9 Years Remaining

Planning for Electric Vehicle Infrastructure to 2030

CITY SCIENCE
endless possibilities

Acknowledgements

Laurence Oakes-Ash BSc FCMA CGMA MCIHT
City Science

Jade Baker-Edwards BEng BSc
City Science

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1. Executive Summary

1.1 CONTEXT

The UK government acknowledges that "transport has a huge role to play in the economy reaching net zero" (DfT, 2020a). Yet, since 1990, transport has seen only a 3% reduction in overall emissions and remains the single largest contributor to the UK's GHG emissions (DfT, 2020a). In an average local authority, transport is responsible for 35.5% of all emissions (City Science, 2020) and is therefore a key concern for policymakers addressing carbon reduction targets.

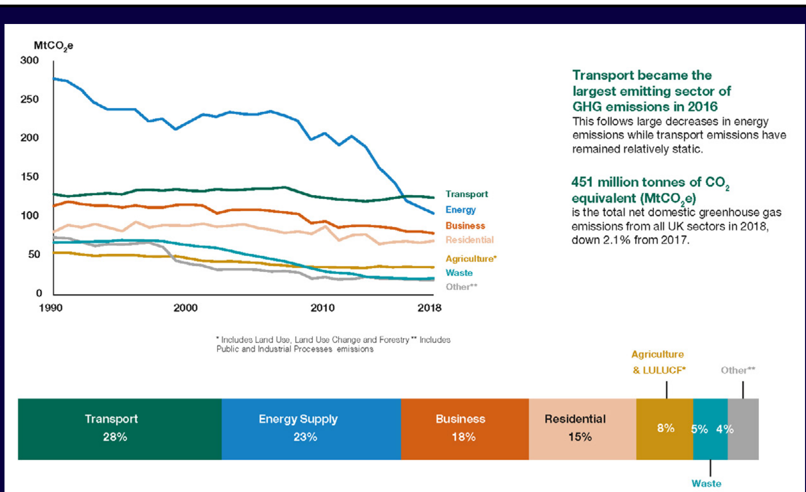
The Ten Point Plan for a Green Industrial Revolution (HM Government, 2020), provides a strong focus on accelerating the transition to Electric Vehicles (EVs) through supporting manufacturers and transforming our national infrastructure. Ten years earlier than initially planned, 2030 will see a ban in the sale of petrol and diesel cars and light vans. Although it will take time for the full fleet to be replaced, the aim is that almost every car will be zero emissions at the tailpipe by 2050 at the latest. The plan encourages radical change and presents an opportunity for local authorities to take a leadership role in decarbonisation.

In order to prepare for 2030, change must begin now. This is an important year to engage with decarbonisation considering that operators of the electrical grid (or DNOs) will also be preparing their five year investment plans through the RIIO-ED2 process. Spanning 2023 to 2028, it is essential that local authorities ensure investment over this period is aligned to their decarbonisation objectives.

However, knowing what investments or initiatives to prioritise is not always easy. Decarbonisation needs to occur across every aspect of our transport system including personal vehicles, public transport and freight as well as in adjacent sectors such as buildings and employment sites. It is therefore often complex to know how best to proceed.

The purpose of this white paper is to collate research on zero carbon fuels across personal vehicles, buses and freight to help local authorities understand what evidence is required, what analysis to undertake and how strategies can be progressed to help accelerate the shift to electric and zero carbon vehicles. The key recommendations below have been drawn from our analysis and are intended to help local authorities navigate the complexity.

Figure 1: 2018 UK Domestic GHG Emissions (DfT. 2020a)



2018 UK Domestic GHG Emissions

"Transport was the largest emitting sector of GHG emissions in 2018"

DfT, 2020a

1.2 TEN KEY RECOMMENDATIONS

1. Set Electrification Goals Within a Wider Decarbonisation Strategy

All strategies should be set within the wider context of local decarbonisation objectives. While electrification is essential, it is not a silver bullet. Maximising demand reduction and modal shift will help reduce the scale, cost and investment associated with electrification strategies and, as a result, should be considered upfront.

2. Engage Early

Much of what needs to be rolled out cannot be achieved without stakeholder involvement and policymakers should not underestimate the scale of the challenge. 2021 is an essential year for engagement with local DNOs as they will be preparing their investment plans for the 2023 to 2028 period. Engagement now will be critical to ensure that plans for transport and electrical infrastructure are aligned. Stakeholder engagement will also be essential to develop a thorough understanding of the baseline situation, to bring together expert knowledge and develop deliverable plans with clearly delineated lines of responsibility will be needed to make personal vehicle use less attractive while improving public transport travel times.

3: Enforce EV Readiness Starting today

Moving forward, all new developments should be net zero ready to avoid costly retrofitting. For transport, this means that standards for EV charge point provision and future-proofed smart electrical infrastructure should be reviewed for residential and commercial sites.

4: Develop the Local Evidence Base

In this paper we pull together key principles local areas will need to consider, however the implementation details will vary at a local level. It is important for local authorities to consolidate their own evidence base. This will naturally cut across both transport and energy and in many cases, may require evidence that has been collated before. This research and modelling will be essential to enabling effective and informed local decisions and strategies.

5. Adopt Whole Systems Thinking

The carbon effectiveness of any solutions will be dependent on the performance across the entire supply chain and infrastructure lifecycle. To maximise the carbon benefits, policymakers will need to consider the whole system, putting in place strategies to ensure supply chains, electrical generation and end-of-life re-use of infrastructure are as sustainable as possible.

6. Consider All Elements of the Transport System

Local authorities need to consider the long-term infrastructure needs for personal vehicles, public transport and freight. In addition to EVs, Public transport and freight are acknowledged within the Ten Point Plan with commitments to invest £140 million to begin transitioning these sectors. Only by considering the cumulative energy demand across all parts of the transport system will local authorities be in a position to work with DNOs and partners to prioritise the investment necessary for the transition to EVs.

7. Establish and Nurture Essential Partnerships for Success

Policymakers will need to establish and embed the governance and engagement mechanisms necessary to coordinate action across all parts of the transport system. This will likely necessitate new forums to engage business and industry, new mechanisms to strengthen partnerships between transport and energy stakeholders, and appropriate governance structures to address challenges and progress investment at different geographic scales.

8. Create and Communicate Clear Roadmaps

Clearly defined ambition supported by robust multi-year action plans will help coordinate activity whilst providing certainty to the local community. Clearly communicated plans, supported by strong local partnerships will de-risk private sector investment, support funding and innovation opportunities, increase public confidence in electrification and as a result, underpin accelerated adoption.

9. Use the Widest Set of Policy Tools

Supporting the transition to EVs will rely on a wide range of policies. As part of their plan-making, local authorities should take a holistic approach to enable identification of a suite of policies and activities to support EV uptake. These could include, among others, coordinating infrastructure investment, updating standards for parking and new developments, incentivising uptake (for example through parking tariffs and other mechanisms), updating licensing arrangements, converting the council's own fleets, supporting businesses and residents through information and targeted assistance and engaging with national consultations and standard development.

10. Regularly Update Plans Considering the Latest and Best Practice

It is recommended that local authorities future-proof their initial plans by addressing technology uncertainty in key sectors through the use of futures techniques. Following adoption, plans should be updated regularly to take account of the latest technical developments and consumer trends. Regular updating will also support a flexible approach and ensure that plans align to best practice as it emerges.

2. Setting Electrification within a Wider Decarbonisation Strategy

Ten years earlier than initially planned, 2030 will see a ban in the sale of petrol and diesel cars and light vans. This means that local authorities will need to take steps to ensure infrastructure in their region is ready for this significant change. Whilst it will take time for the full fleet to be replaced, almost every car will be zero emissions at the tailpipe by 2050 and now likely even sooner (House of Commons, 2018). However, it is important for policymakers to understand where electrification should sit within a hierarchy of changes necessary to fully decarbonise in their region.

There are several crucial preliminary steps that should be undertaken alongside steps to accelerate the transition to EVs. The classic "Avoid, Shift, Improve" framework provides an effective process that can be utilised to frame transport decarbonisation strategies. Without undertaking the full process, policymakers risk switching one set of problems for another. Box 1 describes some of the lesser-known costs of EVs that should be borne in mind when developing transition strategies.

Step 1: Avoid: Overall, 70% of carbon emissions from road transport derive from commuting, business and leisure trips. Policymakers should seek to prioritise demand reduction strategies ahead of electrification to reduce the cost of new and upgraded infrastructure. Efforts to support home working, co-working spaces and replacing personal business trips with digital solutions should be prioritised as we emerge from the COVID-19 pandemic to secure lower demand and improved congestion. Furthermore, integrated transport and land-use planning, and promotion of car sharing should be used to further reduce vehicle miles.

Step 2: Shift: Next, efforts should be taken to encourage users to shift to more sustainable modes of transport. For short distances, an appropriate mix of enablers (e.g. new infrastructure) and deterrents (e.g. low traffic neighbourhoods) should be adopted to support increased active transport. For longer journeys, improvements to public transport and end-to-end journeys should be pursued. One bus alone can take up to 75 cars off the road at any given time, thereby removing the need for many personal vehicle trips over the course of a day (DfT, 2020b). Increasing the efficiency, reliability and appeal of public transport systems whilst exploring deterrents to personal vehicles will be needed to make personal vehicle use less attractive while improving public transport travel times.

Step 3: Improve: In a 2020 RTPI study, City Science set out ambitious pathways for demand reduction and modal shift. However, these ambitious targets still resulted in 45% to 55% of emissions remaining. Once these first two steps have been undertaken, remaining emissions must then be addressed through zero-emission fuels. Here, the transition to electric and hydrogen vehicles, and zero carbon freight and public transport will be critical. If less ambitious pathways for Avoid and Shift are adopted, residual emissions that need to be addressed through electrification will be higher.

In practice, all three steps will need to be progressed simultaneously with modelling helping identify the extent and location of residual demand that will be served by electrical infrastructure. By considering all steps, local authorities will ensure electrification is seen as part of a wider placemaking agenda and that the opportunity cost of investment does not detract from holistic solutions that improve quality of places, promote wellbeing, tackle obesity and reduce inequality.

Box 1: Why Avoid, Shift, Improve is so important to reduce overall societal costs

While EVs offer a plethora of environmental and societal benefits, they are not a silver bullet solution and the transition to EVs will not be free from wider costs. These costs include:

Monetary Cost

The cost of new infrastructure, vehicle replacement and other incentives required to implement widespread transport electrification will undoubtedly be high. For this reason, taking every effort to reduce travel demand prior to switching fuels will reduce the capital cost of transition and increase cost-effectiveness.

Carbon Cost

Science-based carbon budgets cap the total carbon we can emit globally in order to keep global temperatures well below 2°C in line with the Paris agreement. Any vehicle production or new infrastructure has embodied carbon that will detract directly from these global carbon budgets. For example, the energy demand alone for extracting and processing the metals required for producing 2 billion electric vehicles globally will be 4 times the UK's annual electrical output (Herrington, 2020). Policymakers should therefore ensure they consider how to support the wider decarbonisation of supply chains, how re-use and recycling can be promoted and how to inform consumers of the true environmental costs of the options.

Resource Cost

The implications of EVs for natural resources globally are also significant. EV batteries consist of various earth materials which are mined and produced at a significant detriment to the environment. For example, based on annual global production, fulfilment of the UK's 2050 electric car targets will require 200% of the total annual world cobalt production, 100% of the world's total neodymium production, 75% of the world's total lithium production and 50% the world's copper production (Herrington, 2020).

Recycling Cost

Current EV batteries are estimated to last between 10 to 20 years and although recycling processes can divert some materials from landfill, the cumulative burden of EV waste is problematic (Harper et al. 2019). However, improvements in recycling efficiency, battery designs and second-life use of EV batteries will alleviate some of this impact in the future.

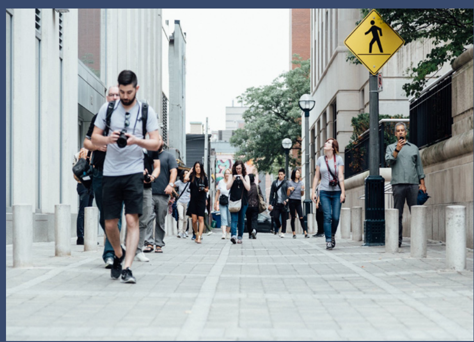
Emissions Cost

EVs do not produce tailpipe emissions and overall, produce less Particulate Matter (PM) than ICEV counterparts. However, due to the higher weight of EVs, the volume of PM10 produced by mechanical wear (from vehicle tyres, brake linings and the road surface) is typically higher than might be expected. While lower than ICEVs overall, EVs can continue contributing to poor air quality.

2.1 KEY CONCLUSIONS

Overall, the following key points should be borne in mind:

- Policymakers must ensure they take steps to minimise travel demand and promote sustainable modes (such as cycling and walking followed by public transport) first. Electrification needs to be seen as part of a hierarchy of action linked to a wider regional decarbonisation strategy.
- Policymakers must ensure that the vehicles they support truly offer the minimum possible environmental impact. Encouraging the uptake of smaller, lighter EVs will help to minimise the carbon, resource and emissions costs. Public information and local policies need to help incentivise environmentally sustainable choices and encourage manufacturers to tailor their products and supply chains appropriately.
- Policymakers must ensure they consider how precious resources can be re-used and recycled to avoid simply off-shoring the carbon impact of production over the long term.

1. Avoid	2. Shift	3. Improve
		
Replace trips with digital solutions	Encourage active travel such as walking and cycling	Introduce zero emission alternatives

3. Understanding the Grid

3.1 CONTEXT

The focus on the electrification of transport and heating in decarbonisation strategies raises concerns over requirements for large scale investment in the electrical grid and network infrastructure (RTPI, 2019). Potential impacts on the grid are a vital consideration when preparing the infrastructure for EVs. Without investment it is likely that the uptake of EVs might cause local shortfalls in electrical network capacity or challenge the resilience of existing infrastructure (Catapult, 2018). To help understand these issues, below we provide a brief explanation of the electrical grid and the potential impact of EVs.

3.2 HOW DOES THE GRID WORK?

The National Grid transmits electricity at high voltages nationwide. The electricity travels from the generation point to Grid Supply Points (GSPs) across the country. From the GSP, Distribution Network Operators (DNOs) are responsible for distributing the electricity at lower voltages to where it is needed. Here, it is sent through Bulk Supply Points (BSPs), which cover smaller areas such as towns, and then to Primary Substations which distribute the supply to individual residential estates.

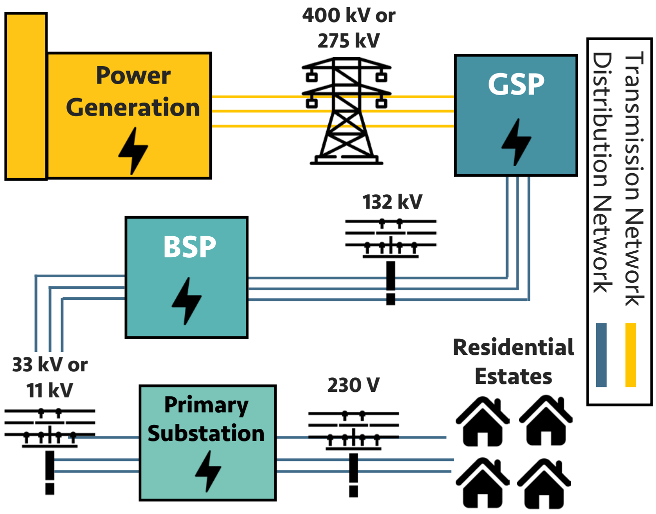


Figure 2: UK electricity supply to homes

3.3 HOW COULD EVs AFFECT THE GRID?

Since network operators have no control over EV uptake, planners face a huge challenge to ensure that future network capacity remains adequate. Currently, the majority of EV owners tend to charge their cars daily upon returning home from work. This increases electricity demand at a time of day where a peak already exists. On a mass scale, this could overload the system, disrupt the energy supply and cause high maintenance costs due to component failure. An increase in national peak demand could also require significant additional new generation in addition to infrastructure investment across the board (Catapult, 2018).

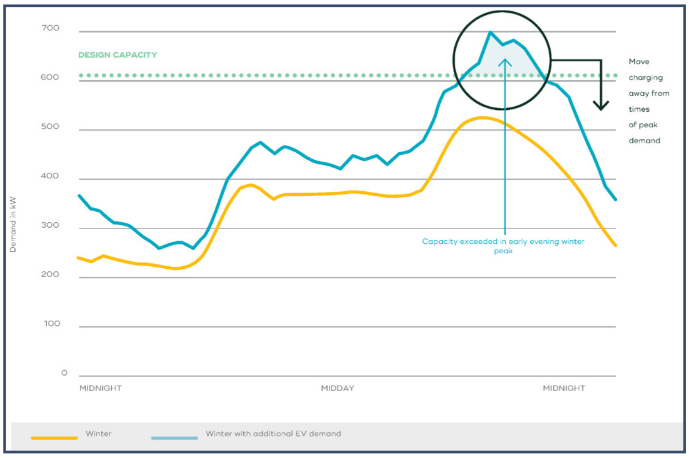


Figure 3: The electricity demand from homes and EVs (Electric Nation, 2018)

> *"It remains a large unanswered question as to whether consumers, en masse, will accept smart charging with the levels of incentives that make it a cost-effective solution compared with conventional reinforcement of electricity networks."*
>
> *Energy Systems Catapult, 2018*

There is optimism that this future energy demand can be "smoothed out" through the use of smart technology (such as Vehicle-to-Grid) at the level of individual vehicles, households, streets or regions. Through the Automated and Electric Vehicles (AEV) Act 2018, the government has the power to mandate that all charge points sold or installed in the UK have smart functionality. The government recently summarised responses to its consultation and is likely to progress this through secondary legislation. However, challenges still remain. Understanding the effects and additional costs of smart charging strategies and their acceptability to consumers remains in its infancy and is creating uncertainty around traditional capacity infrastructure.

The impact on the electrical network depends on a number of considerations including which types of chargers are preferred, when charging takes place, the level of smart controls and the level of distribution-centralisation of the charging infrastructure. Modelling has shown that distributed charging without smart controls would lead to 77.2% higher infrastructure costs than a baseline scenario (Calvillo & Turner, 2020). Alternatively, where smart charging is uniformly adopted, the impact on peak demand could be limited to an 8% increase overall (Catapult, 2018), demonstrating how important it is to coordinate planning and grid investment.

In all cases, investment will be needed in vehicles, charging infrastructure, smart technologies, new generation and the transmission and distribution network to facilitate the transition to EVs. However, the responsibility for investment lies with different actors within the system. Given the reliance on the electrical network, it is important to consider the lead times for capacity investment. As with other major infrastructure, a typical scheme to bring new capacity online might take five years in planning and delivery and is often dependent on local sensitivities (Catapult, 2018). Given the lead times and coordination required, local authorities should engage with their local DNO at their earliest opportunity.

In addition to the 2030 ban on petrol and diesel vehicles there is also another immediate reason to engage with the DNO — the Price Control Review. Price Control Reviews are the critical process for network operators through which the regulator sets policy, performance mechanisms and allowable revenues that a licensee may receive over the license period. In effect, the Price Control Review will set the level of investment in the grid in your area for the coming years. The next Price Control Review (called "RIIO-ED2") spans the period 2023 to 2028 with the majority of key evidence being consolidated through 2021.

The RIIO-ED2 Methodology Decision was published on 17th December 2020 and sets out the timeline for DNO engagement and business plan preparation. A key objective of RIIO-ED2 is to support the delivery of net zero at the lowest cost to the consumer supporting both strategic investments and innovation. To ensure a consistent starting point for investment, Ofgem will publish a common set of forecast assumptions and guidance in January 2021. The assumptions will not restrict DNOs from seeking input from local, regional or stakeholders and input is encouraged throughout the process. However, in bringing forward investment proposals based on local engagement, DNOs must be capable of justifying projections of anticipated demand (Ofgem, 2020). With draft business plans being required by July 2021 and final business plans by the end of 2021, the next few months provide an important window for local authorities to engage and present their evidence regarding the key grid constraints and investment priorities for their area.

Vehicle-To-Grid

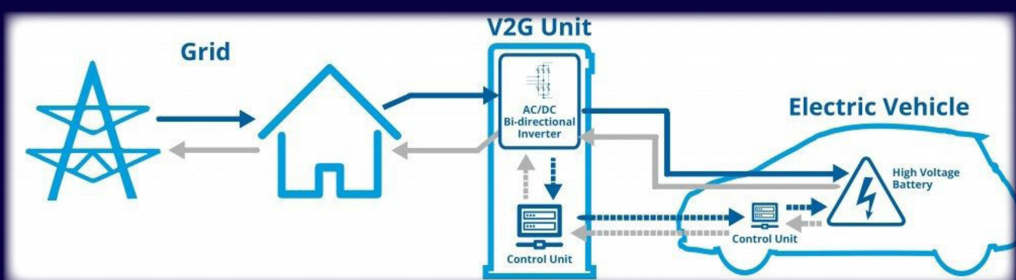


Figure 4: Vehicle-To-Grid diagram (Cenex, n.d.)

4. Electrification of Personal Vehicles

4.1 CONTEXT

Today's consumer profile for the electric car market is evolving from early adopters to mass adoption (IEA, 2020). The market has gained increasing popularity over the last five years due to the promising scope for decarbonising personal vehicles. In turn, this growth has supported a fast-paced evolution of EV technologies. As of September 2020, whilst the number of new petrol and diesel registrations have been falling, electric car registrations have grown by 165% compared to 2019 (SMMT, 2020). Despite this, new EV sales still only make up 5% of overall sales (CCC, 2020). EV uptake is therefore set to scale up even more rapidly over the next decade. The rapidity of this growth and the ban on petrol and diesel from 2030 illustrates the urgent need for policymakers to plan and prepare suitable infrastructure.

UK Government Roadmap

2030: The sale of petrol and diesel cars and light vans will be banned

2035: The sale of hybrid cars and light vans will be banned

4.2 BATTERY ELECTRIC VEHICLES (BEVs)

BEVs run solely from electricity supplied from an on-board battery that is replenished when plugged in to charge. BEVs therefore require relevant drive-up infrastructure to be in place to enable charging. For consumers, the main advantages of BEVs over Internal Combustion Engine Vehicles (ICEVs) are lower fuel and maintenance costs due to the relative simplicity of a battery-electric motor system (Little, 2016). However, barriers to adoption still exist and include:

Range Anxiety

"Range anxiety" is frequently cited as a barrier to BEV adoption (Pevec et al., 2019), however range has increased rapidly in recent years. Based on 2020 car registrations, the weighted average of range in the existing BEV fleet is now 195 miles. This is typically ample for day-to-day use but often not enough for users' more infrequent long-distance trips. Considering the growing number of charging points, range anxiety should diminish further over time.

Charging Infrastructure

Linked to range anxiety, the perceived availability of charging infrastructure is a further cause for concern for consumers (OIES, 2020). This is despite a total of 12,973 charging stations being available at the time of writing (Zap-Map.com, 2020a), in addition to claims that a driver is never more than 25 miles away from a rapid (50 kW) charge point anywhere along England's motorways and major A roads (OLEV, 2020).

Charging Duration

Charging times can vary from 20 minutes to 12 hours. Technological advancements are likely to reduce charging duration in the near future which is a positive development for consumers but adds complexity for planners as faster charging often requires higher power from the grid. Policymakers will need to ensure plans are future-proofed and frequently updated for the latest advancements in technology.

Upfront Cost

Despite running costs of BEVs being considerably lower than ICEV counterparts, the initial cost is a key deterrent due to "most consumers fail[ing] to factor in the total cost of ownership" (OIES, 2020). However, market projections suggest price equivalency with ICEs could be reached by the mid-2020s (House of Commons, 2018).

BEV Charging Infrastructure

Before developing a charging infrastructure strategy, it is important to understand charging from the perspective of EV users so that suitable infrastructure can be planned. For BEVs to be feasible and desirable, users must have convenient access to a charging point.

Charging Speeds

Speed of charging varies greatly and for faster speeds to be available the technology to do so must be supported by both the vehicle and the charge point. Home charging devices are typically slower and provide power over hours with the goal of charging the battery to the full. In comparison, rapid and ultra-rapid chargers provide power for <1 hour with the goal of quickly topping up the charge to facilitate immediate use to complete the journey. Table 1 details the characteristics of the four main categories of charging.

	Slow Charging	Fast Charging	Rapid Charging	Ultra-Rapid Charging
Power	3 kW to 6 kW (AC)	7 kW to 22 kW (AC)	DC units up to 50 kW AC units up to 45 kW	100 kW to 350 kW (DC).
Charging Duration	5 to 8 hours for a full charge for most EVs but around 12 hours for larger batteries.	2 to 5 hours to fully charge a battery depending on the power rating.	45 to 60 minutes for an 80% charge for a standard battery size.	Typically takes 20 to 40 minutes for an 80% charge.
Suitable Locations	Residences, places of work.	Supermarket car parks, shopping centres.	Motorway stations & major roads.	Motorway stations & major roads.
Connector Type	3-pin, Type 1, Type 2, Commando	Type 1, Type 2	CHAdeMO, CCS, Tesla Type 2	CHAdeMO, CCS, Tesla Type 2

Table 1: BEV charging types and attributes

Charge Point Location

Charge point location strongly influences how often they are used and how much revenue they generate (EST, 2017a). Generally, the more powerful the charger, the more expensive it is to install and operate. Furthermore, higher rates of charge increase demand on the grid and threaten to increase peak demand. For these reasons, it is necessary to optimise the location, number and speed of charge points (EST 2017b) and consider journey purpose.

Home Charging: The average car is parked at home for around 80% of the time (RAC Foundation, 2012) which means there is ample opportunity for home charging. For homeowners, the Electric Vehicle Home-charge Scheme covers 75% of charge point installation costs. However, obviously this necessitates space for charging and the authority to make changes to the property. In addition, around only 30% of UK homes have access to off-street parking. On-street charge points may therefore be required in many locations but these raise issues concerning street clutter, parking regulations, charger ownership and potential longer-term conflicts with planning for active travel where road space is constrained. Furthermore, 37% of houses in England are rented (UK Government, 2020). Whilst the government is reviewing the provision of charging point infrastructure for existing rented properties (HM Government, 2018), as of yet there is no policy that places the responsibility of installation on landlords.

Workplace Charging: The Workplace Charging Scheme provides financial support towards the up-front costs associated with installing charge points. Given the issues surrounding installing residential charge points for some residents, it is possible that additional funding by local authorities to increase workplace charging could act as a suitable alternative to home charging.

Destination and En Route Charging: Alternatively, charging can be provided in publicly accessible locations along natural routes. Facilities for destination and en route charge points (such as public and commercial car parks, retail centres and service stations) can present an additional revenue stream for land-owners and help to attract visitors. However, this will often involve different, rapid-charging infrastructure and potentially associated electrical infrastructure upgrades. Policymakers should therefore collaborate with business owners with appropriate advice and support to increase charge point infrastructure to facilitate access to key locations.

Further Considerations

Taxis, private hire and private fleets may also require additional infrastructure, support and incentives to transition to zero carbon fuels. Local authorities should consult relevant businesses to understand their current and future needs and prepare advice and policies to help them on the pathway to electrification.

4.3 HYBRID ELECTRIC VEHICLES

Hybrid vehicles are powered by both an electric motor and an ICE. In self-charging hybrids, the battery is charged solely by the ICE and not through an external plug. In contrast, Plug-In Hybrids (PHEVs) more closely bridge the gap between ICEV and EVs by allowing plug-in battery charging. Considering that the sale of new hybrid cars will also be banned from 2035, policymakers should prioritise infrastructure to support pure electric vehicles.

4.4 HYDROGEN-FUELLED VEHICLES

Although BEVs are predicted to dominate, hydrogen fuelling may also feature in future transport systems, particularly if it is aligned with hydrogen infrastructure and carbon capture to support the decarbonisation of heating (Catapult, 2018). Fuel Cell Electric Vehicles (FCEVs) use electricity to power an electric motor. However, the electricity is generated on board by converting oxygen and compressed hydrogen. By comparison, Hydrogen Internal Combustion Engine Vehicles (HIVEVs) use hydrogen in the same way as petrol and diesel vehicles. In both cases refuelling is similar to ICEVs, where compressed hydrogen is pumped into a tank at a fuelling station. There are generally higher barriers to adoption for hydrogen vehicles compared to battery electric vehicles including:

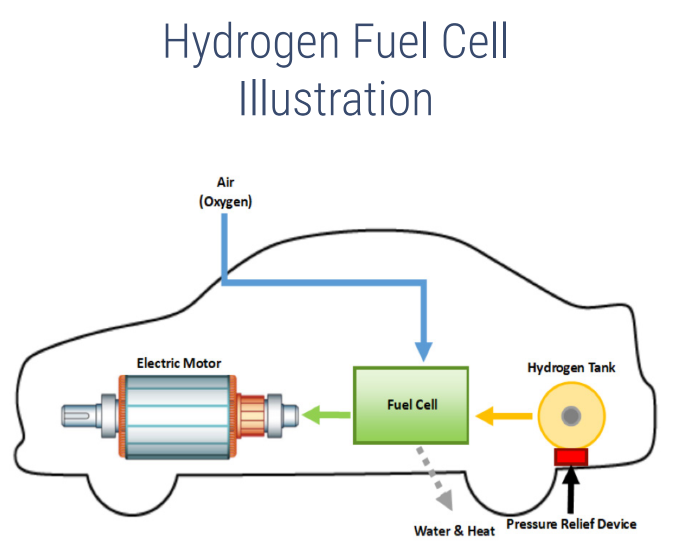


Figure 5: Hydrogen Fuel Cell Illustration

(Firehouse, 2017)

Technology Infancy: FCEV technology is less mature than BEVs and there are currently only 15 hydrogen pump locations in the UK (Zap-Map, 2020b). The future of FCEVs is more uncertain and is likely to take shape over a longer timescale (Catapult, 2018). Much is likely to depend on technological advancement within longer-range applications such as Heavy Goods Vehicles (HGVs).

Monetary and Environmental Costs: Until significant developments in hydrogen production have been achieved, the cost of hydrogen as a fuel for personal vehicles remains high and production processes may limit the carbon benefits if fully zero-carbon approaches cannot be cost-effectively developed.

4.5 PLANNING RECOMMENDATIONS

It is really important that local authorities have a clear plan to support the rollout of EVs in their area as soon as possible. To ensure their regions are EV ready, the following steps should be undertaken:

1. Engage Early: Early engagement is critical to ensuring policies, initiatives and investments are coordinated across the transport and energy sectors. In particular, it is crucial to engage with the local DNO at the earliest opportunity. DNOs will be drawing up draft business plans for the RIIO-ED2 process which will set out investment needs for the 2023 to 2028 period — a time when significant acceleration in EV uptake is likely to occur. Local policymakers should take steps to understand Ofgem's baseline demand forecasts to understand local impacts and to identify areas where use of local assumptions might be more appropriate.

2. Develop a Local Evidence Base: To support engagement with the DNO and other stakeholders, infrastructure planning and prioritisation and development of supportive policies, local authorities will need to develop their own local evidence bases. These will naturally consolidate a comprehensive understanding of the travel patterns of the local population and review current policies but will also include analysis that may not have previously been undertaken such as analysis of capacity on the electrical network, local generation and supply chains.

3. Model a Range of Policy Scenarios: Data modelling will strengthen the evidence base, enabling policymakers to clearly identify investment priorities under different conditions. Modelling can help to predict where EV uptake is likely to occur most rapidly, determine optimal locations for charge points and identify potential impacts on the grid. Furthermore, the impact of possible management practices (such as parking regulations and tariffs, smart charging capabilities and dynamic pricing) can be also be included in this modelling to demonstrate lowest cost solutions.

4. Develop a Clear Vision and Roadmap: The development of a clear roadmap based on the analysis will help to ensure there is certainty within the local area, that relevant funding can be secured, that the transition is achievable and that all stakeholders understand the necessary steps. The plan should encapsulate the wider system including the electricity network, overall CO_2 emission reduction and network investments to ensure effectiveness (Calvillo & Turner, 2020). Furthermore, clear and concise communication of the plan to the relevant stakeholders will be necessary to drive progress, increase confidence with the public and encourage adoption.

5. Address Policy Gaps: Through a review of policies and analysis, policymakers should identify and implement policies that will support the roadmap. NPPF supports the use of local parking standards to promote EV charge points. Likely policy areas to address include:

- Parking tariffs (such as emission-based charging regimes) and enforcement
- Clean Air or other Low Emission Zones
- Charging provision standards for new residential and non-residential developments
- Charging provision standards for existing residential and non-residential buildings
- Charging provision standards for rented housing
- Planning permission for charge points
- Council owned sites for EV charging
- Site locations and support for public rapid charging hubs
- Any changes to the local authority's own vehicle fleet
- Policies to ensure that the whole of society has access to EVs
- The phasing out of ICEV taxi fleets through licensing requirements
- Local incentives and initiatives to disseminate learnings and best practice
- BEV taxation to offset the expected declining in taxation revenue from fossil fuels

Low Emission Zone

(AA, 2019)

EV Parking

EV Refuse Lorry

(Transport Nottingham, 2020)

5. Bus Fleets

5.1 CONTEXT

The 2030 and 2035 ban on petrol and diesel vehicles excludes buses. Yet, the electrification of personal vehicles alone will be insufficient to fulfil the UK's net zero target (Logan et al., 2020). For this reason, major UK transport organisations have made commitments to net zero. The Confederation of Passenger Transport (which represents over 95% of the UK's bus industry) has pledged to only invest in low-emission vehicles from 2025 (Magee, 2020), National Express aims for their bus and coach fleets to achieve this by 2030 and 2035 respectively (National Express, 2020) and TfL aims for all buses to be net zero by 2037 (Mayor of London, 2018). The government maintains that in addition to fully-electric vehicles, other technologies (such as hydrogen) are still being considered as part of a zero-emission bus evolution (DfT, 2020b).

China's fleet of 400 000 currently makes up 99% of the world's total e-bus fleet (Margolis, 2019). Whilst China has been at the forefront of innovation and deployment, the progression of other countries is not accelerating fast enough to meet climate objectives (Li et al., 2019). Shenzhen in China required 8 years to achieve 100% bus electrification while in Belo Horizonte, the planning stages alone took 2 years. This suggests that local authorities with 2030 net zero ambitions must develop implementation frameworks immediately.

Last year in the UK, out of 32 000 buses total, only 377 were fully electric and 200 were located in London (Magee, 2020). Rollout continues to grow, with TfL operating 410 e-buses in January 2021. Oxford and Coventry were recently announced as the pilot locations for the UK's All-Electric Bus Town scheme which will extend the UK's electric bus pilots, developing learnings for local authorities by ascertaining opportunities, challenges and best practice (DfT, 2020). The pilots will compliment what is already being learned from international case studies.

5.2 LOW AND ZERO CARBON BUS TECHNOLOGIES

As with private vehicles there are a range of technology options including fully electric, hybrid and hydrogen-fuelled buses.

(GOV.UK, 2020)

Electric Buses (E-Buses): E-buses are battery powered and can be recharged using direct connection to the power mains, ground-based wireless/inductive chargers or overhead wires. These infrastructure options are typically installed at bus stations but could also placed along the route where infrastructure and funding allows.

Hybrid Buses: Hydrogen buses typically use a mix of diesel and electricity, to achieve a higher fuel efficiency. Hybrids can reduce emissions by 30% to 40% compared to diesel counterparts (GLA, 2019). However, as a hybrid technology they present an interim step rather than offering a solution to full decarbonisation.

Hydrogen-Fuelled Buses: Hydrogen-fuelled buses are a type of FCEV. Hydrogen is stored in tanks often located on the roof of the bus and only takes 3 to 5 minutes to fill. Similar to diesel counterparts, they currently achieve 250 to 400 miles on a single tank, however they are (and are expected to be) more expensive and less efficient than BEV alternatives (Transport & Environment, 2018). Furthermore, further research is needed to ensure that fully carbon-neutral hydrogen can be cost-effectively produced (GLA, 2019). TfL are introducing 20 hydrogen fuel cell buses in summer 2021 in order to better understand the technology and efficiencies.

Hydrogen bus fleets have the potential to also be a scalable technology solution for zero carbon fleets. Opportunities of hydrogen as a technology include fast refuelling times, lighter vehicles and potentially low grid disruption. Current challenges include technology uncertainty, the initial cost of infrastructure and higher fuelling costs based on current system efficiencies. However, with a sufficient fleet size and further technology support, fuel cost parity could be reached through economies of scale.

5.3 LOW AND ZERO CARBON BUSES: BARRIERS TO ADOPTION

While the deployment of low-emissions bus fleets is in its infancy, there are a number of shared implementation issues being experienced globally. Policymakers that hope to promote electrification of their fleet should make themselves aware of the barriers and planning considerations and ensure they have robust plans in place to facilitate engagement with government and the RIIO-ED2 process.

Technology Infancy: The infancy of zero emission technology and limited operational experiences creates considerable uncertainty for operators and planners. Confidence over vehicle range, vehicle availability rate, charging time, energy use, customer satisfaction and projected costs among others, are critical to designing successful bus services. While some early technological challenges have been overcome through international deployments, procurement and service models need to include mechanisms to manage the risks and uncertainties of using any new technology, while remaining flexible for further technological improvements.

Grid Considerations: A typical e-bus has a battery capacity of ~300 kWh. At the scale of hundreds or even thousands of e-buses the cumulative charging requirements could be considerable. Charging mechanisms are also often more centralized for e-buses than for private vehicles. Early planning to understand where charging is likely to take place and early engagement with the DNO is therefore essential to begin understanding the future local infrastructure requirements and timescales for power connection.

Land Availability: Bus operators often lack space within bus stations where the physical requirements for charging infrastructure, new distribution transformers and substations may be significant. At the same time, in many urban areas there is strong competition for space. The service and charging requirements will need to be considered alongside land ownership arrangements, site availability and the need for any further physical infrastructure.

Finance and Procurement: Traditional procurement models can often favour diesel buses which have a lower up-front capital cost and more established operational track record. As a result, the availability for private finance may be lower for zero emission versus traditional bus fleets. Questions around who should bear the cost for infrastructure and fleet upgrades present a further hurdle. Operators should be encouraged to consider the total cost of ownership working closely with the public sector to clearly delineate responsibilities and potential funding options for essential enabling infrastructure.

Institutional Barriers: Governance arrangements, requisite knowledge, available powers and national funding all present institutional barriers. Successful areas will need clear leadership with a collaborative ambition and suitable delivery structures that bring together and mobilise stakeholders towards the common goal. While the All-Electric Town Scheme will help explore best practice for governance arrangements in the UK, local authorities who don't receive funding through this route will also need to consider how they progress their plans.

5.4 PLANNING RECOMMENDATIONS

Local Authorities should not underestimate the planning challenges inherent in transitioning to zero-emission public transport. In most areas, transition to e-buses will represent a sizeable multi-year project. To more forward, policymakers will need to employ a strong directional and collaborative approach. We recommend the following key steps:

1. Create the Forum: Governance, communication with key stakeholders and convening relevant experts will be crucial for the project's success. As a first step, local authorities will need to define their ambition and establish a forum for working collaboratively with the bus operator, the DNO, spatial planners and sufficient technology and service design expertise. This will also be an important opportunity to engage with the RIIO-ED2 process. To increase technology developments and economies of scale, policymakers should also consider collaborating with other local or regional authorities to share knowledge and consolidate demand.

2. Develop a Local Evidence Base: A strong evidence base and demonstration that a number of options have been appraised will be essential. In most cases transitioning to a zero-emission fleet will not be as simple as replacing existing vehicles and routes with their electric equivalents. Instead, a whole systems approach will need to be adopted with business cases demonstrating holistic consideration of levels of service, technology, land availability, grid capacity, route choice, customer experience and cost. Development of adaptive and flexible models to test a range of service designs will be essential.

3. Take Learnings from Pilots: Carefully planned pilots can be important for managing financial and political risk and for ascertaining reliability, charging times and passenger experience (C40, 2020a). However, it will also be important to continuously learn from existing national and international pilots to reduce risk and cost. In the UK, so far TfL has engaged in extensive piloting and their findings could be relevant to your locality.

4. Develop a Long Term Roadmap: Based on the evidence a long-term route plan should be developed with key infrastructure upgrades identified. These upgrade plans should have actionable and time-bound targets for both funding and delivery to ensure alignment between infrastructure and service providers throughout the transition period.

5. Additional Considerations: Additional plans will also need to be made to mitigate new and emerging risks such as plans for battery recycling at end-of-life, continuity plans and service levels for unforeseen events such as power cuts and plans to ensure the electricity itself is transitioned to zero carbon sources.

6. Freight

6.1 CONTEXT

GHG emissions from vans and HGVs increased between 1990 and 2018 (DfT, 2020a). In an average UK region, freight is estimated to account for 30 to 33% of GHG emissions from road transport (City Science, 2020). Of this, 15% to 17% is likely attributed to HGVs, with 14% to 16% attributable to vans or light goods vehicles (LGVs), (City Science, 2020). At the same time, the importance of freight within our economy is growing. For example, it is expected that without intervention, the number of last mile delivery vehicles in major cities will rise 36% by 2030 (World Economic Forum, 2020).

Research by the Centre for Sustainable Road Freight has shown that it is not possible to reduce carbon emissions from the road freight sector by more than 60% without electrification of long-haul vehicles (Ainalis et al., 2020). However, electrification of long-haul vehicles presents significant challenges, stretching technology to support the movement of heavy loads over long distances. As a result, some of the solutions proposed for passenger transport do not work as well for freight (Greening et al., 2019).

As with private vehicles, essential steps to reduce demand should be undertaken as a priority within any freight decarbonisation strategy prior to addressing fuelling of residual activity from zero-carbon sources. Actions to reduce the energy demand from freight will include the following measures which should be considered alongside electrification:

> Greater Efficiency through improved fuel efficiency, vehicle design and fleet design, use of optimisation software and in-car devices to improve driver behaviour.
>
> Improved Logistics Efficiency to improve the efficiency of the overall distribution system, for example, addressing issues such as "empty running" (where it is estimated that at least 20% of trucks drive around empty), (Transport & Environment, 2018).
>
> Consolidation of deliveries through improved industry collaboration.
>
> Modal Shift including using post COVID-19 opportunities to increase the share of rail freight and, within urban areas, increasing the share of cargo bikes.

Beyond these efficiency measures, freight will ultimately need to be fuelled from zero-carbon sources. However, this presents a range of challenges including the early stage of technological readiness and the diverse nature of the road freight sector which comprises a diverse mix of vehicles and organisations.

Comparing 1990 and 2018 UK Transport GHG emissions by mode

Emissions from HGVs and vans have increased since 1990

DfT, 2020a

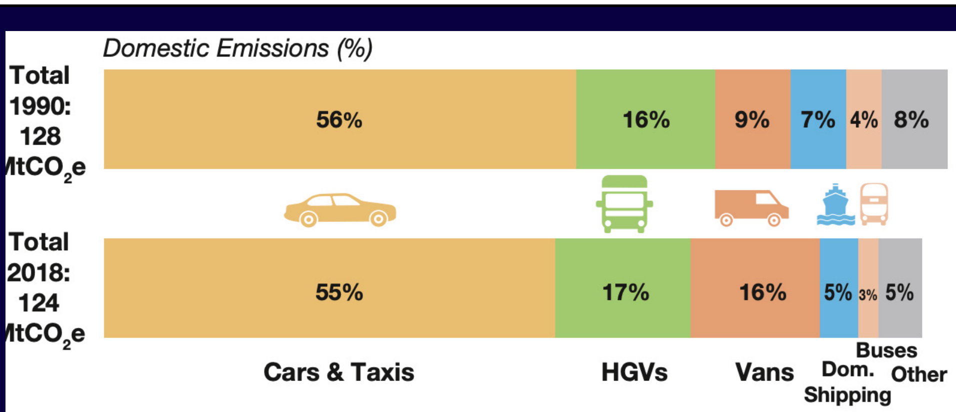


Figure 6: UK Transport GHG emissions by mode (DfT, 2020a)

6.2 LOW AND ZERO CARBON FREIGHT TECHNOLOGIES

As with private vehicles and buses there are a range of technologies that could be adopted with particular debate focused around the most appropriate technology for longer distance trips.

Battery Electric Vehicles (BEVs): Likely to be suitable for urban or last mile delivery vehicles, current BEV battery technologies provide adequate range and potentially reduced running costs. Over longer distances however, large batteries increase cost and weight, reduce payload capacity and also require long charge times. This has led to some authors to conclude that battery technology is likely to be unviable for longer distances. That said, technology continuing to develop with manufacturers such as Tesla already taking orders for their semi-articulated lorry with a 500 mile range.

Hydrogen-Fuelled Vehicles: Given the challenges with BEVs over long distances, hydrogen is also being explored as an alternative. For example, US start-up Nikola is currently developing hydrogen-fuelled trucks with a claimed 750 mile range and 20 minute refuelling time. UK based Arcola Energy's A-Drive hydrogen fuel cell powertrain is being optimised for heavy-duty fleets and faster refuel. Daimler also claims the technology has potential to succeed over the long term by bridging the gap between pure electric and ICEV capabilities for high-payload requirements (Daum, 2020). However, hydrogen has also been criticised due to its low efficiency, resulting high fuel costs, low technology readiness and current production methods (Ainalis et al., 2020; Greening et al., 2019).

Alternatives: As with private vehicles and buses, hybrid options are available. However, hybrid light vans will be banned from 2035, deeming them an unsuitable solution for last mile deliveries moving forward. For HGVs, gas-electric plug-in vehicles could act as a bridging solution between 2025 to 2040 whilst fully electric options are being developed (ETI, 2019).

In addition to the above individual technologies, novel power delivery systems have been proposed, for example an "Electric Road System" or "E-highway" (ERS). An ERS utilises technology similar to a tram or electric railway, enabling vehicles to collect power through contact with an overhead line via a pantograph. A number of studies have concluded that ERS are likely to be the most cost-effective route towards zero/low emission trucking (Transport & Environment, 2018; Ainalis et al. 2020). However, implementation in the UK is likely to be contested due to practical implications including the visual impact of overhead wires, safety concerns and the ongoing maintenance costs for the road network (DfT, 2017).

(Scania, 2016)

6.3 PLANNING RECOMMENDATIONS

The uncertainty around the most appropriate zero carbon freight technology is creating considerable inertia within a sector that represents a considerable proportion of carbon and other emissions. Local authorities wishing to accelerate decarbonisation will need to take an active role in engaging industry and government to unlock the pilots, funding and innovation necessary for success. We recommend the following key steps:

1. Convene Key Stakeholders: Communication channels with key stakeholders, including local operators, will be essential for the development and delivery of a freight decarbonisation strategy. Sub-national transport bodies will also be essential, often conducting research and strategy development over the larger areas where long-distance freight operates. As a first step, local authorities should define their ambition and establish a forum for collaborative working. Given its increasing importance, local authorities should also ensure that freight is considered as a core part of their Local Transport Plan.

2. Consider Coordination Across Different Scales: Strategies for freight will be different at different geographic scales. For example, within an urban area, transition to zero carbon last mile deliveries could be achieved with existing technologies through a combination of suitable charging infrastructure, incentives, education, and support. Across larger areas local authorities may wish to focus on appropriate freight routes to site refuelling infrastructure and promotion of best practice across wider regional stakeholders. Policymakers should ensure their governance arrangements engage the right stakeholders for different geographies and that the evidence base is suitably granular to enable localised insights.

3. Freight Modelling and Evidence: A comprehensive understanding of local freight movements and operational requirements will be required to underpin future solutions, technological developments and roadmaps. Local and regional knowledge sharing will provide a valuable source of information (C40, 2020b) as will modelling to in-fill data that is often difficult to share due to commercial sensitivities.

4. Scenario Modelling: In addition to consolidating data on freight movements, local authorities should also engage with freight operators to understand their existing fleet upgrade plans (if available). Where plans are not yet developed or high uncertainty still remains, technology roadmaps could be developed through stakeholder workshops. Collectively this evidence can be consolidated into a series of scenarios to inform energy systems and infrastructure planning, while considering technology uncertainty.

5. Develop a Strategy: Robust data and scenario modelling will help structure and prioritise activities and policies based on the regional objectives. Analysis will also help identify which freight movements will be addressed by different policies or interventions and allow the impacts of different initiatives to be assessed. The strategy should also identify which interventions can be implemented immediately (for example, movement restrictions within the local authority's control) and those that will require piloting to build confidence in, or secure industry buy-in for a particular technology or process.

7. How City Science Can Help

City Science was established in 2015 with the sole mission of helping our partner organisations decarbonise. It was clear to our founders that the traditional tools and techniques were not well-equipped to accommodate sustainable transport, or decarbonisation. Over the last five years we have developed cutting-edge methods to provide robust evidence, analysis and strategic planning to converge transport, energy and decarbonisation. It is for this reason that our clients come to us for software and services covering:

- Local area energy planning
- Development of local evidence bases
- Decarbonisation strategies
- Public transport strategies
- Freight strategies and modelling
- Demand and scenario modelling
- Integrated modelling of transport and energy systems
- Multi-criteria optimisation of transport and energy systems

CADENCE

Cadence is our award-winning data management and visualisation platform for transport models. Cadence has recently been updated to support electrical network data enabling visualisation and analysis of forecast future demand patterns, key network constraints and investment priorities.

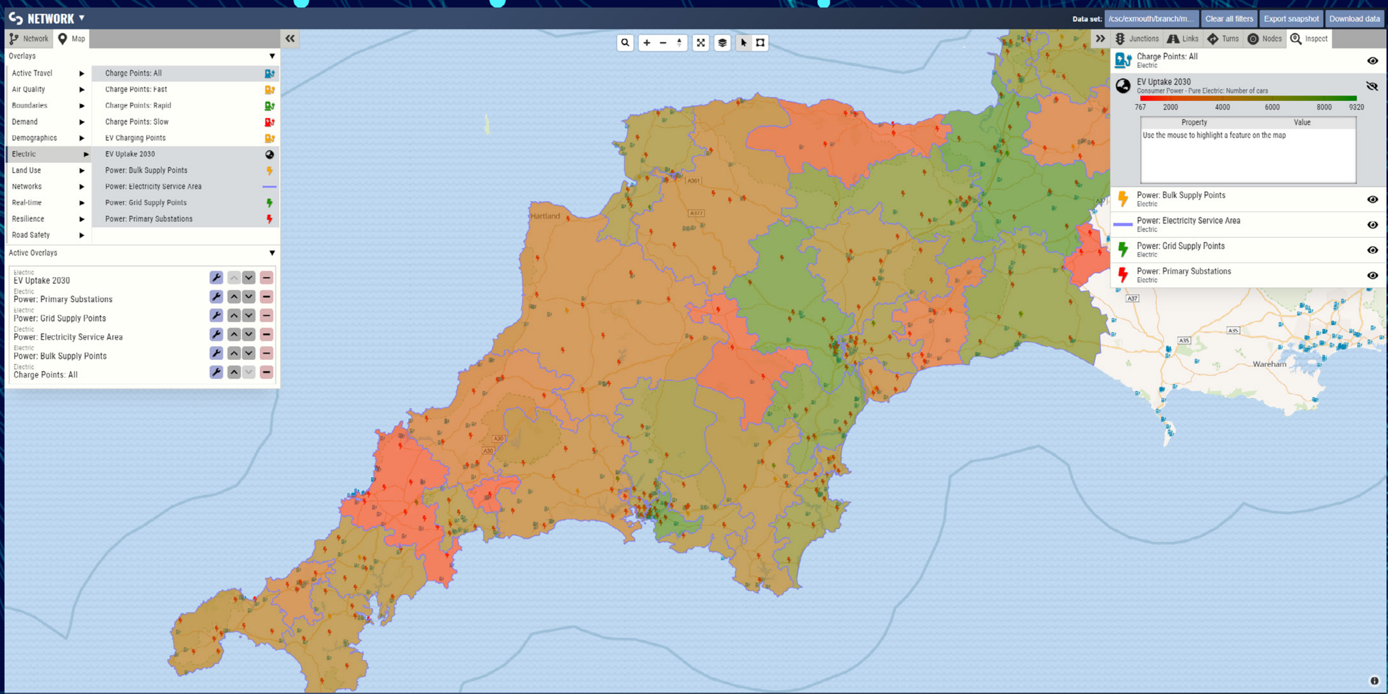


Figure 7: Example EV Uptake Scenarios, ESA, BSPs & Charging Infrastructure for SW England

CONTACT US: For further details or to talk to a member of our expert team, please contact us at info@cityscience.com

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