CHARGE

Transport Model Final Report

Method, Findings and Conclusions

The Charge Project
February 2022

ea technology

PTV GROUP
the mind of movement

smarter grid solutions

1. Introduction

The Charge Project aims to accelerate the planning and connection of public charging infrastructure for electric vehicles (EVs) at the lowest possible costs to GB electricity customers by maximising the use of existing electricity infrastructure assets.

It is essential that GB distributed network operators (DNOs) help enable the transition to EVs and assist the Government in meeting its climate change targets. They have to facilitate the timely and optimised connection of future public EV charging infrastructure to avoid delays, and develop clear guidance and connection standards to expedite the uptake of EVs.

The Charge Project is a blueprint for other DNOs that shows how best to make use of their existing assets, plan for future upgrades, and signal to the industry where network capacity or other flexible solutions are needed. A key component of this blueprint is a transport model.

1.2. Why A Transport Model?

A transport model helps to understand the potential future energy needs of EVs, and therefore to anticipate the requirements for future public charging infrastructure.

The Charge Transport Model focuses on the Manweb region, SP Energy Networks' (SPEN's) licence area covering North and Mid Wales, Liverpool and the Wirral, and parts of Cheshire and Shropshire, as shown in Figure 1 below:

Figure 1: SP Manweb Region/Area of Interest for the Charge Project

Transport models are digital representations of the movement of people using a transport system. They allow transport planners to understand, diagnose and plan mitigation of issues related to the movement of people, such as congestion, for both now and the long-term future. Models are used to assess a range of travel modes, including car use on the road network, and are traditionally calibrated to represent and answer the following:

- **How many** car journeys are made across an area on a typical day or time of day?
- **Who** makes car journeys?
- **From and to where** do car journeys take place?
- **Which route** do cars take to complete their journey?
- **What level of traffic** do these journeys create, and what impact does the transport network have on route and journey choice?

Innovations in the Charge Project extended the usual capability of transport modelling software by developing a representation of EVs and their energy requirements at an individual car level. A DNO can therefore use a transport model like this to explore the following questions:

- How might EVs be driven in the future?
- Where might EVs be parked in the future?
- How might the demand for electricity grow, and how will this affect network capacity and resilience?
- Where is charging infrastructure needed, and where are connection requests likely to be?

1.3. Purpose Of This Report

This report provides a blueprint for other DNOs to enable them to consider the benefits of a transport model and how a model could be implemented for their regions.

The report summarises the development process of the Charge Transport Model and considers how other DNOs can utilise the lessons from the Charge Project. The following is a summary of the sections included within this report:

- **Building A Transport Model:** This section describes how a transport model is built, with examples of how this was done for the Charge Project. The transport model provides the underlying person movements that are input into the EV Scenario modelling.
- **Scenario Planning:** The future of EVs could play out in many different ways, yet it is important to consider the most important plausible futures to guide planning for EVs. This section describes the process for identifying a range of important plausible futures and the scenarios that were used for the Charge Project.
- **EV Scenario Modelling:** This section describes how DNOs can combine a transport model with the outputs from scenario planning to construct future EV scenarios.
- **EV Scenario Outputs:** This section presents the kind of outputs that can be extracted from future EV scenarios, using one of the Charge Transport Model scenarios as an example.
- **Summary:** The report concludes with a summary of the overall blueprint for a DNO to implement its own transport model and the benefits this would bring.

2. Executive Summary

The mass adoption of electric vehicles (EVs) is imperative if the UK is to reach its 2050 emission commitments and net zero aspirations. Yet for many drivers, the transition to EVs will be unrealistic without greater access to public charging infrastructure, with approximately 30% of cars parked on street overnight[1].

Distributed network operators (DNOs) have a vital role to play in facilitating the timely and optimised connection of future public EV charging infrastructure and developing clear guidance and connection standards to expedite the uptake of EVs.

One of the primary aims of the Charge Project is to help DNOs fulfil this role by maximising the use of existing electricity infrastructure assets, while identifying where additional network capacity may be needed in the future. As such, a key focus of the project has been on the development of a transport model, which provides scenario-based forecasts to help anticipate the charging demand and public infrastructure requirements for EVs.

One of the primary aims of the Charge Project is to help DNOs fulfil this role by maximising the use of existing electricity infrastructure assets.

This report describes how the Charge Transport Model – the first of its kind in the UK – was built and details the results that were generated. It is intended as a blueprint for DNOs that wish to understand future demands for EV charging and infrastructure requirement, and make this information available to other bodies such as Local Authorities or chargepoint operators (CPOs).

The Charge Transport Model covers SP Energy Networks' Manweb licence area: North and Mid Wales, Liverpool and the Wirral, and parts of Cheshire and Shropshire. The model's purpose is to guide and inform charging infrastructure decision making by providing insight into the following areas:

- The scale of requirement for EV infrastructure
- How infrastructure needs differ by area
- The likely use case for infrastructure by location
- The effect of EV charging demand on the electricity network

The Charge Transport Model can be freely accessed by anybody via SP Energy Networks' ConnectMore online tool.

The scenarios developed for the Charge Transport Model underline that EV uptake and the subsequent demand for charging are subject to many external factors. While its On Course for Net Zero scenario helps to provide a vision for infrastructure rollout to meet emission reduction targets, the other scenarios describe plausible if less desirable futures, enabling planners to test potential infrastructure rollout against a range of possibilities.

All of the forecasts are based on modelling work and qualitative assessment using multiple criteria and assumptions, including future political and social uncertainty. Results contained within this report should therefore be treated in this context with independent analysis required if investment decisions are being made.

Table NTS0908 available at:
1. https://www.gov.uk/government/statistical-data-sets/nts09-vehicle-mileage-and-occupancy

The Charge Transport Model has already provided a number of key insights:

- If carbon reduction targets are to be met and EV uptake follows the necessary trajectory, networks should be prepared for significant growth in demand between 2025-2035.
  - In the On Course for Net Zero scenario, it's envisaged that EVs in SP Manweb will require about 700MWh electricity per day in 2025 (of which ~25% is estimated to be required in public spaces), growing to 3,000MWh per day in 2030 (of which ~35% is estimated to be required in public).
- The models suggest that by 2030, 50-65% of public charging will come from the 15-25% of drivers that can't charge at home.
  - As such, understanding the demographic of car owners without a driveway is key to planning for public infrastructure.
- Public charging patterns will likely change as uptake progresses, especially as a higher proportion of non-driveway owners switch to EV.
  - As such, it is important that consideration of travel patterns, demographics, household types, and human behaviours is combined with charging data to fully understand how the requirement for public charging might change over time.
- Ultimately, while EV uptake is unlikely to be equitable across society over the next 10 years, the rollout of public infrastructure can play a crucial role in making EVs more viable for drivers who can't charge at home.
  - The results generated from the Charge transport model can help identify what is required to enable EV usage and how this impacts different segments of the population.

This report also makes recommendations about how similar initiatives to the Charge Transport Model can be adopted in other regions of the UK to help accelerate charging infrastructure rollout.

3. Building A Transport Model

The process of building a transport model involves three broad stages:

- Specifying the model inputs and design based on requirements
- Collating and combining input data
- Calibrating the model to sufficiently represent reality against real-world data

For the Charge Project, the transport model has been developed by PTV Group using its Visum software. Visum is a leading tool in the industry, and is used throughout the world to help understand transport systems and how people travel as well as to assess the requirements for infrastructure.

3.1. Specifying The Model Based On Requirements

Several specific requirements were identified for a transport model designed to assess EV infrastructure needs.

Before a transport model is developed, it is important to specify its requirements and compile a scope that achieves these objectives. For the Charge Transport Model, and for similar models that might be developed to understand EV energy demands and infrastructure requirements, the following components in Table 1 were considered:

Table 1: Model Requirement

Model Aspect	DNO Consideration
Area	The model area should include the network licence area, plus sufficient coverage to capture most travel into and out of the network licence area.
Zoning System	A zoning system provides a means to attribute travel demand at an aggregate level across a spatial area. Consider pros and cons of population-based zones or evenly sized zones.
Population Segmentation	Segmenting the population allows differing behaviours to be modelled. Consider what attributes will influence EV uptake and usage (car drivers, income, household type, etc).
Population Activities	A transport model determines the number and location of trips based on activity purpose, such as work or shopping. Consider how these activities tie in with charging types and locations.
Travel Modes	Private car is essential, but other modes may be useful or necessary to determine a representative split of travel options.

Commercial Transport	Out of the Charge Project's scope, but fleets/taxis can be incorporated into transport models if sufficient data can be sourced.
Modelled Days	Models are calibrated to particular day types, i.e., a typical weekday, summer holiday, or winter day. Consider available data, variation in travel patterns, and energy consumption variations.
Road Network	The network should provide realistic routing for the transport model and enable the calculation of end-to-end journey distances. Sufficient detail is needed to calculate these distances accurately.
Public Transport Network	Unless charging for bus or other public transport modes is being considered, this network is only required to provide an approximation of public transport demand.
Trips, Tours or Agents	Tour- or agent-level detail is required for accurate EV modelling to understand range constraints and charging frequency.
EV Decision Making	Consider how the model results will be used and what they will inform. Will the tool help with charging site selection, or assess energy demand to understand electricity network upgrades?
Observed Data	In order for a model to sufficiently represent reality, it is important to calibrate and validate the model using observed data. Empirical data is required to judge the scale of trip making and distribution of demand. Consider sources for origin-to-destination movements (mobile phone, GPS, or survey), traffic flow (road-count data, speed data), and travel-pattern data (trip lengths, mode shares from surveys). Data on EV uptake and usage is important, but sample size and early market bias should be considered.
Forecast Data	Consider which elements will be forecast, and if other published forecasts can be used directly or as a benchmark (such as the National Grid FES or population forecasts). Identify which elements to be forecast are critical and which are uncertain. Consider running scenario workshops to gather expert opinions if certain factors cannot reliably be extrapolated from today's patterns.

3.2. The Charge Transport Model Specification

How was the Charge Transport Model defined and scoped, and what should be considered by other DNOs?

Based on the considerations listed in Table 1, the following choices were made for the Charge Transport Model, and would be recommended for similar models of this type.

3.2.1. Area

Outputs from the model were required for the Manweb licence area, so granular detail was needed in this region, as shown in Figure 2. In addition, the Charge Transport Model includes a spatial representation of the whole of the UK to some extent, so that trips into and out of the region could be considered.

Therefore, within the main study area, trips are fully represented and routed through a detailed congestible network. Outside of this region, trips are modelled if they enter or leave the area, with a simplified network used to provide a realistic approximation of journey distance beyond the Manweb border.

3.2.2. Zoning System

Zones are land parcels that define the start and end points of all trips in the model. In the Charge Transport Model, the zones have been defined at a detailed spatial level across this area, in what is called the Internal area. A buffer area has been created, called the Intermediate area, to provide a transition from the internal region to the external areas, with the External area covering the rest of the UK and allowing for representation of long-distance trips in and out of Manweb.

The model zoning system is shown in Figure 2. The internal area in the Charge Transport Model is made up of zones based on census lower super output areas (LSOAs).

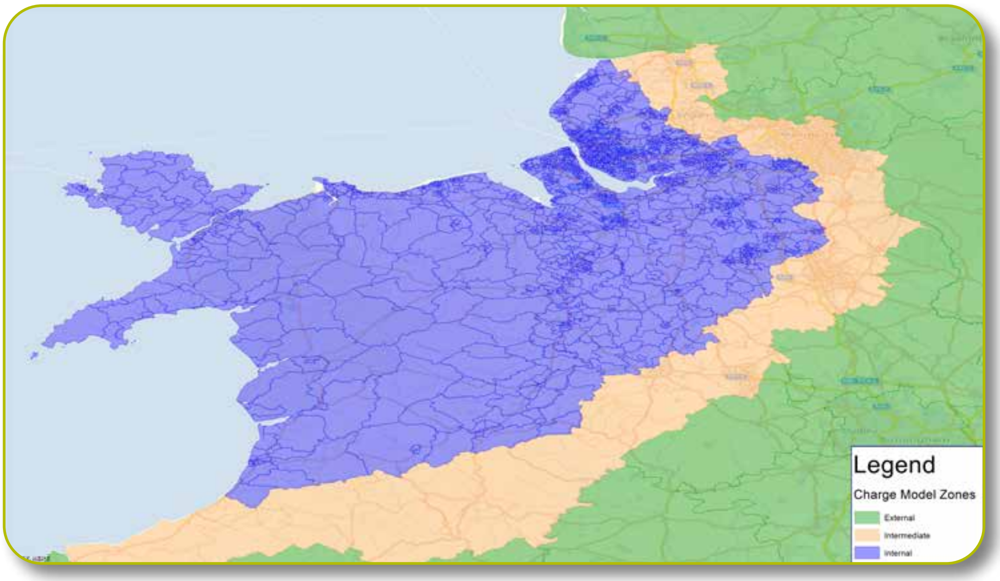

Figure 2: Internal and Intermediate Zone Regions

3.2.3. Population Segmentation

Transport models require the population to be sub-divided into various **person groups** to represent differences in likely travel behaviours. A person group therefore represents a homogenous segment of the population whose travel patterns are defined by fixed parameters and distributions. Within the Charge Transport Model, person group classifications include the area type of the home zone, a person's economic status, their car availability, and their income level. The four attributes that define the person groups are:

- **Location classification:** defines whether the person lives in a rural or urban zone
- **Economic classification:** defines the employment status of individuals within the population, such as employed, retired, or students
- **Car availability:** defines whether people in the person segment have access to a private car
- **Income level:** split into three categories of low, medium, and high, corresponding to approximately 20%, 60%, and 20% of the population, respectively

3.2.4. Population Activities

The population activities (which create the need to travel) defined in the Charge Transport Model are aggregated from those used in the National Travel Survey[2], and for each zone, an attractiveness score has been applied corresponding with the following trip purpose categories:

- **Work & Business**
- **Education** (including escorting trips)
- **Shopping**
- **Other** (covering all other purposes, including leisure, visiting friends and family, etc.)

The attractiveness score for a location is a combination of the 'size' of the activity (e.g., more jobs create more trips) and the accessibility (e.g., harder to get to means fewer trips).

3.2.5. Travel Modes

The following modes are included in the Charge Transport Model:

- Car driver
- Car passenger
- Public transport
- Walk
- Bike

3.2.6. Commercial Transport

It was recognised in the project submission that fleets would be considered as part of UKPN's Optimise Prime project. In order to utilise the findings from that project, the first phase of the Charge Transport Model includes limited provision for commercial vehicles (to represent the total number of vehicles on the road), with passive provision to increase the precision of such movements once information can be shared from UKPN's study.

2. https://www.gov.uk/government/collections/national-travel-survey-statistics

3.2.7. Modelled Days

Models can be built to represent any type of day for which sufficient data exists and travel behaviours are understood to be relatively homogenous. Typically, a model is built to represent an average weekday, and is calibrated with **'average weekday' data**, in which the average weekday is usually defined as a normal working day in school term time when the weather is not severe (snow and ice).

A road network is a key component of a transport model, providing a basis for trips to be realistically routed through the network and creating outputs to show total levels of traffic on each road segment.

If it is the focus of the study, it may also be appropriate to model weekends, a typical summer holiday day, or a winter's day. Relating to EV modelling, travel patterns in the summer holidays can be different, so it might be worth considering additional day types to assess seasonal infrastructure demand.

Travel patterns on a cold winter's day can vary, but this is usually only significant if the weather is severe (resulting in fewer trips). Relating to infrastructure decisions, travel frequency can be slightly lower in cold winter weeks, but patterns (origins and destinations) do not vary too much, assuming it is a winter week during school term time. If it is important to consider increased energy consumption in cold weather, it is recommended that this be modelled with a normal average weekday, but with EV energy consumption parameters amended.

For the Charge transport model, a typical weekday and typical weekend day were modelled.

3.2.8. Road Network

A road network is a key component of a transport model, providing a basis for trips to be realistically routed through the network and creating outputs to show total levels of traffic on each road segment. Often, transport models are used to assess network performance and understand congestion effects, in which case a high level of detail is required for traffic signal timings, lane capacities, and turning capacities.

For EV modelling, the key information required from a road network is (in order of importance):

- **Journey distances:** These are crucial for estimating energy consumption from EVs.
- **Sensible routing behaviours:** The network should reflect reality enough, such that traffic is split appropriately (when compared to observed data) between motorways, A roads, minor roads, etc. The routing information is used to understand where demand for en route charging might be required.
- **Reasonable journey speeds:** The congested speeds in a network should be accurate enough to produce sensible routing. Speed and road characteristics can also be used in EV energy consumption calculations. However, unlike some transport models, accurate journey times (including congestion times at particular junctions) are not considered essential since congestion levels are not a core output. Congestion effects are deemed minimal for EV energy consumption calculations (partly because an EV does not consume much power when idling or travelling at lower speeds).

3.2.9. Public Transport Network

The Charge Project is centred around the use of private cars and, if they become electrified, their associated requirement for charging infrastructure. As such, a full and detailed representation of public transport was deemed out of scope. Instead, a simple public transport network was used to provide journey times and distances for public transport options, with this information used in the demand model to calculate modal split between car and public transport.

3.2.10. Trips, Tours, or Agents

A tour-based model was deemed necessary for the Charge Transport Model. A tour is a sequence of activities that starts and ends at home. The advantage of this model is that it explicitly considers the impact of undertaking more than one activity on a tour. This is important for EV modelling since it provides a representation of trip-chaining, which means the combination of trips can be used to calculate energy demand, and charging demand can be expressed at a number of different location types.

The linkage of this information is lost in a trip-only-based model, which means it won't be possible to determine energy consumption at a per-vehicle level. Agent-based models, on the other hand, provide full detail at the individual level, with travel sequences modelled for a full day or week. Some elements of an agent approach were used in the EV modelling aspect of the Charge Transport Model (see section 5.3) – however, a full agent-based approach was not deemed necessary for the base transport model build.

3.2.11. EV Decision Making

If it is believed that EV trip patterns will be significantly different to petrol/diesel car patterns, then it may be appropriate to model EVs as a separate mode. In this case, it would be possible to model differing travel patterns, or even travel choices that involved (diverting for) charging.

However, for the Charge Project, the aim was to identify optimal charging locations based on typical needs of travel. Thus, trips were modelled as if they were conventional cars to help answer: 'If people choose to travel here, what might the infrastructure requirement be at this location?' The Charge Transport Model therefore suggests locations where infrastructure might be needed based on typical travel behaviours, rather than: 'If infrastructure is located in car park A, how might EV drivers respond to this?'

3.2.12. Observed Data

The focus of the Charge Transport Model was to understand general patterns of demand, rather than the performance of the transport network, which is often the case with transport models. Observed data was therefore collated to help assess the following:

- Does the model sufficiently represent the scale and distribution of travel? Providing a robust representation of the scale of trips between each land parcel is important to help understand where EVs are likely to make trips in the future. Sources such as population, land use, and trip rate information help inform the scale of trips, and sources such as mobile phone data provide an observation of the distribution of trips across a region.

- Are trip lengths sufficiently represented? Accurate trip lengths are important to help understand how far EVs are likely to be driven and, correspondingly, how much energy they will require. Trip-length data from the National Travel Survey – which had been pooled from a large sample – was used to calibrate the model.
- Is the routing of trips sensible? En route charging demand is being assessed in the Charge Transport Model, so it is important that car trips are routed sensibly. Traffic-count data was collated and compared to modelled results to ensure that a representative number of trips were modelled when compared to observed traffic counts.

3.2.13. Forecast Data

Because the EV market is still relatively nascent, forecasting trends purely based on today's patterns was not deemed suitable for the Charge Project. As such, a scenario-building process was undertaken, with key decisions made around what should be forecast and what this should be based on. Many factors were considered to understand what might affect demand for public EV charging, with these factors categorised as follows:

- Is the factor important and likely to significantly affect the modelled outcome? If not, do not model the factor or base values on today's data and hold constant across scenarios.
- Is the factor uncertain, with opinions split on which way the trend might develop? If so, consider varying this factor across scenarios to explore how possible futures might diverge and affect EV infrastructure use. If the factor is not deemed that uncertain, such as population growth, consider aligning values with published forecasts and holding constant across all scenarios.

A detailed explanation of the scenario planning process undertaken for the Charge Project is described in section 4.

3.3. Data Sources For The Charge Transport Model

What data sources should be considered when building a transport model to assess EV infrastructure needs?

Based on the specification and options described in section 3.2, data for the Charge Transport Model was compiled as per Table 2 on page 15.

Table 2: Possible Data Sources for Model Input Data

Model Aspect	Possible Sources of Input Data for a DNO
Population	**Source for Charge Transport Model:** Census data (2017 mid-year estimates) at LSOA for base model. National Trip-End Model (NTEM) for forecast years. **Other options:** Usually population data derived from the census by ONS is best.
Population Segmentation	**Source for Charge Transport Model:** National Travel Survey that provides segmentation of population and their associated travel behaviours. **Other options:** Local household travel diaries or certain phone apps that collect travel behaviours + classification data.
Land Use	**Source for Charge Transport Model:** Census/NTEM for work data to inform number of jobs in each land parcel. Open Street Map derived attractiveness scores for other purposes. **Other options:** The Business Register and Employment Survey (BRES) made available from ONS can also be used to derive work data. Other land-use data could come from Local Authorities or government sources.
Modelled Days	**Source for Charge Transport Model:** Model represents an 'average weekday and weekend' based on traffic count and survey data collected during school term time in non-disruptive weather. **Other options:** Summer holidays, winter's day (see recommendation in section 3.2.7), bank holidays. However, collating sufficient data for more bespoke periods can be difficult.
Road Network	**Source for Charge Transport Model:** TomTom commercial road network, which includes road types, speed limits. Detailed junction modelling was not carried out for the Charge Project. **Other options:** Other commercial sources such as HERE, or OS, or open sources such as Open Street Map.
Public Transport Network	**Source for Charge Transport Model:** Open source Traveline data for buses, transit feed data for rail in GTFS format. **Other options:** the Bus Open Data Service has recently launched, meaning national networks for bus and rail are easily sourced in GTFS format.
Trips, Tours, or Agents	**Source for Charge Transport Model:** Tour information was derived from NTS. Thirty distinct tour types were derived (e.g., HWSH) and allocated to each person group based on NTS tour rates. **Other options:** NTS is a useful source for trip, tour, or agent detail. Local options such as a regional travel survey or data from passive sources such as mobile phone can also be considered.

Observed Data	**Source for Charge Transport Model:** National Travel Survey data showing typical car-trip lengths, mode shares, and trip frequencies. The Liverpool Household Survey providing similar information to the national survey but covering the Liverpool region only. Mobile phone data providing a record of typical car movements at an aggregate level. Traffic flow data from various sources to highlight the typical number of vehicles per road link (where data exists). **Other options:** Bespoke surveys or data collection were not possible for the Charge Project, but in situations where this is feasible, data collection can be carried out to fit the specific needs of the model (mobile phone data specified to the area and needs of the model, survey data with questions relating to parking locations, or other factors for EV infrastructure consideration).
Forecast Data	**Source for Charge Transport Model:** The National Trip-End Model provided population-based forecasts, and SPEN's dFES provided Manweb-wide EV-uptake forecasts. Other forecast assumptions were derived from a combination of current observed data and scenario workshop considerations. (See sections 4 and 5.2, 5.3.) **Other options:** If basing future EV trends on today's patterns, caution should be used due to the small sample of data in today's early adopter EV market. However, as the market grows and more data is collected from bigger samples, deriving trends from observed usage may prove useful for forecasting. Due to many uncertainties, however, it is recommended that a scenario-building process is undertaken to define the factors that will be varied in the model, and to come up with plausible assumptions where empirical data is lacking or not deemed representative. Creating a vision-based scenario – which should align with local or national goals – is also recommended and can help identify the requirement for the target to be reached.

3.4. Calibrating A Transport Model

How to calibrate a transport model to ensure it is fit for purpose.

Calibrating a model is an important step to ensure it represents observed travel patterns to an acceptable level. Calibration of model input data and parameters can be used to adjust demand patterns, or the supply network can be modified so that traffic is more accurately routed in the model. When measuring against observed traffic levels or high-level mode shares and trip lengths, calibration is usually carried out in iterations, with adjustments made to the demand parameters or the network supply before they are compared to observed data again and adjusted further. A schematic workflow of this process is shown in Figure 3.

For the purpose of EV modelling for the Charge Project, the focus of calibration was ensuring demand patterns – such as OD movements and trip lengths – were representative of reality. In general, this approach is recommended for models of this type, with calibration focusing on demand patterns instead of assignment traffic flows.

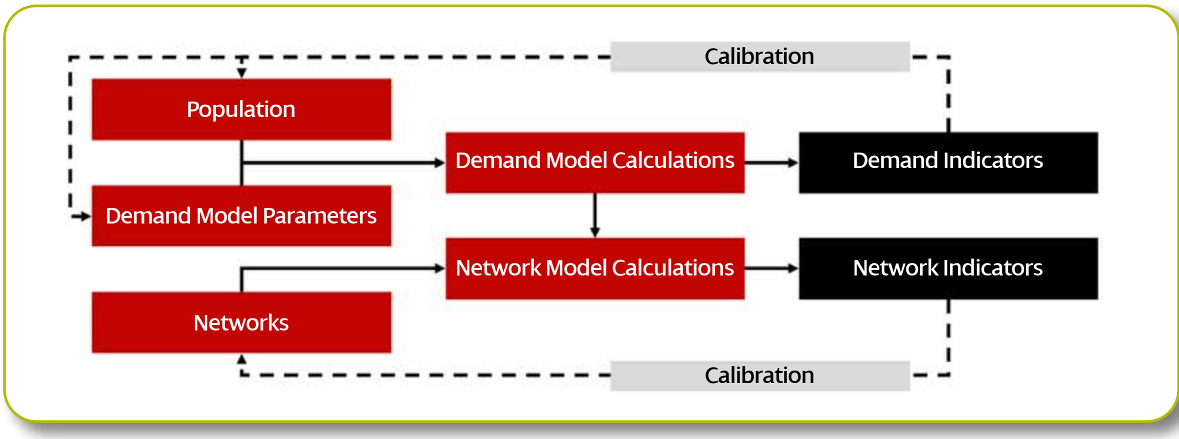

Figure 3: The Calibration Workflow

Using indicators derived from empirical data, the model was assessed to understand how well it was reproducing real-world phenomena. For the Charge Transport Model, the following indicators were assessed and calibrated to:

- Mode shares (e.g., the proportions of people travelling to work by car, public transport, etc.)
- Trip lengths
- Total amount of travel generated and attracted, by area
- Total amount of travel moving between sectors
- In the road-network model, modelled traffic flows were compared against traffic counts

After each model run, outputs were assessed against the indicators above, and adjustments were made to various components of the model until accurate representations against all measures were achieved.

3.5. Charge Transport Model Calibration Summary

Summary of the Charge Transport Model compared to observed data and trends.

The data described in sections 3.1-3.3 should be combined and connected into the model, with commercial software such as PTV Visum allowing this to be done efficiently. With the data in place and an initial model built, the model can be run to represent travel across the area, which can then be compared to empirical data. The DfT's Transport Analysis Guidance[3] (TAG) provides a detailed set of standards that are typically used in the transport modelling industry, with many of these techniques utilised as good practice in the Charge Transport Model build and calibration.

Figure 4 summarises the Charge Transport Model validation, highlighting the scale of the model (> 6 million people represented) and a high-level summary of the mode-share comparisons. Notably, the model represents a good fit against surveyed levels of car activity, with approximately 60% of trips in the model and surveys being carried out by car. Similarly good results were achieved for trip-length comparison, purpose splits, and OD demand movements compared to mobile phone data.

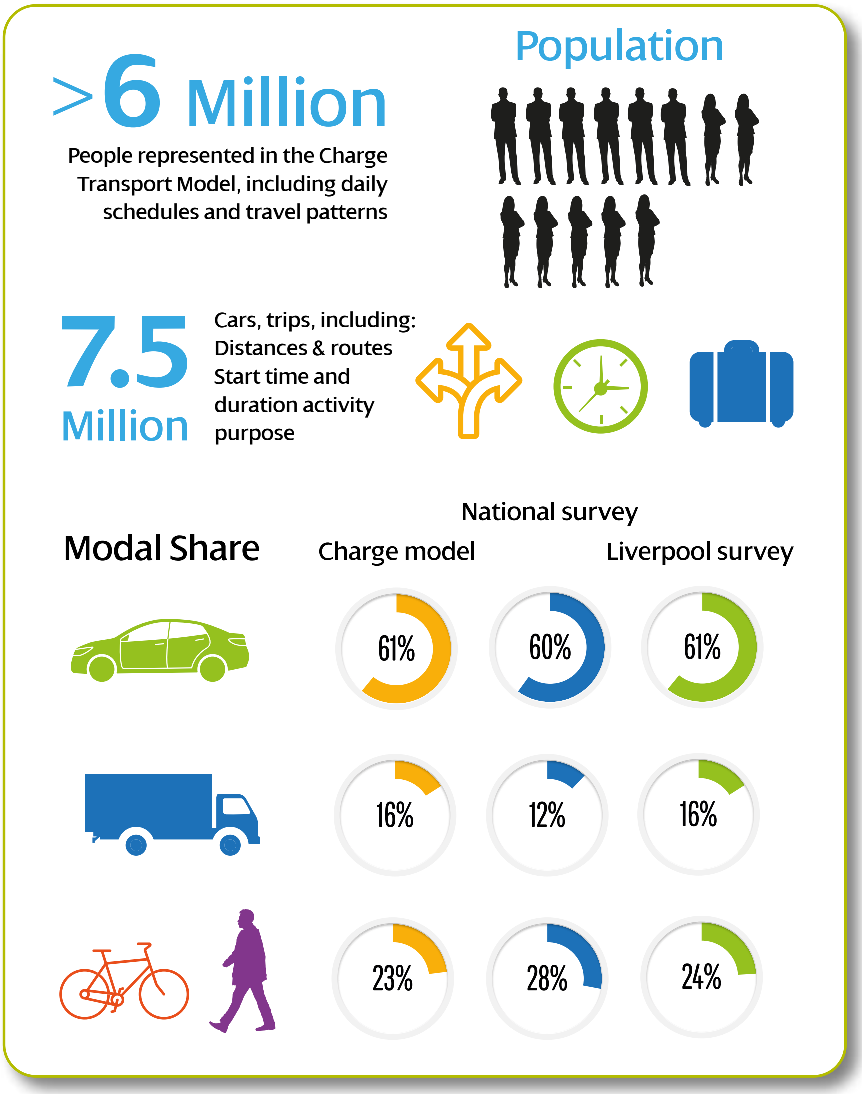

Figure 4: Graphical Summary of the Charge Transport Model Validation Results

3. https://www.gov.uk/guidance/transport-analysis-guidance-tag

4. Scenario Planning

4.1. Why Scenario Planning?

The scenarios developed for the Charge Project are highly relevant for other DNOs and can be used as a blueprint for others to follow and update as the market develops.

Scenario planning allows for the development and testing of several plausible futures based on a collective view of the most important factors and uncertainties. Unlike traditional forecasting, which attempts to predict the most likely single future, scenario planning deliberately considers alternative and possibly divergent futures.

When deciding how to react in the future, scenario planning is not about figuring out which scenario will occur and optimising for such a future. Instead, a set of varied futures are generated that could all be plausible outcomes. If all these futures are deemed to be plausible, albeit with differing likelihoods, the most pragmatic approach is to design a strategy that is robust in the face of multiple possibilities and can react to changing trends.

This approach is summarised in Figure 5 and based on information highlighting the difference against traditional single-future forecasting.

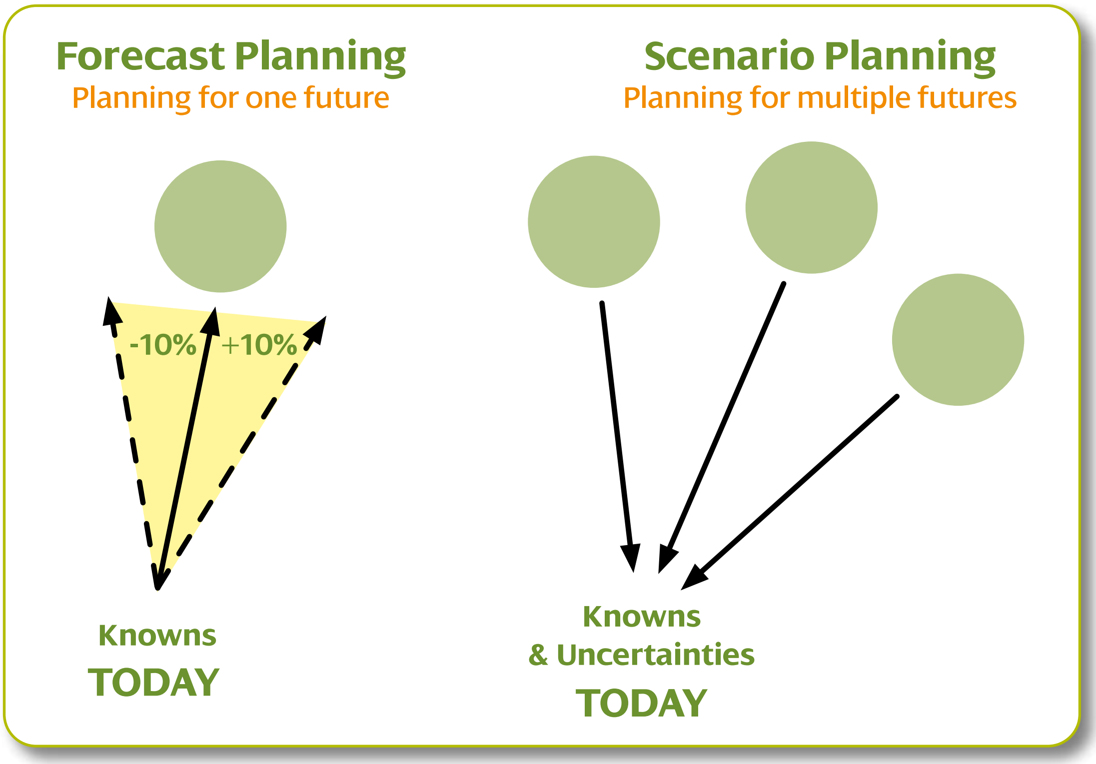

Figure 5: Scenario Planning vs. Traditional Single-Future Forecasting [4]

4. https://medium.com/strategy-dynamics/scenario-planning-part-1-ffcb48f26a1c

4.2 Future EV Scenarios

How scenario workshops can be structured to identify critical uncertainties.

The Charge Transport Model scenarios were developed to envisage futures up to 2050 using the following principles and steps, similar to those utilised in[5]:

- **Establishment of key outcomes:** What are the outcomes to be represented by the scenarios, and what will be assessed by the resultant model?
- **Identification of important variables:** What factors are likely to affect the above outcome, and how much of an influence are they likely to have in the future?
- **Selection of critical uncertainties:** Which are the most important and uncertain variables that will likely determine which path(s) the future may diverge down?
- **Development of scenario narratives:** A qualitative construction of core scenarios that draw on possible variations of the critical uncertainties in the future.
- **Consideration of scenario pathways:** How might the scenarios play out from today through to 2050?

The first and second step were initialised in an ideas workshop held in April 2019. A further filtering of the variables to determine importance, as well as an assessment of uncertainty (steps 2 and 3), were explored during a second workshop in September 2019. Some scenario narratives were then developed and evaluated in further workshops during Autumn 2019.

4.3. Summary Of The Scenario Workshops

How scenario variables were considered and summary findings from the workshops.

Four workshops were held to help develop and evaluate the scenarios presented in this report, with a summary of the findings from these events described in this section.

Workshop 1 was an ‘ideas' event, during which participants were invited to generate ideas relating to the future of EVs and how they would be charged. The variables discussed were also ranked in terms of their importance, as displayed in the word cloud image in Figure 6. The ideas spawned in this first workshop were taken forward to later events, at which uncertainty and scenario narratives were discussed.

5. http://eprints.uwe.ac.uk/24449/1/fd-summary-report.pdf

Figure 6: Word Cloud of Important Variables

The second workshop focused on identifying variables that were both important and uncertain. This exercise helped narrow down the set of factors considered in the first workshop and concentrated on how each one could change and to what extent. Participants were split into two groups, one discussing the effect on energy demand in the future, and the other discussing the development of infrastructure rollout. The energy-demand group judged that BEV cost and supply were the most important and uncertain variables, closely followed by battery range and charger availability. The infrastructure development group considered that policies around infrastructure rollout and SP Energy Networks' own position were important and highly uncertain.

The final two workshops were held at industry conferences to disseminate the initial work on the scenarios and receive external feedback on the plausibility of each future. Summaries of these were presented to delegates, with questions asked to help evaluate the likelihood and coverage of issues. In general, delegates were supportive of the scenarios presented and the issues that had been considered, and useful feedback was provided in relation to the perceived likelihood of each future.

4.4. Recommendations For Scenario Planning

The benefits of scenario planning to help represent uncertain trends.

The scenario-planning exercise provided important input and feedback for the development of scenarios by:

- Canvassing a wide range of opinions on the future of technology, energy, infrastructure, and behaviour
- Generating a range of factors and key drivers that were likely to affect the uptake of EVs and how they would be charged in the future
- Prioritising which factors were the most important
- Identifying critical uncertainties that would likely have a strong effect on future electricity demands from EVs and were uncertain as to how they might develop
- Evaluating the scenarios produced to help assess their plausibility and critique aspects judged to be missing, too optimistic, or too pessimistic

For similar EV modelling projects, the process for scenario planning used in the Charge Project is recommended to help provide a wide range of ideas and thoughts, and to contextualise the inherent uncertainty in forecasting.

The next section details how the learnings from the workshops have been utilised to generate a set of scenarios that are modelled in the Charge Transport Model and presented in the ConnectMore online tool.

4.5. Charge Project Scenario Summaries

How scenario narratives were developed to create plausible futures and test critical uncertainties.

Using the information and knowledge collated during the scenario-planning workshops, scenario narratives were developed to cover a range of plausible futures that would be of relevance to the Charge Project team and their stakeholders. A summary of the scenarios developed is shown in Figure 7 and described in brief below.

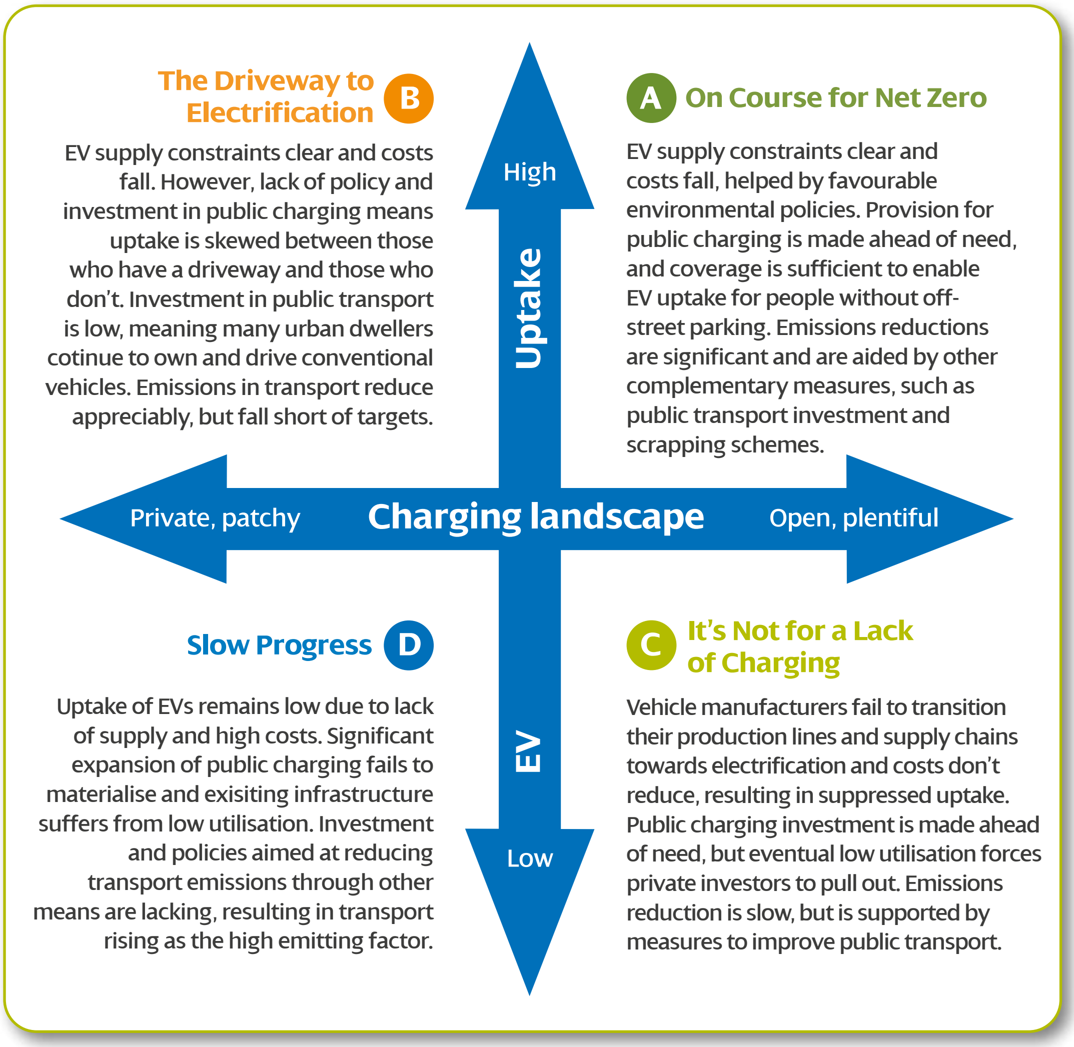

Figure 7: The Charge Project Scenarios

On Course for Net Zero (Scenario A) is a vision-led scenario that aligns with targets and ambitions for decarbonisation and net zero emissions by 2050 (including a staged pathway throughout the 2020s, 30s, and 40s). The scenario assumes **EV uptake will be high** across the Manweb region and that EV ownership is relatively equitable throughout society, including for those that do not have driveways. **Demand for public charging** is consequently **high**, with plentiful coverage and supply of infrastructure assumed.

The Driveway to Electrification (Scenario B) assumes that **EV uptake will be relatively high**, but will be slightly constrained by the lack of infrastructure provision, which limits uptake amongst those without a driveway. **Demand for public charging** is assumed to be relatively **low** since most drivers have access to private charging and, interlinked to this, the rollout of public infrastructure is assumed to be slow and have sparse coverage.

It's Not for a Lack of Charging (Scenario C) is defined by relatively **low levels of EV uptake** due to a lack of vehicle supply and higher costs compared to petrol/diesel equivalents. However, **public charging coverage and supply are assumed to be plentiful,** resulting in relatively high levels of demand from those that do have EVs and a more even level of uptake between those with and without driveways.

Slow Progress (Scenario D) is a pessimistic scenario that assumes **EV uptake** will be **low** as a result of high costs and lack of vehicle availability. Furthermore, the rollout of **public charging** is assumed to be **sporadic** and in **small** numbers. Because of this, a far higher proportion of EV owners are assumed to have a driveway/access to private home charging.

On Course for Net Zero (Scenario A) is a vision-led scenario that aligns with targets and ambitions for decarbonisation and net zero emissions by 2050 (including a staged pathway throughout the 2020s, 30s, and 40s).

5. EV Scenario Modelling

The modelling of scenarios combines the power of the transport model – to help understand travel and demand patterns at scale – with the explorative insight of the scenario stories.

The methods described in this section explain how EVs have been modelled in the Charge Project and how parameters have been defined to test the different scenarios. A similar approach can be adopted by other DNOs seeking to understand demand and infrastructure requirements from EVs. A summary of population forecasts is shown in Figure 8, which details the breakdown between those forecasted to have access to a car and those who do not have access to a car.

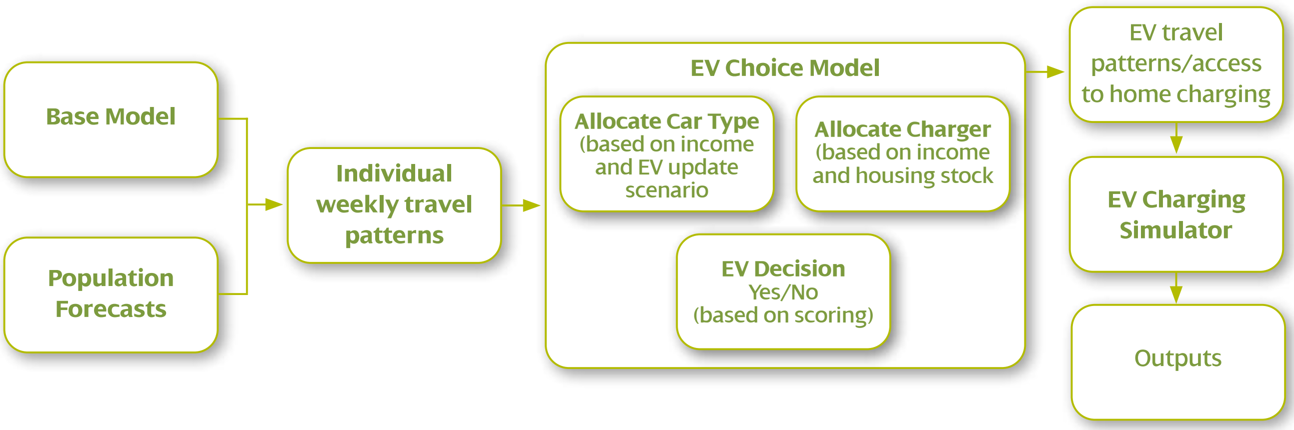

Figure 8: Method Workflow for the EV Scenario Modelling Approach

5.1. Individual Weekly Travel Patterns

Combining the transport model patterns with population forecasts to produce weekly car-travel diaries.

Six forecast years have been explored in the Charge Project to consider how things might change from today until the UK's net zero target year of 2050. Snapshots of possible futures in 2025, 2030, 2035, 2040, 2045 and 2050 have been modelled.

To begin with, the Charge Transport Model described in Chapter 2 is run with future population inputs to extract forecast average weekday and weekend car tours. As described in section 3.2.3, the population has been segmented into person groups to represent diversity in behaviour choice.

Forecasts have been applied to these person-group segments using data from the National Trip-End Model (NTEM), which is produced by the Department for Transport (UK). As well as inputting forecast population levels, work numbers were updated using estimates from NTEM to represent a forecast change in the number of jobs by location.

Forecast models were produced for every day of a typical week, including weekends, and for every scenario year. Because variations in travel patterns weren't central to the scenarios, travel patterns and transport outputs were applied consistently to each scenario – e.g., the number of car trips in Scenario A is the same as the number of car trips in Scenario D (although the proportion of cars assumed to be EVs is very different).

For calculating EV charging demand, it was important to move from the consideration of a single average day to that of a week of travel for each car so that charging activity could be simulated. Visum has advanced functionality that allows trip patterns to be represented for every individual in the model. This means charging patterns can be analysed down to the individual vehicle level and assessed across a longer period of time, i.e., one week rather than a single trip.

To begin with, a synthetic population of individual people who may own a car was generated, based on the population forecasts. Car tours from the transport model were then allocated to those people, resulting in weekly travel diaries for every car in the model. The weekly car patterns were calibrated using NTS data to replicate typical vehicle patterns in a week, and to ensure weekly distances driven were representative.

5.2. EV Choice Model

Defining where and how much EV uptake might occur in each scenario.

The input to the EV Choice Model is the weekly travel diary for each car and information about its owner, such as their level of income. This is run through the EV choice modelling process, resulting in a decision as to whether the car is an EV and the level of access to home charging. The steps in the process are explained further below.

With the scenario narratives underpinning the logic behind each scenario, specific parameters were defined to influence responses in the model. These parameters cover three categories and define how EV choice and charging behaviours have been modelled:

- The EV uptake rates
- Car type (standard/luxe and age), income, and likely provision of home charging to determine who has an EV
- EV charging patterns and behaviours

A summary of these assumptions and the sources which have guided them is provided in Table 3 on page 26.

Input Parameter(s)	Definition	Source(s)	Comments
EV Uptake Rates	The number of EVs represented in each modelled year and scenario	Scenarios A & D based on SPEN's dFES scenarios[6], Scenarios B & C based on input from scenario-planning workshops	The number of EVs represented in each scenario directly relates to the total amount of energy that will be needed to supply them, so this is an important attribute
Car Types, Income, Access to Home Charging	The characteristics that define who is more likely to get an EV	Various sources ([7],[8],[9],[10]) plus data from EV Up project[11]	Income and car type determine who is more likely to own a new car; potential for home charging is seen as a key factor in EV uptake
EV Charging Behaviours	Assumptions that define where drivers are likely to charge their EV in the future	Charging profiles collated by National Grid[12] plus assumptions, discussed in the scenario-planning workshops	These behaviours determine what type of charging might be preferred in the future, and where demand for electricity might occur

Table 3: Summary of Charge Project Scenario Inputs and Parameters

6. https://www.spenergynetworks.co.uk/userfiles/file/SPM_DFES_-_Main_report.pdf
7. https://www.theverge.com/2020/6/16/21292629/tesla-model-3-long-range-plus-epa-rating-aerodynamic-wheels-mass-reduction-efficiency
8. https://www.autocar.co.uk/car-review/nissan/leaf/first-drives/nissan-leaf-long-term-review
9. https://www.ons.gov.uk/peoplepopulationandcommunity/housing/datasets/medianpricepaidbylowerlayersuperoutputareahpssadataset46
10. https://www.nomisweb.co.uk/datasets/cs049
11. https://www.spenergynetworks.co.uk/pages/evup.aspx
12. https://www.smarternetworks.org/project/nia_ngso0021

5.2.1. EV Uptake Rates

To help maintain consistency in forecasting, overall EV numbers were derived from SPEN's dFES[13]. This contains two forecasts for EV uptake, one high and one low. The high-EV-uptake forecast is used in the On Course for Net Zero scenario (A), and the low-uptake forecast is used in the Slow Progress scenario (D). Uptake rates in scenarios B and C were derived to fall between the upper and lower forecasts, as shown in Figure 9.

The application of uptake rate assumptions within the choice model is explained in 5.2.4.

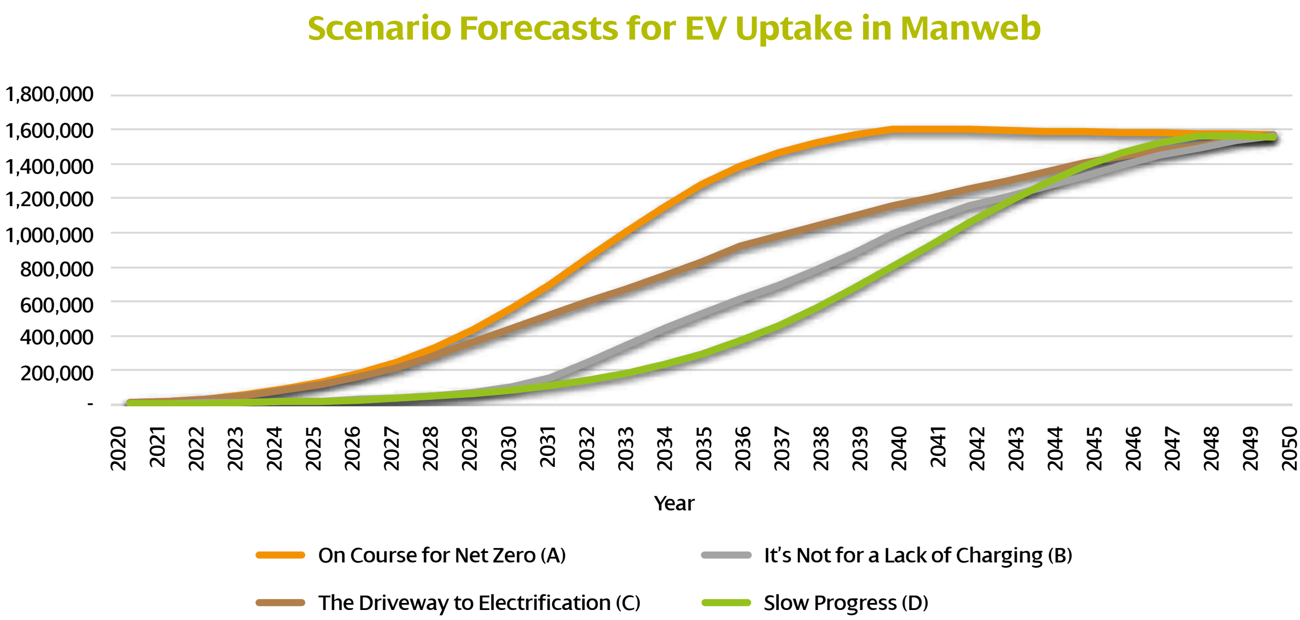

Figure 9: Scenario-Based EV-Uptake Forecasts for Manweb

5.2.2. Allocating Car Types

Defining car types across the population.

Currently, in the early stages of the EV market, there is a limited supply of second-hand EVs, and the new vehicles, in some cases, are more expensive than petrol/diesel equivalents. As such, income is used to determine who is more likely to buy a new vehicle (which could be electric), and then who is likely to own them as they get older and cheaper.

In the Charge Transport Model, travellers are split into income brackets of high (~20% of the population), medium (~60%), and low (~20%). In addition to this information, indices of deprivation data[14, 15] and house price data have been used as indicators to help differentiate income at a zonal level. Figure 10 below shows the assumed breakdown of vehicle type and age based on income, with proportions consistent with published data[17].

13. https://www.spenergynetworks.co.uk/userfiles/file/SPM_DFES_-_Main_report.pdf
14. https://www.gov.uk/government/statistics/english-indices-of-deprivation-2019
15. https://gov.wales/welsh-index-multiple-deprivation-full-index-update-ranks-2019
16. https://www.ons.gov.uk/peoplepopulationandcommunity/housing/datasets/medianpricepaidbylowerlayersuperoutputareahpssadataset46
17. https://www.gov.uk/government/statistical-data-sets/veh02-licensed-cars

This breakdown has been constructed based on the assumption that newer, luxury-type vehicles are more likely to be owned by high-income individuals and older vehicles are more likely to be owned by low- to medium-income individuals. The splits between luxury and standard and vehicle ages have also been controlled to fit current patterns.

The application of car type assumptions within the choice model is explained in 4.2.4.

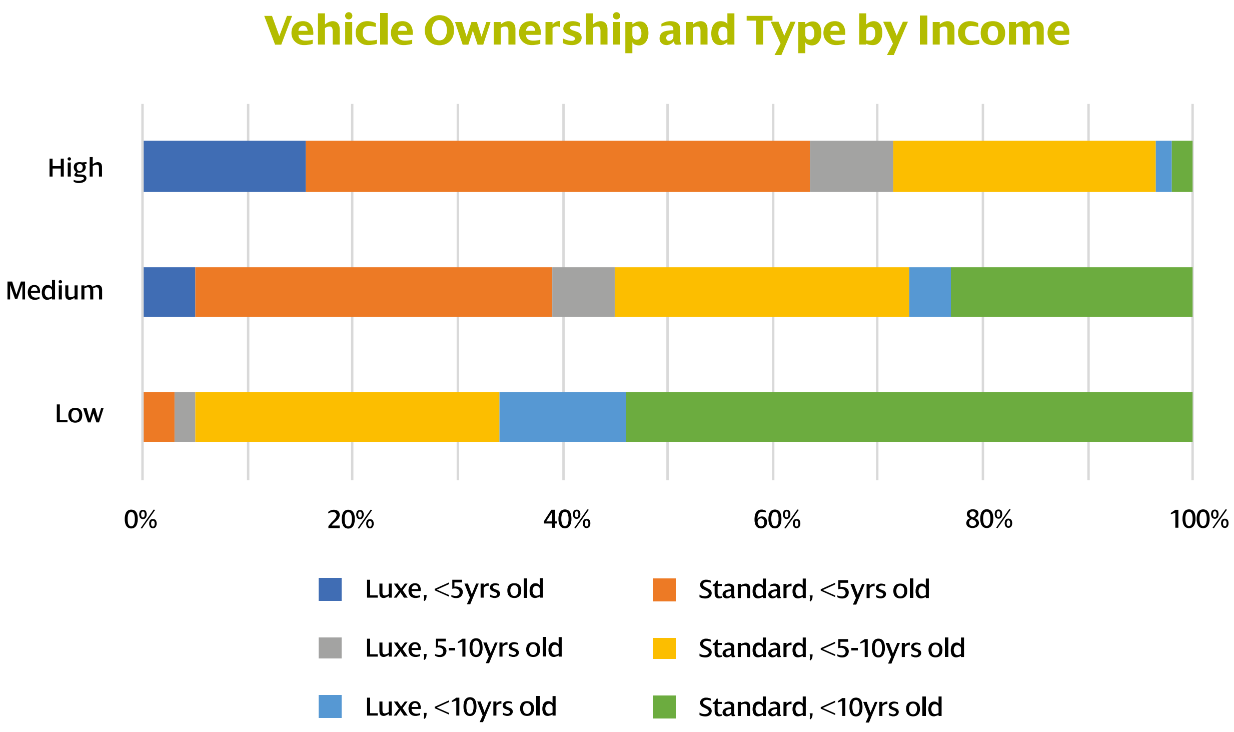

Figure 10: Vehicle Ownership Splits by Type and Income

5.2.3. Allocating Household Type

Access to private home charging, i.e., off-street parking, was viewed as a key determinant of uptake in the Charge Project scenario-planning workshops. In all scenarios in the earlier years, it is assumed that uptake will be higher among segments of the population that live in households with potential access to private at-home charging. A variety of data sources have been used to identify which areas have higher levels of off-street parking:

- **EV Up data** (~74% of households have off-street parking[18]): This was a separate piece of work carried out on behalf of SPEN to identify the number of properties in the Manweb region that have access to off-street parking. Access to off-street parking is estimated using OS building data to calculate the amount of space within the bounds of a residential property and whether this space is sufficient for one, two, or more vehicles (or no vehicles). This data has been supplied at the LSOA level and matches the zoning system in the Charge Transport Model.

18. https://www.spenergynetworks.co.uk/pages/evup.aspx

- **Census dwelling type data**[19] (~73% of households estimated to have off-street parking): This data categorises residential buildings based on their type, such as detached, semi-detached, terraced, or flat. This data corresponds to each zone in the model, and parameters have been estimated (in comparison to the EV Up data) to calculate the percentage of each building type that has off-street parking.
- **National Travel Survey parking data** [20] (~72% of vehicles are parked off-street overnight): This data is based on responses from a representative sample of the population and asks where a vehicle is parked at night (garage, private property off-street, on-street, etc). This information has been used to control the overall levels of off-street parking.
- **Census tenure type** [21] (~64% of households are owned by the occupant): This data defines how many households in an area are owned, rented, or otherwise. Household ownership has been used to infer who is more likely to be able to install a private property charger.

The household type and the likelihood of a car having off-street charging potential was calculated at a zonal level throughout Manweb. A summary of this data is shown in Figure 11, which details the number of cars (in the base year) for every Local Authority area, split into derived categories of off-street charging potential and home ownership.

The application of household type assumptions within the choice model is explained in 5.2.4.

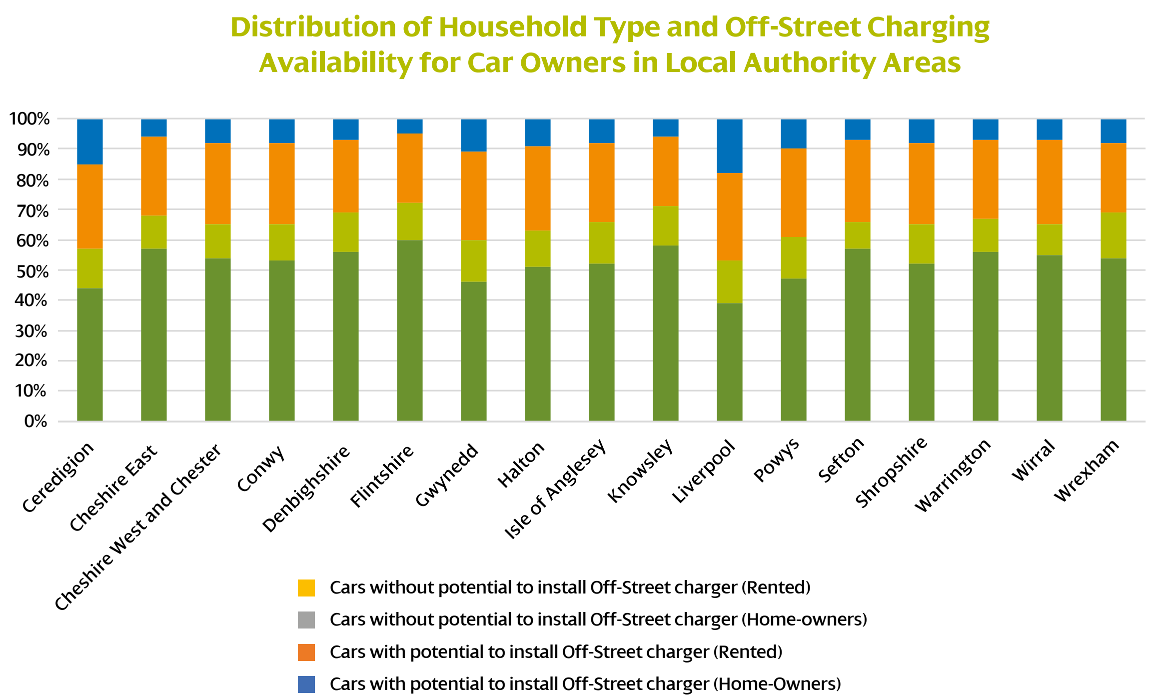

Figure 11: Access to Off-Street Charging by Local Authority Area within Manweb

Table NTS0908 available at:
19. https://www.nomisweb.co.uk/datasets/cs049
Table NTS0908 available at:
20. https://www.gov.uk/government/statistical-data-sets/nts09-vehicle-mileage-and-occupancy
21. https://www.nomisweb.co.uk/datasets/cs049

5.2.4. EV Decision

Using the data and assumptions as specified above, each car in the model was firstly assigned a type (standard/luxe and age), based on income level and the forecast number of cars per type in its zone. This process was modelled in a stochastic fashion, with income used as an influencing weight on car type and controlled to the targets specified in Figure 11.

Cars were then allocated to a household type based on the housing stock availability within the zone and the income of the owner, where higher income individuals were deemed more likely to be homeowners living in a house with the potential for off-street charging. Again, this process was applied in a stochastic manner but controlled to the overall levels.

Finally, each car-owning individual was modelled in the EV Choice Model, which determined the EV owners in each scenario. The following factors were weighted and combined to generate an 'EV score', with the drivers with the highest EV score assigned an EV:

- Income (high, medium, low; and zonal income weight)
- Car type (new, second-hand, or old; and luxury/standard)
- Potential for home charger
- Potential for workplace charger
- Weekly car-travel distance and maximum trip distance
- Random weight (this was used to introduce diversity into the EV uptake choice, which meant it was possible, albeit with smaller odds, that an individual could be assigned an EV if they had a low income and no access to a home charger)

5.3. EV Charging Simulator

How to calculate the demand for charging once EVs have been assigned to the population.

After EV choice is assigned to the population, charging behaviours affect when and where energy demand will be. Charging behaviours are assumed to result from a combination of hard factors that are modelled, such as access to off-street at-home charging or trip patterns that constrain charging to being carried out after a long journey; and soft factors that are not explicitly modelled, such as cost differences between types of charging or people's preference for a certain type of charging.

For hard-constrained trips – i.e., very long-distance trips that exceed the range of the vehicle – en route charging can be the only option. For most other charging events, however, it is likely that the driver will have a choice. For instance, an EV driver who does not have a private home charger may travel from home to work, then to the shops, then back home again. If the combined distance of these trips is not greater than the vehicle's range, then it is feasible that the driver could have the following choices:

- Charge at work
- Charge at the shops
- Charge en route during any trip
- Charge in a public residential setting near their home
- Do not charge at all

The Charge Transport Model was therefore configured to choose a charging location according to the scenario-based preferences, in combination with the hard constraint of range. The following steps were used to determine charging choice at an individual level:

1. Every driver was assigned a minimum range threshold, which represented the level they would prefer to not let their range drop below. This was assigned randomly between 30 and 70km of remaining range.
2. Remaining range was calculated after every trip based on trip distance. This figure accumulated with successive trips.
3. The option of charging was determined for every destination and en route trip. Nearly all locations were allowed to be considered potential charging locations, except if the driver was not parked for more than 15 minutes (which ruled out escort-based trips). If a trip terminated at home, the option for charging was determined based on whether the driver had been assigned a home charger or not. For those with a home charger, the option of private home-based charging was allowed; for those without, the option of public residential charging was allowed.
4. Where the remaining range dropped below the driver's range threshold, all previous potential charging locations from that driver's travel patterns were selected.
5. From the set of potential charging locations, a location was chosen based on the scenario-based probabilities.
6. Where a charging event was chosen, the vehicle's range was reset on the assumption that the charging event had topped up the battery. The location and energy drawn from the charging session were recorded.
7. The process was continued from the previous charging event, with all subsequent trips considered new charging events.
8. The charging model was calibrated so that, on average, approximately three charging events took place per driver per week (which is consistent with current empirical charging data collated by National Grid[22]). A calibration step was also introduced so that the total amount of distance driven by all EVs in the modelled week was recovered through charging events (i.e., for every 1,000 miles driven, enough charging events were chosen such that 1,000 miles of range was recovered).

22. https://www.smarternetworks.org/project/nia_ngso0021

6. Results and Findings

The main purpose of the results from the Charge Transport Model is to feed the ConnectMore tool. This chapter summarises the range of outputs that can be extracted from the Charge Transport Model and reproduced in other DNO licence areas to help assess EV infrastructure needs, including:

- **Number of EVs** in the region, estimated down to small land area (LSOA). Where these EVs will be parked overnight, and whether they are likely to have access to off-street parking and charging, is also modelled.
- **Trip patterns of EVs** for each scenario, including where and how often they are likely to be driven.
- **Energy demand** based on trip patterns and assumed battery sizes and efficiencies. This can be used to estimate the growth in electricity demand in residential and public charging settings.
- **Infrastructure requirement** based on energy demands. This includes details of where and how much infrastructure might be required, based on the likely number of vehicles and their energy demands.

6.1. Results Production

How data from the Charge Transport Model can be displayed and analysed.

Scenario model data has been produced for the four Charge scenarios (A, B, C, D) and six years (2025, 2030, 2035, 2040, 2045, 2050), and summarised to determine when, where, and how often future EV drivers might wish to charge. As described in the previous section, charging behaviours are estimated at an individual level, but for the purposes of results outputting, have been aggregated into two spatial layers:

- **Trip-end charging** at the **zonal level**, which contains the aggregation of individual charging behaviours assigned to the zone where the demand for charging is generated. These charging events are assumed to take place when the car is parked and the driver is undertaking an activity for a reasonable amount of time (such as staying at home, being at work, or visiting the shops or other locations).
- **En route charging** at the **road link level**, which contains the aggregation of trips across the road network with attribute data at the road link level. These charging events are assumed to take place at some point on the way from a trip origin to a destination, and are carried out with the main purpose of charging the vehicle.

6.1.1. Trip-End Charging

For trip-end charging, each event is assumed to take place at a parked location within one of the 1,985 model zones within Manweb. The number of charging events (by location type) has been tallied for each zone and summed to represent a **typical 24-hour day**.

An example of this output with zonal totals for charging events is shown in Figure 12.
In addition, the following metrics are calculated for each zone at a daily level:

- Number of assumed **car arrivals** into the zone (this number is inclusive of all cars in the model, including all EVs and non-EVs)
- Number of assumed **EV arrivals** into the zone (whether charging or not)
- Number of anticipated **charging events**

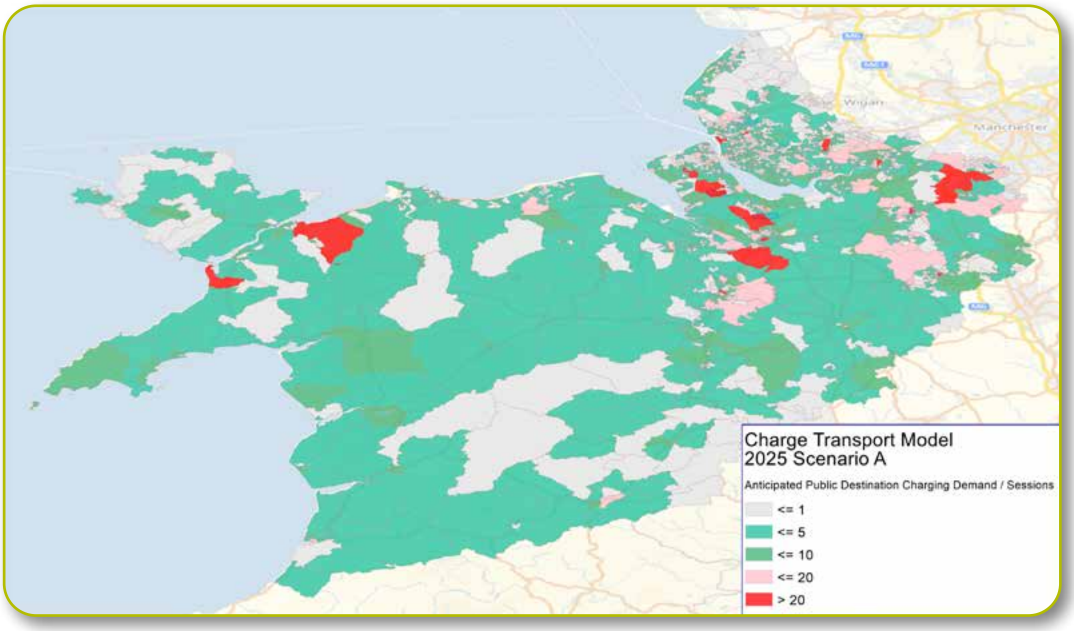

Figure 12: Number of Charging Events Per Zone, Scenario A 2025

From the model, each vehicle trip has an associated start and end time, and a time when the next trip is assumed to take place (from which the dwell time is calculated). For all modelled charging events, the following metrics are recorded:

- The **start hour of the charging event**, which is assumed to be the time that the vehicle arrives and starts charging (rounded down to each one-hour period across 24 hours).
- The **dwell time** of the activity, which corresponds to the length of time the car is assumed to be parked before embarking on a subsequent trip. The dwell time therefore is not equivalent to the charging time. In many cases the charging time is likely to be shorter, and in all cases could not exceed the dwell time.

Trip-end charging events are categorised into one of four location types:

- **Private, off-street home-based charging:** These charging events can only take place at the EV driver's home (home zone) if that driver has been assigned a home charger.
- **Private workplace charging:** These charging events can only take place at an EV driver's work location (work zone) when arriving for a work activity. Dedicated workplace charging provision is assumed based on the scenario input, with a proportion of employed EV drivers assumed to have access to a workplace charger.
- **Public residential charging:** These charging events can only take place within an EV driver's home zone. Within the model, some EVs are assigned a dedicated on-street charger, which is assumed to be located directly outside their property. In other cases, public residential charging demand can be generated if it is assumed charging takes place in a public location within the vicinity (same zone) of the driver's home. In these cases, it is assumed that the EV driver parks their car in a public car park and walks home from there.
- **Public destination charging:** These charging events can take place in any non-home zone for any purpose, including work (if that driver is not assumed to have a dedicated workplace charger), shopping trips, or any other. Since trip-end events are associated with an activity that lasts at least 15 minutes (and often several hours), these events are assumed to take place in public car parks, supermarkets, or tourist or shopping locations, or on-street in a public (non-residential) setting.

For each charging event, the amount of electricity that is assumed to be required is calculated and represented in kilowatt hours (kWh). The kWh amount is based on the assumed state of charge of the EV's battery at the end of the current trip, as well as the size of the battery, i.e., if an EV is assumed to have a 50kWh battery and a 50% state of charge at the end of the trip, then up to 25kWh can be required from the current charging event. The amount of energy required is summed at a zonal level for a typical day.

6.1.2. En Route Charging

As well as demand for charging that is assumed will take place at parked locations i.e., at home, at work, or in a public car park, demand for rapid en route charging has been estimated. As described in the previous section, the propensity of EV drivers using rapid charging has been varied across scenarios and years as the rollout of infrastructure and technology is assumed to improve.

Unlike trip-end charging, which the model designates as taking place within a zone while the driver attends an activity, en route charging is assumed to take place as a **stop-off during a trip**. In the model, en route charging events can be deemed necessary if the EV is undertaking a long-distance trip, but they can also take place on shorter trips, similar to how drivers may stop on the way home from work to top up at a petrol forecourt (which is especially the case if the driver is assumed to not have a dedicated home charger).

Trip-end demand is designated to the arrival zone because it is assumed a driver would want to charge reasonably close to their final destination i.e., within walking distance. For en route charging, however, demand could be satisfied at any number of locations along a route between the trip origin and destination. As such, en route charging demand has not been assigned to a fixed location, as this will depend on a deterministic view of the coverage of infrastructure at that point in time.

Instead, en route charging demand is tallied for all segments of an EV's route on the assumption that if a charger were to be located somewhere on the driver's way, they could stop off and charge. Demand for en route charging is therefore presented in a similar way to traffic flows in a transport model with demand assigned to the road network across the Manweb region. An example output of assigned EV en route charging demand, alongside all other EV traffic and non-EV traffic is shown in Figure 13.

The model results can therefore be used to indicate the potential demand for an en route charging site that is close to the road network, with figures provided to indicate:

- Total number of all vehicles estimated to use a road within a day
- Total number of EVs estimated to use a road within a day
- Total number of EVs estimated to use a road within a day and that have a requirement to charge en route

For example, in the 2025 Scenario A model, approximately 15,000 vehicles are estimated to drive on the M56 motorway between junctions 12 and 14 on a typical day, of which approximately 1,500 are assumed to be EVs, and of which ~70 are assumed to need to charge somewhere along their route. Thus, if a rapid en route charging site were placed near one of the junctions on this route, the maximum estimated daily demand for charging, according to this scenario, would be ~70 EVs.

Figure 14 shows the demand for en route charging in the On Course for Net Zero scenario (scenario A) in 2025. The orange bars indicate the level of general, non-EV traffic; green indicates EV traffic; and blue indicates the volume of EV traffic with a requirement to charge en route.

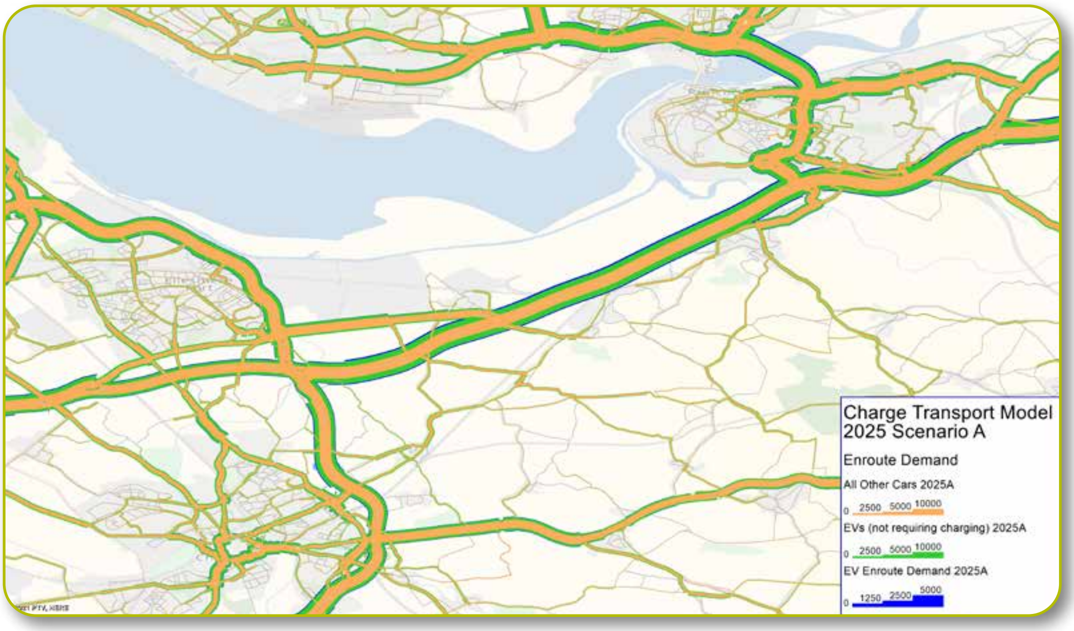

Figure 13: Example of En Route Charging Demand Data from Charge Transport Model

ea technology
PTV GROUP the mind of movement
smarter grid solutions
SP ENERGY NETWORKS

6.2. EV Uptake

Results showing how EV uptake might develop across Manweb.

As described in section 5.2, the modelling of EV uptake was influenced by a range of factors. EV uptake was calculated at an individual car level, but for presentation purposes these numbers have been aggregated to the zonal level and Local Authority (LA) level. Figure 14 and Figure 15 therefore show the number of EVs modelled and the percentage uptake, respectively, for 2030 for each scenario and local authority within the Manweb region.

Numbers show that Local Authorities in England, such as Cheshire West and the Wirral, are assumed to have the highest number of EVs, regardless of scenario.

These numbers show that LAs in England, such as Cheshire West and the Wirral, are assumed to have the highest number of EVs, regardless of scenario. Largely, this is a consequence of the population in these areas – which is higher than in Ceredigion, for example.

However, the influence of income and off-street charging provision can also be seen. Areas such as Liverpool and Knowsley have predominantly terraced housing stock, and average incomes are also lower than in authorities such as Cheshire West. As a consequence, the proportion of EV uptake is expected to be the lowest in these authorities regardless of scenario.

The modelled impact of public charging confidence can be seen in the comparison in uptake in Liverpool in Scenario A (high confidence in and high availability of public charging), which has 27% uptake, and Scenario B (low confidence in and low availability of public charging), which has only 20% uptake. Although this result is the product of the scenario factors, it does help to highlight how the widespread provision of public charging might influence uptake.

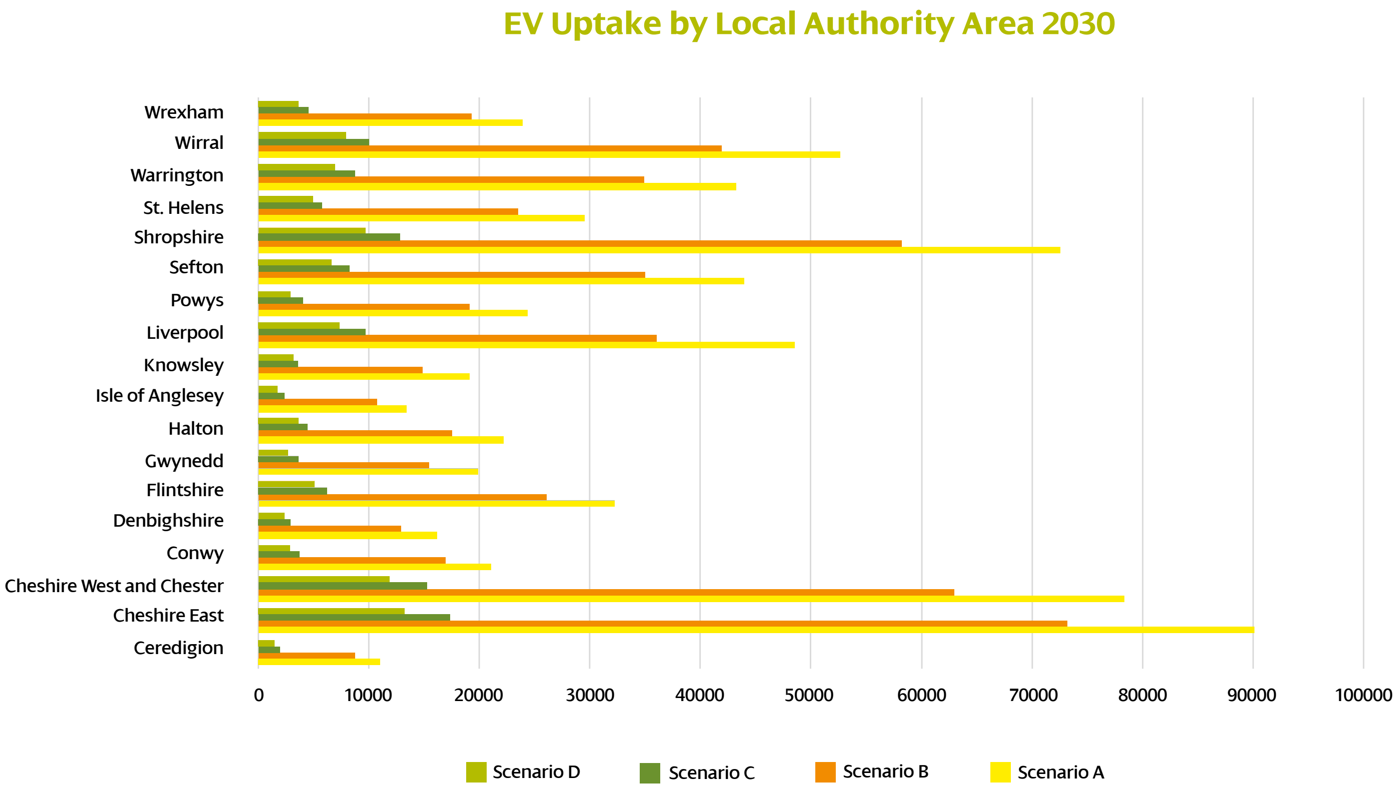

Figure 14: Scenario-Based 2030 EV-Uptake Forecasts for Local Authority Areas

At a zonal level (which are smaller than Local Authority areas), the differences in EV uptake are more marked. For instance, in the 2030 Scenario A forecast (On Course for Net Zero), EVs make up ~35% of the car stock on average. However, several zones – such as LSOA: E01007003 in Bootle (Sefton LA) – have an uptake rate of below 15%. This is a consequence of only 15% of houses having off-street parking and income levels well below the regional average.

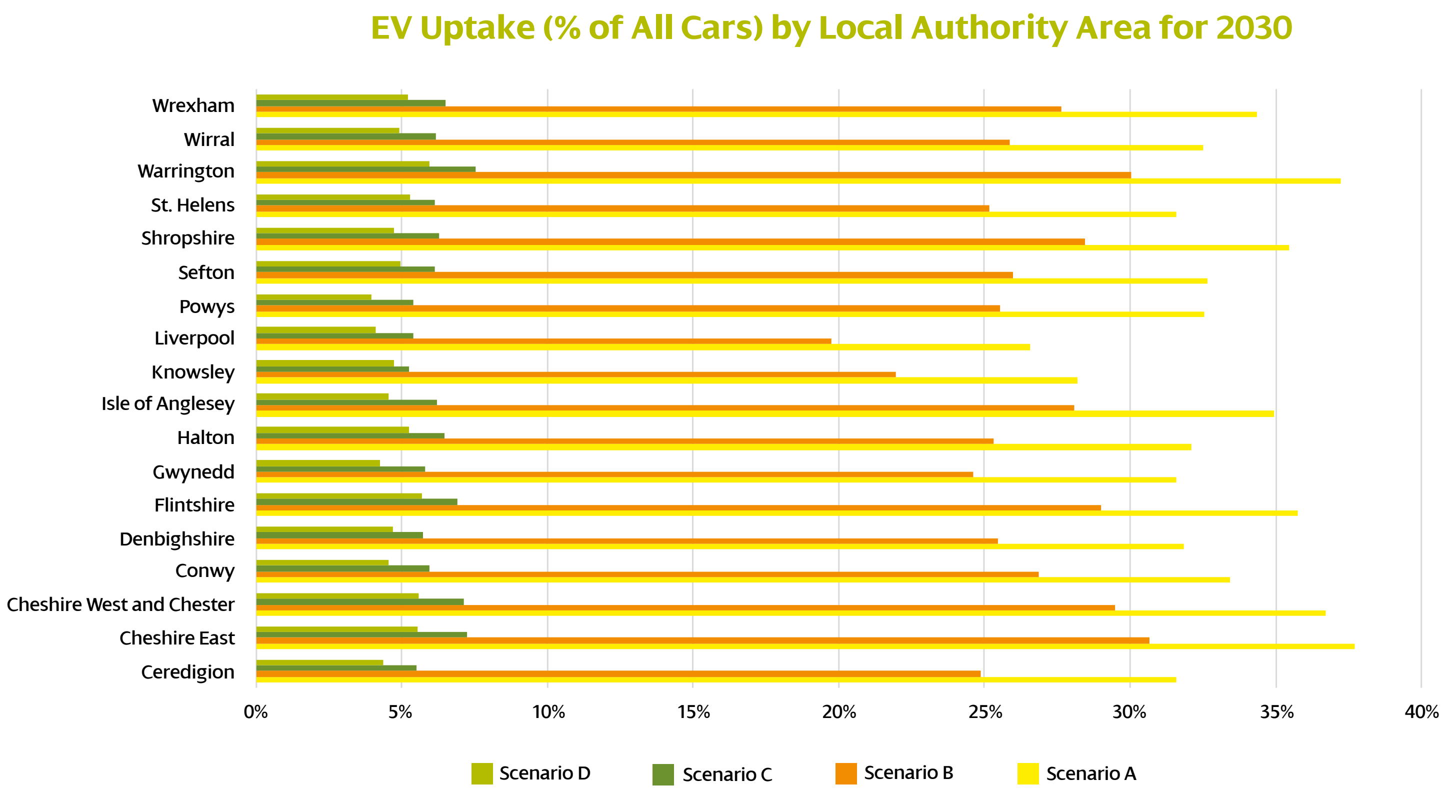

Figure 15: Scenario-Based 2030 EV Uptake Forecasts for Local Authority Areas as % of Cars

On the flip side, some zones are anticipated to have over 45% EV penetration – such as LSOA: E01018411 outside of Holmes Chapel in Cheshire. Over 75% of properties in this zone are assumed to have off-street parking, and income levels are much higher than the average. Figure 16 shows a plot from Visum of EV uptake per zone in the 2030 Scenario A.

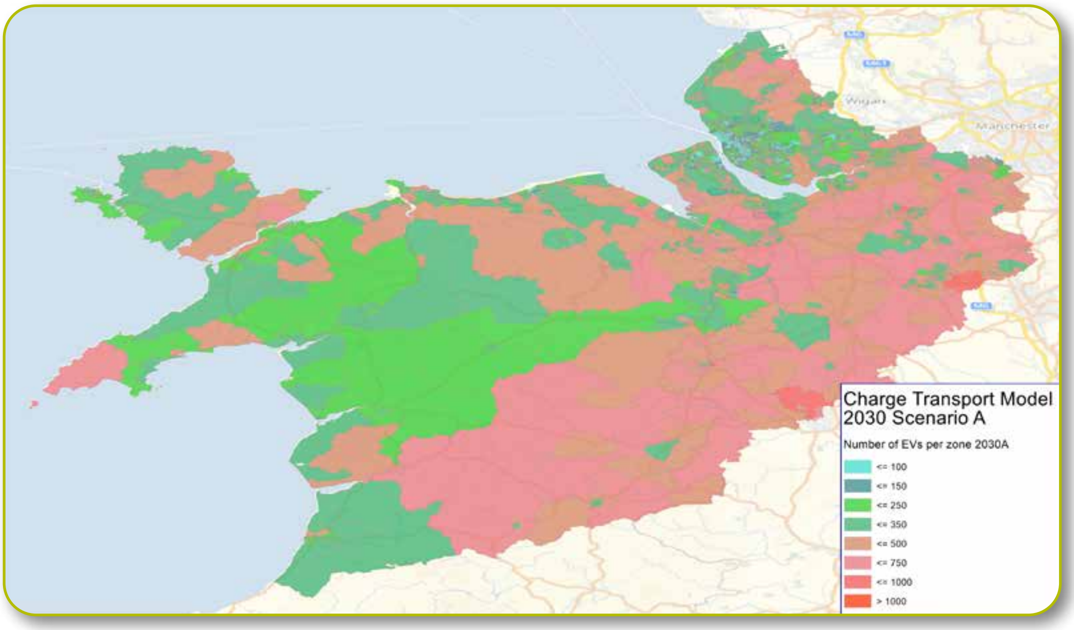

Figure 16: EV Uptake Per Zone from the 2030 Scenario A Model

From consultation in the scenario-planning workshops, the influence of a driveway was seen as a major factor in EV uptake. Even where public infrastructure is assumed to be good and widely available, it was felt that more people with a driveway would get an EV during the transitionary phase (present day - 2030) because it is simpler, more convenient, and cheaper to charge at home.

Data in the Charge Transport Model also revealed another set of factors that suggested uptake would be higher from those with driveways: income and home ownership levels. This is because properties with driveways (and/or garages) are typically more expensive, requiring a higher income. Similarly, home ownership is also associated with higher incomes, and it was felt that earlier adopters of EVs were more likely to be homeowners since they could install a chargepoint on their land without landlord consent.

Data in the Charge Transport Model also revealed another set of factors that suggested uptake would be higher from those with driveways: income and home ownership levels.

From the EV Up, National Travel Survey, and census tenure data, it is assumed that approximately 60-65% of car-owning properties in Manweb have access to off-street parking and would be able to install a private charger. With a driveway being a key factor in assumed EV uptake, the Charge Transport Model estimates the proportion of EVs that will have access to off-street charging or not.

Figure 17 shows the results from the two high-uptake scenarios in 2030. In the Driveway to Electrification Scenario (B) in 2030, 85% of EVs are assumed to have access to a private home charger. This reflects the idea that if the public infrastructure is poor and expensive and has sparse coverage, owning an EV will not be a viable option for many without a driveway.

In the On Course for Net Zero scenario (A), which is defined as having a widespread, competitively priced, and good-quality infrastructure provision, it is assumed that a significant majority of people without driveways in the model will get an EV. Despite this, 78% of EVs are still assumed to be owned by people with access to private charging, due to the reasons given above (higher incomes and more likely to have access to a driveway). These trends are reflected in the other scenarios and years, with EV uptake higher in scenarios with better public charging, but still less than the proportion of cars with access to off-street parking. This phenomenon only changes from 2040 onwards, when the infrastructure provision is assumed to be mature and uptake exceeds 75% across the whole population.

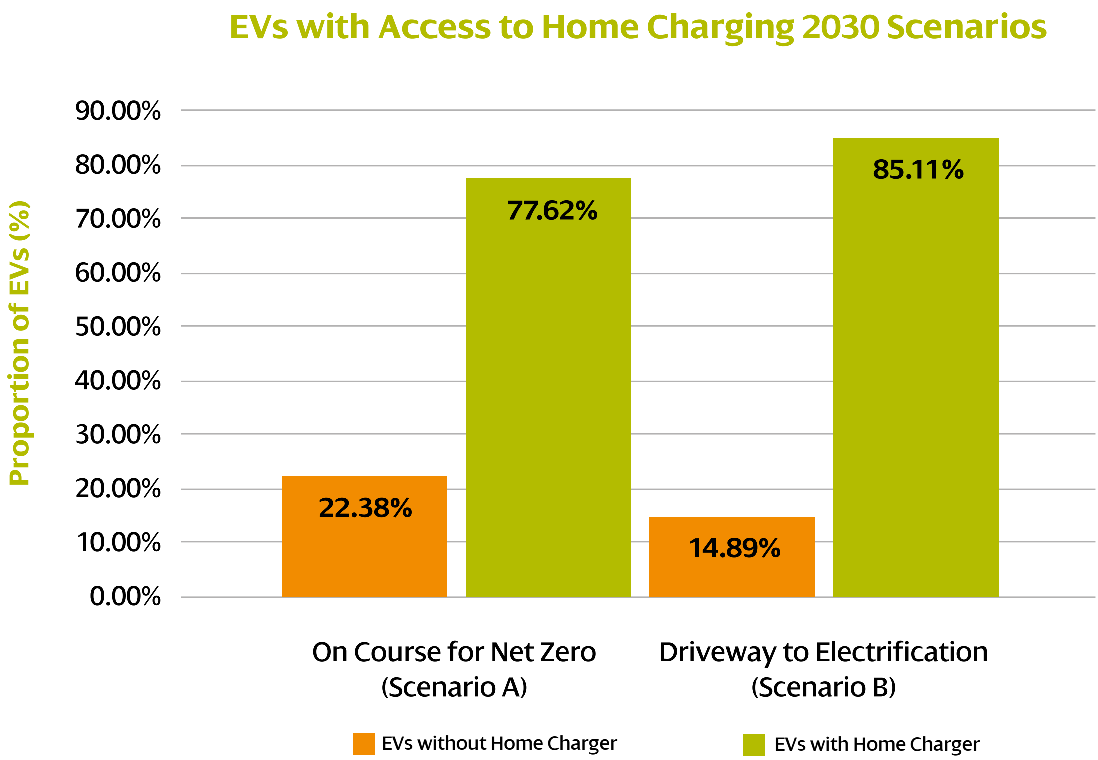

Figure 17: EVs with Access to Home Charging: 2030 Forecasts

6.3. Demand For Charging

Where and how much energy might be required for EV charging across Manweb?

Charging choices are made based on a range of factors, as described in section 5.3. For each individual charging event, the following information is tallied by the model:

- The zone location
- The activity purpose and the type of charging used, i.e., public destination charging if the individual is shopping
- The dwell time for that activity (equivalent to the time the car is assumed to be parked)
- The energy drawn from the charge in kWh

Charging event data is the principal output of the transport model fed into the ConnectMore online tool, with granular data provided at a zonal level. For further information relating to the charging demand outputs from the model, please see ConnectMore[23]. Since detailed data is available in an interactive tool, this section focuses on some high-level results and comparisons between the scenarios and years.

Figure 18 shows the aggregated energy demand for charging across the whole Manweb region for each scenario in 2025, broken down by charging type. As described in the previous section, most EV owners are assumed to have access to a private home charger (regardless of scenario), and therefore, unsurprisingly, energy demand from residential properties with private charging dominates.

In the two scenarios with poor public infrastructure (B and D), the proportion of home charging is higher – mainly because there are fewer EV drivers without a driveway. This factor is consequently reflected in the demand for public charging; for instance, even though overall demand is similar between A and B, public destination demand is three times higher in scenario A (~60MWh per day compared to ~20MWh).

23. https://www.spenergynetworks.co.uk/pages/connectmore_interactive_map.aspx

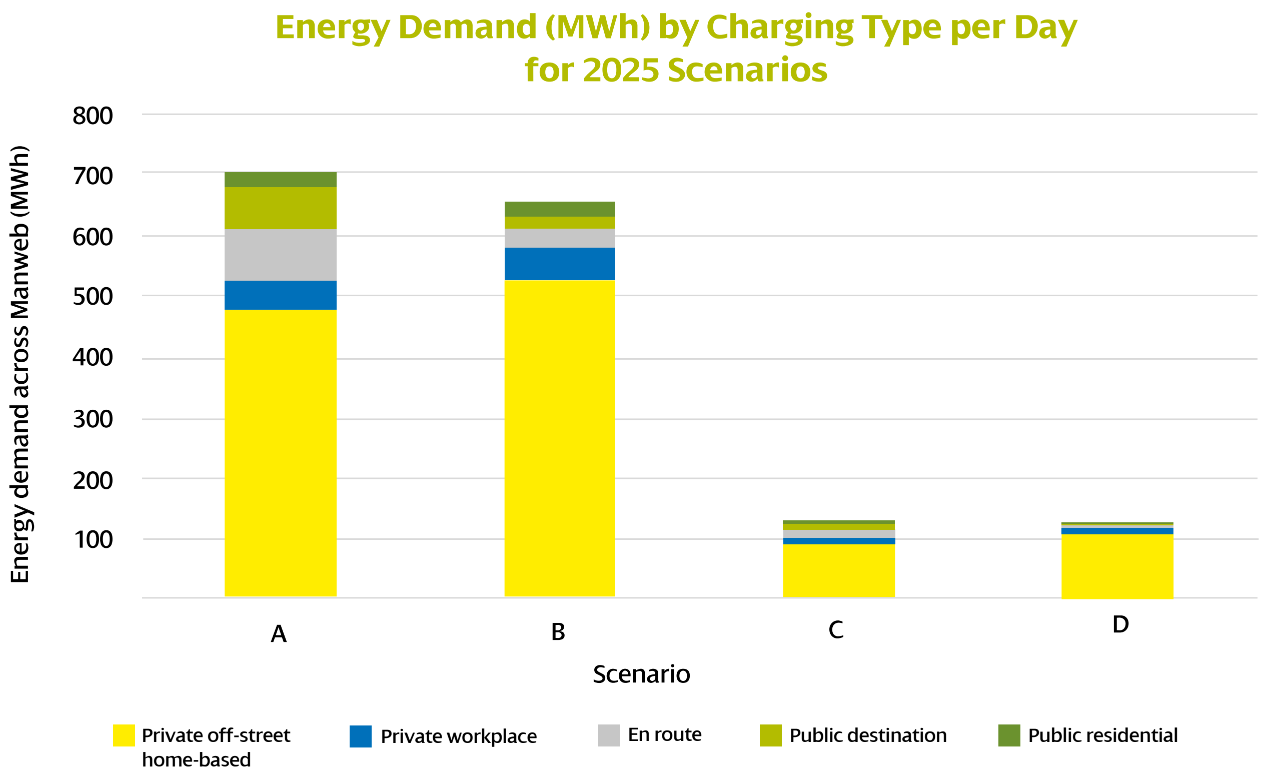

Figure 18: Energy Demand in the 2025 Scenarios

Figure 19 shows the energy demand data by charging type in the 2030 scenarios. Noticeably, the overall demand for energy is much higher than in 2025 (compare the y axis), reflecting the expected growth in EV uptake over that period. Energy drawn at private off-street locations still dominates, but demand for public charging is assumed to grow in all scenarios as the infrastructure market matures and the number of EVs without home charging increases.

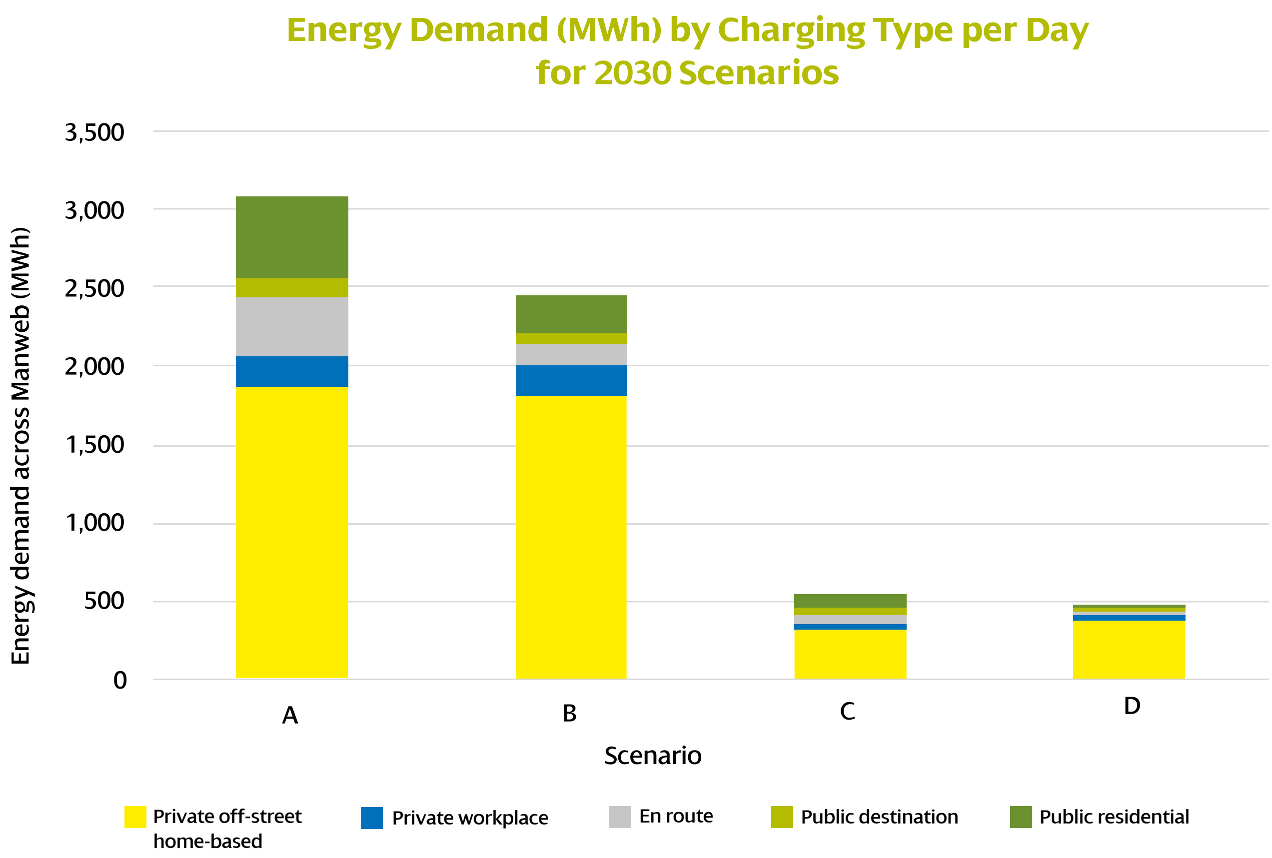

Figure 19: Energy Demand in the 2030 Scenarios

Figure 20 shows the demand for charging in 2030 Scenario A, split by location type and whether the driver has a home charger or not. As shown in Figure 18, approximately 78% of EVs in 2030A are modelled as having access to a home charger. Because of the assumed convenience and cost of home charging, this is deemed the preferred option if it is available, with 60% of total energy drawn at residential properties (equivalent to 77% of charging demand for those with a driveway). Because EVs without a driveway cannot charge at home, they are fully reliant on public or workplace charging. In this scenario, these users make up 22% of the EV stock, but account for more than half the demand for public charging (~630MWh vs. 420MWh).

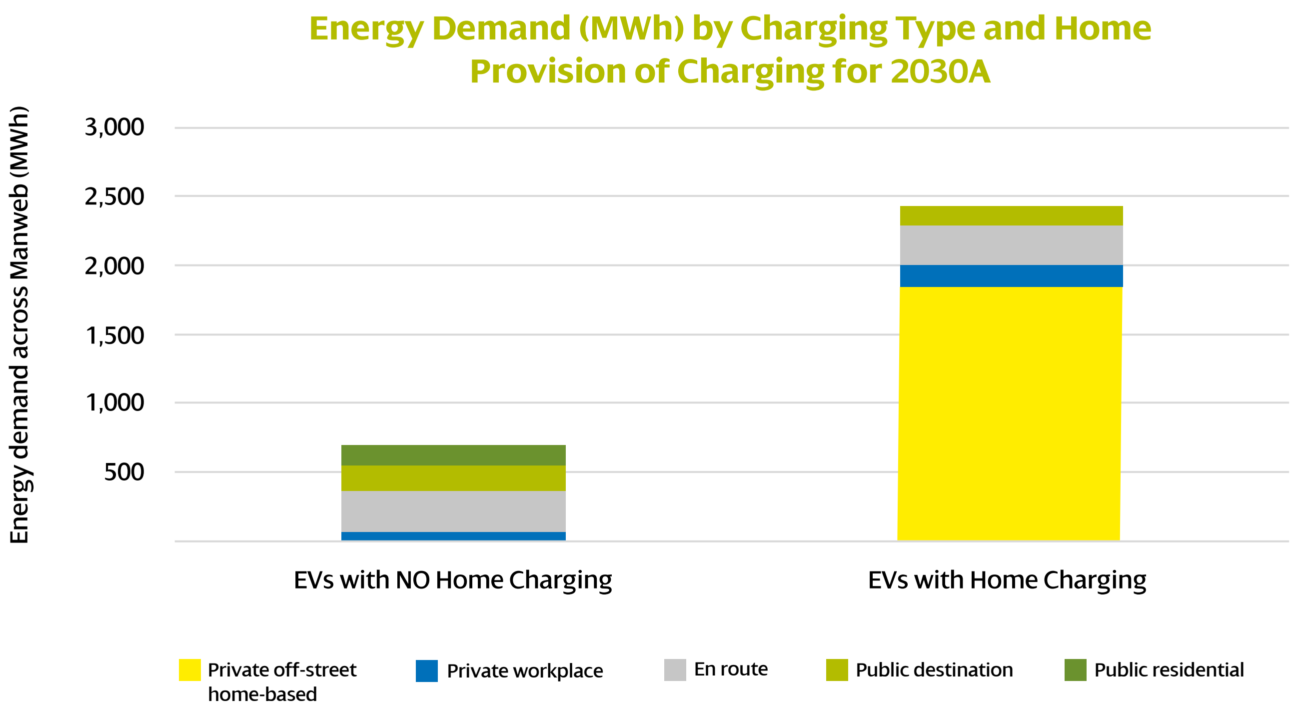

Figure 20: Charging Demand (MWh) Per Day by Charging Type and Home Provision for 2030A

The anticipated split in public charging demand from those with, and those without, a home charger is further exemplified in Figure 21. This shows the demand for public destination charging in 2025A, represented with figurative dots and broken down into demand from those with a home charger (red dots) and those without a home charger (green).

In the 2025A scenario, 85% of EV owners are assumed to have a home charger, but similar to the 2030 scenarios, most of the demand for public charging comes from the 15% of EVs that cannot charge at home. The segmentation that the model provides can therefore be used to assess the requirement for infrastructure based on different needs.

For sections of the population who do not have the ability to install a home charger, the need to install adequate public infrastructure is arguably greater than for those who can charge at home (and may simply have chosen to charge in public if it is convenient but not strictly necessary).

Thus, the model results can be used by Local Authorities to help plan infrastructure equitably, enabling uptake from all groups.

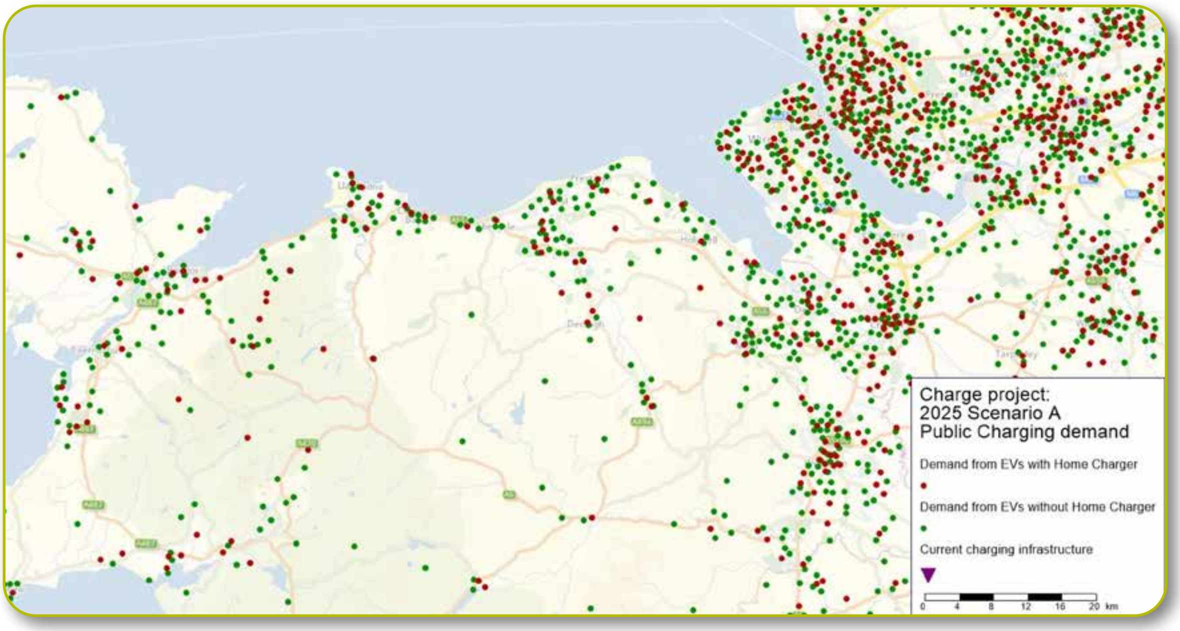

Figure 21: Visual Display of Public Charging Demand

7. Conclusion

7.1. Summary

This report describes the delivery of, and results from, a transport model – the first of its kind for a UK DNO.

The model, built as part of the Charge Project, provides scenario-based forecasts to help anticipate the charging demand and infrastructure requirements for electric vehicles (EVs). Results from this work have fed into the ConnectMore online tool, providing the public and stakeholders with data to understand and better plan for the rollout of further charging infrastructure. By making this tool freely available, SPEN is helping to enable the uptake and usage of EVs across its licence area.

The report describes how the model was built and details the results that were generated. It should be used as a blueprint for other DNOs or bodies wishing to understand future demands for EV charging and infrastructure requirements. If you are interested in repeating elements of this approach, please get in touch or follow communications via the **Charge Project website**[24].

7.2. How to Interpret the Results

How the model results can be used to guide infrastructure decision making.

The Charge Transport Model results are being made available via a public website called ConnectMore. This tool will provide users with the data and insights from the Charge Transport Model, helping them to make better-informed EV infrastructure decisions. Following conversations with key stakeholders and through development of this work, the Charge Transport Model results can be used to highlight:

- **What is the scale of requirement for EV infrastructure?** Depending how EV uptake develops, the transport model results help to quantify the likely scale of infrastructure required to support future EV charging needs. This information can be used to support regionwide policy and planning.
- **How are infrastructure needs likely to differ by area?** The model provides granular data to show what sort of and how much infrastructure might be required in each area. For instance, Liverpool is likely to require more public charging than smaller cities in the region if EV uptake in the city is to be equitable. This is because access to private charging (parking) is more limited in areas of the city, and because commuting distances into the city are greater than those to small towns. The results from the model can help quantify this and highlight where and what type of infrastructure might be needed.
- **What is the likely use case for infrastructure if it is installed in a certain location?** For each scenario, the transport model provides detailed requirement patterns by granular area, including the number of potential charging sessions, the possible amount of energy required, and the likely dwell time and time-of-day profiles that can be used to inform utilisation calculations.

24. https://www.spenergynetworks.co.uk/pages/charge.aspx

- **What effect might EV charging demand have on the electricity network?** Using the detailed spatial data from the model, the DNO can anticipate how demand for electricity might develop across the region. This includes how much demand might come from residential properties (and by what time of day), as well as how many connection requests might be made for public charging and where. This information can be used to support future network planning, including the scale of upgrades required and to what extent flexible services could be implemented to manage the demand.
- **What sort of future is desired and how can we build towards this future?** The scenarios developed for the Charge Project help underline that the future is uncertain and that EV uptake and the subsequent demand for charging are subject to many external factors. However, the scenarios can help highlight what a desirable future might or might not look like, as well as what provision of infrastructure is likely if this future is to come to fruition. With climate change and the need to decarbonise becoming an ever more urgent topic, the On Course for Net Zero scenario helps to provide a vision for infrastructure rollout to help meet climate targets. The other scenarios describe plausible but less desirable futures, allowing planners to test their infrastructure plans with a range in mind and to take the decision of least regret.

7.3. Key Insights

Key insights from the transport model that can help guide planning on a wider scale.

The Charge Transport Model provides detailed results for various scenarios and future years, and across small spatial areas (LSOAs); these can be accessed via the ConnectMore tool and used to guide local infrastructure decisions. However, some general trends and insights have been observed from this work that could have implications for other DNOs, Local Authorities, or Government:

- The demand for energy is clearly tied to how EV uptake progresses, and exactly how uptake will progress is uncertain. However, if carbon reduction targets are to be met and EV uptake follows the necessary trajectory, **networks should be prepared for significant growth in demand between 2025 and 2035.** In the On Course for Net Zero scenario, it's envisaged that about 700MWh of electricity will be required for EV charging per day in 2025 (of which ~25% is estimated to be needed in public locations), growing to 3,000MWh per day in 2030 (of which ~35% is estimated to be in public locations).
- Buying or leasing an EV (or any new car, for that matter) is dependent on a certain level of income. Correspondingly, owning or living in a property with off-street parking (which is more likely to be a detached house) is also closely tied to income. As a result, we can expect that EV uptake is unlikely to be equitable across society in the next 10 years. Although these factors cannot be entirely avoided, the rollout of public charging infrastructure will make EV usage easier for those without a driveway. Consequently, the rollout of **public infrastructure can play a crucial role in making uptake of EVs more equitable.**

- Demand for public charging is likely to follow a Pareto effect: most EV drivers will be able to charge at home, but **most of the demand for public charging is likely to come from those without home charging.** The Charge model has been used to estimate - varying by scenario - that by 2030, 50-65% of public charging will come from the 15-25% of drivers that can't charge at home. Therefore, understanding the demographic of car owners without a driveway is key to planning for public infrastructure.
- Public charging patterns will likely change as uptake progresses, especially as a higher proportion of non-driveway owners switch to EVs. Thus, it may not be appropriate to extrapolate behaviours and demand patterns based on current charging patterns. Instead, it is important that a **consideration of travel patterns, demographics, household types, and human behaviours across the whole population is combined with charging data to fully understand how the requirement for public charging might change over time.**

7.4. Repeating The Approach In Other Areas

How similar models and methods can be applied elsewhere.

The Charge Transport Model has been built to cover the Manweb region in the North-West of the UK. However, the approach can easily be adopted in other regions to help understand EV infrastructure requirements. The following steps and recommendations are made so that this work can be repeated elsewhere:

- A transport model provides a comprehensive understanding of travel patterns across a region, which, in turn, provides crucial information to inform EV infrastructure requirements, such as how many EVs might be visiting an area and – based on detailed trip patterns – how much energy might be required during charging sessions.
- A tour-based demand model provides a good representation of aggregate travel patterns based on observed data, and also the detail required to understand the accumulation of vehicle distances and locations where charging could take place. Visum has an in-built tour-based demand model that can be configured using the same parameters as those developed for the Charge Transport Model.
- If a tour-based model is used, it is recommended that suitable data is sourced to help define the tour patterns in the model. For the Charge Project, England's National Travel Survey was used, and this is recommended for other regions. Outside of England, similar surveys, which provide in-depth travel diary information, are recommended as a primary source.
- Demand patterns are more important than traffic and congestion modelling. Often, transport models are built to understand congestion levels across a network, but in the case of planning for EV infrastructure, this is not deemed so necessary. However, the calibration of the model demand and trip-length patterns is important to help anticipate where and how much energy is required for charging.

- Scenario planning is recommended to help understand uncertainties and focus the specification of the model. This exercise for the Charge Project helped identify desirable outcomes that could support decarbonisation plans, but also highlighted possible divergent futures that should be considered before decisions are made. If this process is repeated, the scenario framework developed for the Charge Project could be repurposed and replicated elsewhere.
- An EV infrastructure transport model is a powerful decision-support tool that helps to quantify the requirements for infrastructure and should be used as part of a holistic approach to plan future charging networks. In the Charge Project, the transport demand data is provided alongside electricity network capacity data to help show where charging might be needed and where chargepoints can be installed at the lowest cost. These tools should be used alongside traditional site selection – including land provision, civil considerations, parking provision, and business case development.