Public

tRESP

Consistent Planning Assumptions: Methodology and Detailed Design

NESO
National Energy System Operator

Contents

Scope and Structure

Scope of CPAs in tRESP

Consistent Planning Assumptions (CPAs) are a critical component in driving consistency across Distribution Network Operator (DNO) plans. The tRESP Pathways provide the scale of low-carbon technologies expected in the short- and long-term, and the CPAs describe the network impact from these low-carbon technologies. It is expected that both will be used by DNOs to inform their business plans for the next electricity distribution price control period from 2028 to 2033 (known as ED3).

Building on insights gained from the last distribution price control period (known as ED2), where significant variances among DNOs were observed[1], the focus for ED3 is on areas that most significantly influence demand growth and future DNO investment. According to Future Energy Scenarios[2] (FES) 2025, electric vehicles (EVs) and residential heat pumps are the biggest drivers for increased peak demand by 2050 (Figure 1), contributing to over 50% of the increase between 2024 and 2050 in Holistic Transition.

Defining a consistent set of planning assumptions for these key areas will enable consistent derivation of network impact, providing confidence of network plans to Ofgem and other stakeholders. National Energy System Operator (NESO) recognises the importance of reflecting national and regional differences, and by establishing criteria that do not prescribe single values, we set out a consistent methodology that accommodates national and regional variation. This approach strengthens confidence among national and regional stakeholders.

This pragmatic approach focuses on establishing a robust foundation in key areas with the greatest uncertainty and impact, rather than attempting to address all areas simultaneously.

[1] Ofgem, RIIO-ED2 Final Determinations Core Methodology, November 2022

[2] Future Energy Scenarios (FES) | National Energy System Operator

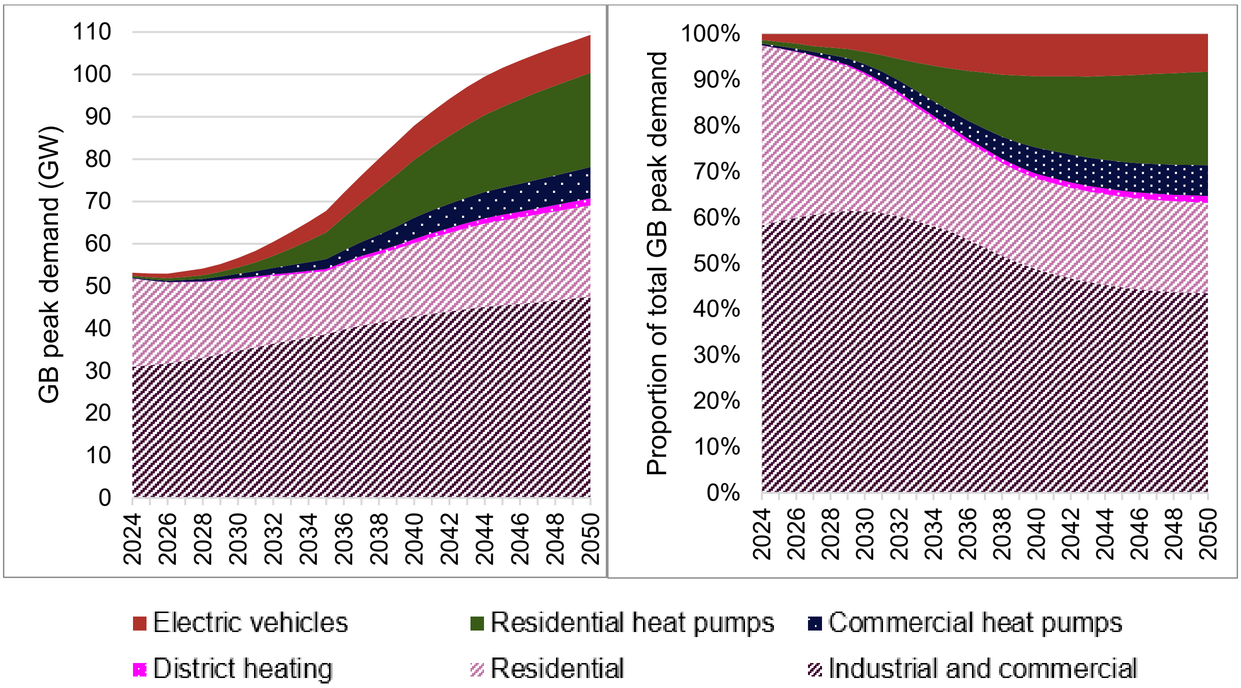

Figure 1: FES 2025 Holistic Transition peak demand (excl. losses) breakdown 2024-2050.

In Figure 1, the striped areas (underlying residential, industrial and commercial (I&C) demand) are excluded from tRESP Pathways and CPAs. Dotted areas are included in tRESP Pathways but do not have CPAs provided by tRESP, and solid areas (residential heat pumps and EVs) are included in tRESP Pathways and have CPAs. (Source: FES 2025, Table ED1).

The structure of CPAs for tRESP

Given the varying calculation methods and values employed by DNOs, there is a clear need for standardisation. Consistent planning assumptions cannot be effectively set if they are applied inconsistently, as this would undermine their purpose. To achieve consistency and drive standardisation, a common modelling approach should be adopted by all DNOs.

The Energy Networks Association (ENA) has highlighted the importance of this requirement, particularly for EVs and heat pumps. Their work suggests that oversimplifying electrical load modelling could compromise the detailed refinements achieved through Distribution Future Energy Scenarios (DFES) methodologies developed over the years.[3]

We will set out Consistent Planning Assumptions (CPAs) to be the combination of the expected modelling approach and a set of modelling assumptions for estimating demand from EVs and

[3] Energy Networks Association, Open Networks, *Summary of DNO DFES Electrical Load Forecasting Assumptions*, February 2025

residential heat pumps on a distribution network asset. This set of assumptions is what we mean by CPAs i.e. the CPA is the whole modelling approach, not a kW per EV or heat pump.

Based on our defined modelling approach and assumptions (the CPAs), we will:

- indicate a default of each individual CPA
- indicate the resulting default diversified impact on demand from an EV or heat pump based on our CPAs
- set out the minimum process for the modelling approach DNOs are expected to employ when implementing the CPA

The process outlined in the later sections establishes the default approach and minimum process for DNOs to use in planning for ED3, setting everyone on the same path to enable the use of consistent assumptions. This approach enables each DNO to specify additional details, using insights from recent DFES work. For example, separate modelling for cars and vans is permitted if it aligns with the proposed methodology.

Consistency where CPAs are not provided

Detailed consistent planning assumptions are provided for EVs and residential heat pumps. This section sets out broad guidelines to drive consistency for technologies other than EVs and heat pumps, and how the different components fit together to create an overall peak demand estimate.

Broad guidelines:

- Network impact from all tRESP Pathways building blocks (volumes of different technology types, as defined in the Pathways methodology and detailed design) should be included in ED3 load estimates.
- NESO will not set out what other demand/generation drivers should be included in total demand/generation estimates, but expects each DNO ensures there is no double counting against tRESP publications.
- NESO will not provide detailed processes for DNOs to use every building block in the tRESP Pathways and expects DNOs to apply DFES methods to assess the network impact from building blocks where CPAs are not provided. If no such methods are in place, NESO can support to provide a high-level process and assumptions.
- Overall peak demand should be determined from the contribution of all the different technologies (both those in the tRESP Pathways and other inputs such as core domestic and non-domestic demand including data centres and industrial decarbonisation). This should take into account that different Low Carbon Technologies (LCTs) such as EVs and heat pumps, and other demand sources, may have different time of peak individually (indicated by their profile). So the aggregate demand profile of the network asset would be the sum across all the constituent load types. It is appreciated that there will be differences in coincidence between LCTs and underlying load, with the different peaking times for different substations contributing to the overall peak demand of the substation.

- Best practice is to use the overarching criteria to evaluate each planning assumption associated with other building blocks, but alignment with this will not be tested by NESO/Ofgem.
- All methodologies should be transparent and available to business plan assessors.

These guidelines will help to drive broader consistency without setting out detailed processes and assumptions for all tRESP building blocks. This approach allows us to prioritise the quality of implementation for detailed EV and heat pump processes within the tRESP time constraints.

How Values for tRESP CPAs are Defined

As described earlier, we set the CPAs as the expected modelling approach and set of modelling assumptions for estimating demand from EVs and residential heat pumps on a distribution network asset. For each individual CPA, we indicate a default, which can be a single value, a range of values with a single default within that range, or a set of values (for example, the heat pump size is a set of values by dwelling category [4]). All CPA defaults include a source reference.

To justify the selection of the values, we designed a list of overarching criteria to evaluate the assumptions. The overarching criteria serve as a foundational guide to ensure all assumptions are evaluated consistently for factors such as data reliability, relevance and locationality (Table 1). These criteria were selected because they are broad enough to apply to assumptions for a wide range of technologies, ensuring a uniform approach across various contexts.

Table 1: Overarching criteria used to evaluate the reliability of planning assumptions.

Criteria	Definition
Based on reliable source	Based on a credible, reliable source, e.g. Government sources, consumer trials, peer-reviewed journals.
Be relevant	Based on data/assumption pertaining directly to the technology and/or impact in question.
Be up-to-date	Source data was gathered as recently as possible (considering reliability and relevance). The latest version of the data is being used. Technological advancements or changes in consumer behaviour in recent years have not made the assumption out-of-date.

[4] The dwelling categories in the CPAs are detached, semi-detached and end-terraced, mid-terraced and flats, or assumptions are stated as being applicable to all dwelling categories.

Be location-specific	The assumption is location-specific and relates to a Great Britain (GB)-specific study. Where data quality justifies and implementation is practicable, it may be available by Scotland, Wales and the UK Government-defined English regions [5], by local authority, DNO licence area or Grid Supply Point feeding area.
Considers changes through time	Where technological advancements or other changes in efficiency/performance are expected to impact this assumption over time, this should be quantified.
Weather and climate impact	If weather or climate change are expected to impact this assumption, this should be quantified.

The default for each CPA is set as follows:

- Identify the data source/s based on the overarching criteria.
- Conduct a sensitivity analysis to test (a) the sensitivity of the modelled network impact to the assumption, and (b) the impact of national and regional variation within the assumption on the modelled network impact.
- Determine a default (single value, a range of values, or a set of values). Depending on the outcome of the sensitivity analysis, the default value may depend on the location of the modelled network asset.

We engaged with stakeholders, both informally with the DNOs, and through the formal tRESP consultation, to gather feedback on a set of draft CPA values. Following this process, the CPA values were updated, and supported with additional sensitivity analysis where necessary.

Table 2 presents two examples of how the CPA values are defined, along with the demonstrated alignment with the overarching criteria. This information, along with the default values, are provided for all CPAs in a spreadsheet. A full list of the CPAs can be found in Table 3 (EVs) and Table 4 (heat pumps). It is expected that each DNO will apply the CPAs in their network demand modelling and network impact assessment for ED3 business planning, as per the User Guidance in Appendix 4. The User Guidance sets out the approach for DNOs to apply specific CPAs along with the conditions under which DNOs may adopt more granular modelling that is set out in the minimum process.

[5] Noting that the English RESP regions are different to the UK Government-defined English regions

Where the CPAs are provided on an annual basis, the years refer to the period from 1st April to 31st March, in line with the tRESP Pathways definition of years. That is, the baseline year, 2025, refers to the year ending on 31st March 2025.

Table 2: Examples of CPA value definitions.

CPA		EV: Vehicle mileage	Heat pumps: Size of heat pump
Description		The number of kilometres travelled in one year per vehicle.	The heat pump installation size.
Scope		Defined for Lct_BB001, Lct_BB002, Lct_BB003, Lct_BB004	Defined for four dwelling categories (detached, semi-detached and end-terraced, mid-terraced, flats), and for existing stock and new builds.
Unit		km/year	kW
Data source		a) DfT TRA0206 table b) DfT TRA8905 table c) DfT VEH0105 table	a) Building Research Establishment: Dwelling heat loss b) GOV.UK Council Tax: stock of properties, 2024 (Table CTSOP 4.0)
Link/s		https://www.gov.uk/government/statistical-data-sets/road-traffic-statistics-tra#traffic-volume-in-kilometres-tra02 https://www.gov.uk/government/statistical-data-sets/road-traffic-statistics-tra#traffic-volume-in-kilometres-tra89 https://www.gov.uk/government/statistical-data-sets/vehicle-licensing-statistics-data-tables	https://tools.bregroup.com/heatpumpefficiency/dwelling-heat-loss https://www.gov.uk/government/statistics/council-tax-stock-of-properties-2024
Criteria	Based on reliable source	Government published data	Based on English Housing Survey Data using the Building Research Establishment Standard Assessment Procedure (the UK's National Calculation Methodology for energy rating of dwellings) and published government data.
	Be relevant	DfT tables log mileage and total vehicle stock for Lct_BB001-2 (cars and taxis, light commercial vehicles,	Developed as part of the Domestic Annual Heat Pump System Efficiency Estimator, data provided by dwelling category.

	motorcycles), and Lct_BB002-3 (heavy goods vehicles, buses and coaches).	
Be up to date	Road traffic data updated annually, vehicle stock data updated quarterly.	Analysis conducted within last 10 years.
Be location specific	Datasets are GB-specific and are available for Scotland, Wales and the UK Government-defined English regions [6], with some data available by local authority.	UK-based analysis based on English Housing Survey data. Dwelling age data from council tax data for England and Wales. Data has not been disaggregated by nation and region.
Considers changes through time	Not considered.	Captured through dwelling thermal efficiency factor instead (although separate values provided for new builds).
Weather and climate impact	N/A	Not considered (captured through other CPAs).
Default values	Default values are values for the licence area each network asset sits within. Additional detail can be added by using different vehicle type categories (e.g. defining mileage for cars and light commercial vehicles separately) and/or by defining values at higher geospatial resolution.	Default values are provided based on the average age of dwellings in England and Wales. Additional regionality can be added by calculating an adjusted weighted average of data from the Building Research Establishment (BRE) for the distribution of dwelling stock ages in a particular nation or region.

[6] Noting that the English RESP regions are different to the UK Government-defined English regions. England - Office for National Statistics A list of nations and these English regions are listed on the mapping tab in the CPA value workbook.

Detailed Design: Load Profiles

Representative days

Weather conditions and 1-in-20 winter

In the context of tRESP, our focus is on modelling an average weather condition per season, so for winter an average cold day rather than a 1-in-20 winter scenario. This approach aligns with the ED2 planning framework and current Grid Code requirements, ensuring that we address typical seasonal demand patterns effectively. The tRESP outputs are specifically tailored to electricity demand use cases, which are crucial for ED3 network planning.

Half-hourly profiles are critical for understanding how technology counts or installed capacity should be translated into network load impact and then capacity need. Where feasible, RESP aims to drive consistency in this process, including by providing standardised profiles for representative days within a year for EVs and residential heat pumps. This section sets out the number of representative day profiles within a year that are provided as part of tRESP CPAs, and the type of day that they represent. Details of how these profiles should be used are discussed in the sections describing the end-to-end processes: *Electric vehicles*: *end-to-end process and list of assumptions and Heat pumps*: *end-to-end process and list of assumptions*.

NESO recognises that the assumptions regarding *flexibility* and *diversity* will affect the nature of the profiles and how they can be used in network planning. Both topics are addressed below.

Key research questions:

- How many representative day profiles within a year should be provided as part of CPAs, and what type of day will they represent?
- How should the representative day profiles be utilised by DNOs?

Our decision:

For EVs and heat pumps, we provide normalised half-hourly profiles for four representative days within a year:

- Peak demand winter day
- Peak demand summer day
- Peak demand shoulder season day [7]
- Overall minimum demand day

The three peak day profiles represent the day in which the peak half hour occurs within the relevant season in an average weather year, for each demand technology. The overall minimum demand day profile represents the day in which the minimum demand half hour occurs across

[7] Peak demand shoulder season day refers to the day on which the highest high demand occurs during intermediate temperature months.

the entire year, for each demand technology. Figure 2 illustrates these representative days (please note that this diagram is for illustrative purposes only and does not provide the actual tRESP profiles). For EVs, the correlation between weather conditions and demand profiles is weaker than for heat pumps, and no differences between representative days are captured within the CPAs.

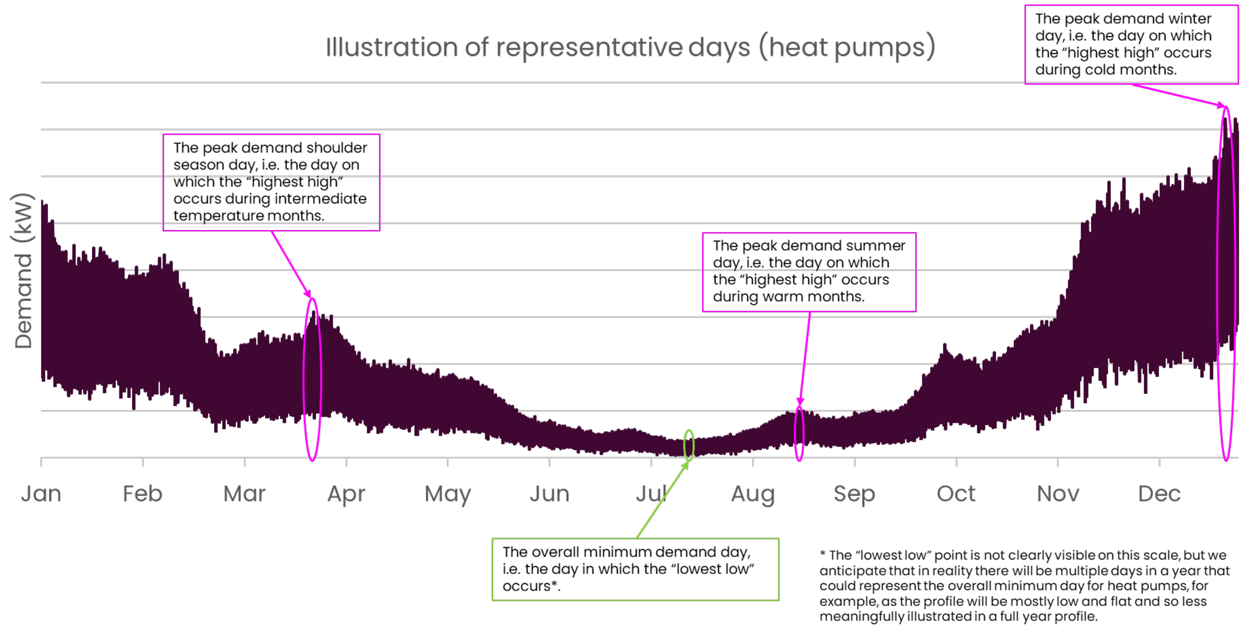

Figure 2: Illustration of representative days within a year.

We have chosen to provide representative peak profiles for different seasons to reflect variation in demand across the year and to drive consistency in network constraint analysis, as assets will be evaluated with temperature dependent (i.e. seasonal) ratings.

The three peak profiles are not rigidly aligned to specific months of the year, so DNOs can evaluate for their peak for each season rather than a specific month. If a DNO's process requires network constraint analysis in a specific month, profiles can be assigned to the most appropriate months by each DNO based on average ambient temperatures, to reflect national and regional variation in annual temperature profiles. For example, in some nations and regions the warmest month in an average weather year may be July, and in other nations and regions it may be in August.

DNOs that consider seasons other than summer, winter and shoulder (i.e. spring/autumn) or individual months may interpolate between the three provided peak day profiles. We will not set out a specific approach to interpolation (which could introduce significant unnecessary complexity), but DNOs should justify their interpolation approach based on ambient temperature profiles or other relevant factors in the nation or region.

For heat pumps, the outside air temperature associated with each representative day profile is provided for information, but no adjustment is required based on this temperature as DNOs will account for the outside air temperature through the scaling of daily electricity consumption (see *Heat pumps: end-to-end process and list of assumptions* for more details).

Table 3 and Table 4 state the EV and heat pump technology archetypes for which representative day profiles will be provided.

The peak profiles should be used by DNOs to support the assessment of import headroom per asset. By aggregating the peak demand day profiles across all technologies, DNOs can find the peak demand per asset for each of the three weather periods (summer, winter and shoulder season). More details about how the half hourly peak profiles for EVs and heat pumps should be utilised in combination with other CPAs and the Pathways outputs are discussed in *Guidance to use tRESP CPAs: End-to-End Modelling Processes and Interactions with Pathways*.

The overall minimum day profiles should be used to support the assessment of assets' export headroom. We recognise that the peak storage and renewable generation profiles are also critical for assessing export network headroom. DNOs already use site-specific generation data assumptions, and the generation capacity and headroom assessment interact with DNO planning approaches for generation and storage (including implementation of the "Tactical Solutions" for storage connections agreed via ENA in 2023[8]).

Given the time constraints for tRESP and the focus on EVs and heat pumps, we do not provide peak generation profiles. Our expectation regarding the broad process for using the overall minimum demand day profile in the assessment of generation network headroom is to:

1. identify the maximum generation day
2. aggregate overall minimum demand day profiles across all technologies
3. combine aggregated overall minimum demand profiles and maximum renewable generation day profiles to calculate net demand at each asset
4. identify need for export-driven reinforcement based on the profile produced in step 3.

Flexibility

Demand-side flexibility and variation in consumer behaviour will impact the shape of electricity demand profiles and therefore the peak demand to consider in network planning. At present, there is notable variation in the approach to flexibility taken by DNOs. It is important for NESO to provide clarity on the flexibility and consumer behaviours that will be captured in the tRESP CPAs and Pathways, to drive consistency and enable DNOs to align network planning processes.

We have divided flexibility into three broad categories:

- **Flexibility in response to price signals without formal contracts**, such as demand shift in response to time-of-use (ToU) tariffs.
- **Contracted flexibility services by DSOs/ DNOs through market mechanisms**, such as the local constraint market and distribution reserve services, and contracted demand turn up and down.

[8] Battery Storage Connections - Tactical Solutions Guidance Notes – Energy Networks Association (ENA)

- **NESO-contracted flexibility services through electricity market mechanisms**, including the balancing mechanism, capacity market, frequency response and reserve services (e.g. Short Term Operating Reserve).

In addition to these flexibility behaviours, we will also discuss the impact of different consumer space-heating behaviour. Whilst this is not strictly 'flexibility', the impact on heat pump profiles can be addressed in a similar way to flexibility behaviour.

Key research questions

- Which aspects of flexibility will be included within CPAs/Pathways?
- How will flexibility be captured within the design of CPAs/Pathways?

Our decision

In the tRESP CPAs, we account for demand shift in response to price signals for EVs and the impact of differences in consumer space-heating behaviour for heat pumps. Further details about the behaviours considered for each technology are explained in this section. Flexibility for other technologies (e.g. smart appliances) are not considered in tRESP. Demand turn down events under certain contracted local flexibility market schemes are not considered, as we do not plan for scenarios in which consumers must reduce demand to account for network constraints.

For all technologies, contracted flexibility is not included as part of tRESP. Understanding and quantifying the need to procure flexibility services will need to be performed by DNOs, forming part of optioneering exercises for investment planning. NESO's RESP does not set out the approach to quantifying the impact of contracted flexibility.

Electric vehicles

For EVs, we consider the flexibility behaviour based on demand shift in response to static time of use (ToU) tariffs i.e. (i.e. peak/off-peak).

For tRESP, we only consider flexibility behaviours for domestic EV chargers. We recognise that there are some cases where flexible behaviour may be exhibited by non-domestic EV chargers. For example, electric bus depots in grid-constrained locations may have specific charging patterns to avoid peak hours. Where DNOs have evidence of flexible charging behaviour for non-domestic EV chargers, these may be applied by exception in specific locations, accompanied by supporting evidence.

Demand shift in response to dynamic pricing (e.g. dynamic wholesale price trackers) is not considered as part of tRESP CPAs. We recognise that this can cause challenges for network planning, as dynamic pricing could result in consumption within standard peak hours, effectively reducing diversity. However, there is limited available data for this behaviour at present, and so it is not feasible to provide an evidence-driven profile for the tRESP CPAs.

Similarly, vehicle-to-grid (V2G) services are not included as a flexibility behaviour within the tRESP CPAs. While the technology can provide additional capacity to the grid during standard peak hours, the change by energy supplier Octopus to move from a fixed V2G window to dynamic pricing (demonstrated by the change in its V2G tariffs) suggests a more dynamic and unpredictable operation.

Additionally, only a limited number of trials have examined consumer behaviours with this emerging technology, and there is a lack of reliable, high-resolution data for developing evidence-based profiles. We recognise that the 2025 FES model the capacity available for participation in V2G, e.g. based on customers with both a suitable vehicle and charge point. However, FES recognises that there is limited evidence to support assumptions on the proportion of those consumers that will be systematically using the technology, e.g. actively participating on a supplier's V2G tariff. Reliance on V2G behaviour for distribution network impact assessment will risk understating required network capacity in the next ten years.

EVs are sometimes deployed in conjunction with a home battery, particularly if the home also has solar panels installed, which provides further flexibility capabilities. In general, home batteries have a smaller capacity than the battery capacity of an EV, and so we expect that a battery would not significantly impact the profile of a domestic EV charger. We anticipate that domestic batteries will instead have more of an impact on other electricity usage in the home and so will affect the general demand profile rather than the EV charging profile specifically.

Heat pumps

For heat pumps, differences in demand profiles are primarily driven by variability in consumer space-heating behaviour. We have assumed that hot water is not the main driver of peak demand, so we have only considered behaviour in the context of space-heating. This could include consumer space-heating behaviour profiles such as:

- Daytime – heating during the day and not during the night
- Bimodal – two main heating periods, one in the morning and one in the evening
- Continuous – steady heating usage throughout the day and night

It may also be interesting to consider a continuous profile but with peak hour avoidance (including through the use of thermal storage), i.e. steady heating usage throughout the day and night but with added flexibility to turn down during peak hours. Data for this type of profile is currently very limited, so has not been included within the detailed design for tRESP. Given the uncertainty in the shape of these profiles and the scale of adoption, assuming peak hour avoidance is not undertaken by consumers at all offers a conservative approach.

How will flexibility and consumer behaviour for EVs and heat pumps be captured within the design of CPAs?

Flexibility and consumer behaviour will be reflected in the tRESP CPAs in two ways:

1. Different *profiles* for each type of flexibility/consumer behaviour.

For EVs, there are two behaviour profiles provided for domestic EV chargers (no flexibility and static demand shift). Please note that for EVs, differences between representative days are expected to be minimal (if any), and so are not represented as part of tRESP CPAs. For heat pumps, where different behaviour profiles are identified in the available data, they will be provided for each of the representative days.

2. A CPA providing the *proportion* of the technology counts assigned to each type of flexibility/consumer behaviour.

   This CPA should be combined with the representative day profiles to derive a weighted average day profile that captures the range of flexibility/consumer behaviours considered. The provided proportional split will apply across all RESP nations and regions.

For EVs, we draw on data from FES 2025 to provide the proportion of the technology counts exhibiting flexibility behaviour. For heat pumps, we utilise information from innovation trials and published sources for the consumer space-heating behaviour profiles. However, as there is currently limited data regarding how consumer space-heating behaviour may evolve through time, this is not captured in the tRESP CPAs. As a result, the consumer space-heating behaviour profiles and proportions are provided for reference only. We recognise that the approach to flexibility is likely to evolve through time. This approach enables us to capture this evolution of behaviours, by varying the proportional split between years where data is available.

Diversity

Diversity in electricity demand can have a significant impact on peak demand analysis, so standardising the approach to diversity is key to driving consistency in network planning. For tRESP, DNOs will calculate the aggregated technology profiles for each network asset, so NESO will not perform diversity corrections directly. However, NESO should provide the necessary information for DNOs to account for diversity at different network levels.

Key research questions

- How should we drive consistency in the DNO approach to diversity correction?
- How should DNOs utilise the tRESP CPAs on diversity?

Our decision

The normalised half-hourly profiles for each technology, as described within the *Representative days* and *Flexibility* sections, are be 'fully diversified'. This means that they account for the reduction in peak demand that is associated with multiple end users, reflecting the fact that not all end users will operate at their maximum capacity simultaneously.

As the profiles provided by NESO are diversified, DNOs will need a way to 'un-diversify' the profiles when assessing assets with a lower number of end users, for example at lower voltage levels. To drive consistency in this approach, we provide diversity-correction curves to modify the profiles, by linking the technology count on a network asset with a scaling factor to be applied to the fully diversified profile. As part of this information, we provide the minimum technology count at which the profile should be considered 'fully diversified' i.e. no scaling factor needed.

For EV chargers, diversity-correction curves are provided based on the number of EVs. For heat pumps, diversity-correction curves are provided based on the number of residential heat pumps installed. Given the scope of the tRESP CPAs is for EVs and residential heat pumps, we do not provide diversity-correction curves for other technologies.

Note that the diversity-correction curves are related to the technology counts, as opposed to the asset voltage level or an asset type or the number of customers and stakeholders served by an asset, as the number of low carbon technologies supported by a network asset can vary significantly between and within RESP nations and regions. We recognise that the technology count at each asset will change depending on the year of the Pathway, which should be reflected in the approach. However, there is a need to balance this with the time required by DNOs to conduct this detailed analysis for every year. In Appendix 4, we provide guidance on the expected minimum frequency for determining the technology count per asset.

As a default, diversity-correction curves are applicable to the whole of GB. An example diversity-correction curve is shown in Figure 3. For this illustrative curve, the minimum count for full diversification could be set at 80. The threshold for determining the point at which the minimum count for full diversification is reached is set at 1.2. That means that the minimum count for full diversification is the lowest count (of heat pumps or EVs) that gives a diversity correction of <1.2.

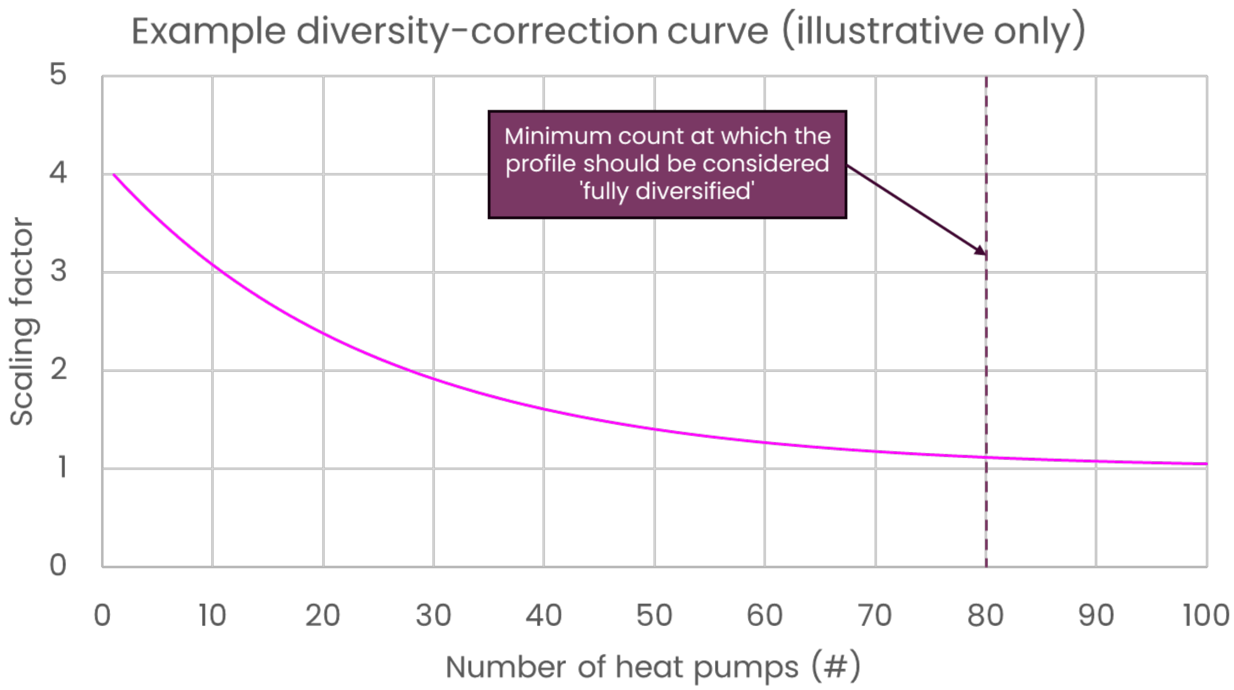

Figure 3: Illustrative example of a diversity-correction curve.

The diversity-correction curves are provided as a lookup table. Each row of the table corresponds to a specific range of EVs or heat pumps to which the correction factor applies, rather than being expressed as a mathematical function. The correction factor for each range represents the modelling results for the number of EVs or heat pumps at the lower end of the range (a conservative estimate) and we do not expect DNOs to interpolate between the values of this function.

Process for electric vehicles

We provide diversity-correction curves for each of the EV charger types. DNOs should follow this process to 'un-diversify' the profiles per network asset:

1. For each representative day and EV charger type, derive the weighted-average fully-diversified kW profile across all flexibility behaviours, if applicable (using the relevant representative day profiles and proportion split for flexibility behaviours as provided by the tRESP CPAs). See *Electric vehicles: end-to-end process and list of assumptions* section below for further discussion about the units of the profiles.
2. Determine the number of EVs supported by the asset of interest.
3. If the number of EVs is equal to or higher than the minimum technology count for full diversification, use the weighted-average fully diversified kW profile.
4. If the number of EVs is lower than the minimum count for full diversification, scale the weighted-average fully-diversified kW profile linearly, using the scaling factor taken from the diversity-correction curve.

Please note that this approach is not intended for the sizing of assets when the sample size is N=1. Since the methodology relies on fully diversified profiles that are normalised to annual consumption (kW/kWh annual), there is an inherent assumption that every day is the same. However, for EVs, we expect charging frequencies of less than once a day and therefore a scaling of the diversified profiles does not accurately assess capacity needs for very small samples.

Process for residential heat pumps

For heat pumps, DNOs should follow this process to 'un-diversify' the profiles per network asset:

1. For each representative day, derive the weighted-average fully-diversified kW profile across all consumer behaviours (using the relevant representative day profiles and proportion split for consumer behaviours as provided by the tRESP CPAs). *See Heat pumps: end-to-end process and list of assumptions* section below for further discussion about the units of the profiles.
2. Determine the number of residential heat pumps supported by the asset of interest (this is not split by dwelling category but in total).
3. If the number of residential heat pumps is equal to or higher than the minimum technology count for full diversification, use the weighted-average fully diversified kW profile.

4. If the number of residential heat pumps is lower than the minimum count for full diversification, scale the weighted-average fully-diversified kW profile linearly, using the scaling factor taken from the diversity-correction curve.

The profile derived from this process should be used across all residential heat pump dwelling categories within the tRESP CPAs.

We recognise that in extreme cold weather conditions, diversity of heating demand is significantly reduced as heating is likely to be turned on consistently. As we are considering a winter average cold spell for tRESP, rather than a 1-in-20 winter, we have not considered the impact on diversity in this scenario.

Guidance to use tRESP CPAs: End-to-End Modelling Processes and Interactions with Pathways

This section outlines the process of translating Pathway outputs related to EVs and heat pumps into electricity network demand, as well as the consistent planning assumptions required for this process.

As indicated earlier, the process outlined here establishes the default approach and minimum process for DNOs to use in planning for ED3, setting everyone on the same path to enable the use of consistent assumptions. This approach enables each DNO to specify additional details, using insights from recent DFES work. For example, separate modelling for cars and vans is permitted if it aligns with the proposed methodology.

Electric vehicles: end-to-end process and list of assumptions

When modelling EVs and their demand, it is important to recognise that demand is not stationary as vehicles move around and charge at different locations. Since demand aligns with charging patterns rather than vehicle registration addresses, a distinction between EV numbers and actual demand should be considered.

Key research questions

- How should half-hourly load profiles be applied to derive peak demand contribution from EVs – to each EV (kW/number), to each charge point (kW/unit or kW/kW installed), or to the annual electricity consumption from EVs (kW/kWh)?
- What is the modelled relationship between EVs and EV charging units?
- What calculation process captures our aims to drive consistency, enable national and regional variation and ensure transparency of assumptions without oversimplifying the complexities involved?

Our decision

The minimum end-to-end modelling process for deriving demand from EVs is set out in Figure 4.

Public

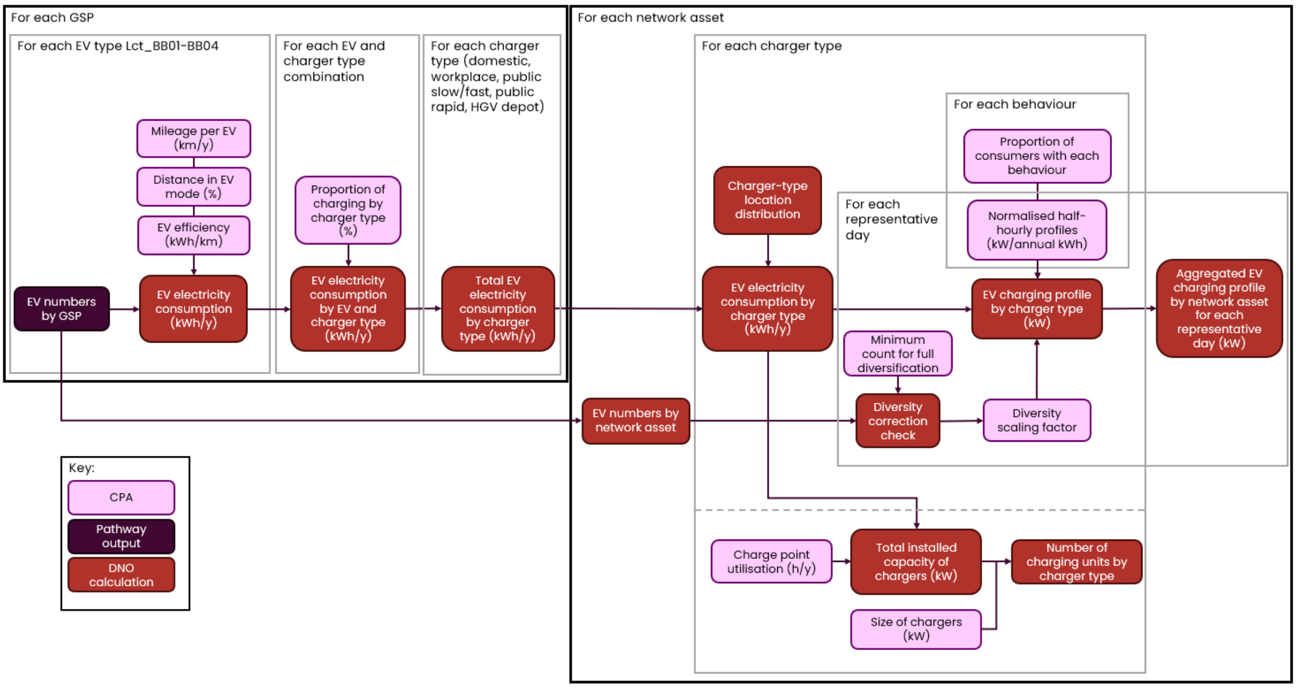

Figure 4: Electric vehicle (EV) demand modelling process.

The Pathway output for the number of EVs at Grid Supply Point (GSP) resolution, along with assumptions on the mileage and efficiency are used to calculate the annual energy demand for each vehicle type. This annual demand is then distributed to different charging types (domestic, workplace, public slow/fast, public rapid, HGV depot). The total annual consumption by charger type is then further distributed to each downstream network asset.

This distribution to network assets could draw from local data, for example, based on parameters such as access to off-street parking (which impacts the proportion of domestic charging), workplace locations, and public charging infrastructure. Noting the catchment areas for low voltage network assets are small, they may not contain all charging types. While the vehicles registered within these areas may fulfil their domestic charging requirements at their registered address, the workplace and public charging is likely to happen elsewhere. Consequently, the level of public and workplace charging varies between different assets, and the charging distribution observed at the GSP level is not expected to be uniform across all downstream primary and secondary substations.

All EV *demand* seen at GSP level is expected to be reflected at the downstream primary substations within that GSP, consistent with normal network running arrangements, but it is not expected to all be reflected at secondary substations. For example, while domestic, workplace, and some public charging would be reflected at the secondary substation level, public rapid charging might connect directly to higher voltages and only be reflected at the primary level.

It is also acknowledged that public rapid charging e.g. along motorway services areas and major trunk roads, may lead to EV demand at a primary substation to be inconsistent and higher than the EV demand associated with vehicles registered in the primary feeding area based on disaggregation of the Pathways. Where this occurs, DNOs should flag primaries where such public rapid charging leads EV demand to be disproportionate to EV vehicle numbers, and the rationale for this such as connections data. See further guidance on the application of EV04: proportion of charging by charger type in Appendix 4: User Guidance for Specific CPA Values.

For each representative day, and each asset, a diversity correction check is performed to test whether the diversity correction factor is needed or not. Where different behaviours are defined for the half-hourly load profiles, the proportion of consumers with each of those behaviours is applied to the profiles to create a weighted average profile for each charger type and representative day. These normalised half-hourly profiles are then applied to generate the half-hourly demand contribution from EV charging (kW per half-hour per year), scaled by the diversity correction factor if necessary. This half-hourly demand contribution from EV charging can then be combined with other demand drivers to calculate the overall peak demand at each network asset by representative day each year.

Below the dotted line in Figure 4, the process also shows how the number of charging units can be calculated. A charge point utilisation assumption is used to convert the EV electricity consumption to installed capacity which in turn is used to calculate the associated required number of charging units. While the number of charging units is not used as a direct input to calculate network peak demand, this output can be used as a validation against the modelled demand per distribution network asset and may be useful for other stakeholders.

The resulting consistent planning assumptions are listed in Table 3. Please note that the scope column refers only to the building blocks or charger types for which this assumption is defined. Details on how the assumption may change through time and how regionality is reflected is covered in *How Values for tRESP CPAs are Defined*. The detailed design of the load profile, including which representative days are considered is covered in *Detailed Design: Load Profiles*.

Table 3: EV consistent planning assumptions.

CPA	Description	Scope	Unit
Vehicle mileage	The number of kilometres travelled in one year per vehicle.	Defined for Lct_BB001 & Lct_BB002, Lct_BB003 & Lct_BB004	km/year
Distance in EV mode	The proportion of vehicle kilometres travelled that use the electric component of plug-in vehicles (for	Defined for Lct_BB002, Lct_BB004	%

	full battery EVs, this is 100%).		
EV efficiency	The amount of electrical energy an EV consumes to travel one kilometre, with lower values indicating higher efficiency.	Defined for Lct_BB001 & Lct_BB002, Lct_BB003 & Lct_BB004	kWh/km
Proportion of charging by charger type	The distribution of charging demand to different charger types, defined for each vehicle type. Represented as the proportion of required charging energy (kWh) from each charger type.	Defined for Lct_BB001, Lct_BB002, Lct_BB003, Lct_BB004 as proportion of charging met by domestic, workplace, public slow/fast, public rapid, and HGV depot charging.	%
Proportion of consumers by behaviour	The proportion of domestic charging events that use the flexed charging profile.	Defined as annual %	%
Normalised half-hourly profiles	The half-hourly diversified demand contribution for each charging type, normalised against the annual	Defined for domestic (normal, flexed), workplace, public slow/fast, public rapid, and HGV depot charging. [9]	kW/annual kWh

[9] While the process is set up to enable the EV profiles to be defined for each representative day, a single profile for each charger type (and flexibility type) is provided, applicable across all representative days.

	consumption for that charger type.		
Charge point utilisation	The total time a charging station is actively used to charge EVs, measured in hours per year.	Defined for domestic, workplace, public slow/fast, public rapid, and HGV depot charging.	hours/year
Size of chargers	The average rated capacity of each charger type or the maximum amount of electrical power that a charger can deliver to an EV at any given moment.	Defined for domestic, workplace, public slow/fast, public rapid, and HGV depot charging.	kW
Diversity-correction curve	The 'un-diversification' scaling factor to be applied to the fully diversified profile based on the number of EVs on a network asset.	Defined for domestic, workplace, public slow/fast, public rapid, and HGV depot charging.	N/A (scaling factor)
Minimum count for full diversification	The minimum number of EVs at which the profile should be considered fully diversified.	Defined for domestic, workplace, public slow/fast, public rapid, and HGV depot charging.	Number (#) of EVs

Heat pumps: end-to-end process and list of assumptions

Heat pump demand profiles can vary depending on multiple factors including the size of the heating system, the weather condition and the type of dwelling. For instance, the weather conditions could vary significantly in different parts of GB and thus impact the amount of energy consumed by residential heat pumps over a period of time.

We are looking to reflect these specificities in the diversified residential heat pump profile produced by our process. The network impact would be derived by combining the number of heat pumps at GSP level with CPAs as they will have direct impact on the peak load observed and its timing.

Key research questions

- How should the difference in heat demand supplied by residential heat pumps in different nations and regions be captured in the process?
- What calculation process captures our aims to drive consistency, enable national and regional variation and ensure transparency of assumptions without oversimplifying the complexities involved?

Our decision

The minimum end-to-end modelling process for deriving demand from heat pumps is set out in Figure 5.

The tRESP Pathways provide the number of residential heat pumps at GSP level, which is further disaggregated by each DNO to network assets at lower voltage level. DNOs should estimate the number of heat pumps installed by at least four dwelling categories – detached, semi-detached and end-terrace, mid-terraced, flats.

The total heat pump capacity installed at each network asset (kW_{th}) is calculated using the average heating system size (kW_{th}), defined for each dwelling category. This process could be further enhanced by DNOs by breaking down the dwelling stock into more dwelling categories (based on factors such as number of rooms, building age, tenure, rural/urban location), but that would be beyond the minimum process. Improvements in building energy efficiency through time are captured by the dwelling efficiency factor, applied to the heat pump capacity. While we recognise that in practice, the installation size does not scale directly with the thermal demand of the household, the heating system size used in these calculations represents the optimal heat pump size for a building with a specific heat loss and is used primarily to calculate the daily energy consumption of a heat pump. Therefore, as the energy efficiency of a dwelling improves, the heat loss is lower and the optimal heat pump size decreases.

A temperature difference is defined for each representative day as the difference in the daily average outdoor air temperature and the target indoor temperature (fixed at 21°C [10]). The daily average outdoor air temperature varies by location and reflects the conditions described in the definition of representative days (see *Representative days*). The daily electricity consumption from residential heat pumps at each network asset is calculated by combining the thermal heat pump capacity installed, the average heat pump efficiency - defined by a Coefficient of Performance or Seasonal Performance Factor (COP/SPF) - and the specific heat pump heat

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[10] Based on Microgeneration Certification Scheme, *Heat Pump: Design Standard* (2025), Table 1 (using the internal design temperature for living rooms), derived from Chartered Institution of Building Services Engineers, *Guide A Environmental design* (2015, updated 2021)

output (which includes space heating and hot water). A normalised diversified heat pump profile of electricity demand (kW_e/daily kWh_e) is then applied to this daily electricity consumption to generate the half-hourly demand contribution from heat pumps (kW per half-hour per year), scaled by the diversity correction factor if necessary. This process should be carried out for each representative day.

To calculate the daily electricity consumption from the heating systems for peak demand summer and overall minimum demand days, Equation 1 will be used. On these representative days there is only a requirement for hot water and not space heating, and as such, the CPA related to the specific heat output will not be dependent on the temperature difference for these representative days on the summer and overall minimum day.

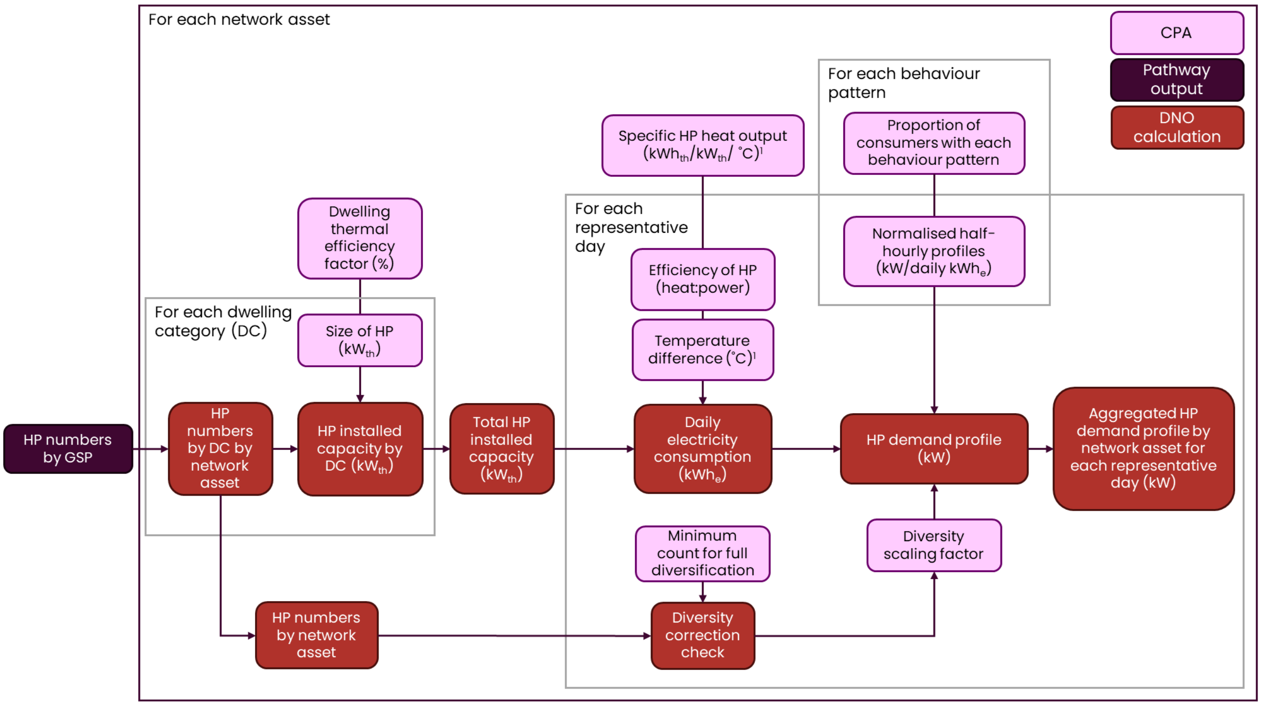
$$Q_{elec}[kWh_e] = \mathrm{C}_{\mathrm{heat}}[\frac{kWh_{th}}{kW}] \times Size_{heat}[kW]/\eta_{heat} \tag{1}$$

where $\mathrm{C}_{\mathrm{heat}}$ is the specific heat output for outdoor air temperature above the heating threshold, $Size_{heat}$ the size of the heating system and η_{heat} the efficiency of the heating system.

For the peak demand winter and peak demand shoulder season days, Equation 2 will be used.

$$Q_{elec}[kWh_e] = \mathrm{C}_{\mathrm{heat}}[kWh_{th}/kW/\Delta T] \times Size_{heat}[kW] \times Diff[°C]/\eta_{heat} \tag{2}$$

where $\mathrm{C}_{\mathrm{heat}}$ is the specific heat output for outdoor air temperature below the heating threshold, $Size_{heat}$ the size of the heating system, $Diff$ the temperature difference between the target indoor air temperature and the outdoor air temperature and η_{heat} the efficiency of the heating system.



[1] For the peak demand summer day and overall minimum demand day, the units for Specific HP heat output are instead kWh_{th}/kW_{th}, and the temperature difference CPA is not used.

Figure 5: Residential heat pump modelling process.

The resulting consistent planning assumptions are listed in Table 4. Please note that the scope column refers only to the dwelling categories or representative days for which this assumption is defined; details on how the assumption may change through time and how regionality is reflected is covered in *How Values for tRESP CPAs are Defined*. The detailed design of the load profile, including which representative days are considered is covered in *Detailed Design: Load Profiles*.

All the CPAs listed in Table 4 are applicable across both Lct_BB005 (non-hybrid heat pumps) and Lct_BB006 (hybrid heat pumps) and are based on data associated with non-hybrid heat pumps. We acknowledge that, in practice, there are likely to be some differences in the installation and operation of hybrid systems compared to non-hybrid heat pumps. For example, hybrid heat pump systems may have a smaller heat pump installed capacity as they are supported by supplementary heating technology. However, there is significant uncertainty in the technology, configuration and behaviour of hybrid heat pump systems. These systems are not currently installed at scale, and so data availability is very limited. Using data from non-hybrid heat pumps for both hybrid and non-hybrid systems offers a conservative approach, given the expected smaller capacity of hybrid heat pumps. Additionally, initial Pathways analysis suggests that the number of hybrid heat pump systems is expected to be low compared to overall housing stock, and so the materiality of any differences is expected to be low.

Table 4: Heat pump consistent planning assumptions.

CPA	Description	Scope	Unit
Size of heat pump	The heat pump installation size.	Defined for four dwelling categories (detached, semi-detached and end-terraced, mid-terraced, flats), and for existing stock and new builds.	kW
Dwelling thermal efficiency factor	A factor to account for improvements in building fabric efficiency, defined as a proportion of the baseline efficiency (i.e. the factor is 1 at baseline and less than 1 in future years).	Defined as a global assumption across dwelling categories (but projected improvements are not applicable for new builds).	%
Efficiency of heat pump (COP/SPF)	A measure of efficiency of the heat pump that indicates how much heat energy is produced for every unit of electrical energy consumed.	Defined for each representative day, for each DNO licence area.	heat:power
Specific heat pump heat output	Defined as the daily thermal output of the heat pump (kWh_{th}) relative to the installed capacity (kW_{th}). For the peak demand winter day and peak demand shoulder season day, it is defined relative to the temperature difference between target inside air temperature and the outdoor air temperature (˚C).	Defined for peak demand winter day and peak demand shoulder season day, and for peak demand summer day and overall minimum demand day.	For peak demand winter day and peak demand shoulder season day: $kWh_{th}/kW_{th}/$ ˚C For peak demand summer day and overall minimum demand day: kWh_{th}/kW_{th}

Temperature difference	Temperature difference between target inside air temperature (assumed to be 21˚C) and the outdoor air temperature.	Defined for each representative day (except overall minimum demand day) [11], for each DNO licence area.	˚C
Normalised half-hourly profiles	The half-hourly diversified demand contribution from heat pumps, normalised against the daily electricity consumption for that heat pump type and consumer behaviour.	Defined for each representative day and type of consumer behaviour.	kW_e/daily kWh_e
Proportion of consumers with each behaviour pattern	Percentage of consumers exhibiting each behaviour pattern.	Defined as a proportional split between types of consumer behaviour.	%
Diversity-correction curve	The 'un-diversification' scaling factor to be applied to the fully diversified profile based on the number of heat pumps on a network asset.	Defined for each representative day.	N/A (scaling factor)
Minimum count for full diversification	The minimum number of heat pumps at which the profile should be considered fully diversified.	Defined for each representative day.	# of heat pumps

Energy efficiency, new builds and demolition rate

In addition to demand growth from new low carbon technologies, such as EVs and heat pumps, it is important to consider the change in demand due to energy efficiency, new builds and demolition rate. FES 2025 modelling suggests that reduction in residential baseload demand

[11] The temperature difference CPA only applies for peak demand winter day and peak demand shoulder season day.

(defined as the electrical load from lighting and appliances) from 2024 baseline is 29% by 2035 and 40% by 2050[12] in the Holistic Transition Pathway.

Key research questions

- How will tRESP drive consistency in the impact of residential energy efficiency, new builds and demolition rate on residential baseload demand?

Our decision

Residential baseload demand is not considered as part of the tRESP Pathways; therefore, we do not set out a detailed modelling method to assess the impact of residential energy efficiency. However, we set out the following expectations for residential baseload for ED3 business planning:

- Separate representation of drivers: There are three main drivers to the change in residential baseload demand: New residential dwelling growth (increase in demand), demolition rate (decrease in demand) and energy efficiency (decrease in demand). The demand from new residential dwellings should be modelled separately from the aggregated changes in demand driven by energy efficiency improvements and demolition rate. This separation will enable comparison and consistency checks between DNOs.
- The tRESP will not provide Pathways or CPAs for new residential dwelling growth or demolition rate.
- Alignment to FES**:** The scale and pace of reductions in non-new build residential baseload demand must be consistent with the FES 2025 Holistic Transition Pathway.

The percentage-based reduction in energy demand based on the FES 2025 Holistic Transition are provided as a consistent planning assumption. These projections are a modified version of the data published in the FES 2025 data workbook to remove the impact of population growth and to incorporate more up-to-date baseline data. The trends therefore represent the residential appliance and lighting electricity consumption (kWh/household) of existing buildings compared to the base year. It is expected that each DNO also models demand from new buildings, but we recognise that new build growth rates vary both between and within nations and regions. Therefore, we only set consistent assumptions for the change in demand of existing buildings and not for the overall change in residential demand.

The FES 2025 projections are based on Energy Consumption in the UK (ECUK) data and consider how demand per appliance and appliance ownership change through time. For appliances, these trends are built from a regression analysis of the historic ECUK data, deterministic factors like social trends, government policy or global events, and benchmarks for the bottom limit of the consumption per appliance, based on reported external projects and stakeholder engagement. In addition to the ECUK data, the projections for lighting demand also consider daylight hours and weather effect, building types and population densities, building utilisation, lighting requirements, and commercial information to determine the energy use of light bulbs across different types of

[12] FES 2025, Holistic Transition, ED1 Table.

technologies. For further information on the FES 2025 methodology, please refer to the Modelling Methods [13] and the FES Pathways Assumptions workbook [14].

[13] NESO, FES 2025 Modelling Methods: How we model FES: NESO pathways to Net Zero
[14] NESO, FES 2025, FES: Pathway Assumptions 2025 (workbook), available from: https://www.neso.energy/publications/future-energy-scenarios-fes/fes-documents

Appendix 1: Sensitivity Analysis

Sensitivity analysis: balancing national and regional variation and consistency

It is important to consider national and regional variation in assumptions, as this can significantly influence the resulting peak demand.

We conducted sensitivity analyses on each CPA, using a broad range of values to determine their impact. This approach enables identification of the appropriate range for assumptions, clarifies where national and regional differences should be considered, and indicates where variations in values could cause inconsistencies.

The following sections set out a few examples of these sensitivity analyses and our resulting minded to position for setting the CPA values.

Electric vehicle sensitivity – mileage

According to statistics from the Department for Transport and the Driver and Vehicle Licensing Agency [15], the average mileage of vehicles varies significantly between Scotland, Wales and the UK Government-defined English regions.

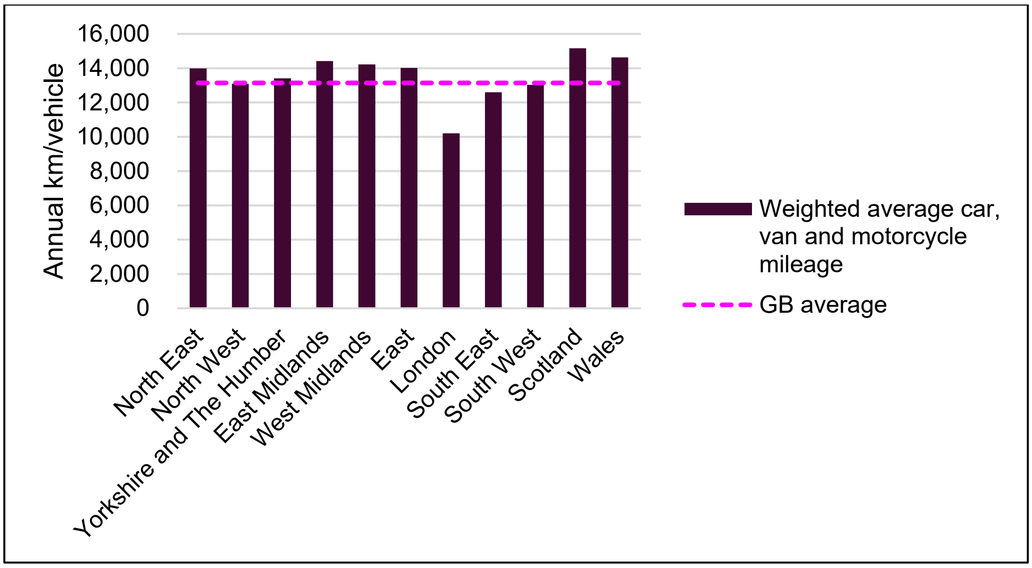


Figure 6: National and regional variation in annual vehicle mileage. Figures represent the 2024 weighted average mileage for cars, vans, and motorcycles. Source: DfT and DVLA[15].

Following the calculation process in Figure 4, the mileage assumption has a linear correlation with the resulting peak demand (assuming all other parameters are fixed). This means that

[15] Department for Transport and Driver and Vehicle Licensing Agency, data tables TRA0206 (from: Road traffic estimates (TRA) - GOV.UK, 2024 data) and VEH0105 (from: *Vehicle licensing statistics data tables - GOV.UK*, 2024 Q4 data).

increasing the mileage by 148% (difference between London average and Scotland average) results in a 148% increase in peak demand contribution from EVs (Figure 7).

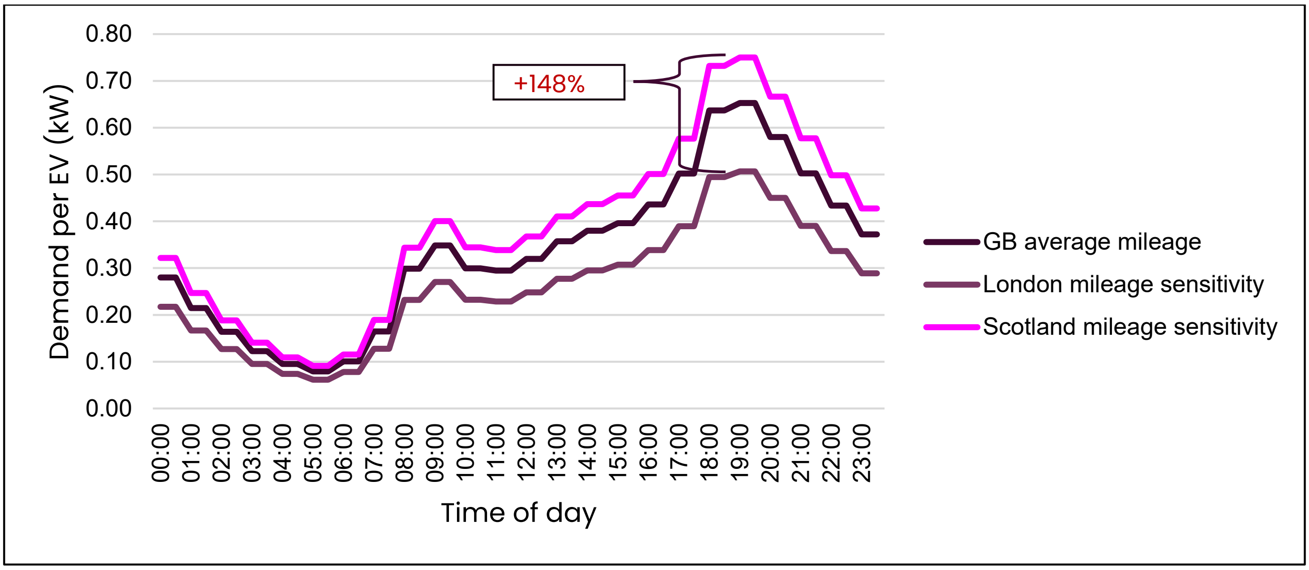


Figure 7: Sensitivity analysis for the impact of national and regional variation in vehicle mileage on EV charging demand. EV charging profile for cars, vans and motorbikes (BB001 and BB002) per vehicle (fully diversified) in a selected year (using example profiles).

This example clearly demonstrates the trade-off between national and regional variation and consistency – there is a clear, recorded difference between Scotland, Wales and the UK Government-defined English regions when it comes to the average annual distance driven by each vehicle, but reflecting this in the calculations results in an inconsistency in the demand per EV modelled.

Minded to position

For assumptions such as mileage, where there is clear, reported difference between the nations and regions, our position is that these differences should be captured within the modelling. It is necessary to acknowledge the range in peak demand impacts, as these differences may reflect actual conditions. Overlooking them could result in underestimating impacts in specific areas. Therefore, our minded to position is to set the default value to the nationally or regionally specific values from the datasets identified. This means that the default value for a network asset in London is different to the default value for a network asset in Scotland. This ensures that neighbouring network assets use more consistent values, thereby reducing discrepancies between them. We recognise that Scotland, Wales and the UK Government-defined English regions do not align exactly with the DNO licence areas, and noting that the English RESP regions are different to the UK Government-defined English regions. We also note it may not be feasible to set different assumptions for assets within the same licence area. In these cases, values from neighbouring regions may be applied, provided that the values used are clearly documented by each DNO.

Electric vehicle sensitivity - efficiency

The Department for Transport TAG data book[16] defines EV efficiency for cars and vans in separate categories; however, in tRESP, we consider a single vehicle category for cars, vans and motorcycles.

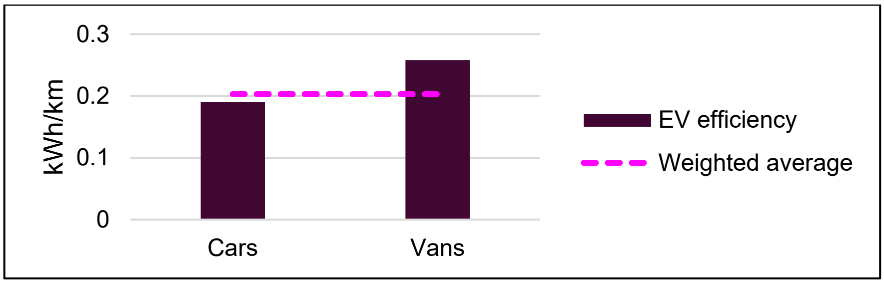


Figure 8: EV efficiency in 2025 for cars, vans, and a weighted average. Source: DfT.

Some DNOs might wish to conduct analysis for these vehicle types separately by disaggregating the outputs from the tRESP Pathways into subcategories. If the allocation of vehicles assumed by DNOs is not consistent with the allocation used to calculate the weighted average, the resulting demand will differ from that derived using the weighted average. While the impact on peak demand depends on the extent of this difference, sensitivity analysis suggests that this is not material. For example, doubling the share of vans (from 20% to 40% of the total), an unlikely extreme, results in an increase in per-vehicle peak contribution of 6%. Note that this has little effect on total network peak demand since EVs are only one component.

Minded to position Since the impact on overall peak demand is minimal, we propose letting DNOs choose whether to model vehicles in separate categories, as long as their methods are clearly documented and data used comes from the specified source.

Heat pump sensitivity – external temperature

As demonstrated in Figure 5, the heat pump demand depends on the assumed temperature difference (difference between target inside air temperature and the outdoor air temperature) for each representative day. The weather conditions across GB vary, and the outdoor air temperature at each representative day could be defined as different values, depending on the location. Testing an outdoor air temperature range between -8˚C and 2˚C for a peak winter day suggest a per-heat pump peak demand contribution between 1.7 kW and 2.4 kW.

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[16] Department for Transport, TAG data book - GOV.UK, May 2025

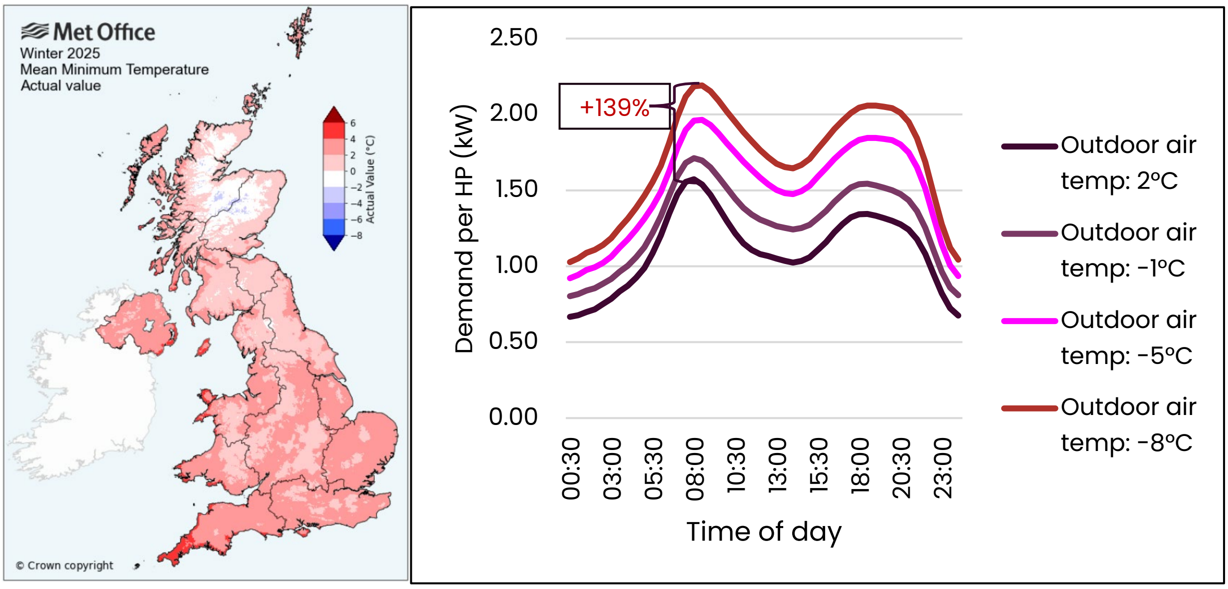

Figure 9: Sensitivity analysis for the impact of outdoor air temperature on the demand per heat pump on a winter peak day.

Minded to position

For assumptions such as temperature difference, where there is clear, reported difference between the nations and regions, our position is that these differences should be captured within the modelling. Therefore, our minded to position is to set the default value to a nationally or regionally specific value. This means that the default value for a network asset in Scotland is different to the default value for a network asset in the South West.

Appendix 2: Supporting Information

Supporting information: decision on representative days

Given the short timescales of tRESP and the prior development of profiles by DNOs, in the tRESP detailed design we aimed to identify the minimum viable set of half hourly profiles that should be included as part of tRESP CPAs.

All DNOs agreed that the peak demand winter day and peak demand summer day were on the critical path for peak demand forecasting and investment planning. Some DNOs indicated that they may not use the shoulder season peak demand profiles. Feedback from other DNOs highlighted that, as asset ratings are seasonal, it is important to clarify the approach for spring and autumn. A particular area of concern was raised around intermediate cool days, as if only summer and winter profiles are provided, DNOs may choose to use winter profiles for colder shoulder months which could result in notable over-sizing of assets. On this basis, we believe that the peak demand shoulder season day profile provides important nuance and should be included in the tRESP CPAs.

As an alternative to the overall minimum demand day, we also considered providing a profile to represent the demand on the peak generation day of the year. This is potentially a more accurate way of calculating export-driven reinforcement needs, as it is likely that export-driven capacity constraints are driven by the peak generation half-hour. However, accurately capturing the behaviour of each technology archetype during the day of peak generation is challenging, particularly given national and regional variation in generation profiles resulting from different generation technology mixes and weather conditions. The overall minimum demand day offers a slightly more conservative approach but avoids the risk of under-sizing assets as a result of mis-characterising demand on the peak generation day.

Several other representative day profiles were considered during the detailed design process, including:

- representative day profiles for each month
- average (as opposed to peak) demand day profiles
- representative day profiles for 365 days in a year
- separate weekday and weekend profiles

Further justification for the exclusion of the above representative day profiles in the tRESP CPAs is discussed in the following sections.

Providing monthly (as opposed to seasonal) sets of representative day profiles would provide more nuance regarding seasonal variation in technology profiles and could drive improved consistency between DNOs. This is only relevant to certain DNOs, as several only consider seasons, rather than months, in demand forecast modelling. We have chosen not to provide monthly profiles as overly prescriptive monthly variation could prevent national and regional variation from being captured. We believe that interpolating between the three seasonal profiles, accounting for nation and region-specific weather patterns and behaviours, should strike the balance between consistency and national / regional nuance for DNOs that perform demand forecast modelling on a monthly basis.

Some DNOs utilise average demand day profiles per month or season (in addition to peak demand day profiles). In particular, average demand days may be useful for sense-checking or characterising the normal running arrangement of an asset in the baseline year, and for supporting consistency checks with the expected total annual energy demand for a given technology. However, it is our expectation that peak, rather than average demand days will drive asset capacity constraints. We therefore do not perceive average demand days to be on the critical path for investment planning.

We recognise that some DNOs consider annual demand profiles for 365 days per year. As for the average demand day profiles discussed earlier, a full year profile could support consistency checks with the expected total annual demand for a given technology. 365 days per year is an unrealistic level of detail for tRESP, which is disproportionate for a required process and would be more likely to cause inaccuracy in the demand forecasting process. As the profiles will be provided on a kW/(kWh/year) basis for EVs, this will still facilitate alignment with total annual demand checks (see the section *Guidance to use tRESP CPAs*: *End-to-End Modelling Processes and Interactions with Pathways* for further discussion). For heat pumps, the total annual demand is not a direct output from the tRESP CPAs, but DNOs may calculate total annual, monthly or seasonal heat pump demand assumptions based on the tRESP CPAs to facilitate DNO modelling. However, this is not an expectation in the tRESP CPAs.

DNOs were also consulted on the need for separate weekday and weekend representative day profiles. Feedback indicated that this separation is not considered in most current DFES processes and so has not been included in the tRESP detailed design.

Supporting information: decision on end-to-end EV modelling process

To determine the end-to-end EV modelling process, we set out the following research questions:

- How should half-hourly load profiles be applied to derive peak demand contribution from EVs – to each electric vehicle (kW/number), to each charge point (kW/unit or kW/kW installed), or to the annual electricity consumption from EVs (kW/kWh)?
- What is the modelled relationship between EVs and EV charging units?
- What calculation process captures our aims to drive consistency, enable national and regional variation and ensure transparency of assumptions without oversimplifying the complexities involved?

The first research question is a crucial pre-requisite to determine the end-to-end process. Four key options were considered:

1. EV contribution to peak demand is derived from applying half-hourly demand profiles directly to the number of vehicles modelled. The profile is represented in units of kW/number of vehicles.
2. EV contribution to peak demand is derived from applying half-hourly profiles to the charge points modelled. The profile is represented in units of kW/number of charge points.
3. EV contribution to peak demand is derived from applying half-hourly profiles to the charge points modelled. The profile is represented in units of kW/kW installed capacity of charge points.
4. EV contribution to peak demand is derived from determining the annual electricity consumption from these vehicles and how this demand splits between different charging types. Then profiles of the half-hourly demand relative to the annual demand are applied. The profile is represented in units of kW/annual kWh for each different charging type.

When modelling the number of EVs, the location of these vehicles usually represents the location of the vehicle registration (e.g. the address of the vehicle owner). However, vehicles are mobile and will not exclusively charge at their home location with a single charger type. Option 1 was considered too simplistic as it does not account for this distinction between vehicle location and charging location, charging Options 2-4 are all currently used by different DNOs in their DFES. Table 5 was developed in collaboration with networks through a technical working group to compare these options.

Table 5: Pros and cons for different half-hourly load profile options for the end-to-end EV modelling process.

Profile type	Pros	Cons
Demand relative to units installed (kW/number)	• Easy to standardise (e.g. NIC work).	• Not easily scalable (implicit assumption that all units are the same size unless creating profiles for a wide range of installation sizes).
Demand relative to installed capacity (kW/kW)	• Easily scalable (e.g. allows for varying charge point installation size by location). • Clear relationship with charge point capacity and installation size, which facilitates comparison against actual installations and industry standards.	• Relationship with annual electricity consumption not clear. • Calculation method sensitive to assumptions on charge point utilisation (see sensitivity analysis mentioned earlier).

Demand relative to energy consumption (kW/kWh)	• Easily scalable (e.g. different housing types having different energy demands). • Clear relationship with annual electricity consumption, which facilitates comparison against other sources (e.g. FES). • Modelling of charge points not necessary (method does not rely on assumptions with high uncertainty).	• No assurance against charge point installation size, can lead to challenges of comparison against actual installations and industry standards. • Calculation method has low traceability of assumptions (e.g. heat pump or EV charging capacity not direct inputs and require back calculation).

To further understand the difference in these approaches and support our decision, we must answer the second research question: what is the relationship between EVs and EV charging units? Figure 10 details the required calculation steps. Determining the capacity and number of charging units depends on an assumption of the utilisation of each charge point type, measured in the number of hours a charging station is actively used to charge EVs per year.

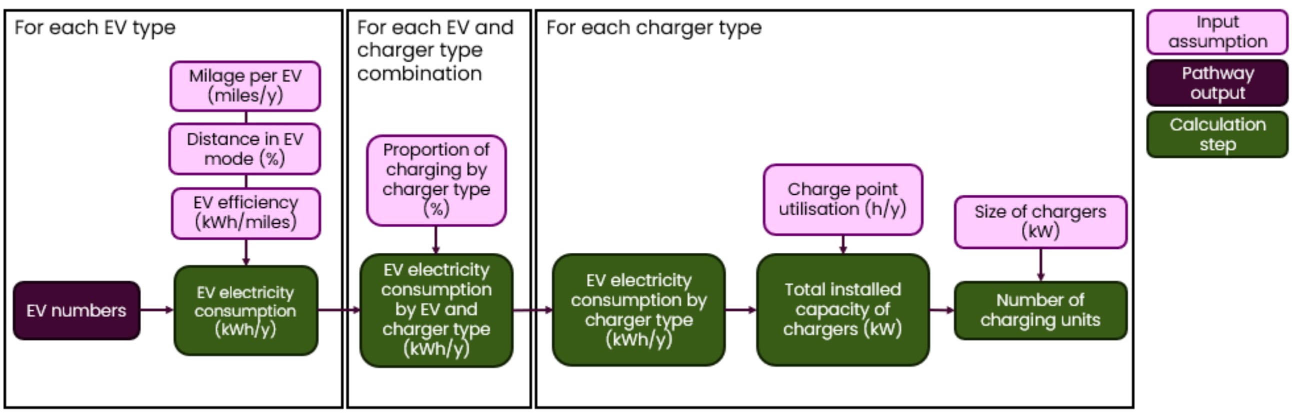

Figure 10: The modelled relationship between EV numbers and associated EV charging units.

In figure *10, first the annual electricity consumption from EVs is calculated for each different vehicle type, then this demand is distributed to different charging types. This demand is converted into the required installed capacity for EV charge points through an assumption on the utilisation of these charge points. The size or rated capacity of these charges is then used to calculate the number of units.*

Public

Two alternative approaches to determine EV demand were tested with a model. One that applied a kW/kW installed load profile to the total installed capacity of chargers (determined through the process in Figure 10) and the other used a kW/kWh profile and the calculation process in Figure 4. Additionally, a sensitivity analysis was performed on the utilisation assumption in the former approach. We found that the former approach was highly sensitive to the utilisation assumption with the change in EV peak demand contribution scaling with a change in the utilisation assumption (Figure 11). Charge point utilisation can vary significantly by location and there is currently no comprehensive dataset available that logs this information. Furthermore, the utilisation of charge points is expected to change through time (as more EVs are on the road, higher utilisation of public charge points is expected[17]), however, these future trends are uncertain. Therefore, our recommended option is to apply a kW/kWh profile and the calculation process in Figure 4.

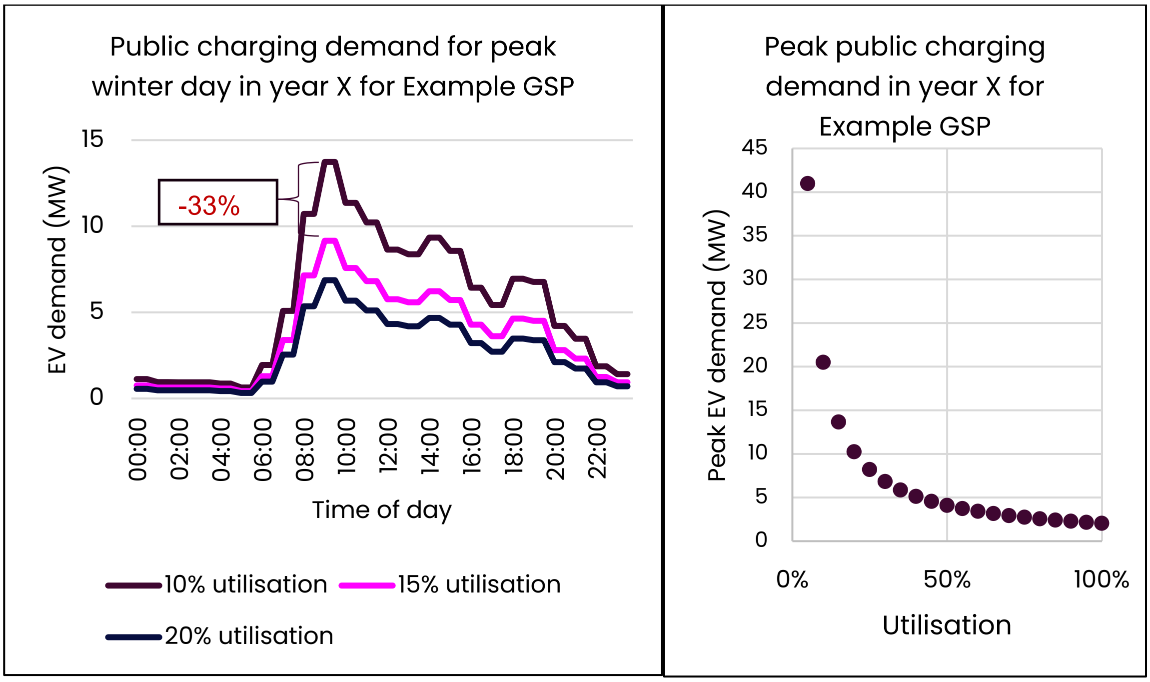

Figure 11: Results of sensitivity analysis. Left: Changing the public charging utilisation assumption from 10% to 15% results in a 33% drop in EV peak demand for a representative GSP and year. Right: Peak public charging demand as a function of utilisation factor.

Who did we engage with to reach this decision?

We discussed modelling of EVs and their demand with GB electricity DNOs and Ofgem (both through bi-laterals and in technical working groups). We also engaged with the National Infrastructure and Service Transformation Authority (NISTA, formerly NIC) and Regen to discuss the findings of their electricity distribution network study[18].

[17] The ICCT, Quantifying the electric vehicle charging infrastructure gap in the United Kingdom
[18] NIC, Electricity distribution networks: Creating capacity for the future

Appendix 3: Glossary of Terms and Acronyms

Term / Acronym	Definition / Full Form
CPA	Consistent Planning Assumption
DNO	*Distribution Network Operator - Any Electricity Distributor in whose electricity distribution licence the requirements of Section B of the standard conditions of that licence have effect (whether in whole or in part).*
DFES	Distribution Future Energy Scenarios
DfT	Department for Transport
ED2	Electricity Distribution period Two – the current electricity distribution price control, running from April 2023 to March 2028
ED3	Electricity Distribution period Three – the next electricity distribution price control, running from April 2028 to March 2033
EVs	Electric vehicle - *vehicles wholly driven by an electric motor that is wholly powered through a battery and does not produce any tailpipe emissions*
ENA	Energy Networks Association
FES	Future Energy Scenarios
GB	Great Britain
GSP	Grid Supply Point - interface between transmission and distribution
Holistic Transition	One of the FES Pathways to net zero
I&C	Industrial and Commercial *e.g. electricity demand*
kW	Kilowatt (unit of power)
kWh	Kilowatt hour (unit of energy)
LCT	Low Carbon Technology: *LCTs is the collective term for the following technologies:* *• Heat pumps at existing connections that do not lead to a new or modified connection*

	• Electric vehicle (EV) chargers, both slow and fast charging, at existing connections that do not lead to a new or modified connection *• Photovoltaics (PV) connected under Engineering Recommendation G98* *• Other renewable Distributed Generation (DG), excluding PV, connected under Engineering Recommendation G98* *• Renewable DG not connected under Engineering Recommendation G98*
OFGEM	Office of Gas and Electricity Markets
tRESP	Transitional Regional Energy Strategic Plan