segments[48] were capable of a real-world range of up to about 150 miles.[49] Manufacturer investments have since resulted in the arrival of an increasing number of C- and D-segment models offering a range of 200-250 miles.

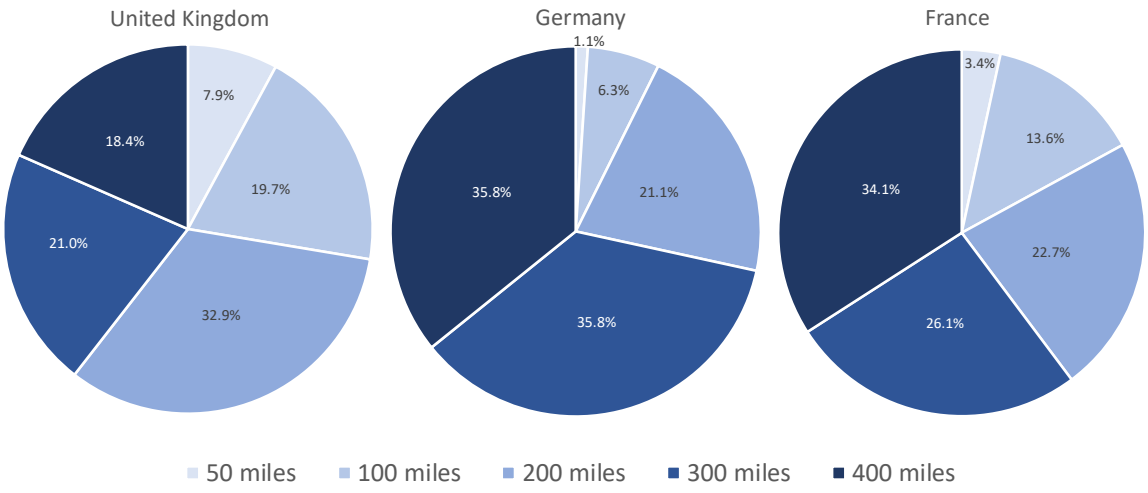
However, a delicate balance must be struck between required range, the size or weight of the battery pack (to deliver the range) and the resultant price of the vehicle. Until there is a major step-change in battery chemistry innovation that spawns the commercialisation of higher energy density batteries at scale, and thus significantly reduces the cost per kWh of energy, longer range BEV models on the market are likely to be more costly to both the consumer and the environment as they are fitted with a larger battery pack. They are also likely to be found in the upper passenger car segments.

The findings from a study show the majority of UK consumers (61%) expect a driving range of up to 300 miles from a BEV, whereas 72% of German and 60% of French consumers expect a minimum driving range of at least 300 miles (Figure 12).[50] With a lower expectation of vehicle range, correspondingly UK consumers expect to charge their vehicles more often and therefore require adequate provision of charging infrastructure.

As battery range improves, and given most UK consumers' expectation of range, it is arguable that range anxiety is no longer as critical as **charging anxiety**, which is the ability to find an available chargepoint **on demand**, i.e. at the point of need. The "innovators" and "early adopters" of BEVs, to borrow from the Rogers innovation diffusion parlance,[51] are likely more savvy in planning their use of their BEVs around the need to charge and where to charge, hence may consider perceived range or charging anxiety as being less pronounced. They are also more likely to put up with inconveniences that come with using early-stage infrastructure, such as unreliable legacy chargepoints, multiple network membership RFID cards, or waiting for in-use chargepoints to become available. Some of them are also more likely to be able to afford BEVs in the upper segments that offer longer driving range. Even among BEV enthusiasts, however, there are complaints of disappointment with public charging infrastructure.[52]

[48] For a glossary of car segments, see Appendix B.
[49] Dermott, H. (2018), Development of the UK Public Chargepoint Network, RAC Foundation, available at https://www.racfoundation.org/wp-content/uploads/Development_of_the_UK_CPN_Harold_Dermott_December_2018.pdf.
[50] Deloitte (2020), Global Automotive Consumer Study: Europe, available at https://www2.deloitte.com/content/dam/Deloitte/global/Documents/Manufacturing/gx-2020-global-automotive-consumer-study-europe.pdf.
[51] For the Rogers Adoption Curve, see https://en.wikipedia.org/wiki/Diffusion_of_innovations.
[52] See for example, https://www.linkedin.com/posts/joe-howick-8a01454_my-first-step-into-full-electric-vehicle-activity-6834032134299148288-UNHU, https://www.linkedin.com/posts/tobyposton_charging-woes-continue-tried-two-successive-activity-6829438998834888704-_4fm, https://www.linkedin.com/posts/iain-macbeth-81583a11_whilst-we-know-that-the-ev-charging-infrastructure-activity-6842836219643207680-flQM and Coward, R. (2022), "Streets ahead? What I've learned from my year with an electric car", The Observer, 8 January, available at https://www.theguardian.com/environment/2022/jan/08/streets-ahead-what-ive-learned-from-my-year-with-an-electric-car.

Figure 12: Minimum driving range consumers expect from a battery electric vehicle.



N.B. Calculations have been adjusted from km to miles and respondents stating "Don't know" removed from the sample.

Source: SMMT analysis of data from Deloitte (2020), Global Automotive Consumer Study: Europe, available at https://www2.deloitte.com/content/dam/Deloitte/global/Documents/Manufacturing/gx-2020-global-automotive-consumer-study-europe.pdf.

However, the "early majority" and "late majority" consumers, i.e. the mainstream market, are unlikely to be as savvy, forgiving or indeed affluent. For every BEV enthusiast, or innovator or early adopter, who claims the charging experience is straightforwardly simple, there is a sizeable number of people who complain BEVs do not work for them due to painful charging experiences. These mainstream market consumers, representing the majority of motorists, are those we need to win over by giving them the peace of mind and confidence that there is adequate charging infrastructure on demand. These are unlikely to be BEV, or indeed motoring, enthusiasts, but consumers for whom the car is largely a functional product. To ensure all consumers are put at the heart of this transition to ZEVs by 2035, they need to be convinced that **the charging experience, which includes finding an available and reliable public charger on demand, is as easy as, if not easier than, refuelling**. This is why charging infrastructure expansion must be consumer-centric.

Consumer-centricity: adequacy, experience and equity

Consumer-centricity means putting **consumer interests first** in every aspect of charging infrastructure development and expansion, including policy-making. The early-stage market in the past decade had seen the competing interests of CPOs, local authorities, electricity Distribution Network Operators (DNOs), motorway service station operators, car park operators and businesses result in patchwork rollout and maintenance of public charging infrastructure. Some public chargers have, for example, ended up in the wrong places, concentrated mostly in highly profitable locations, or been poorly maintained.

Given the end of sale of petrol and diesel cars and vans is just eight years away, and a ZEV mandate is expected to be introduced from 2024, from now henceforth government must ensure consumer

interests are prioritised ahead of all other stakeholders' in any policy decision on charging infrastructure. In other words, charging infrastructure must be fit for purpose in the eyes of consumers, otherwise the success of the transition could be at stake. Consumer-centricity should be based on the following three principles and their corresponding litmus test questions from the perspective of consumers:

- **Adequacy**
  There must be at least adequate charging infrastructure to enable motorists to find an available and working public charger on demand. This means there needs to be a binding commitment and a coordinated plan to significantly uplift the number of public chargers of the right types in the right places.

  Consumer litmus test: Can I confidently and easily find an available and working public chargepoint at the point of need?

- **Experience**
  The experience of charging a plug-in vehicle must be as "uneventful" as refuelling, which is a straightforward process that motorists have become more than familiar with. This means there must be regulation on a minimum standard of reliability, ease of payment, pricing transparency, information provision, accessibility and security associated with public chargepoints. A fit-for-purpose regulatory body must monitor the market and enforce the regulation.

  Consumer litmus test: Is my charging experience as easy as, or inferior to, the refuelling experience today?

- **Equity**
  No socio-economic groups or communities should be disadvantaged or left behind. This means the above principles of adequacy and experience must equally apply to consumers in locations that are nominally not profitable for CPOs, such as those in rural areas or reliant on on-street residential charging. Public charging must also be affordable so that consumers are not penalised in the pocket for not having the luxury of a private driveway and access to a dedicated home charger.

  Consumer litmus test: Are my access to a charger, my overall charging experience and the cost of my charging more or less on par with people in other locations?

Much of the success of the transition to ZEVs is riding on whether government's forthcoming EV Infrastructure Strategy will put consumer interests first. Left to purely commercial interests, rollout of public chargepoints will focus predominantly on the more profitable rapid and ultra-rapid chargers at the expense of slow and fast on-street chargers, which are mainly loss-making. Yet charging overnight on residential streets, or during relatively longer dwell times at workplaces and destinations, is by far more convenient and affordable to consumers, as well as can better facilitate grid management through demand side response. Instead of giving consumers confidence by investing in plentiful public chargepoints ahead of need, commercial priorities will always focus on maximising the utilisation of existing chargepoints. Indeed, if utilisation rates and profitability are the priority, consumers in rural areas will likely suffer from underprovision. Providing real-time chargepoint availability information (i.e. whether it is in use) is deemed to be commercially damaging, yet it is squarely in the interest of consumers to know which chargers are available at the point of need.

Currently, while new cars and vans from 2035 are decreed to be zero emission and there will be binding targets for zero emission vehicle sales from 2024, there is a glaring lack of a quid pro quo mandate, or

conditionality, for delivering commensurate charging infrastructure, despite consumer-centric infrastructure being fundamental to a successful transition. Automotive alone cannot ensure the success of this transition. Much depends on how committed all stakeholders are in making it happen. Government's EV Infrastructure Strategy must include **binding commitments and delivery targets** on sectoral stakeholders to deliver their respective contributions to the cause, not least as a commensurate condition of the forthcoming ZEV mandate.

Uplifting the number of public chargepoints

As home charging will be the backbone infrastructure, we think this segment will continue to grow despite government's decision to end EVHS support for single unit properties from April 2022. However, as discussed above, there is a limit to the number of dwellings where a dedicated private home charger could be installed. Our modelling suggests by 2030 there could be 5.85 million home chargers in the UK.

However, we believe the key to a successful transition to 2030 and 2035 is a significant expansion of charging infrastructure of all types across the country. This includes significantly uplifting the number of public chargepoints to the extent that there is perceived adequate provision among mainstream consumers. As vehicle manufacturers are investing billions in plug-in vehicles even when a clear path to profitability is yet to be found, government and the charging infrastructure sector must play their part by equally investing boldly in expanding public charging infrastructure **ahead of need**.

However, estimating the number of chargepoints required in the future is challenging given the number of variables involved, for example, the size of the plug-in parc, consumers' preferred charging type (i.e. where people mostly charge their cars), battery sizes and vehicles' power architecture. Modelling-based projections of public chargepoints needed in the UK by 2030 range from a relatively low estimate of 280,000 by the Climate Change Committee,[53] to mid-range estimates of 430,000 by the International Council on Clean Transportation[54] and 480,000 by Transport and Environment,[55] to a high of up to three million in a study backed by the Renewable Energy Association.[56] The EV Energy Taskforce is currently finalising its modelling based on the Energy System Catapult's CVEI model, early findings of which suggest up to 700,000 "non-home" chargepoints could be needed by 2030.[57]

Our modelling suggests **between 689,000 and 2.33 million public chargepoints** are required by 2030 depending on how and where people prefer to charge their cars in the future (Figure 13). This is based on our long-term market and parc outlook and current vehicle survival rates (Figures 3 and 4).[58] Our

[53] Climate Change Committee (2020), Sixth Carbon Budget, available at https://www.theccc.org.uk/publication/sixth-carbon-budget/.
[54] Nicholas, M. and Lutsey, N. (2020), Quantifying the electric vehicle charging infrastructure gap in the United Kingdom, International Council on Clean Transportation, available at https://theicct.org/sites/default/files/publications/UK-charging-gap-082020.pdf.
[55] Mathieu, L. (2020), Recharge EU: How many charge points will EU countries need by 2030, Transport and Environment, available at https://www.transportenvironment.org/discover/recharge-eu-how-many-charge-points-will-eu-countries-need-2030/.
[56] Estimates are for charging infrastructure at "commercial and industrial" sites, defined as "workplaces, retail stores or motorway service stations". Aurora Energy Research (2018), Opportunities in Electric Vehicle Charging at Commercial and Industrial Sites, available at https://www.r-e-a.net/wp-content/uploads/2019/10/Aurora_Report_Full_Opportunities_in_EV_charging_at_CI_sites_October_2018.pdf.
[57] Brown, D. et al. (2021), "Encouraging Investment in Public EV Charging in the UK", EV Energy Taskforce, available at https://secureservercdn.net/160.153.138.177/272.732.myftpupload.com/wp-content/uploads/2021/10/EVET_Encouraging_Investment_in_Public_EV_Charging.pdf?time=1640724007.
[58] SMMT (2021), New car market and parc outlook to 2035, by powertrain, available at https://www.smmt.co.uk/2021/06/smmt-new-car-market-and-parc-outlook-to-2035-by-powertrain/.

analysis suggests plug-in cars will comprise 27% (9,273,000) of the car parc by 2030 (BEV 20.1%, PHEV 6.9%). We consider the following to be public chargepoints:

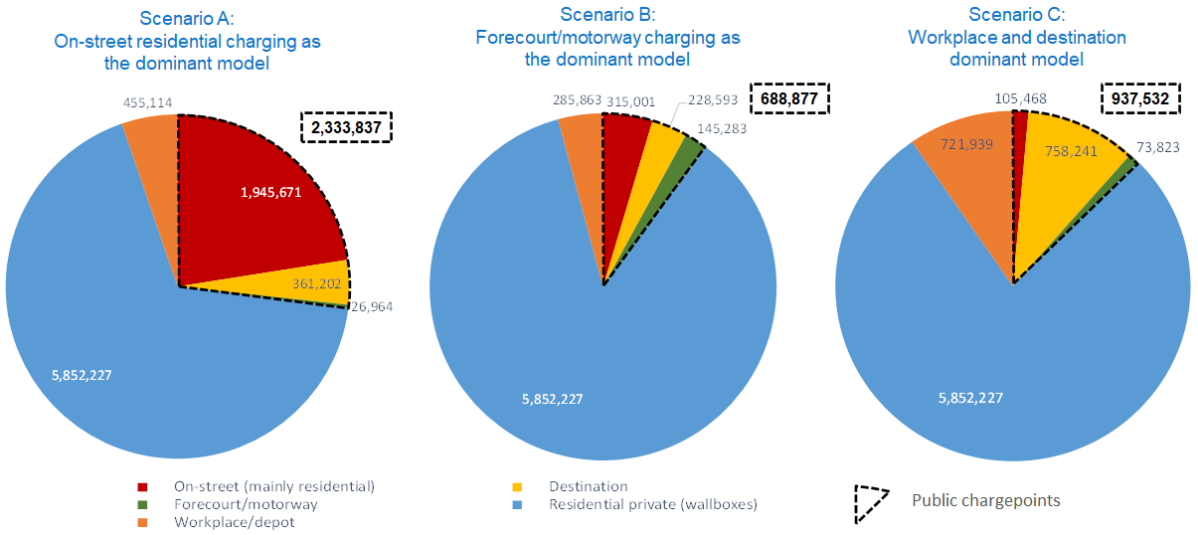
- *On-street chargers (mainly residential)*
  These are predominantly 3-22kW chargers found mostly in residential streets and in some streets in towns and cities. 3kW slow public chargers are expected to be mostly phased out by 2030. 5.5kW lamppost chargers are subsumed under 7kW fast chargers. We also assume there are a small number of 50kW rapid chargers on streets in cities, such as those in London.

- *Destination chargers*
  These are mostly 7-22kW fast chargers, and a small number of 50kW rapid chargers, found in places where there are likely to be mid-to-long dwell times such as supermarkets, retail parks, entertainment venues, hotels, places of interest/tourism and public car parks.

- *Forecourt/hub/motorway chargers*
  These are typically either 50kW rapid chargers or 150-350kW ultra-rapid chargers. While most commonly found at motorway service areas until recent years, they are also likely to be located at dedicated electric charging forecourts or stations with amenities, which seek to replicate the fuel forecourt model with transient traffic, or local hubs, which seek to provide local residents with a rapid charge. Some may also be co-located at fuel forecourts.

Workplace/depot chargepoints and home chargers in dedicated off-street parking spaces, insofar as these are not open to the public via community charging schemes or networks, are considered as private chargepoints.

Figure 13: Plug-in vehicle charging infrastructure required by 2030 to meet the end of sale of petrol and diesel cars and vans.



Source: Analysis based on modelling by Frost & Sullivan and SMMT.

To account for the uncertainty of which charging model(s) could be the predominant type by 2030, we have modelled three scenarios. The key assumptions and outcome analysis of each scenario are summarised as follow and set out in Table 5. More details on our assumptions and analysis can be found in Appendix C.

Table 5: Plug-in vehicle charging infrastructure required by 2030, cars to public chargepoint ratios and the cost of delivering public chargepoints.

	Scenario A: On-street residential charging as the dominant model	Scenario B: Forecourt/hub/ motorway charging as the dominant model	Scenario C: Workplace and destination charging as the dominant model
Plug-ins on the road			
Total plug-ins in the parc by 2030		**9,273,000**	
of which are BEVs		6,909,000	
of which are PHEVs		2,364,000	
Number of chargers required by use case			
PUBLIC CHARGERS required, of which are	**2,333,837**	**688,877**	**937,532**
On-street (mainly residential)	1,945,671	315,001	105,468
Destination	361,202	228,593	758,241
Forecourt/hub/motorway	26,964	145,283	73,823
PRIVATE CHARGERS required, of which are	**6,307,341**	**6,138,090**	**6,574,166**
Off-street residential (private home chargers)	5,852,227	5,852,227	5,852,227
Workplace/depot	455,114	285,863	721,939
Dwellings to on-street residential charger ratio*	**7:1**	**43:1**	**129:1**
Number of public chargers required by power rating			
PUBLIC CHARGERS required, of which are	**2,333,837**	**688,877**	**937,532**
Fast public chargers (7-22kW)**	2,293,860	541,694	855,961
Rapid/ultra-rapid public chargers (50-350kW)	39,977	147,183	81,571
Cars to public chargepoint ratios			
Plug-in cars to public charger ratio	3.97	13.46	9.89
Plug-in cars to **fast** public charger (7-22kW) ratio	4.04	17.12	10.83
BEVs to **rapid/ultra-rapid** public charger (50-350kW) ratio	172.82	46.94	84.70
Cost of delivering public chargers			
Cost of delivering the required additional PUBLIC CHARGERS***, of which are	**£17,603,794,430**	**£13,647,803,519**	**£10,712,432,348**
On-street (mainly residential)	£13,525,424,905	£1,889,095,625	£547,352,300
Destination	£2,319,940,605	£1,422,644,900	£4,933,238,700
Forecourt/hub/motorway	£1,758,428,920	£10,336,062,994	£5,231,841,348

* The average number of dwellings in the UK that are unable to have a dedicated, private home charger sharing an on-street residential chargepoint.
** Slow public chargers (3kW) are expected to be mostly phased out by 2030. 5.5kW lamppost chargers are subsumed under 7kW fast chargers.
*** Includes hardware, wiring and installation, and grid connection.

Source: Analysis based on modelling by Frost & Sullivan and SMMT.

Scenario A: On-street residential charging as the dominant model

Key assumptions

- The vast majority of people will still want the convenience of charging at home, mainly overnight, whether or not they have off-street parking or could install a dedicated home charger. This means those without off-street parking, or could not install a dedicated home charger, will want to charge on their residential streets.
- On-street residential charging remains cheaper than forecourt/hub/motorway and destination charging.
- A sizeable proportion of BEVs in the parc are unable to support ultra-rapid charging. These are likely to be either earlier generation models, including used BEVs, or low-cost entry-level BEVs.

Should the vast majority of consumers who do not have a private driveway and a dedicated home charger wish to charge their cars overnight on their residential streets by 2030, as many as 2.33 million public chargers are required, dominated understandably by on-street residential chargers (1.95 million). This translates into one on-street residential charger for every seven dwellings in the UK that are unable to install a dedicated home charger for various reasons. Our estimates suggest 13.55 million (47%) dwellings in the UK are not able to have a dedicated home charger due to the lack of off-street parking, living in multi-unit dwellings, communal garages or wiring challenges.

While this scenario may represent the most equitable form of charging, as it means even consumers who do not have a home charger can plug in relatively affordably overnight while the car is stationary, it is also the least profitable for CPOs and the most expensive to deliver, costing £17.6 billion including hardware, wiring and installation, and grid connection.

Scenario B: Forecourt/hub/motorway charging as the dominant model

Key assumptions

- The vast majority of people will want to charge at forecourts and hubs, or motorway service areas if they are en-route, just as they refuel today.
- The convenience, familiarity and speed of refuelling today will be close to fully replicated at charging forecourts. This means traffic will be largely transient and people expect to be on their way again in about 10-15 minutes, apart from those using 50kW rapid chargers at local hubs.
- The cost of charging at forecourts/hubs/motorway will fall and become more affordable to the mass market.
- The vast majority of BEVs in the parc are capable of supporting ultra-rapid charging.

Some observers and experts have suggested the future will be the opposite of on-street residential charging. Should the vast majority of consumers desire the convenience and speed of today's refuelling experience at forecourts and have BEVs that are capable of supporting ultra-rapid charging, as relatively few as 689,000 public charges are required by 2030. While there will still need to be about 315,000 on-street chargers, as many as 145,000 rapid and ultra-rapid chargers (50-350kW) will be required to serve a largely transient fleet at forecourts, hubs or motorway service areas. This far exceeds government's expectation of around 6,000 ultra-rapid chargepoints across the Strategic Road Network by 2035.[59]

[59] Department for Business, Energy and Industrial Strategy, Department for Transport, and Office for Low Emission Vehicles (2020), Policy paper: Government vision for the rapid chargepoint network in England, available at https://www.gov.uk/government/publications/government-vision-for-the-rapid-chargepoint-network-in-england/government-vision-for-the-rapid-chargepoint-network-in-england.

At a cost of £13.6 billion, this model is also expensive to deliver, largely because of the cost of grid connection to cater for high-power charging. This is where government's £950 million Rapid Charging Fund to future-proof grid connections provides much needed support. However, even if the cost of charging at forecourts, hubs or the motorway falls in the future, consumers are still expected to pay a premium to use these services compared to the cost of using 7kW on-street or destination chargers. Speed and convenience come at a price.

Scenario C: Workplace and destination charging as the dominant model

Key assumptions

- The vast majority of people prefer to opportunity-charge whenever and wherever the car is parked, particularly for an extended period of time.
- There is an abundance of workplace/depot and destination chargers, supplemented by forecourt/hub/motorway chargers for en-route/transient traffic.
- Businesses and organisations are willing to install workplace and destination chargers.
- People without off-street parking and a dedicated home charger will not necessarily need to charge on-street at home due to an abundance of other options.
- All these other options are more or less equally convenient, accessible and affordable.

In contrast to the two preceding scenarios, there could be a third and more evenly distributed scenario where, thanks to significant investments by businesses and organisations, destination and workplace charging leads the way. With some 758,000 destination chargers and 722,000 workplace chargers in place by 2030, the vast majority of which are 7-22kW fast chargers and supplemented by 74,000 forecourt/hub/motorway chargers, consumers are almost spoilt for choice as they are able to charge relatively affordably whenever and wherever the car is parked as well as occasionally splurge on the convenience and speed of an ultra-rapid charge when in transit. As such, the need for on-street residential chargers is relatively lowest under this scenario.

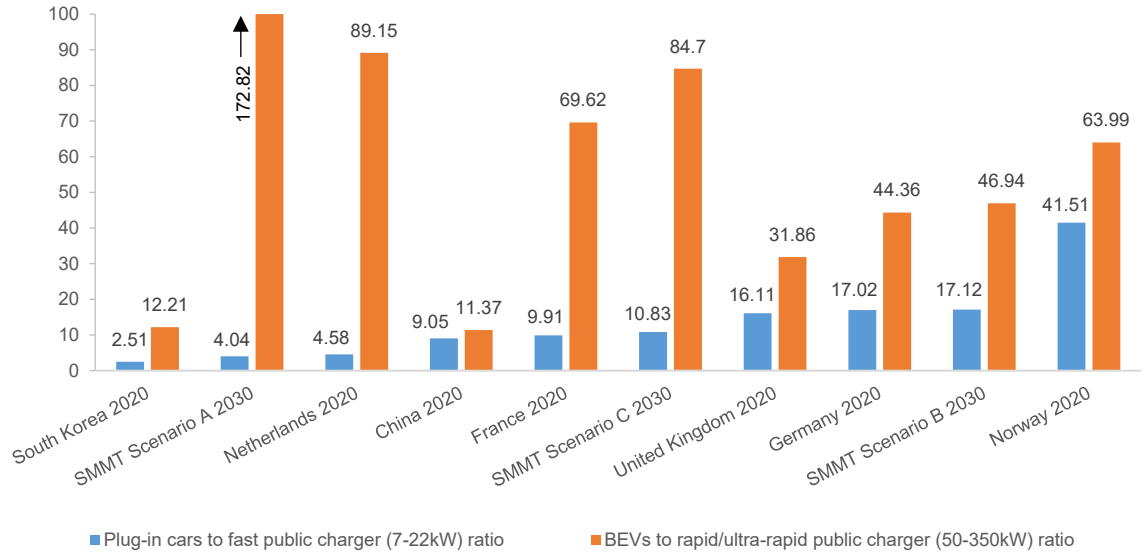
This scenario may create the illusion that it is the cheapest to deliver (£10.7 billion) because a large amount of the investment burden is actually transferred to employers who provide workplace charging, which is nominally private charging. Should this be the preferred model, government may need to invoke the primary powers it has recently propose to take to require new and existing non-residential car parks to install chargepoints.

Whichever scenario prevails in the future, it is clear that a very substantial increase in charging infrastructure is required to support the plug-in vehicle parc by 2030 and commensurate with government's end-of-sale deadlines and ZEV mandate. Public chargepoints alone **must increase by between 1,431% and 5,078%**, depending on scenario, from today's provision. These figures cannot be dismissed or ignored just because of their sheer magnitude, as over time more consumers, not fewer, will require public charging infrastructure. While it is expected that most consumers with off-street parking will continue to charge at home, this proportion, which is around 80% today, is expected to fall as an increasing number of mainstream consumers who have previously been put off switching to plug-in vehicles because they have no access to off-street parking finally make the switch.

In terms of plug-in cars to fast (7-22kW) public charger ratios, as shown in Table 5, Scenario A delivers relatively the most encouraging ratio by 2030 (4:1), whereas Scenario B (17:1) represents further deterioration from today (16:1). However, even Scenario A by 2030 will not deliver the ratio seen in South Korea today and could just about rival today's ratio in the Netherlands' (Figure 14).

In terms of BEVs to rapid/ultra-rapid public charger ratios, none of the scenarios – including the forecourt/hub/motorway dominant scenario – could deliver ratios that match those seen in South Korea, China, Germany and the UK itself today. This means even our most optimistic scenario implies there could be at least slightly longer queues at rapid/ultra-rapid chargers by 2030.

Figure 14: Cars to public chargepoint ratio comparisons between SMMT 2030 scenarios and selected major countries in 2020.



N.B. Fast chargers (7-22kW in UK definition) are referred to as slow chargers by IEA in its report. These may also be referred to as normal chargers in the EU. Rapid/ultra-rapid chargers (≥50kW in UK definition) are referred to as fast chargers by IEA and in the EU.

Source: Analysis based on modelling by Frost & Sullivan and SMMT, and data from International Energy Agency (2021), Global EV Outlook 2021, available at https://www.iea.org/reports/global-ev-outlook-2021.

CHAPTER 4
A MULTI-PILLAR APPROACH TO DELIVERING CONSUMER-CENTRIC INFRASTRUCTURE

To achieve the best possible outcomes, the £1.3 billion government investment in infrastructure, as well as a share of the recently announced £620 million additional funding, must now be complemented by a strategic, rather than a patchwork, approach to delivering consumer-centric charging infrastructure commensurate with government policy to end the sale of non-zero emission cars and vans by 2035. This strategic approach to delivery must put consumer interests above all else and should comprise three inextricably linked and mutually reinforcing pillars: **binding targets**, **proportionate regulation** and **enabling support**.

Binding targets to ensure adequate provision and social equity

As discussed in the previous chapter, whichever scenario prevails in the future, a very substantial increase in charging infrastructure is required to support the expected future plug-in vehicle parc. While new cars and vans are mandated to be zero emission by 2035 and binding targets for zero emission vehicle sales will be introduced from 2024, there is yet any quid pro quo mandate for delivering the commensurate charging infrastructure.

While some may argue that market forces should dictate that public charging infrastructure will expand organically, and therefore only investment instead of binding targets are needed, evidence we presented in this paper shows that despite soaring plug-in vehicle sales since the beginning of 2020 charging infrastructure expansion has not kept pace. While there is no doubt charging infrastructure rollout will increase, there is no guarantee provision will expand organically to the level commensurate with vehicle uptake, let alone expand ahead of need, so that there is at least adequate amount of public chargepoints to give confidence to consumers.

As we have also argued, left purely to the market, there is a substantial risk that rollout of public chargepoints will prioritise **commercial rather than consumer interests**. Investing conservatively in charging infrastructure expansion to maximise utilisation and revenues will take precedence over ambitious expansion to ensure comprehensive provision ahead of need across the country.

Gigabit broadband rollout is a good example and precedent that demonstrates why binding targets are effective where organic growth will not deliver the desired outcomes. After years of sluggish gigabit-broadband rollout by telecommunication companies, in November 2020, government announced a target for at least 85% of UK premises to have access to gigabit broadband by 2025, which itself was a reduction from the original target of 100%.[60] In September 2020, 27% of UK premises had a gigabit broadband connection available. Thanks to the ambitious target, in just eight months, the figure had increased to 38.7% in May 2021.[61] Just as consumers have a universal "right to connect" in the modern Internet age, consumers should have a **universal "right to charge"** befitting the coming age of zero

[60] House of Commons Library (2021), Research Briefing: Gigabit-broadband in the UK: Government targets and policy, 30 April, available at https://commonslibrary.parliament.uk/research-briefings/cbp-8392/.
[61] House of Commons Library (2021), Data Dashboard: Constituency data: broadband coverage and speeds, 17 September, available at https://commonslibrary.parliament.uk/constituency-data-broadband-coverage-and-speeds/.

emission mobility. Government should therefore replicate in public chargepoint rollout what it has boldly decreed in gigabit broadband rollout with demonstrable success, as evidence thus far suggests.

Binding targets for charging infrastructure provision should not be viewed negatively. If reasonable and well designed, they reflect positively on government's zero emission mobility ambitions, hold government to account and provide **long-term signals and direction for investment**, a view shared by the European power and charging infrastructure sectors.[62] DNOs' anticipatory investments to upgrade local networks and CPOs' investments in rolling out new chargers can be better targeted if there is greater certainty on where chargepoints will be needed based on ambitious but well-designed targets. Binding targets are also a policy tool that gives consumers **certainty and confidence** to switch to ZEVs, as it sets out government commitment and call-to-action to achieve a specific goal by a specific time.

Binding targets

As a condition of the forthcoming ZEV mandate, we urge government to put consumer interests at the heart of this transition to zero emission mobility by also introducing a **charging infrastructure mandate** from 2024 that includes **binding targets** of public chargepoint provision on a **graduated basis**. This means these targets should not be static but should be adjusted to be commensurate with expected plug-ins on the road over time driven by the ZEV mandate and predicated on robust modelling that is periodically reviewed. There should also be flexibility to adjust the targets should local conditions or charging needs change. The focus of these binding targets should primarily be on the type of chargepoints that are less likely to follow an organic growth path. A new regulatory body that is independent of sectoral vested interests, Office of Charging (Ofcharge), which we will discuss further in the next section, should coordinate and regulate these binding targets.

The overarching aim of this mandate is two-pronged: to significantly uplift the number of public chargepoints so that all consumers have the confidence to transition to ZEVs by 2035 and are able to charge on demand, and to ensure this transition is socially equitable so that no socioeconomic groups or communities are disadvantaged or left behind.

We suggest the following binding targets for delivery of public charging infrastructure:

- **Ratio of plug-in vehicles per fast (7-22kW) public charger in each of the economic regions**

  As slow (3kW) and fast (7-22kW) chargers, particularly those on residential streets and in rural areas, are typically less profitable relative to rapid (50kW) and ultra-rapid (150-350kW) chargers, there is a risk future infrastructure rollout may naturally gravitate disproportionately towards the more investable segments.

  As we have explained earlier in this paper, a cars-to-charger ratio is a more meaningful metric to measure public charging infrastructure adequacy as it gives an idea of chargepoint density and the potential pressures at a given location, as well as the implied ease of finding an alternative chargepoint when one is in use.

[62] Eurelectric (2021), Position paper: Revised Alternative Fuels Infrastructure Regulation (AFIR), available at https://www.eurelectric.org/publications/eurelectric-position-paper-revised-alternative-fuels-infrastructure-regulation-afir/; and Bonnet, M. (2022), "Higher charging infrastructure targets will prevent two-track Europe in EV shift", Euractiv, 14 January, available at https://www.euractiv.com/section/electric-cars/opinion/higher-charging-infrastructure-targets-will-prevent-two-track-europe-in-ev-shift/.

However, neither a national ratio nor a local authority-level ratio is likely to be meaningful. The former fails to capture regional charging needs and variations in the size of the plug-in parc, while the latter may erroneously account for plug-in vehicles registered in a postcode area but used, parked or charged elsewhere.

Instead, government should task Ofcharge to convene all relevant local stakeholders within each region to form a detailed, evidence-based forecast of likely future local demand for and current provision of public charging infrastructure. Ofcharge should then set a reasonable ratio for each of the 12 economic regions based on vehicle parc data, near-term forecast of vehicle purchase, the potential of dwellings to have a dedicated private home charger, an informed estimate of workplace (private) charging availability and the extent of rapid/ultra-rapid charging provision at forecourts or local hubs (but not motorway service areas). Data on the latter three variables should be sourced from the local authorities within each region.

The ratio of plug-in vehicles per fast (7-22kW) public charger should cover both on-street as well as destination chargepoints. Slow chargers may be included in the mix, although we expect most 3kW public chargers to be either phased out or upgraded to fast chargers by the end of this decade. 5.5kW lamp post chargers should fall within the fast charger category.

This target, like carbon budgets, should be **binding on government itself**. As there is no regional authority that is directly accountable for the performance in each region, government should assume overall accountability but delegate responsibilities, by way of a statutory duty for planning and delivery oversight, to local authorities, whose combined performance influences the ratio of the region. Local authorities should be required by law to rectify any shortfall vis-à-vis the target ratio within six months, unless there are mitigating circumstances that justify the shortfall.

The target ratio should be reviewed annually for its relevance. For instance, an increase in workplace charging availability or provision at forecourts in a region may mean its plug-in vehicles-to-fast public charger ratio could be relaxed. Conversely, if pressures on existing fast public chargers are mounting, the ratio could be tightened on a graduated basis.

- **Minimum number of rapid/ultra-rapid (50-350kW) public chargers per forecourt/hub/motorway service area**

Similar to government's current aim to have at least six ultra-rapid (150-350kW) open access chargers at motorway service areas in England by 2023, or as many as 12 at larger sites,[63] there should be a binding target for the minimum number of rapid/ultra-rapid chargers at each forecourt and local hub depending on the size of the site and expected traffic throughput.

As forecourts, hubs and motorway service areas are likely to serve transient traffic or charging events with much shorter dwell times, and users are more likely to use these premium services out of their own choice, ratios may not be the most appropriate target metric.

The target, which should be **binding on CPOs**, is to be reviewed every two years for its relevance based on vehicle parc and charger utilisation data. It is not expected that there will

[63] Department for Business, Energy and Industrial Strategy, Department for Transport, and Office for Low Emission Vehicles (2020), Policy paper: Government vision for the rapid chargepoint network in England, available at https://www.gov.uk/government/publications/government-vision-for-the-rapid-chargepoint-network-in-england/government-vision-for-the-rapid-chargepoint-network-in-england.

be material underprovision of rapid and ultra-rapid chargers, as these are the relatively more profitable chargers in a CPO's portfolio.

Alternative options of binding targets include setting a requirement for a minimum proportion of fast (7-22kW) public chargers that CPOs must operate within its overall portfolio, mandating a minimum power output per plug-in vehicle, or simply aiming for an absolute number of public chargepoints by a certain date. We believe the two binding targets we proposed above are more equitable than any of these alternative options.

Mandating a minimum proportion of fast (7-22kW) public chargers within a CPO's portfolio is simple, straightforward and not unlike vehicle manufacturer obligations under the forthcoming ZEV mandate and affordable housing obligations of developers. However, not all CPOs operate in this segment of the market. This may also inadvertently discourage some CPOs from entering or operating in this segment in favour of the more profitable rapid and ultra-rapid charger (50-350kW) segment.

Mandating a minimum power output per plug-in vehicle, as the European Commission has proposed,[64] misses the point of ensuring the provision of public charging infrastructure meets consumer needs and fails to align with the consumer-centricity principles of adequacy and equity. For example, the Commission's target of 1kW power output for every BEV means, in theory, the requirement is deemed to be fulfilled should just 29 units of 350kW ultra-rapid chargers be installed in a country where there are 10,000 BEVs on the road. This ignores the different charging needs of consumers and fleets, local requirements and the varied use cases that demand different charging solutions.

Mandating an absolute number of public chargepoints is probably the least prudent option of all, since no one can predict with absolute certainty the optimum number of chargers required in the future. This also does not take into account local or regional needs. The example that comes closest to this is Germany, which set a non-binding aim for one million publicly accessible chargepoints by 2030 as part of its Climate Action Programme 2030.[65]

Social equity

Besides to ensure there will be adequate charging infrastructure to serve a rapidly growing plug-in vehicle parc, the options explored above focus primarily on the type of chargepoints that are less likely to follow an organic growth path in order to also promote social equity.

The vast majority of plug-in vehicle users today have access to off-street parking. However, while most users will continue to charge at home, as more consumers purchase plug-in vehicles the proportion of off-street (home) charging is likely to decrease, and on-street and destination charging will be essential to support users without access to off-street parking.[66] A wider network of on-street residential charging will also be helpful to grey fleet drivers (fleet drivers who need to take the vehicle home), many of whom require both home and workplace charging. Some fleet operators may be reluctant to transition to plug-in vehicles when drivers are required to take them home but there is no charging infrastructure near the

[64] Proposal for a Regulation of the European Parliament and of the Council on the deployment of alternative fuels infrastructure, and repealing Directive 2014/94/EU of the European Parliament and of the Council, COM(2021) 559 final, 14 July 2021, available at https://ec.europa.eu/info/sites/default/files/revision_of_the_directive_on_deployment_of_the_alternative_fuels_infrastructure_with_annex_0.pdf.
[65] European Commission (2020), Integrated National Energy and Climate Plan: Germany, available at https://energy.ec.europa.eu/system/files/2020-07/de_final_necp_main_en_0.pdf.
[66] Engel, H., Hensley, R., Knupfer, S. and Sahdev, S. (2018), "Charging ahead: Electric-vehicle infrastructure demand", McKinsey & Company article, 8 August, available at https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/charging-ahead-electric-vehicle-infrastructure-demand#.

employees' residence. Fleets have also highlighted that operating in rural places is challenging owing to inadequate public charging infrastructure.[67]

Total number of public chargepoints, or even the number of chargepoints per 100,000 population, will not accurately reflect the needs of rural communities. Some rural populations may have relatively fewer plug-in vehicles, while others are blessed with off-street parking and electrical wiring that allow for the installation of dedicated home chargers. A sensible approach is therefore to prioritise public charging infrastructure deployment in areas where people's mobility is dependent on plug-in vehicles but where little home charging is available, hence the proposed cars-to-charger ratios. Without binding targets, rural areas, where public chargepoint utilisation is relatively lower than in urban conurbations, are more likely to be deemed uninvestable propositions and therefore neglected.

While some believe the predominant charging model of the future will be the same forecourt model where consumers refuel their petrol and diesel vehicles today, this is predicated on the assumption that most BEVs across all price points in the future are capable of supporting ultra-rapid charging, particularly at rates nearer to 350kW. At this rate, dwell times are relatively short and charging forecourts serve mainly transient traffic, similar to today's fuel forecourts. It is assumed there is less need for other types of chargers, especially the unprofitable on-street residential chargers, to cater for consumers without off-street parking.

Although an increasing number of new BEV models coming to the market are capable of supporting ultra-rapid charging, it remains unclear if future mass market models at the lower-end segments will also have relatively large batteries and be equipped with power architecture that is capable of ultra-rapid charging, especially at rates nearer to 350kW. Furthermore, it is likely that by 2030 there will still be earlier generation BEVs on the road that may have been sold on in the used car market. Many of these unfortunately do not support ultra-rapid charging. It would be highly unfortunate, as well as detrimental to social equity, if less affluent consumers who own lower priced or earlier generation used BEVs that do not support ultra-rapid charging are left with relatively far fewer on-street residential or destination chargepoints, while the more affluent consumers avail themselves of the convenience and abundance of ultra-rapid charging forecourts or hubs.

Another often-ignored issue is the price differentials between on-street/destination and forecourt/hub/motorway charging.[68] Rapid and ultra-rapid chargers are today typically more expensive to use than slow and fast chargers. Motorway chargers are premium services. The promise of significantly lower BEV running costs compared to like-for-like ICE vehicles is largely predicated on the savings accrued from home charging versus refuelling. Such savings will no longer be as significant should consumers regularly recharge at ultra-rapid forecourts. The less affluent and those without off-street parking may find themselves being forced to regularly pay more to charge at forecourts if the cheaper-to-use on-street residential chargers are in short supply.

In fact, the affordability of public charging itself should be reviewed to ensure consumers are not effectively "penalised" for not having a private driveway or garage. While domestic electricity attracts

[67] Roberts, G. (2021), "Charge point availability in rural areas proves challenging to fleets", FleetNews, 16 December, available at https://www.fleetnews.co.uk/news/latest-fleet-news/electric-fleet-news/2021/12/16/charge-point-availability-in-rural-areas-proves-challenging-to-fleets.

[68] For comparisons, see for example de Prez, M. (2021), "Public charging cost differences highlighted in new study", FleetNews, 17 February, available at https://www.fleetnews.co.uk/news/latest-fleet-news/electric-fleet-news/2021/02/17/public-charging-cost-differences-highlighted-in-new-study; and Cuff, M. (2021), "Expensive public chargers drive up the cost of electric car ownership", inews.co.uk, 6 March, available at https://inews-co-uk.cdn.ampproject.org/c/s/inews.co.uk/news/environment/expensive-public-chargers-drive-up-cost-electric-car-ownership-901346/amp. For a recent increase in prices of public charging, see Page, F. (2021), "UK EV charging firms raise prices as energy crisis bites", Autocar, 25 November, available at https://www.autocar.co.uk/car-news/business-environment-and-energy/uk-ev-charging-firms-raise-prices-energy-crisis-bites.

5% Value Added Tax (VAT), the full VAT rate of 20% is applied to electricity consumed at public chargepoints – even if these are on-street chargers at residential areas. Government should **reform the VAT regime for public charging** by applying the lowest rate (i.e. 5%) for electricity used to charge plug-in vehicles across the board regardless of where the vehicle is charged.

It would be highly unfortunate, as well as detrimental to social equity, if less affluent consumers who do not have off-street parking and a home charger have few other options but to pay considerably more to use public charging networks. For some less affluent consumers, the cost of taking up multiple network memberships could be a further barrier to plug-in vehicle uptake, while others are put off by some rather steep pay-as-you-charge rates.

Nationally coordinated, locally delivered plan

Binding targets must go hand in hand with a **nationally coordinated but locally delivered infrastructure plan** involving all key stakeholders to ensure a national network of public chargers of **the right types are found in the right places** – serving the right needs and achieving as high utilisation as possible.

Instead of simply providing funding to local authorities, or other organisations, that may sometimes result in chargepoints installed where convenient or where there is least local resident resistance, this strategic plan has to be led and orchestrated by central government, with statutory duty placed on local authorities to plan for and oversee the delivery of charging infrastructure at the local level. As implementation and tactical decisions are effectively made compulsory for local authorities, government should also ensure adequate enablers and resources are in place.

While industry and central government hold information on where plug-in vehicles are registered, local authorities have the best knowledge and insights on the charging needs of local residents and businesses, as well as how vehicles are used, the spatial dynamics and the traffic patterns in local areas. Leveraging on these knowledge and insights, local authorities should convene all key relevant stakeholders such as CPOs, DNOs, fleet operators, car park operators and local businesses to plan for charging infrastructure. The London EV Infrastructure Strategy and Delivery Plan are an exemplar of such a coordinated approach, albeit at the regional authority level, that brought together disparate stakeholders to achieve consensus on planning and delivery of future chargepoints.[69]

There should be minimum requirements in public chargepoint planning, commissioning and delivery, along with an associated parking space, that meet the needs of **light commercial vehicles**, which have a larger footprint and different form factor compared to cars. While many rapid and ultra-rapid charging locations at motorway service areas and forecourts are now able to accommodate longer and larger vehicles, most slow and fast chargers on urban and suburban streets and destinations could not.

There is also a need to harmonise the fragmented system of obtaining planning permission for charging infrastructure installation across different local authorities. Centralised coordination raises the prospect of leveraging economies of scale and achieving interoperability by design. Local authorities must also vigorously enforce against the use of charging bays by non-plug-in vehicles, or light commercial vehicle charging bays by passenger cars. We will discuss in greater detail how local authorities could be supported in a later section in this chapter.

[69] Transport for London (2019), London Electric Vehicle Infrastructure Delivery Plan, available at http://lruc.content.tfl.gov.uk/london-electric-vehicle-infrastructure-taskforce-delivery-plan.pdf; and Transport for London (2021), London's 2030 Electric Vehicle Infrastructure Strategy, available at https://tfl.gov.uk/ruc-cdn/static/cms/documents/london-2030-electric-vehicle-infrastructure-strategy-december-2021.docx.

Although this paper focusses on charging infrastructure in the context of the transition to a zero emission new car and van market by 2035, we believe any well thought through national plan should at least also factor into consideration the need to future-proof motorway charging for heavy duty vehicles. When planning for ultra-rapid charging at motorway service areas, installing electrical capacity ahead of need, with a view to meeting the charging requirements of heavy duty vehicles, will avoid costly future disruptions caused by excavations and engineering works.

Proportionate regulation for consumer experience and expansion of provision

In addition to binding targets for delivery of charging infrastructure, there are areas where government must regulate in order to ensure the best outcomes for consumers. A survey by the Electric Vehicle Association England shows that the average satisfaction rating among plug-in vehicle users with the current state of public charging infrastructure is just 2.16 out of 5.[70] New regulatory measures must include setting minimum standards of consumer experience, reforming building regulations to mandate chargepoints in new residential and non-residential buildings, introducing a statutory duty on the part of local authorities to plan for and oversee the delivery of chargepoints on a proportionate and graduated basis, requiring a minimum number of chargepoints in non-residential car parks, and banning long-term exclusive arrangements at motorway service areas. Although government has announced its intention to regulate on some of these, we think it is now important that government follows through and goes further by enacting regulation on the following.

Ease of access and payment

Despite the Alternative Fuels Infrastructure Regulations require infrastructure operators to provide ad-hoc access to all chargepoints deployed after 17 November 2017 and to all legacy chargepoints by 18 November 2018,[71] many plug-in vehicle users are still required to have a membership account with various public chargepoint networks and risk being stranded and unable to charge their vehicles if they do not have an account.

A ubiquitous open access (implying ad-hoc access and payment) and interoperable (implying ad-hoc access through roaming) network of public chargepoints is essential to providing a coherent user experience and promoting healthy competition among CPOs. We believe **all public chargepoints**, not just rapid and ultra-rapid chargers, must offer ad-hoc access and payment via contactless debit/credit card and network roaming. Roaming is particularly important to certain segment of plug-in vehicle users, such as fleets. Legacy chargepoints must be retrofitted to offer these options.

This does not preclude the operator offering a membership option, which may provide the consumer with additional benefits, but using and paying for public charging must be as easy as paying for fuel today, where downloading an app or taking up membership is not a prerequisite for access. The consumer charging experience must be as simple as refuelling a petrol or diesel vehicle. Few sensible people would “upgrade” to a product that offers an inferior experience, or that makes life more complicated.

[70] Electric Vehicle Association England (2021), Improving Drivers’ Confidence in Public EV Charging, available at https://www.evaengland.org.uk/wp-content/uploads/2021/04/EVA-England-Consumer-Charging-Survey-Report.pdf.
[71] See the Alternative Fuels Infrastructure Regulations 2017, available at https://www.legislation.gov.uk/uksi/2017/897/regulation/5/made.

Improving reliability

There is nothing more disappointing for plug-in vehicle users than to turn up at a chargepoint only to find it is out of order or in a state of disrepair. Infrastructure reliability is absolutely vital for improving overall consumer experience. Some operators have struggled to maintain legacy infrastructure, or failed to uphold maintenance agreements with local authorities, resulting in legacy infrastructure falling into a state of disrepair.

While the reliability rates of public chargepoints in the Netherlands regularly hit an enviable 99%, one study discovered the average reliability rate of chargepoints in the UK was just 91.7%.[72] This is corroborated by analysis commissioned by government which shows that in August 2019 around 8% of public chargepoints were out of service.[73] Only 6% of drivers surveyed by the Electric Vehicle Association England who use the public charging network have never had an issue with a charger,[74] while 57% of a private hire fleet's BEV drivers complained that rapid chargers were often found to be broken or damaged.[75] The most recent edition of the Zap-Map annual EV charging survey shows that the lack of reliability and ease of use are the key issues associated with the lowest ranked charging networks.[76] Plug-in vehicle users should expect reliability from the public infrastructure network. Having a significant number of public chargepoints out of action is frustrating and inconvenient for consumers and sends the wrong message to those who are considering switching to plug-in vehicles.

Government must therefore follow through with its plan to regulate for a minimum reliability rate with penalties for repeated non-compliance. To be on par with the reliability rate commonly seen in the Netherlands, the mandated minimum reliability rate should be 99%, measured per operator per annum. A 24/7 helpline where calls are either toll-free or charged at the local rate should be made a requirement so that those who need assistance when struggling to use a chargepoint can obtain help and faulty chargepoints can be reported. There should also be statutory requirements obliging the operator to begin repairs on a chargepoint within 24 hours of a fault being reported and setting out the maximum downtime allowed before penalties are imposed.

Real-time information provision

The availability and accessibility of real-time information about public chargepoints is important to enable plug-in vehicle users to plan their journeys and charging needs, or access infrastructure on demand. Plug-in vehicle users need to know not just where chargepoints are located, but also information on power ratings or pressure, connector type, price, payment options available, state of repair, availability, physical access restrictions and operating hours (if applicable). Although some CPOs warn of the commercial sensitivities of real-time chargepoint **availability** information, surveys have shown that is indeed one of the data types highly valued by consumers. 98% of respondents in a survey by the Electric Vehicle Association England believe having access to real-time data ahead of a charging event, including information on whether chargers are in use and queue length, would save

[72] Dermott, H., Development of the UK Public Chargepoint Network, RAC Foundation, 2018, available at https://www.racfoundation.org/wp-content/uploads/Development_of_the_UK_CPN_Harold_Dermott_December_2018.pdf.
[73] Department for Transport and Office for Zero Emission Vehicles (2021), Public consultation: The consumer experience at public chargepoints, available at https://www.gov.uk/government/consultations/the-consumer-experience-at-public-electric-vehicle-chargepoints/the-consumer-experience-at-public-chargepoints.
[74] Electric Vehicle Association England (2021), "EV drivers seek key reforms to improve confidence in public EV charging", 15 April, available at https://www.evaengland.org.uk/2021/04/15/ev-drivers-seek-key-reforms-to-improve-confidence-in-public-ev-charging/.
[75] Roberts, G. (2021), "Addison Lee calls for urgent investment in EV charging network", FleetNews, 10 December, available at https://www.fleetnews.co.uk/news/latest-fleet-news/electric-fleet-news/2021/12/09/addison-lee-calls-for-urgent-investment-public-ev-charging-network.
[76] Goodall, O. (2021), "Revealed: UK electric vehicle charge point networks ranked", Zap-Map, 10 December, available at https://www.zap-map.com/drivers-rate-electric-vehicle-charging-networks-uk/#more-151755.

them time,[77] while another survey shows that over 80% believe it is essential to know if a chargepoint is available in advance.[78] We agree that the "must have" data types set out in government's consumer experience consultation should be mandated.[79]

Government should create, fund and maintain a national platform that collects and displays static and dynamic information on all public chargepoints. Such a portal is to replace the National Chargepoint Registry, which does not provide real-time data and is not fit for purpose; the fact that Zap-Map remains the go-to source for consumers, industry and stakeholders is testament to this. A good example of information provision is ChargePlace Scotland, which, although operates as a single network of over 1,500 public chargepoints, has details on location, type, status and availability displayed on a live map. Government must set clear data sharing standards, including a common data format, that infrastructure operators can adhere to and that will facilitate the integration of information into navigation systems or apps.

We agree with government proposal of a hybrid (federated-centralised) data architecture that will allow CPOs to manage their own data while sharing it with a centrally administered data broker through a push mechanism. This approach provides a single unified Application Programming Interfaces (APIs) for the development of apps and integration into navigation and fleet management systems. Coupled with AI-enabled range predictors that are already available, these could help gradually eliminate range and charging anxiety, as well as enhance the consumer experience in interacting with charging infrastructure.

However, the real-time data sharing architecture that will be developed must be future-proofed for changes in the mobile communications sector. Due to the relatively low data throughput and bandwidth requirement for transmitting real-time data from public chargepoints, it would seem reasonable to install basic circuit switching technology that underpins 2G and 3G equipment. However, given that these mobile networks are likely to be switched off by the end of this decade and certainly no later than 2033, public chargepoints should be equipped with packet switching technology that enables LTE (4G) and/or 5G.

Pricing transparency

There is currently no consistent approach to pricing at public chargepoints. Some operators charge for electricity drawn (p/kWh), while others the time spent charging (p/minute, or £/30 mins, or £/hour). Some also charge a membership subscription or connection fee. Findings from OZEV's own research disclosed at stakeholder workshops revealed that, as of 19 August 2020, there were 150 pricing options across 48 networks, with eight operators charging on a time or per session basis and 12 operators charging connection fees. In such a confusing landscape, it is difficult for consumers to compare the cost of charging between different networks.

We take the view that all CPOs should charge for the electricity they provide in p/kWh, commensurate with how drivers are charged to refuel ICE vehicles today (p/litre) and, for those who also charge their vehicles at home, consistent with the pricing format for domestic electricity use. This, however, should neither preclude operators from charging additional fees to discourage undesirable consumer

[77] Hink, C. (2021), "Improving drivers' confidence in public EV charging", Electric Vehicle Association England, 19 May, available at https://www.evaengland.org.uk/2021/05/19/improving-drivers-confidence-in-public-ev-charging/.
[78] Cenex (2021), EV chargepoint experience survey, available at https://www.cenex.co.uk/app/uploads/2021/03/GECO-Infographic.pdf.
[79] Department for Transport and Office for Zero Emission Vehicles (2021), Public consultation: The consumer experience at public chargepoints, available at https://www.gov.uk/government/consultations/the-consumer-experience-at-public-electric-vehicle-chargepoints/the-consumer-experience-at-public-chargepoints

behaviour, such as overstaying the charging event, nor dictate pricing levels. These fees, or discounts, along with any parking charges, should be displayed in a standardised way to avoid confusion.

Regulatory body

In conjunction with regulating for minimum standards of consumer experience, we strongly believe a new regulatory body that is independent of sectoral vested interests in the ilk of Ofgem, Ofcom and Ofwat should be set up to monitor for compliance and enforce regulatory standards on ease of payment, reliability, real-time information provision and pricing transparency. Just as Ofgem actively monitors energy prices to ensure the most vulnerable consumers are protected, the new regulatory body, **Office of Charging (Ofcharge)**, should likewise monitor price levels and the affordability of public charging and have powers to intervene as necessary. As discussed in the previous section, Ofcharge's remit should also include coordinating and regulating the binding targets of charging infrastructure provision.

Ofcharge should also be tasked with hearing complaints from consumers and undertaking formal investigations, as well as given powers to issue financial penalties. Social media is littered with numerous complaints of broken down public chargepoints, poor customer service and consumers left in the lurch, but with no recourse to formal complaint mechanisms or protections. Regulation without enforcement is less effective, whereas the creation of a regulator with powers to act will ensure market participants comply with regulations. However, where complaints are related to competition issues, Ofcharge should work with the Competition and Markets Authority, who has primary purview on these issues.

Chargepoints in new buildings and buildings undergoing major renovation

Following a public consultation in 2019, government recently unveiled plans to create a new requirement under the English Building Regulations for new residential and non-residential buildings, as well as existing ones undergoing major change of use and renovation, to install charging infrastructure.[80] We welcome government's proposal to create a national requirement that is applied across all of England. Leaving it to the discretion of each local planning authority to implement an agreed national standard for chargepoints risks creating a postcode lottery for new dwellings with chargepoints. This might result in the uptake of plug-in vehicles disproportionately skewed towards local areas where the planning authorities are more proactive in implementing the national standard.

We take the view that:

- Every new individual dwelling with an associated parking space must have a chargepoint.
- Every new multi-dwelling building, or existing ones undergoing major renovation, with more than ten parking spaces must have at least one chargepoint and ducting for chargepoints in other spaces. By 2030, this should increase to at least one chargepoint for every other parking space and ducting for the remaining spaces.
- Every new non-residential building, or those undergoing a major renovation, with more than ten parking spaces must have at least one chargepoint and ducting for at least 20% of the remaining spaces. This should be provided even when there is no alteration to the car park

[80] Department for Transport and Office for Low Emission Vehicles consultation, "Electric vehicle chargepoints in residential and non-residential buildings", 15 July 2019, available at https://www.gov.uk/government/consultations/electric-vehicle-chargepoints-in-residential-and-non-residential-buildings.

itself. The proportion of chargepoints required by 2030 should increase to 50% and ducting for the remaining spaces.

- Every existing non-residential building with 20 parking spaces must have at least one chargepoint and ducting for at least 20% of the remaining spaces by 2025. By 2030, there should be at least one chargepoint for every five parking spaces and ducting for at least 75% of the remaining spaces.

We believe 7kW AC Mode 3 untethered chargers should be mandated as the minimum, as they are most suitable for future-proofing the charging requirements at the majority of homes and non-residential buildings. As mentioned in the previous chapter, we expect 7kW chargers to be the norm for most charging use cases with long dwell times. This does not preclude the installation of some higher power chargers, particularly in non-residential buildings. However, government policy should also allow room for flexibility in terms of installing tethered chargers. In the context of home charging, there will be some consumers who would prefer tethered chargers simply because they are easier to use, quicker to plug-in, cleaner in a wet and cold environment, and less likely to be stolen or misplaced.

However, we suggest caution needs to be exercised to ensure this does not lead to an unintended consequence of housing developers awarding contracts to chargepoint manufacturers/suppliers who offer the most economically attractive home chargers that meet only the most basic specifications set out by government. This could price chargepoint manufacturers/suppliers with better or more sophisticated products out of the market.

We think small-and-medium enterprises (SMEs) should not be exempted from the proposed requirements for new non-residential buildings and non-residential buildings undergoing major renovations. Given about 98% of registered companies in the UK are SMEs, the catchment for exemption could indeed be very sizeable, rendering the policy proposal nearly meaningless. SMEs should instead be supported to install charging infrastructure, as this will ensure their business fleet, staff or customers can more easily make the transition to plug-in vehicles. Exemptions should only apply to micro enterprises. A micro enterprise is defined by the Financial Conduct Authority as a company that employs fewer than ten persons and has a turnover or annual balance sheet that does not exceed €2 million.[81]

Statutory requirements to plan for and oversee the delivery of charging infrastructure

We agree with recent government proposal to place a statutory duty on local authorities to plan for and deliver charging infrastructure.[82] Ultimate legal responsibility for planning for sufficient charging infrastructure should lie with the Secretary of State for Transport, with powers delegated to local authorities. As set out in the previous section on binding requirements, local authorities are best placed to understand the needs of residents, businesses and visitors in a specific geographical area. Without a statutory duty, there is a risk charging infrastructure could be deprioritised to give greater, albeit due, attention to other key areas where local authorities have a statutory duty to plan, budget for and deliver services. Each local authority should therefore be required to develop a local charging infrastructure strategy and delivery plan. We believe the responsibility to **oversee the delivery** of charging infrastructure on a proportionate and graduated basis should rest with local authorities.

[81] See the Financial Conduct Authority Handbook online, available at https://www.handbook.fca.org.uk/handbook/glossary/G2623.html.
[82] Office for Zero Emission Vehicles (2021), Public consultation: Future of transport regulatory review: zero emission vehicles, available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1020983/future-of-transport-regulatory-review-zero-emission-vehicles-print-version.pdf.

Oversight of infrastructure delivery is not the same as executing the delivery of chargepoints, which should be left to the private sector. It also does not mean local authorities should venture outside their core competencies by running the charging network or being responsible for its maintenance. Instead, it means local authorities, guided by its own strategy and delivery plan, should set the conditions of tender, conduct the selection process, commission the winning bids to install chargepoints and monitor the operations of privately run charging networks. However, local authorities must be sufficiently supported through funding and other forms of assistance from central government, as we will discuss in the next section.

We also support government proposal to require landowners to install chargepoints in new and existing non-residential car parks that are not covered by existing legislation.[83] We believe this requirement should apply to all publicly accessible (i.e. destination charging) and restricted access car parks (i.e. workplace charging). Exemptions, however, may be considered where costs to install chargepoints are prohibitively excessive or where there is insufficient power capacity, unless government funding is available to defray the costs of grid connection and/or reinforcement. Minimum requirements should be set on a graduated basis. For a start, we would suggest the minimum requirements should follow those for new non-residential buildings, i.e. non-residential car parks with more than ten spaces should have a minimum of one chargepoint and ducting for 20% of the remaining spaces. However, the proportion of chargepoints required by 2030 should increase to 50% and ducting for the remaining spaces.

Banning long-term exclusive arrangements

While we support government proposal to ban long-term exclusive arrangements at motorway service areas, we neither agree with the requirement for a minimum of two CPOs per site nor deem it necessary. We think explicitly prohibiting monopolies will suffice, and the market should then be left to decide if more than one CPO are indeed interested to operate and compete at a given site.

Enabling support to incentivise and facilitate delivery

Binding targets and proportionate regulation can only deliver the desired consumer-centric charging infrastructure commensurate with the expected size of the plug-in parc if the infrastructure sector and local authorities are enabled by a raft of support measures. These support measures should work **in combination**, and are partly aimed at **de-risking** private investment, creating **investable propositions** to address genuine market failures and avoiding **stranded assets**, and partly meant to plug recognised **resource gaps** at the local authority level.

Mixed high-low utilisation blocks for long-term tenders

As discussed previously, on-street and rural charging are unattractive propositions for CPOs due to low utilisation and/or low returns. Local authorities, who should have a statutory duty to plan for and oversee the delivery of charging infrastructure, should design mixed high-low utilisation blocks for long-term tenders of at least 15 years. Tenders issued by local authorities should require both urban and rural, as well on-street and off-street (mainly destinations and council building and car parks), coverage, thus resulting in successful bidders operating high-utilisation urban and off-street chargers that offset potential losses from low-utilisation rural and on-street chargers.

[83] Office for Zero Emission Vehicles (2021), Public consultation: Future of transport regulatory review: zero emission vehicles, available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1020983/future-of-transport-regulatory-review-zero-emission-vehicles-print-version.pdf.

Modified contracts for difference

In some locations, the mixed block tenders described above may carry limited appeal because returns from the high-utilisation block may still struggle to offset the losses from the corresponding low-utilisation block. In such cases, government should step in to de-risk CPO investment and help create an investable proposition through a form of contracts for difference. Akin to price guarantees, government should set a fair expected annual revenue (strike price) for normal operations in specifically targeted low-utilisation blocks and cover the shortfall in the CPO's verified annual revenues.

As the aim of this approach is to ensure the CPO makes a fair rather than excessive return, the CPO is obliged to pay government back the difference between its annual revenues and the revenue guarantee, should the former exceed the latter. Alternatively, the "credit" could be carried over to the following financial year, provided the tender contract has not expired. In order to ensure the CPO remains motivated to operate and maintain the chargers in these low-utilisation blocks despite revenue is guaranteed, the tender must include stringent service level agreements including meeting the national standard for reliability, which we believe should be 99%.

The level of revenue guarantee should be reviewed on an annual basis to account for forecast consumer demand, cost of technology and operations, general economic conditions and the performance of the CPO in the most recent financial year. When there is adequate evidence that shows the market in a particular local area has reached maturity, for example when there are three consecutive years of "credit" accrued, the modified contracts for difference can be discontinued.

This approach should help de-risk CPO investment and give CPOs the confidence to operate in potentially commercially unattractive locations, while standing in good stead to make profits in the corresponding high-utilisation locations. It also represents justified use of public funds to address a genuine market failure and ensure social equity in access to charging. This measure is an alternative to the utilisation-linked loans proposal by the EV Energy Taskforce.[84]

Anticipatory demand-led approach through an online portal

To help local authorities better design mixed high-low utilisation blocks for long-term tenders and more accurately plan for where to commission and deploy on-street residential and rural chargepoints, they should adopt an anticipatory demand-led approach, aided by an easily accessible online portal that enables user logging of chargepoint requests ahead of actual need.

This is an adapted version of the Dutch model where new chargepoint installations follow user demand. Local residents intending to purchase or lease a plug-in vehicle within the next six months should be able to log requests online to indicate future need in areas where there are insufficient chargepoints. The local authority is then obliged to commission and oversee the installation of a chargepoint in the location of need within **six months** of a request being logged. Targeted installations of chargepoints that then follow will give consumers the confidence to proceed to finalising the intended purchase or lease. However, in order to prevent disingenuous requests, the local resident is required to pay a **refundable deposit** to the local authority when logging the request.

[84] Brown, D. et al. (2021), "Encouraging Investment in Public EV Charging in the UK", EV Energy Taskforce, available at https://secureservercdn.net/160.153.138.177/272.732.myftpupload.com/wp-content/uploads/2021/10/EVET_Encouraging_Investment_in_Public_EV_Charging.pdf?time=1640724007.

While initiatives like Charge My Street are commendable, they are but disparate efforts by either local communities or local authorities that will still leave plenty of not-spots in the country. What is needed is a national online platform that is capable of logging requests from anywhere in the country to ensure breadth of coverage and signposting them electronically to the appropriate local authorities for action. This also gives visibility to where demand is most acute and holds local authorities accountable for delivering on local residents' charging needs. This approach will also enable local authorities to proportionately allocate resident parking to plug-in vehicle charging based on genuine need and help DNOs to more accurately plan ahead in the event the local network where new chargepoints will be installed may need reinforcement.

Supporting and resourcing local authorities

Statutory duty placed on local authorities to plan for and oversee the delivery of charging infrastructure must be accompanied by greater support and increased resources. Charging infrastructure expertise within local authorities varies markedly across the country, as evidenced by the variance in the number of chargepoints available in local authority areas. While some London boroughs and Milton Keynes already have a sizeable network of public chargepoints, many other local authorities are still conducting feasibility studies on chargepoint installation.

In order to strengthen local authority expertise, it is necessary for government to provide **resource funding** for the recruitment of dedicated zero emission transport personnel. This should be in addition to capital funding that is already made available through the ORCS and other schemes. The ORCS itself could be allocated based partly on the ratio of plug-in vehicles per fast (7-22kW) public charger in each of the economic regions as suggested earlier. This gives a better idea of the projected regional plug-in vehicle uptake and nuanced demand for local on-street chargers, which in turn provides local authorities in each region with greater clarity on the likely amount of capital funding available.

It is encouraging that work is under way to develop a uniform national guidance document to assist local authorities with charging infrastructure implementation. Commissioned by government to be delivered through the Institution of Engineering and Technology, this guidance document could be an invaluable, single point of reference to effectively plan, deliver and implement the necessary chargepoints in a local authority area. It is hoped that this document will provide clear and consistent guidance for local authorities to align technical standards, minimum access requirements and planning regulation, with the primary aim of speeding up the approval process. This should include a procurement framework and best practices that set out minimum information requirements to be displayed on chargepoints.

Guidance should also be provided on planning for adequate parking provision, access requirements, the ease of handling charging cables in restricted spaces and access to the chargepoint interface, while mitigating the potential for conflict between vehicle charging and other public highway users. The overall process for local authorities to provide on-street residential charging should be simplified and harmonised, with clear and consistent guidance on things such as consultation, planning permission and access requirements. Plans to provide charging infrastructure should be considered as part of wider local authority regeneration, place-making and energy infrastructure policies.

However, we urge government to go further by establishing a **dedicated national body** to assist local authorities with all matters pertaining to charging infrastructure planning and implementation and to be the custodian of the uniform national guidance discussed above. As this national body should be the main touchpoint with local authorities, it should also assume the role of developing regional cars-to-charger ratios that form the binding targets proposed above in consultation with all local stakeholders.

As such, this body, in addition to providing a national focal point for standardised processes and advice to local authorities, should also be the de facto enforcement body of the binding targets. In order to make best use of public resources and promote a joined-up approach, we believe this body **should be part of Ofcharge**, whose remit should be wider than just monitoring the market and enforcing a minimum standard of consumer experience. Ofcharge's role should therefore be three-pronged:

- To monitor the market, including for price levels and affordability, and enforce minimum standards of consumer experience;
- To coordinate, set, regulate and review binding targets of charging infrastructure provision across each of the 12 economic regions;
- To function as the custodian of a uniform national guidance and as a single point of contact for local authorities on all matters pertaining to charging infrastructure planning and implementation.

In addition, guidance should include how local authorities could encourage and support local businesses to install workplace chargers. When processing and approving new planning applications for depots, regional distribution centres and/or commercial vehicle parking, local authorities should be advised to future-proof charging infrastructure for commercial vehicles by planning for it during initial development, as this is less expensive than retrofitting electrical installations later. Local authorities should also look into providing adequate charging facilities for light commercial vehicles where there are impediments to accessing on-street chargers designed for passenger cars. Measures could include dedicated commercial vehicle parking with chargepoints, or simply widening and lengthening on-street parking bays with chargepoints to accommodate the sizes of most light commercial vehicles.

So as to assist local authorities in the planning permission process for new depots equipped with charging infrastructure, all DNOs should be required to publish power and capacity heat maps in their respective operating regions, an initiative the Energy Networks Association is currently looking into.

CHAPTER 5
ENSURING ELECTRICITY NETWORKS ARE FUTURE-PROOFED AND FIT FOR PURPOSE

Smart charging and vehicle-to-grid as demand side response mechanisms

Smart charging, also known as managed charging, is shifting the time of day when a plug-in vehicle charges, or modulating the rate of charge at different times, in response to signals such as load constraints on the local electricity network or dynamic electricity tariffs. Vehicle-to-grid (V2G) enables BEVs to provide energy storage services to the electricity networks via a bi-directional charger. Consumers will be able charge their BEVs at times of low electricity demand and/or high renewable electricity output and potentially sell surplus electricity back to the local and national networks at times of peak demand.

In principle, the automotive industry welcomes and supports the use of smart charging and V2G as demand side response mechanisms to help delay the need for costly electricity network reinforcements to meet increased demand from plug-in vehicle charging and to potentially offer consumers savings on their energy bills.

We also support the government's requirement for all private chargepoints sold or installed in the UK to have smart functionality and comply with minimum device-level standards, using powers under Section 15 of the Automated and Electric Vehicles Act 2018.[85] To this end, we welcome the recent passing of the Electric Vehicles (Smart Charge Points) Regulations 2021 in Parliament to mandate device-level requirements relating to cyber and data security, grid stability, and safety and monitoring of energy consumption.[86] Notwithstanding its promise, V2G has yet to be widely adopted and will likely become more popular when there is greater proliferation of devices and vehicles with bi-directional capability and increased availability of attractive consumer propositions.

Current annual road transport demand for electricity (at 2020 levels) stands at 1.3TWh, 85% of which comes from cars. National Grid ESO predicts this annual demand could be as high as 39.2TWh by 2030 and 84.1TWh by 2035, a 2,900% and 6,400% rise respectively. However, this high-end forecast is based on the assumption that there will be 13.0 million BEVs and 1.0 million PHEVs on the road by 2030 and 27.4 million BEVs and 800,000 PHEVs on the road five years later.[87] By contrast, our outlook suggests there could be 6.9 million BEVs and 2.4 million PHEVs in the car parc by 2030, rising to 15.3 million and 3.1 million respectively by 2035 (Figure 4).[88]

In an average cold spell during winter, if all plug-in vehicles were charging at the same time during the evening peak, power demand could reach a high of 10.0GW by 2030 and 21.2GW by 2035. Compared

[85] Automated and Electric Vehicles Act 2018, available at https://www.legislation.gov.uk/ukpga/2018/18/contents/enacted.
[86] The Electric Vehicles (Smart Charge Points) Regulations 2021, available at https://www.legislation.gov.uk/ukdsi/2021/9780348228434/contents.
[87] National Grid ESO (2021), Future Energy Scenarios, available at https://www.nationalgrideso.com/future-energy/future-energy-scenarios/fes-2021. Highest annual electricity demand by road transport is based on its Leading the Way scenario.
[88] Based on our "central" scenario in SMMT (2021), New car market and parc outlook to 2035, by powertrain, available at https://www.smmt.co.uk/2021/06/smmt-new-car-market-and-parc-outlook-to-2035-by-powertrain/. The potential impact of a ZEV mandate had not been accounted for at the time of publication.

to just 326MW today, this means 31 times more power will be needed during the winter evening peak by 2030. By 2035, the total could be 65 times more than today.[89]

However, smart charging must not be regarded as a **panacea** for network capacity constraints or indeed an **ersatz substitute** for much needed electricity network reinforcements. In order to ensure electricity networks are prepared and fit for purpose for the escalated uptake of plug-in vehicles, it is not always possible to rely on smart charging or V2G alone for load balancing and peak shaving. Depending on the extent to which consumers engage in smart charging, which could vary widely from 19% to 76% of households, smart charging could reduce peak power demand by as little as 12.2% or as much as 61.0% by 2035.[90]

Government and Ofgem must put in place frameworks that enable DNOs to commit to well justified **anticipatory investments** in local networks that are most constrained so that households do not have to choose between charging a plug-in vehicle and putting the kettle or electric cooker on. However, as many household electricity bills will increase due to growing plug-in vehicle uptake, Ofgem must also ensure the consumer is protected while investments into networks and flexibility services continue to gather pace in the next price control period.

While we agree that the smart charging secondary legislation alluded above is a necessary first step that regulates at the device level, we advocate the careful development of a **future-proofed** longer-term solution that allows consumers to manage energy consumption and household loads in a smart manner and based on their own choices. This is in contrast to a short-term solution that solely targets plug-in vehicle charging for load limitation purposes. Any short-term solutions, besides being premature, could be costly and unnecessary. We are also concerned that a supposed short-term solution could, by inertia or path-dependency, roll over into the longer term, thus pre-empting the adoption of more holistic, innovative and modern solutions. Furthermore, European and global standards for interaction between vehicles and charging infrastructure are currently being developed (e.g. ISO 15118, IEC 63110). They will enable functionalities such as smart grid integration and V2G. Once these international standards are adopted, short-term country-specific solutions are likely to become obsolete, potentially resulting in stranded investments.

Smart charging and the extent of load limitation

We believe, as a long-term solution, the DNO's ability to influence load must be limited to the **boundary of the home only**, and not exercising control beyond the meter. This concept allows the consumer to prioritise load within the home at times of constraint to meet their immediate needs. We are opposed to the DNO exercising direct control of the load to the chargepoint, which effectively discriminates against the use of electricity for charging plug-in vehicles. The DNO should be concerned with the behaviour of the network connection point (i.e. up to the meter), not individual devices behind the meter.

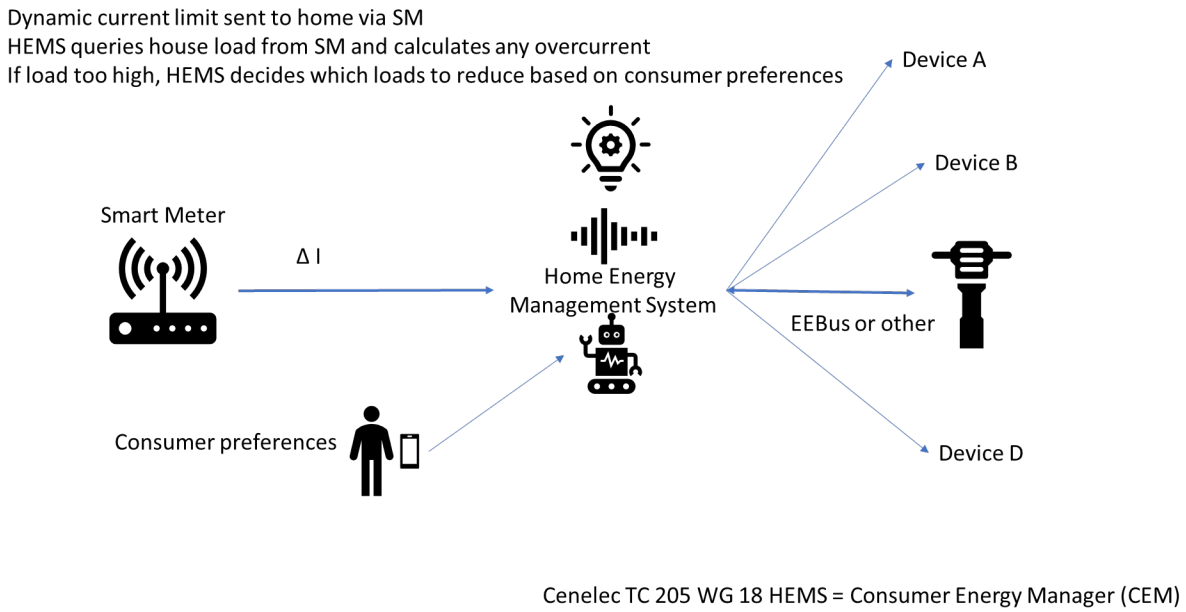
Load limitation at the boundary of the home is likely to be more supportive of plug-in vehicle uptake as it **does not single out the plug-in vehicle** as the only "appliance" that is being targeted for the purpose of load balancing and grid protection. If there is indeed an unavoidable need to temporarily constrain the load to households in a local network area, consumers must be given the ability to determine and

[89] National Grid ESO (2021), Future Energy Scenarios, available at https://www.nationalgrideso.com/future-energy/future-energy-scenarios/fes-2021. Highest peak power demand is based on its Leading the Way scenario.
[90] National Grid ESO (2021), Future Energy Scenarios, available at https://www.nationalgrideso.com/future-energy/future-energy-scenarios/fes-2021.

prioritise for themselves which appliances should have their loads temporarily reduced. Discriminating against the plug-in vehicle sends all the wrong messages to a market undergoing transition to ZEVs and creates an unhelpful consumer impression that living with a plug-in vehicle is full of hassle.

Although the plug-in vehicle is arguably the only relevant smart appliance in the household today that draws relatively substantial amount of power (7kW), it is expected that there will be multiple smart appliances in the future that, when considered collectively along with electrification of heating, may present load limitation challenges. Instead of focusing on merely the plug-in vehicle as supposedly the only controllable smart appliance in the household, a **whole-of-the-home** energy management approach through the home energy management system (HEMS) would therefore make more sense if we aim to future-proof the energy system in the context of the future smart home (see Figure 15). It will also mean flexibility services can be deployed at the whole-of-the-home level, not just for plug-in vehicle charging.

Figure 15: An illustration of whole-home energy management approach through the HEMS.



Source: Illustration courtesy of WP3 “Smart Charging Technical Requirements” of the EV Energy Taskforce.

Direct control by the DNO should be possible only as a **measure of last resort** for genuine emergencies or safety-critical conditions, e.g. to avoid a black-out. All other flexibility needs should be met by integration of plug-in vehicles and other decentralised/distributed energy storage into flexibility markets, leaving the choice of participation to consumers. However, last-resort direct load control must be in the form of whole-of-the-home constraints, rather than discriminate against electricity for transportation. Government, through Ofgem, must introduce **statutory limitations** on the use of mandatory constraints, where the DNO is obliged to reinforce the constrained local network within a prescribed timeframe after excessive use of direct load control.

Incentivising uptake of smart charging through market-led mechanisms

Smart charging will only help plug-in vehicle users reduce energy bills if there are active and well-functioning flexibility markets that offer consumers flexible time-of-use tariffs. Regulatory frameworks must therefore encourage the development of flexibility services and markets that incentivise consumers to participate in smart charging in the first instance and V2G thereafter, while electricity suppliers should design and roll out attractive propositions to consumers at pace.

Market mechanisms that incentivise consumers to voluntarily take up smart charging are generally more acceptable and effective than mandatory mechanisms. Example of market-led mechanisms include time-shifting charging based on a range of time-of-use tariffs and plug-in vehicle-friendly electricity tariff. Providing consumers with clear, simple and fair value exchange, coupled with the assurance that their charging/mobility requirements will not be compromised, is more likely to drive adoption and spawn innovative business models. On the contrary, mandatory mechanisms are likely to be viewed as draconian and may even deter consumers from switching to plug-in vehicles.

On a day-to-day basis, simple, transparent and convenient flexibility propositions should be used to optimise charging behaviour by considering user preferences vis-à-vis incentives in order to influence the charging in a way that protects the local network. There must, however, always be an override option for the consumer. For consumers who are keen to embrace smart charging but not interested in active participation to make the most of the incentives, their smart chargers should be programmed by default to avoid charging when the network is most constrained, as long as there is still an override option.

Regulatory frameworks must underpin the creation of consumer-centric **flexibility markets**. This means although financial incentives are used to influence consumer behaviour and choices, consumers should ultimately be in control of when they can use the domestic electricity they pay for to charge the vehicle they have bought. Regulation must not create a system that discriminates against the use of electricity for transportation and reduces consumer freedom to prioritise their own electricity use within a given constraint, which otherwise disincentivises the purchase of plug-in vehicles and participation in flexibility markets. Flexibility services will require the digitalisation and modernisation of the energy system, as set out in a government policy paper and the Energy Digitalisation Taskforce's report, to enable consumers to actively participate in energy markets and facilitate real-time load management.[91]

Furthermore, maximising the use of smart charging must not ignore potential integration with micro-generation (e.g. solar PVs, domestic wind turbines) and/or domestic energy storage. It would make for poor consumer experience should the smart chargepoint receive a signal instructing it to disconnect or reduce the electrical current to a plug-in vehicle due to excessive demand on the local network when certain households are able to temporarily use their stored energy from solar PVs to continue charging their plug-in vehicles uninterrupted.

There are also existing solutions that would allow for a higher level of interaction between the plug-in vehicle and the chargepoint that might result in better user outcomes while still enabling energy network stability management. For example, the charging of many newer generation of plug-in vehicles can be controlled from the car itself or via an app on the user's smartphone. A vehicle can be plugged in to a chargepoint but will not start taking power until such a time as desired, or programmed, by the user.

[91] Department for Business, Energy and Industrial Strategy, Ofgem, and Innovate UK (2021), Policy paper: Digitalising our energy system for net zero: strategy and action plan, available at https://www.gov.uk/government/publications/digitalising-our-energy-system-for-net-zero-strategy-and-action-plan; and Energy Systems Catapult (2022), Delivering a Digitalised Energy System: Energy Digitalisation Taskforce report, available at https://esc-production-2021.s3.eu-west-2.amazonaws.com/2022/01/ESC-Energy-Digitalisation-Taskforce-Report-2021-web.pdf.

This could be programmed to take advantage of lower electricity tariffs later in the evening or based on expected start time of the next journey coupled with expected energy required for the journey (i.e. range). Market mechanism such as price signals or time-of-use tariffs are important enablers for this approach.

Similarly, V2G services must also be integrated with smart charging, micro-generation and domestic energy storage to offer consumers and the grid holistic flexibility services. Collectively, these may well render DNO/supplier-managed smart charging unnecessary. In any case, integration is pivotal because it is unrealistic and impractical to expect consumers to participate in each of these flexibility services via separate platforms. Integration and convenience are fundamental to consumer participation and key to giving consumers control of their own energy use.

In many ways, it is arguably even more important to fully and transparently educate consumers on any potential adverse impact of V2G to help them make informed choices on participation. At the moment, due to the lack of longitudinal data and wide enough participation, the potential longer-term impact of V2G on vehicle battery degradation is still poorly understood. V2G will put additional discharge (and hence charge) cycles on the battery. With likely increased regulation requirements mandating a certain capacity retention over time, and many vehicle manufacturers providing warranty assurance for battery degradation, future design of batteries and warranties will need to ensure they can meet the degradation requirements within regulation while accounting for the impact of increased charge-discharge cycles as a result of V2G. It would be both costly and unfair for vehicle manufacturers to effectively subsidise the energy sector, who will benefit from the delayed need to invest in reinforcing or upgrading electricity networks, through the increased need to replace degraded batteries under warranty. Increased battery replacements could also lead to increased environmental costs and raw material depletion to produce the batteries.

Setting minimum requirements for the next phase of smart charging

Smart charging technology that facilitates demand side response and flexibility services is expected to be rolled out mainly in private home chargers and, to an extent, depot chargers. Given that long dwell times, particularly overnight when there could be excess electricity generation or when tariffs are most attractive, are essential to facilitate meaningful demand side response and participation in flexibility markets, smart charging technology is unlikely to be suitable for rapid and ultra-rapid charging.

When developing the next phase of legislation to support system-wide implementation of smart charging, government should only legislate on aspects where there is deemed to be either genuine market failure or the required solutions cannot be delivered organically by industry. In keeping with principles of better regulation, only the minimum necessary requirements should be mandated by legislation, which itself must not result in the unintended consequence of stifling innovation.

In setting minimum requirements that will be mandated by legislation, the following must be taken into account:

- Instead of reinventing the wheel legislation must incorporate existing industry standards and best practices.
- Minimum requirements must be broad enough to accommodate likely future solutions, such as micro-generation and domestic energy storage.

- Minimum requirements ought to take into account similar or equivalent measures in Europe, as country-specific legislation will only create divergent standards and solutions, which will ultimately increase the cost of development and compliance.

Consumers must be able to freely switch **electricity supplier** and/or **plug-in vehicle brand or model** without any impact on using the smart chargepoint, as required under the new Electric Vehicles (Smart Charge Points) Regulations 2021.[92] The equivalent of the debacle of smart meter displays "going dumb" when households switched energy suppliers must be avoided at all cost. No consumer would like to be saddled with an incompatible home charger when they switch electricity suppliers or buy a new plug-in vehicle of another brand/model. In order to promote interoperability, we believe future amendments to the regulation must go further by requiring smart chargers to also be compatible with any HEMS devices through open APIs.

Load limitation and communication

Where load limitation is required, the DNO should send a signal to the entity responsible for the operation of the smart chargepoint, who would then execute a supply intervention. **There should not be a separate communication path for DNOs**. A separate communication path will only increase complexity and add additional cost. Furthermore, in the context of the future HEMS, the DNO's demand can be addressed by the HEMS based on consumer presets that will temporarily limit the power to certain appliances. The only exception to this is when the DNO intervenes in a genuine emergency to prevent a black-out. However, as we have emphasised above, this must be done in the context of a statutory requirement with clear consumer protection in terms of frequency and/or duration of intervention, and must be linked to another statutory requirement for reinforcement if used excessively.

In the vast majority of cases, the chargepoint communicates the **maximum current** that the vehicle can draw. This is in line with BS EN 61851:2011(2019) which states that the AC chargepoint indicates "the available current to the vehicle" or "the maximum current to be drawn by the vehicle".[93] It also sets out an external demand for power reduction by stipulating "such a demand may originate from the grid", so the available or maximum current may be varied dynamically. However, due to physical constraints and to avoid damage to the battery pack, it should be noted that in all cases the vehicle chooses how much, if any, current it draws between zero and the indicated (potentially dynamic) maximum. For example, above 80% state of charge, the charging current continually decreases to protect the battery. Some chargepoints will end the charging cycle if the vehicle somehow exceeds the maximum current.

Smart charging requirements must always include a **minimum charging current**, which is far more acceptable than simply turning off the mains supply to the charging equipment, as this can potentially cause damage to battery contactors if repeated. It may also initiate car alarms and customer warnings via an app. The ability to then restart charging is as much a feature of the charging equipment as the vehicle, but charging may not restart altogether.

As such, smart charging that involves turning down the pulse-width modulation (PWM) sent from the charging equipment to the vehicle is a better solution. This tells the vehicle what upper limit on the current is imposed, while not dipping below a minimum current. In the case of PWM and in situations such as the loss of communications, which could be the loss of chargepoint operator connectivity or the loss of smart meter connectivity in the context of HEMS, the chargepoint should ideally default to charge

[92] The Electric Vehicles (Smart Charge Points) Regulations 2021, available at https://www.legislation.gov.uk/ukdsi/2021/9780348228434/contents.
[93] BS EN 61851-1:2011 was the original British standard for electric vehicle conductive charging system. Now updated and superseded by BS EN IEC 61851-1:2019 "Electric vehicle conductive charging system. General requirements", available at https://shop.bsigroup.com/ProductDetail/?pid=000000000030414455.

at maximum capacity, but **not less than 10A**, in a simple immediate charge mode until the battery is full. Below this threshold, most plug-in vehicles will not charge.

What the chargepoint **must not** do in any communications outage is adopt a minimum low output setting such as 2.3kW or 3.7kW. This would greatly increase charging times and could negatively impact on the user's mobility needs. Furthermore, there is a risk lowering the output to the bare minimum could be open to abuse, where communications are deliberately brought down as a means of reducing load, or following a communications outage this "safe load" setting results in no urgency to rectify the issue.

Additionally, while the concept of proportional import load control makes sense, 0-100% in steps of 10% is not consistent with the minimum communicable current from BS EN/IEC 61851, which is 6A, below which the vehicles ceases to draw current. For example, 10% of 7kW is 0.7kW (≈3A), which is below the statutory minimum draw for plug-in vehicles and is therefore ineffective. In addition, forcing a chargepoint to go below 10A will simply encourage users to switch to a dumb Mode 2 charging device that typically delivers 10A in the UK.

A common number of steps regardless of the maximum capability of the device seems onerous for low capacity chargepoints. Ten steps between 10A and 16A (or 32A), which are typical UK maximum currents, seem excessive. Where IEC 61851 is applied, increments are limited to 0%, 30%, 70% and 100% coded via PWM. An alternative that should be considered is 2A increments between 10A and the chargepoint maximum. However, any solution must be based on international or European standards, e.g. IEC 63110 / ISO 15118.

Data sharing and protection

Various stakeholders are increasingly interested in accessing and using the growing amount of plug-in vehicle data to better understand user behaviour and to facilitate their own business processes or commercial offerings. Vehicle data (e.g. battery state of charge, battery state of health) and charging data, insofar as private charging is concerned, belongs to the consumer and is specific to a vehicle, which has a unique Vehicle Identification Number, and which in turn can be traced to a personal identifier. The processed information can ultimately lead to insights on personal behaviours. Such data can be shared subject to the owner's consent, but **cannot be presumed open**, which effectively implies default opt-in to data sharing.[94] There is no reasonable cause to justify a default opt-in for this purpose under the UK General Data Protection Regulation, the Data Protection, Privacy and Electronic Communications (EU Exit) Regulations 2019, and the Data Protection Act 2018.

The consumer should always be able to determine and limit who his/her data is shared with. The automotive industry already upholds high levels of data protection in full compliance with existing data protection and privacy laws and regulations. Customers are provided with options regarding the processing and use of their personal data. Many vehicle manufacturers are signatories to the *ACEA Principles of Data Protection in Relation to Connected Vehicles and Services.*[95]

[94] Open data is data that anyone can access, use and share. See definitions by the European Commission available at https://www.europeandataportal.eu/elearning/en/module1/#/id/co-01 and the Open Data Institute available at https://theodi.org/article/what-is-open-data-and-why-should-we-care/.
[95] ACEA (2015), Principles of Data Protection in Relation to Connected Vehicles and Services, available at https://www.acea.be/publications/article/acea-principles-of-data-protection-in-relation-to-connected-vehicles-and-se.

Ensuring the electricity is as clean as the vehicles

Our analysis based on our long-term market and parc outlook to 2035 (Figures 3 and 4) suggests the resultant BEV parc between 2021 and 2035 will save a total of 160.6 $MtCO_2e$, equivalent to about 6 million cars taken off the road in the 15-year period. To put this into perspective, the amount of CO_2 saved between 2021 and 2035 is equivalent to about 3.5% of the combined greenhouse gas emissions budgeted under the Fourth, Fifth and Sixth Carbon Budgets for the period between 2023 and 2037, and about 30.8% of UK's territorial emissions in 2019 alone (522 $MtCO_2e$).[96]

However, all the emissions avoided at the tailpipe will be futile if the electricity used to manufacture and charge ZEVs still originates from fossil sources. As the UK transitions to a zero emission new car and van market by 2035, government must now ensure the electricity that is used to power and produce ZEVs by then is just as clean. Otherwise, a sole focus on zero tailpipe emissions risks merely shifting emissions from a more obvious source to one that is less obvious. The Climate Change Committee expects renewable energy in the UK's electricity mix will continue to increase over time and reach up to 90% by 2050.[97] This means there is still every possibility the cleanest vehicles on our roads will still be produced and charged using dirty electricity up to 15 years after non-ZEVs are phased out from the UK market. As such, we commend government for recently committing to decarbonise the country's electricity system by 2035.[98]

Government must now go further and faster by cementing its bold and ambitious commitment in law. This means, in order to ensure the electricity used to power and produce ZEVs by 2035 is as green as the new cars and vans themselves, government must mandate **100% grid decarbonisation by 2035** and turbocharge the greening up of electricity generation by legislating for a **binding target of 90% of electricity to be generated from renewables** under normal operation by 2035 so that the electricity grid is virtually zero carbon. The shortfall under normal operation or when output from wind and solar generation is low should be buffered by other clean technologies, such as nuclear, and energy storage.

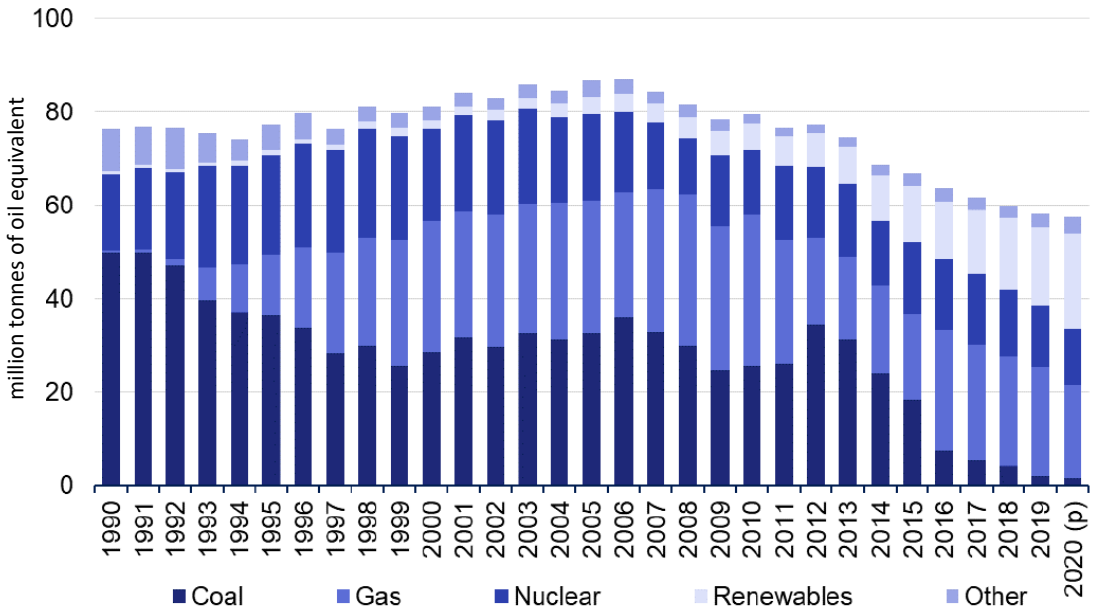
By introducing a mandate in law, along with a binding target, government is sending a strong message to industry, consumers and the international community that the UK is serious about its Net Zero ambitions. This is particularly important at a time when despite the urgency of the Net Zero and climate change agenda, 60% of renewables-prioritising electricity utilities in the world have actually not ceased concurrently expanding their fossil fuel portfolio.[99]

Renewables are playing an increasingly prominent role in electricity generation in the UK, making it possible for consumers to charge their plug-in vehicles today with electricity that is partly generated from zero carbon sources. A record 42.9% of the UK's electricity was generated by renewables in 2020 (Figure 16). However, 41% of the country's electricity was still produced by fossil fuels.[100] Even during the record-breaking run of 67 consecutive days of coal-free electricity generation between April and

[96] Greenhouse gas emissions budgeted over the Fourth (2023-2027), Fifth (2028-2032) and Sixth (2033-2037 Carbon Budget periods were 1,950 MtCO2e, 1,725 MtCO2e and 965 MtCO2e respectively. See Climate Change Committee (2020), Sixth Carbon Budget, available at https://www.theccc.org.uk/publication/sixth-carbon-budget/.
[97] Climate Change Committee (2020), Sixth Carbon Budget, available at https://www.theccc.org.uk/publication/sixth-carbon-budget/.
[98] HM Government press release, "Plans unveiled to decarbonise UK power system by 2035", 7 October 2021, available at https://www.gov.uk/government/news/plans-unveiled-to-decarbonise-uk-power-system-by-2035.
[99] Alova, G. (2020), "A global analysis of the progress and failure of electric utilities to adapt their portfolios of power-generation assets to the energy transition", Nature Energy, available at https://doi.org/10.1038/s41560-020-00686-5.
[100] Department for Business, Energy and Industrial Strategy and the Office for National Statistics (2021), Provisional UK greenhouse gas emissions national statistics 2020, available at https://www.gov.uk/government/statistics/provisional-uk-greenhouse-gas-emissions-national-statistics-2020.

June 2020,[101] about a tenth of our electricity during the period was still imported from Europe, much of which was coal-generated.[102]

Figure 16: Fuel mix for UK electricity generation, 1990-2020.



N.B. 2020 figures are provisional.

Source: Department for Business, Energy and Industrial Strategy and the Office for National Statistics (2021), 2020 UK greenhouse gas emissions, provisional figures, available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/972583/2020_Provisional_emissions_statistics_report.pdf.

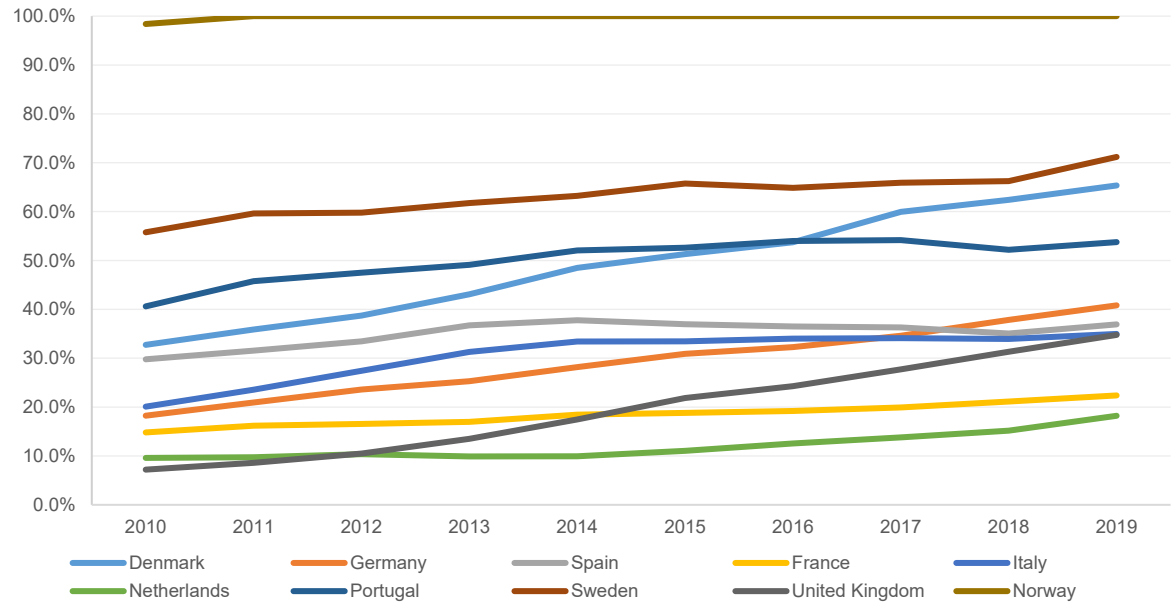
As a matter of concern, the welcome and seemingly inexorable rise of renewables has recently lost momentum. Both the share of electricity generated by renewables and the growth rate in renewable generation capacity have fallen.[103] In the first two quarters of 2021, renewable electricity generation stood at 34.7TWh and 26.9TWh, or a 16.0% and 9.6% year-on-year decrease, respectively. Renewables made up 41.6% of electricity generation during the first quarter of 2021, which was 5.6% lower than in the same quarter in 2020. In the second quarter when renewables' share of electricity generation slumped further to 37.3%, the share of electricity generated from fossil fuels increased to 43.4%, its highest share since the second quarter of 2019. Just when investment in renewable electricity generation capacity is expected to gather momentum, its growth has slowed since the start of 2020, with just 65MW and 134MW added in the first and second quarters of 2021 respectively, a modest 1.5% and 1.4% increase on the same periods in 2020.

[101] Murray, J.S. (2020), "UK's record run without coal power ends at 67 days", BusinessGreen, 17 June, available at https://www.businessgreen.com/news/4016627/uk-record-coal-power-free-run-67-days.
[102] Watson, D. (2020), "Renewables: Let's address reality", IET Engineering & Technology, 15 June, available at https://eandt.theiet.org/content/articles/2020/06/renewables-let-s-address-reality/.
[103] Department for Business, Energy and Industrial Strategy and the Office for National Statistics (2021), Energy Trends: UK renewables, available at https://www.gov.uk/government/statistics/energy-trends-section-6-renewables.

Despite the National Grid ESO suggesting the country is on track for periods of zero carbon electricity by 2025,[104] the carbon intensity of our electricity was approximately 5% higher year-on-year in the first four months of 2021. Notwithstanding several record-breaking days, the grid was on average 20% dirtier in April 2021 than in April 2020, with a carbon intensity of 200g CO_2/kWh, owing largely to 22% higher gas-fired generation.[105]

In terms of the proportion of electricity consumed that came from renewable sources, it is clear the UK has some way to go before it can compare favourably with other major European economies (Figure 17).[106] In 2019, the most recent year where data is available, 34.8% of the electricity consumed in the UK came from renewable sources, whereas the percentage in Spain was 36.9%, Germany 40.8%, Portugal 53.8% and Sweden 71.2%. 100% of the electricity Norwegian consumers used to charge their plug-in vehicles came from renewable sources, making their electricity truly as clean as their vehicles. Seen in this light, zero emission mobility in Norway can lay claim to genuine "green credibility", as both the vehicles and the electricity used to charge them are just as clean.

Figure 17: Share of renewables in gross electricity consumption, 2010-2019.



Source: SMMT analysis of Eurostat data, available at https://ec.europa.eu/eurostat/web/energy/data/shares.

The UK's electricity grid has decarbonised at a faster rate than many other countries in the last decade. While National Grid ESO targets operating a zero carbon electricity system by 2025, this will depend to a large extent on the sources of electricity generation.[107] Given we are now on track to end coal power by 2024 at the latest, early full decarbonisation of our electricity is the next logical step towards Net

[104] "Great Britain on track for periods of zero carbon electricity in 2025" on the National Grid ESO website, available at https://www.nationalgrideso.com/news/great-britain-track-periods-zero-carbon-electricity-2025.
[105] edie (2021), "UK's electricity grid emissions up year-on-year, despite net-zero pledge", 20 May, available at https://www.edie.net/news/10/UK-s-electricity-grid-emissions-up-year-on-year--despite-net-zero-pledge/.
[106] Eurostat, Energy from Renewable Sources, available at https://ec.europa.eu/eurostat/web/energy/data/shares.
[107] "Zero carbon explained" on the National Grid ESO website, available at https://www.nationalgrideso.com/electricity-explained/zero-carbon-explained.

Zero. Securing fully clean electricity by 2035 is crucial not just for ensuring zero emission mobility has genuine green credibility, but also for cutting carbon emissions by 78% compared to 1990 levels.

To fully decarbonise our electricity system and for renewables to generate 90% of our electricity under normal operation by 2035, the target of 40GW of offshore wind capacity by the end of the decade is not sufficient.[108] Government will need to at least double its 2030 offshore wind target and roll out new grid-connected batteries at an unprecedented speed and scale. There should be specific deployment targets and increased investment in solar power, onshore wind, floating wind and green hydrogen capacity. One estimate suggests up to 108GW of offshore wind capacity will be needed by 2035, more than twice government's target and a tenfold increase on our current offshore wind capacity.[109] National Grid ESO suggests between 34GW and 77GW of new wind and solar generation could be required to meet demand by 2030, in addition to as much as 13GW of new electricity storage to help balance periods of high and low renewable output.[110]

However, increased investment alone will not get us there. There should also be innovative reforms to electricity markets.[111] One of the central reforms, as we have alluded to when discussing smart charging and V2G, is to unlock flexibility on the demand side to give further impetus to renewables. Active and mature flexibility markets that also integrate behind-the-meter technologies, micro-generation and energy storage will eventually create sufficient system resilience to externalities and safeguard our long-term energy security.

[108] 40GW of offshore wind capacity target as set out in HM Government (2020), The Ten Point Plan for a Green Industrial Revolution, available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/936567/10_POINT_PLAN_BOOKLET.pdf.
[109] Aunedi, M. et. al (2021), "Net-zero GB electricity: cost-optimal generation and storage mix", IDLES Programme White Paper, Imperial College London, available at https://spiral.imperial.ac.uk/bitstream/10044/1/88966/7/EFL_Net%20Zero%20GB%20Electricity_White%20Paper.pdf.
[110] National Grid ESO (2021), Future Energy Scenarios, available at https://www.nationalgrideso.com/future-energy/future-energy-scenarios/fes-2021.
[111] See for example ideas discussed in Day, G. (2021), "Can we mandate electricity markets to deliver a decarbonised grid by 2035?", Energy Systems Catapult, available at https://es.catapult.org.uk/insight/can-we-mandate-electricity-markets-to-deliver-a-decarbonised-grid-by-2035/.

CHAPTER 6
SUMMARY OF KEY MEASURES REQUIRED

We summarise below, by way of a seven-point plan, the strategic commitments and policy measures that we believe are required to deliver consumer-centric charging infrastructure for a successful transition to a zero emission new car and van market by 2035.

APPENDIX A
Definitions of plug-in vehicle charging in the UK

In the UK, chargepoint power ratings, or speed, are categorised as follow:

- Slow: 3-5kW
- Fast: 7-22kW
- Rapid: 43-50kW
- Ultra-rapid: ≥100kW

The European equivalent of slow and fast chargers are often known as standard, or normal, chargers, while what is known as rapid in the UK is often called fast in Europe. As such, it follows that ultra-rapid chargers are also called ultra-fast chargers on the continent, although in some quarters they are also known as high-power chargers.

Until recently, chargepoint statistics in the UK sometimes referred to *connectors* and *devices*. A *device* is the chargepoint hardware, sometimes known as the pole, in the ground or on the wall. A device may have one or more *connectors*. For example, it may have two AC 7kW connectors, one on each side, to allow two plug-in vehicles to charge simultaneously. A rapid charging device may have a CCS and a CHAdeMO connector. For the purpose of this paper, we refer to connectors mainly as chargepoints, as each connector represents a single point of electric current delivery to a vehicle, unless stated otherwise. Each charging location, sometimes known as a *station* or a *hub*, may have one or more devices. For example, it is not uncommon for a rapid or ultra-rapid charging hub to have at least four devices.

Owing to the legacy of infrastructure development, there are different types of connectors for different vehicles, not unlike the prevalence of USB, USB-C and Lightning charging cables/ports for smartphones today. The choice of connectors depends on the charger type, i.e. the socket, and the vehicle's inlet port. These are divided into two main categories depending on the power ratings, or speed:

- Slow-fast chargers (3-22kW) for AC charging: UK 3-pin, Industrial Commando, Type 1, Type 2
- Rapid-ultra-rapid chargers (43kW-350kW) for DC charging (except 43kW, which is on AC): CHAdeMO, CCS, Tesla's proprietary supercharger connectors

Despite the seeming confusion and complaints on the supposed lack of interoperability of connectors, there is now convergence in Europe where most modern plug-in vehicles use **Type 2 for slow and fast** charging and **CCS for rapid and ultra-rapid** charging.[112]

[112] For a more detailed explanation on connectors and speeds, see https://www.zap-map.com/charge-points/connectors-speeds/.

APPENDIX B
Passenger car segments

A-segment: Mini
Engine size normally less than 1.0cc, body style "miniature", normally two doors, length normally not exceeding 3050 mm.

B-segment: Supermini
Normally between 1.0-1.4cc, body style bigger than Mini, length normally not exceeding 3745 mm, performance greater than Mini, more variety of trims per range.

C-segment: Lower Medium
Normally between 1.3-2.0cc, length of saloon normally not exceeding 4230mm.

D-segment: Upper Medium
Normally between 1.6-2.8cc, length of saloon normally not exceeding 4470mm.

E-segment: Executive
Normally between 2.0-3.5cc, body style generally bigger than Upper Medium, normally four doors, length of saloon normally not exceeding 4800 mm, more luxuriously appointed.

F-segment: Luxury Saloon
Normally upward from 3.5cc, most luxurious available.

G-segment: Specialist Sports
Sports coupes, sports saloons, traditional sports.

H-segment: Dual Purpose
Sport utility vehicles, 4x4 off-roaders.

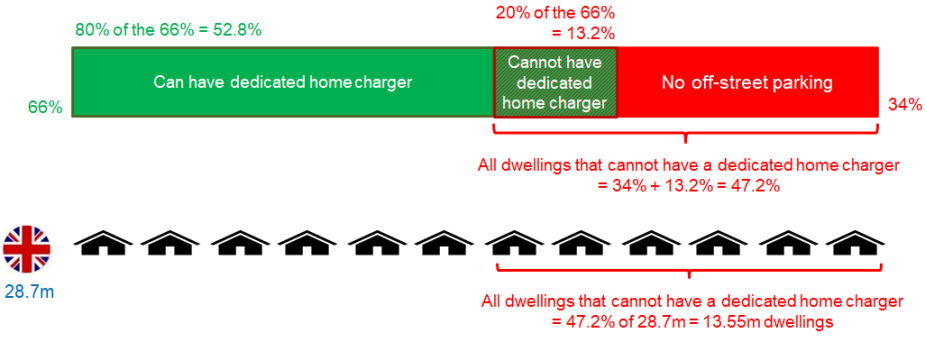
APPENDIX C
Modelling of chargepoints required by 2030: assumptions and outcomes

The following are the underlying assumptions and the outcomes of a modelling exercise by Frost & Sullivan and SMMT to estimate the amount of charging infrastructure required to deliver on government's 2030 end-of-sale deadline.

Technical assumptions associated with three charging scenarios

Across all scenarios

- % of the car parc are plug-in cars by 2030: 27% (9,273,000), comprising BEV 20.1%, PHEV 6.9%)
- Passenger cars in the parc in 2030: 34.3m (currently c.35.1m; some displacement due to MaaS and other factors)
- % of dwellings without off-street parking: 34%
- % of dwellings with off-street parking that cannot have a dedicated, private home charger: 20%
- Total number of dwellings in the UK: 28.7m



Scenario A: On-street residential charging as the dominant model

- % of time the car is charged at home: 80%
- Battery sizes: marginally larger than today; optimised for cost and range (and payload, if commercial vehicle)
- 800V architecture: a sizeable proportion of BEVs in the parc cannot support ultra-rapid charging

Scenario B: Forecourt/hub/motorway charging as the dominant model

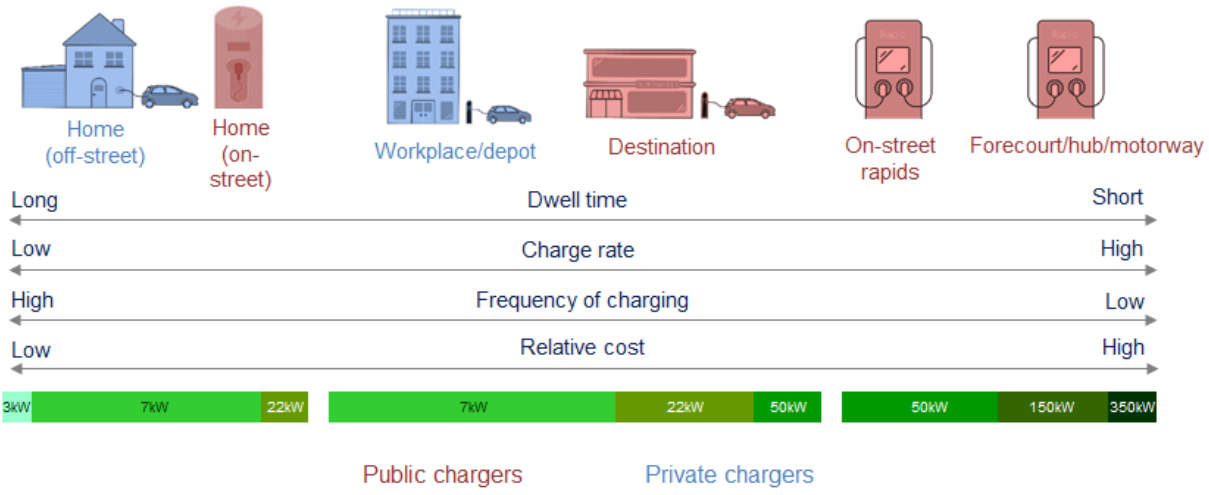
- % of time the car is charged at home: 50%
- Battery sizes: significantly larger than today; cost falls markedly
- 800V architecture: vast majority of BEVs in the parc are capable of supporting ultra-rapid charging

Scenario C: Workplace and destination charging as the dominant model

- % of time the car is charged at home: 50%

- Battery sizes: mixed (some only marginally larger, while others significantly larger than today); cost falls steadily; but still optimised for cost and range (and payload, if commercial vehicle)
- 800V architecture: mixed (some BEVs in the parc are capable of supporting ultra-rapid charging)

Types of chargepoint and their estimated distributions



Cost assumptions

Infrastructure costs = hardware + wiring and installation + grid connection

Hardware costs

- Estimates are based on expected industry average by 2030 from Frost & Sullivan research.

Wiring and installation costs for non-forecourt/hub/motorway chargers

- Estimates for 7-22kW chargers are based on Steer research. Not adjusted for inflation by 2030.
- Estimates for 50kW chargers are based on desk research derived from various electrical installers. Not adjusted for inflation by 2030.

Grid connection costs for non-forecourt/hub/motorway chargers

- Estimates for 7-22kW chargers are based on Steer research. Not adjusted for inflation by 2030.
- Estimates for 50kW chargers are based on a DNO's figures. Not adjusted for inflation by 2030.

Wiring, installation and grid connection for forecourt/hub/motorway chargers

- Estimates and assumptions of wiring and grid connection costs are from a DNO. Estimates of installation costs are based on desk research. Not adjusted for inflation by 2030.
- Key technical assumption: power factor 0.8, hence 1kVA = 0.8kW

Scenario A: On-street residential charging as the dominant model

Charging infrastructure required by location and type

Red font indicates public chargepoints

Location/type	7kW	22kW	50kW	150kW	350kW	TOTAL
Off-street residential (private home charger)	5,794,284	57,943				**5,852,227**
On-street (mainly residential)	1,489,116	446,735	9,820			**1,945,671**
Workplace/depot	380,125	48,380	26,609			**455,114**
Destination	319,305	38,704	3,193			**361,202**
Forecourt/hub/motorway			17,030	8,870	1,064	**26,964**
TOTAL	**7,982,830**	**591,762**	**56,652**	**8,870**	**1,064**	**8,641,178**

Cost of delivering the required public charging infrastructure

	On-street (mainly residential)	Destination	Forecourt/hub/ motorway	TOTAL
Hardware cost (7kW chargers)	£1,044,493,070	£221,275,050		**£1,265,768,120**
Hardware cost (22kW chargers)	£2,154,741,075	£183,402,630		**£2,338,143,705**
Hardware cost (50kW chargers)	£145,252,200	£48,204,405	£222,740,820	**£416,197,425**
Hardware cost (150kW chargers)			£360,360,000	**£360,360,000**
Hardware cost (350kW chargers)			£86,941,100	**£86,941,100**
Wiring, installation and grid connection costs	£10,180,938,560	£1,867,058,520	£1,088,387,000	**£13,136,384,080**
TOTAL COST	**£13,525,424,905**	**£2,319,940,605**	**£1,758,428,920**	**£17,603,794,430**

Scenario B: Forecourt/hub/motorway charging as the dominant model

Charging infrastructure required by location and type

Red font indicates public chargepoints

Location/type	7kW	22kW	50kW	150kW	350kW	TOTAL
Off-street residential (private home charger)	5,794,284	57,943				**5,852,227**
On-street (mainly residential)	282,870	31,430	701			**315,001**
Workplace/depot	239,854	43,610	2,399			**285,863**
Destination	205,589	21,805	1,199			**228,593**
Forecourt/hub/motorway			98,340	38,377	8,566	**145,283**
TOTAL	**6,522,597**	**154,788**	**102,639**	**38,377**	**8,566**	**6,826,967**

Cost of delivering the required public charging infrastructure

	On-street (mainly residential)	Destination	Forecourt/hub/ motorway	TOTAL
Hardware cost (7kW chargers)	£188,058,410	£140,536,690		**£328,595,100**
Hardware cost (22kW chargers)	£142,588,350	£101,526,975		**£244,115,325**
Hardware cost (50kW chargers)	£3,132,585	£17,127,915	£1,489,957,170	**£1,510,217,670**
Hardware cost (150kW chargers)			£1,669,054,464	**£1,669,054,464**
Hardware cost (350kW chargers)			£759,345,360	**£759,345,360**
Wiring, installation and grid connection costs	£1,555,316,280	£1,163,453,320	£6,417,706,000	**£9,136,475,600**
TOTAL COST	**£1,889,095,625**	**£1,422,644,900**	**£10,336,062,994**	**£13,647,803,519**

Scenario C: Workplace and destination charging as the dominant model

Charging infrastructure required by location and type

Red font indicates public chargepoints

Location/type	7kW	22kW	50kW	150kW	350kW	TOTAL
Off-street residential (private home charger)	5,794,284	57,943				**5,852,227**
On-street (mainly residential)	94,290	10,477	701			**105,468**
Workplace/depot	671,117	32,031	18,791			**721,939**
Destination	671,117	80,077	7,047			**758,241**
Forecourt/hub/motorway			46,978	23,489	3,356	**73,823**
TOTAL	**7,230,808**	**180,528**	**73,517**	**23,489**	**3,356**	**7,511,698**

Cost of delivering the required public charging infrastructure

	On-street (mainly residential)	Destination	Forecourt/hub/ motorway	TOTAL
Hardware cost (7kW chargers)	£54,166,610	£471,061,570		**£525,228,180**
Hardware cost (22kW chargers)	£41,071,065	£383,854,815		**£424,925,880**
Hardware cost (50kW chargers)	£3,132,585	£108,268,995	£689,480,400	**£800,881,980**
Hardware cost (150kW chargers)			£1,008,741,888	**£1,008,741,888**
Hardware cost (350kW chargers)			£292,373,060	**£292,373,060**
Wiring, installation and grid connection costs	£448,982,040	£3,970,053,320	£3,241,246,000	**£7,660,281,360**
TOTAL COST	**£547,352,300**	**£4,933,238,700**	**£5,231,841,348**	**£10,712,432,348**

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