Centre for Net Zero
Powered by Octopus Energy

Electrifying Transport

Centre for Net Zero:
Review of existing research for the UK market

July 2021

About Us

Centre for Net Zero is an Open Research Lab leading ground-breaking research on the biggest questions in the energy transition; making our data, models and reports freely available for everyone to understand, challenge and build on.

Our mission is to realise faster, fairer and more affordable paths to net zero, to secure our planet's future for generations to come.

We're backed by Octopus Energy, a leading industry innovator. Our research is informed directly by real world scenarios and insights from the front line of the energy industry.

Electrifying Transport

What is this document?

What is the status quo?

Where do we see the biggest gaps?

What is this document?

This document summarises published evidence about how to electrify cars and vans within the UK and where there are gaps in understanding. The document is the result of a review of more than 70 items of regularly and recently cited academic and industrial analysis, conducted by Centre for Net Zero in June and July 2021.

It follows our review of research for the decarbonisation of home heating published in June.

We have sought to prioritise accessibility - this document is therefore considerably shorter than more traditional literature or evidence reviews. We welcome feedback, particularly in cases where we have missed or misconstrued certain analysis. We intend to update this document regularly to reflect our best view.

What is the status quo?

Electric vehicles are increasing their share globally, but there remain barriers to mass market adoption, including economic, technical and social factors.

Research has traditionally focused on the optimisation of the grid to support EV deployment, different charging methods to provide ancillary services and benefit customers, and improvements in battery costs. By contrast, there has been less focus on social factors that influence the adoption of electric vehicles.

Where do we see the biggest gaps in existing research?

Research need	Our plan
Explicitly considering the fairness of the EV transition, addressing issues including up-front costs and availability of charging solutions.	Rather than considering impacts and tipping points 'on average', we are creating an agent-based model which reflects the diversity of UK households and businesses and can simulate their behaviour in response to policy and technology changes. We will explore the potential for targeted interventions to create a more inclusive and equitable transition.
Building a detailed understanding of real-world charging behaviours and flexibility.	Drawing insight from smart meter data and other sources, our work will reflect real-world use of EVs, different charging patterns and response to changing electricity prices. We will consider what data we can share to support the wider research community.
Learning more about how decarbonisation of transport and heating can complement one another.	Our agent-based model will cover the decarbonisation of both heat and transport and explore the relationships between the two, including household attitudes, network requirements and flexibility to adapt consumption profiles.

Contents

The case for electrification

1 - Greenhouse gas emissions

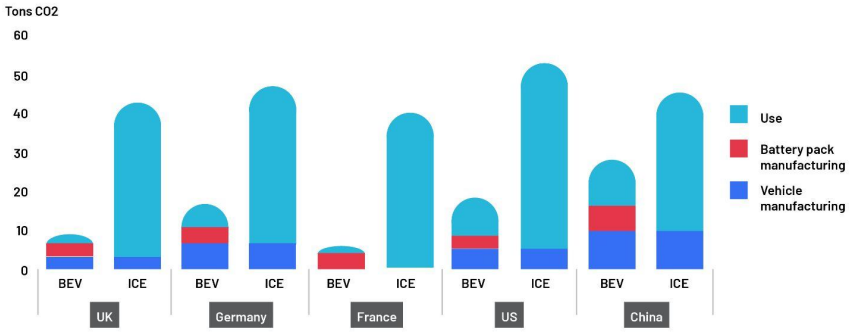
Transport was the largest contributor to UK greenhouse gas emissions in 2019, accounting for 27%, with 19% coming from cars and vans alone [1]. Electrification can have a major impact in reducing these emissions, particularly as electricity is increasingly sourced from renewables.

Fuel consumption is not the only source of GHG emissions derived from vehicles; emissions from production and end-of-life also need to be considered.

- Production: Manufacture of battery-powered electric vehicles (BEVs) can release 5-7 tCO2e more than the equivalent internal combustion engine (ICE), which is broadly attributable to production of the battery pack [2,10]. Batteries also use scarce materials such as cobalt
- Use: This phase accounts for more than 50% of the total GHG emissions for BEVs [3,4], directly related to the production of electricity, which accounts for 90% of the total impact in this phase [3]. Several studies concluded that **even if the integrity of the electricity mix was based on coal, BEVs would still be significantly less polluting than PHEVs and ICEs** [5,6]
- End-of-life: Different materials can be recycled from both types of cars, such as glass, steel, aluminum, copper, plastic, etc. Recycling and proper disposal reduces the environmental impact in the life cycle of these vehicles [3,7]

BEVs can lead to a reduction of 47% air pollution levels even where electricity is not produced from renewables [5]. However, a global share of 26-40% of BEVs is required to have a significant effect on air quality improvements [8,9].

Life-cycle emissions of medium segment BEVs and ICEs produced in 2020 and used for 250,000 km in different countries [10]



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2 - Policy interventions

There were 10 million electric vehicles on the roads globally in 2021, representing 1% of total vehicles. Of those, two-thirds were pure battery EVs, as opposed to plug-in hybrids [1]. In the UK, EV car registrations doubled in 2020, reaching 176k new registrations of which 62% were BEV [1]. These figures fall considerably short of the numbers we need to hit decarbonisation targets.

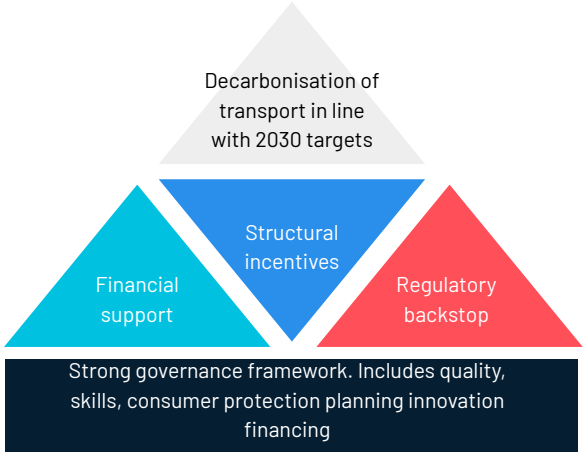
As a response to this, the UK government has offered grants for EVs. These were launched in 2011, extended in the Budget 2020 [2] and again in March 2021 [3]. The UK government's ten point plan [5] sets a date of 2030 for the end of petrol and diesel cars and 2035 for vans.

Funding has also been made available to develop charging infrastructure [4]:

- £400m charging infrastructure investment fund
- £500 grants for EV owners to install home charge points
- Push for charge points to be installed in new build homes and lampposts

Following the recommendations from the CCC [6], the government should develop a comprehensive policy package to support the supply and uptake of EVs to enable the delivery of the 2030 phase-out of new petrol and diesel cars and vans. This means not only direct grants, but stronger infrastructure support, strengthening the supply chain nationally and ensuring fairness and transparency for consumers.

A wide range of policy levers have been proposed [9]



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Critical factors for EV adoption

3 - People & behaviour

The UK has one of the highest EV adoption rates in Europe, following Germany and France in absolute terms only [1].

Research shows that the majority of UK EV owners purchased them to reduce their environmental impact and benefit from reduced taxes [2].

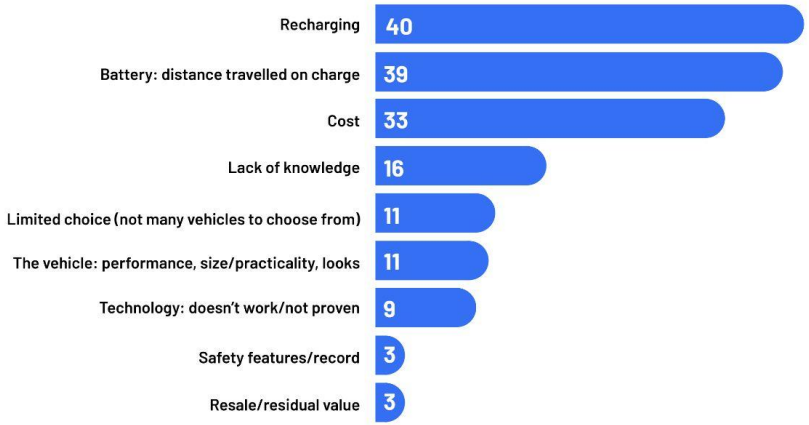
Current EV owners are predominantly wealthy, young or middle-aged families with access to off-street parking, with salaries of £46,000 per year or more living in detached or semi-detached houses, where private parking is available [2]. While 70-80% of UK households have access to a private garage, driveway or carport, which could be used for home charging [3,4], millions of homes remain reliant on public charging infrastructure -particularly in cities-.

The high cost of EVs is a concern for a third of people, but even more prevalent is 'range anxiety' and concerns about the time taken to charge the vehicle [5]. Moreover, the lack of an established second-hand market currently limits EV adoption to more affluent consumers [2,6].

40% of the population surveyed in the UK considers green time-of-use tariffs as important to adoption. These enable consumers to use electricity at times when it's more readily available and cheaper. EV owners are more likely to consider renewable technologies to heat their homes [2].

Improving on-street charging points and reducing prices for BEVs are therefore critical to achieving a fairer transition that works for everyone.

Factors deterring people from buying an EV in the UK [7]



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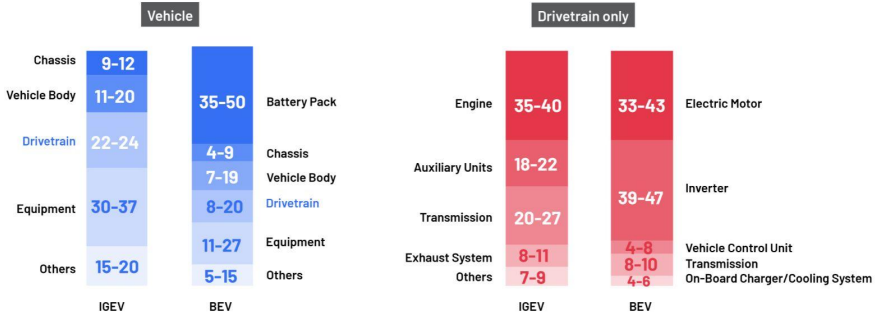
4 - Cost of BEVs

One of the main factors limiting EV adoption is the high upfront cost [2]. The battery accounts for up to 50% of the total vehicle for BEVs [2,4], making vehicles 40-60% more expensive than comparable ICE vehicles on average [4]. However, continued cost reductions in the manufacturing of Lithium-ion batteries is expected to bring BEVs to parity with ICEs as soon as 2025 [4,5].

As a relatively nascent market, there have been a limited number of models available to date. In 2016, only 30 different EV models were present in the EU according to the EEA [3]. By 2020 more than 370 EV models were available worldwide (BEVs and PHEVs) [1].

In terms of operating costs, BEVs have a significant advantage over petrol and diesel vehicles, since the former are more efficient [3,6] and electricity prices are lower. However, there are some concerns about equality and fairness due to the fact that customers without access to off-street private parking can pay as much as five times more for electricity to charge their cars [7].

Batteries are the main contributor to high CAPEX in BEVs [2]



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5 - Charging points: speed

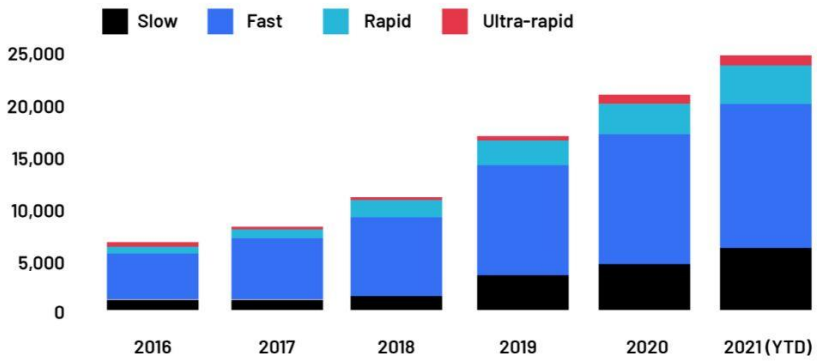
The UK has more slow charging points than most European counterparts. However, compared to 2019 values, the proportion of slow chargers has decreased considerably, from 20% in 2019 to 7% in 2020 [1]. The major motivation for purchasing home charge points in the UK, usually from the dealership or an electricity supplier, was a faster charging speed compared to a regular electricity socket [1].

The European Alternative Fuels Observatory showed that the number of EV charge points per 100km of road in the UK has increased from 42 in 2011 to 570 in 2019. Despite this, most charge points still have a charge rate of less than or equal to 22kW [2,3].

Apart from the number of chargers and connectors, the quality of service provided needs to be taken into account. The minimum requirements that these chargers should provide include [4]:

1. 24/7 availability in an open and non-discriminatory basis
2. The provision of fair and transparent prices
3. An up-time requirement of 97%
4. Standard interoperability protocols for communication between the EV, the charger, and the central management system
5. Compliance with smart charging and other smooth grid integration minimum requirements to offer ancillary services to the grid and better prices for the final consumer

Number and type of charging points in the UK [1]



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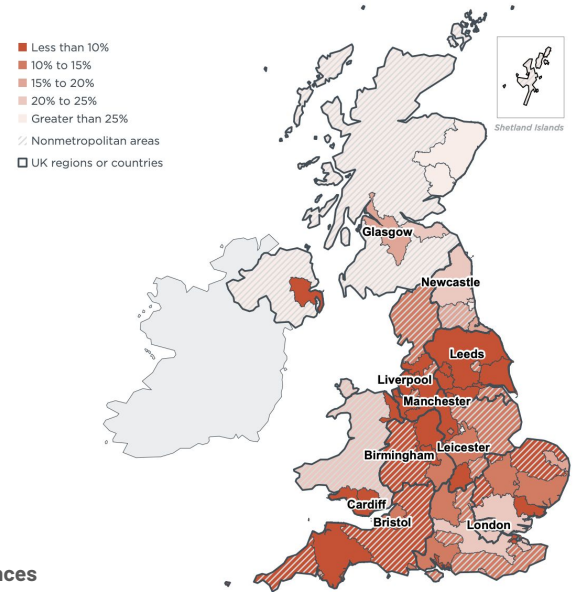
6 - Charging points: coverage

As highlighted previously, there are issues around equality that have to be addressed to properly stimulate EV adoption across the country.

In the UK, approximately 140k charging points are installed in private, off-street parking spots. By contrast there are around 25k public charging points at 15k locations[1], of which 4.5k are 'on-street' [2]. More than 7.8 million UK households without off-street parking would require efficient public charging to adopt BEVs. Currently, only 10% of these households have access to public charging within a five minute walk, and each public charger has to serve 55 cars on average [2,3]. As the number of EVs grows, more public chargers will be needed to offer services for these drivers. It has been estimated that a third of fleet cars will also be dependent on on-street charging stations [3]. Estimates for the required scale of public charging in 2030 range from 400k to 2.3m[4,5].

Moreover, local authorities are not obliged to provide electric charging points. In January 2018, just five councils in the whole of the UK had taken advantage of the On-Street Residential Charge point Scheme [6], and some councils have had complaints due to the installation of charging stations [7]. There is clearly a lot to do to bring chargers to the wider public.

Charging infrastructure in 2019 as a percentage of that needed by 2025 [8]



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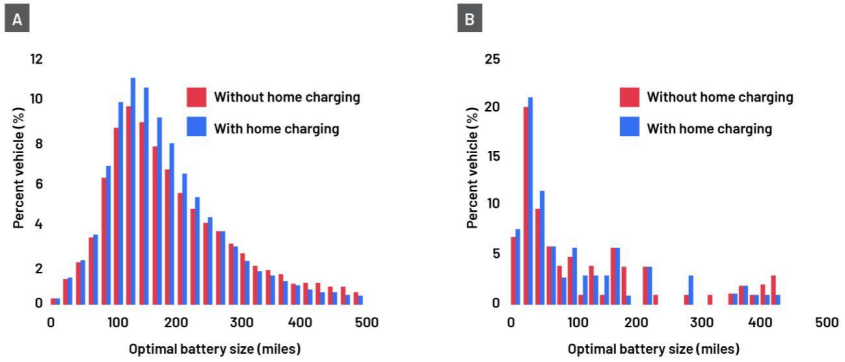
7 - Battery sizing

With almost 20% of the total market share of BEVs in the UK, the Nissan Leaf is the most popular BEV in the UK [1]. Its characteristics satisfy private consumer needs (such as commuting to work) and allow for vehicle to grid and smart charging [2]. However, as more models continue to enter the market with different battery ranges and characteristics, cost parity between BEVs and ICEVs is expected to be reached in 2025 [3].

The distance these cars can travel with a fully powered battery is an important metric to assess their viability for different uses. Smaller batteries are cheaper and lighter, but could also exacerbate range anxiety [4,5]. Larger batteries are most costly to manufacture [6] and can distort charging behaviours and load profiles [7,8].

The critical question to address is the minimum battery range required for private use and fleet BEVs to satisfy customer needs and improve utilisation of public grid connections across the UK. The answer is not universal or easy to address. Studies have tackled this issue in different geographical areas in the world, with a focus on China [9,10]. They show that EVs with battery ranges below 300 miles are enough to cover different transportation needs for both private and fleet BEVs.To minimise the need for large batteries, further investment in public charging points and a better utilisation of infrastructure are paramount.

Optimal battery size for taxis (a) and private vehicles (b) in Beijing [9]



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Adoption & Impact

8 - Expected EV adoption

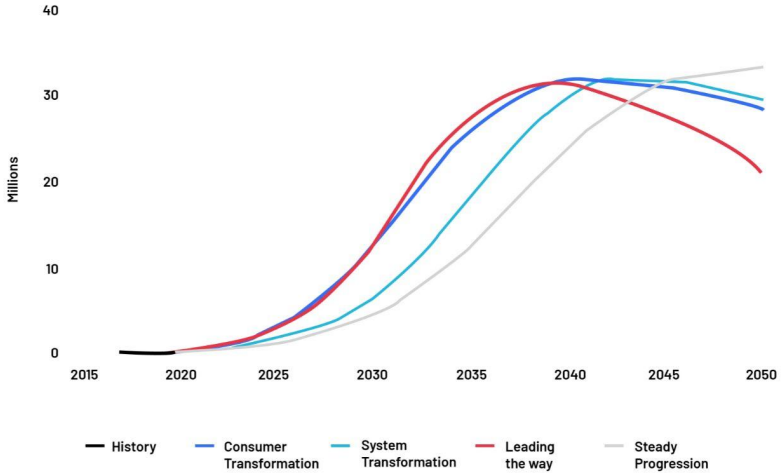
Many organisations and studies have taken different approaches to forecast the adoption of BEVs [1-3]. In the interest of simplicity, we have only considered official European or UK governmental scenarios.

The European Federation for Transport and Environment expects 225k charging locations to be built in the UK by 2025 and 500k by 2030 [4].

The UK government bases its analysis on the number of EVs on the annual projections provided by National Grid [5]. In their Future Energy Scenarios, four different scenarios are considered in which the electrification of transport is key to achieving net zero targets. Even in their slowest decarbonising scenarios, from 2040 there are no new ICE or PHEVs sold, leading to a completely electrified fleet by 2050 at the latest [6]. Under all National Grid scenarios, there is an exponential increase in the number of EVs through 2030, with some reduction in the number of EVs on the road by 2050 due to greater use of public transport and/or shared mobility solutions.

Hydrogen and biofuels are conventionally considered essential to decarbonise heavy duty vehicles [6], but some assert that their electrification will quickly become viable [7].

Number of BEVs on the road that National Grid estimates throughout 2050 in their Energy Future Scenarios [6]



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9 - System impacts and flexibility

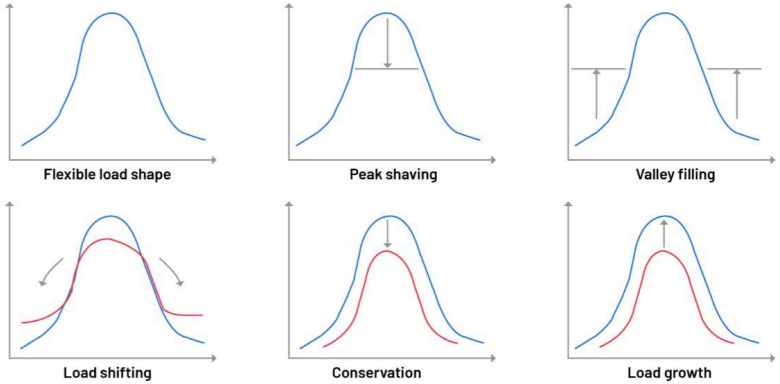
The introduction of EVs to decarbonise the transport sector could potentially reduce its total energy consumption due to technology and efficiency improvements[1].However, that energy demand needs to be supplied with electricity (rather than petrol/diesel). According to the scenarios projected by National Grid, this increase in electrical demand could be as high as 100 TWh [2].

The UK's electricity infrastructure has been built to reliably cover episodes of extreme peak loads with a procurement target of 110% of the maximum expected demand [3]. If not properly planned and managed, the addition of EVs and heat pumps could require transmission and distribution network upgrades costing up to £40 billion [3,4]. However, both EVs and heat pumps could actually help alleviate these problems by shifting their loads and providing demand side response (DSR) [4].

There are two fundamental ways in which EVs can help reduce the peak load:

- Smart charging: charging is scheduled according to a time of use tariff, or in response to a control signal (e.g. from a system operator). This effectively reduces the peak load and spreads it over other hours of the day, reducing the need to install additional capacity [5-9]. Some companies, like Octopus Energy or EDF, offer such smart tariffs [10,11]
- Vehicle to grid (V2G): covered in the next section

Different methods to avoid peak periods [12]



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10 - Vehicle to grid

Vehicle to grid (V2G) charging refers to the capability of an EV to export electricity from the battery to the grid to provide various grid services [1,2]. In order for V2G to scale, some fundamental issues must be addressed:

- Costs and ability to monetise flexibility: V2G chargers are currently significantly more expensive than smart or conventional chargers [4]. Additionally, National Grid requires each unit to be physically inspected on site [4]. New policies will have to be introduced to make V2G viable [3,5]
- Aggregation model: An aggregator is an agent that brings together the capacity of many batteries to control their charging/discharging behaviour [3]. There is no single model for how V2G revenues are shared between aggregator, customer, charge point owner and automotive company [4]. Regulation is yet to be defined and more work is required to properly assess its validity to provide the benefits mentioned
- Battery degradation:since the battery will need to charge and discharge more frequently to provide V2G services, this process can decrease the internal resilience of the battery and therefore the available battery capacity over time [6]

Despite these challenges, some studies have already shown the potential benefits of V2G technologies [1,5,7], and there are some studies that are assessing the validity of this solution in real life [8,9]. Even though more evidence is needed to conclude the real-life costs savings and earnings of V2G compared to other technologies, preliminary studies show that there might be several advantages in terms of CO2 reduction and costs.

Benefits of V2G services (right) compared to conventional (left) and smart (centre) charging methods [7 adapted]

EV types			
Whole-system benefits (£/EV/year)	567-773	102-150	412-883
Carbon benefits ($g/CO_2/km$)	37-52	36-50	48-243

Negative impact Positive impact

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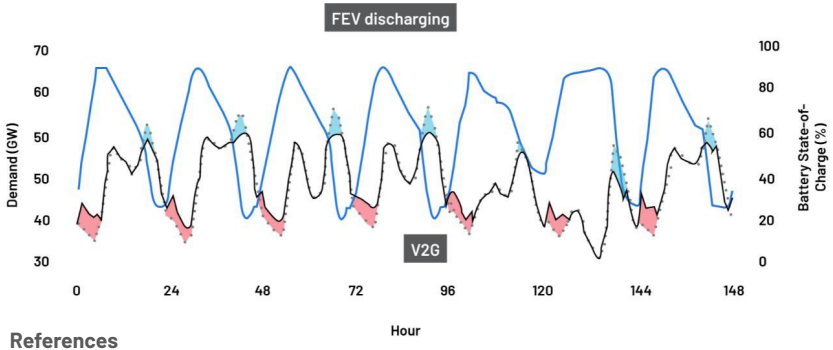
11 - Fleet management

The electrification of company-registered vehicle fleets is a critical component of the energy transition. In the UK, fleets account for around 50% of new vehicle registrations. Businesses and organisations replace vehicles more regularly than average households (typically every 4-6 years). They may have particularly stringent requirements for range/charging, vehicle type and cost. Where fleets regularly 'return to base', the availability of sufficient network capacity is a significant consideration.

When scheduling fleets and their charging, new approaches will be needed to take account of charging requirements [1]. Some of the main challenges include optimising the total energy cost by minimising energy losses [2], improving operations [3], reducing peak charging requirements [4,5] decentralised coordination for cost reductions [6] and grid performance improvements while fulfilling energy requirements for a large EV fleet [7].

Different EV fleets might present radically different needs and characteristics: it is not possible to optimise a rental EV fleet or a taxi fleet in the same way as a privately owned fleet that operates in an established pattern [8]. In particular, fleets which 'return to base' each evening will present different challenges to those that 'return to home' with the employee. Others may depend on public charging infrastructure (such as rental cars and taxis) [8,9].

Fleet management can help flatten the demand curve [10]



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12 - Supply chains

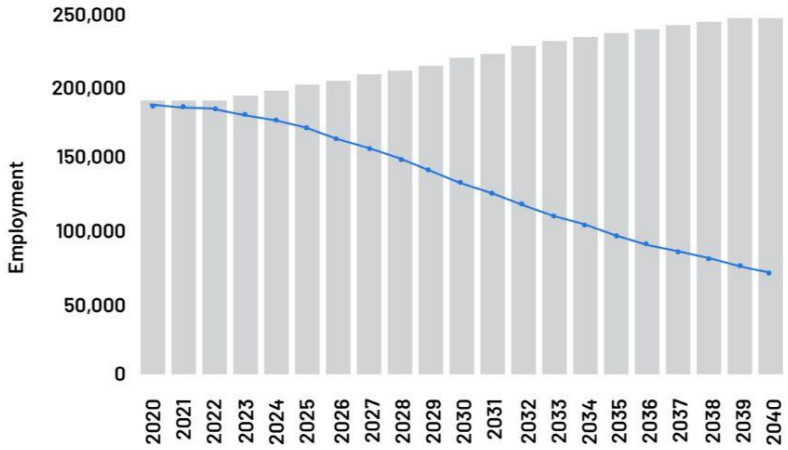
Batteries are one of the most important components of a BEV. Asia has dominated the manufacturing of batteries and has driven down its cost. In turn, this has led to the UK and Europe becoming heavily dependent on Chinese exports. This situation has been exacerbated by a slow response from vehicle manufacturers and limited governmental support until just a few years ago. However, the EU is aiming for a battery production as high as 130 GWh by 2023 [1,2].

With the expected demand projections, the UK could support one battery manufacturing facility by 2022 and a second one by 2025 [3]. Tesla recently committed to its first European factory, to be built near Berlin in Germany "due to Brexit"s uncertainty" [3,4]. Despite this, Nissan announced in early July 2021 that they will invest more than £1bn in their EV and battery factories in Sunderland. This investment will potentially result in the creation of 4,500 new jobs across the EV supply chain [5]. Moreover, Britishvolt has recently announced that £2.6bn will be invested in a new gigafactory that could potentially produce as much as 300k batteries for electric cars by 2027 [6].

If the UK is not able to attract more investment into the construction of these gigafactories, there is a risk that the car manufacturing industry will eventually move closer to the location of battery production. This means that the automotive sector in the UK could be severely affected, with the potential loss of 114k automotive jobs [3].

A study by McKinsey suggests that £5-18bn needs to be invested into battery supply markets in the UK by 2040 [7] and the Faraday Institution expects 8 national gigafactories to be built by 2040 in order to satisfy UK demand [2]. This could benefit the automotive sector with the creation of 83k new full-time equivalent jobs by 2040 [3].

UK automotive industry jobs to 2040 in the absence Of battery manufacturing [3]



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