SPEN Distribution Future Energy Scenarios - Methodology

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Version history

Version	Date	Description	Prepared by	Approved by
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2.0	31/03/2020	Draft updated	AP	JG
3.0	01/05/2020	Initial publication	AP	JG
4.0	01/11/2021	DFES 2021 publication	AP	MV
5.0	03/09/2025	DFES 2024 publication	EZ	MV
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1 Introduction

1.1 Background

The SP Energy Networks (SPEN) Distribution Future Energy Scenarios (DFES) are geographically granular forecasts which assess three credible future scenarios for reaching 2050 Net Zero targets, and one scenario which falls short of Net Zero but progresses in decarbonisation objectives. These scenarios cover a range of uncertainties, including differing levels of consumer ambition, policy support, economic growth and technology development. They are informed by engagement with industry, government and other key stakeholders.

National Energy System Operator's (NESO's) Future Energy Scenarios (FES) provide the national whole-energy system context and quantitative trajectories for DFES, including projections of future electricity demand, generation and flexibility. The 2025 edition of FES introduces updated assumptions, modelling improvements and policy alignment which materially affect the scale, timing and composition of demand and supply that must be spatially distributed across regions, Grid Supply Points (GSPs) and Primary Substations (PSSs). These updates have been reflected in this DFES update to ensure alignment with transitional Regional Energy Strategy Planning (tRESP) and Consistent Planning Assumptions (CPAs), which both impact DFES modelling for the first time in 2025 (please see section 2.1.4 for further information).

DFES enables SPEN to understand how generation and demand may evolve over the next 25 years, and to assess and prepare for the required changes to facilitate the UK's transition to Net Zero greenhouse gas emissions.

SPEN has commissioned Baringa, supported by Field Dynamics[1], to help develop these scenarios. SPEN have specified that the planning scenarios must be holistic from a whole energy systems perspective, and need to consider all generation and demand within SPEN areas - at a granularity of individual Primary Substation (PSS), Grid Group (GG)[2], and Grid Supply Point (GSP) level, including:

- Distribution network connected generation (and storage)
- Distribution network connected consumers
- "Behind the meter" (BtM) generation (e.g. small-scale solar photovoltaic (PV) or storage)

1.2 Structure of this report

The purpose of this report is to review in detail the methodology used to produce the SPEN 2025 DFES, and to review the key results. In brief the structure is as follows:

- Section 2.1 provides an overview of the high-level principles used to frame the pathways

[1] https://www.field-dynamics.co.uk/

[2] Equivalent to Bulk Supply Point (BSP)

- Section 2.2 provides a high-level overview of the approach to create the pathways
- Section 2.3 provides more detail on the approach for each generation element
- Section 2.4 gives a more detailed explanation of the approach for each demand element

2 Scenario development methodology

2.1 High-level principles

The energy system is evolving at pace. The understanding of future customer needs provided by DFES enables SPEN to plan, design and prepare their distribution network to meet changing customer needs. Granular regionally reflective scenarios assess a range of credible future pathways including how much electricity will be consumed and generated, as well as indicators of where and when. These forecasts will be used by SPEN to underpin detailed network capacity assessments and network planning activities.

The NESO FES are used to inform DFES, remaining consistent with the scenario framework and main building blocks. However, as these forecasts are for the whole of GB, they need to be significantly augmented to provide a much more regionally reflective view. This is achieved using a combination of extensive top-down and bottom-up assessments to produce detailed forecasts at PSS, GG, and GSP level out to 2050. DFES uses SPEN's network data combined with project pipeline, regional ambitions and development plans, external geospatial data sources, local knowledge, stakeholder inputs, outputs from innovation projects and incorporates regional Net Zero legislative targets.

This analysis covers both SP Manweb (SPM)[3] and SP Distribution (SPD)[4] licence areas, and the methodology has been designed to apply in a consistent manner across both with regional sensitivities due to different legislative targets.

When developing scenarios, the following high-level principles have been adhered to:

- Scenarios cover a wide range of likely possible outcomes, including a number consistent with future Net Zero emissions outcomes
- Scenarios are holistic and internally consistent as much as possible
- Assumptions are based on publicly available sources and SPEN network data
- Methodologies are simple, transparent, and credible
- Scenarios are informed by engagement with industry, government and other key stakeholders

[3] SP Manweb (SPM) – the Distribution Network Operator for Merseyside, Cheshire, North Shropshire and North Wales, own the distribution network at 132kV, 33kV, 11kV and LV into the home.

[4] SP Distribution (SPD) – the Distribution Network Operator for Central and Southern Scotland, own the distribution network at 33kV, 11kV and LV into the home.

2.1.1 Use of GB FES

NESO produces an annually updated set of energy scenarios for Great Britain, the Future Energy Scenarios[5] (FES). FES provides a range of credible pathways for the GB energy system out to 2050. They represent possible demands for, and sources of, gas and electricity, in an interlinked and holistic manner, whilst also considering the wider set of energy system options that affect these (e.g. the role of hydrogen, bioenergy or district heating). In developing FES, NESO gathers feedback from a wide range of stakeholders on the assumptions and approach taken.

FES provide a regularly updated and internally consistent set of whole energy system scenarios that are widely used by industry, academia, and government. The scenarios are not projections of how the GB energy system will develop and no probabilities for the likelihood of each scenario are given. The scenarios can, however, be used to understand the impact of different potential pathways and their sensitivity to different assumptions.

FES are presented on a GB system wide basis, though NESO makes assumptions for each transmission zone independently before aggregating this to the GB total.

In 2024 NESO moved to a "Pathway" system of modelling the technological and consumer transformations required to meet Net Zero targets. This change reflects a more directed approach towards modelling, emphasising the decisive action needed to align network planning and development activities with the infrastructure investment and consumer behavioural transition required to meet Net Zero.

SPEN align with the FES in developing load planning scenarios. In some cases, the assumptions in FES for the SPEN regions have been used directly to develop the scenarios outlined in this document, either because SPEN have been involved in the development or because they apply to GB and can reasonably be applied to SPEN regions without adjustment.

However, in many areas the FES assumptions can be refined to better match the knowledge SPEN has of the SPEN areas. This is documented in the following subsections.

The three Net Zero compliant pathways in FES 2025 (shown in Figure 1) are reflective of whole system strategic transformation and are characterised by:

1. The extent to which electrification versus hydrogen is used in system transformation and the shift to renewable energy.
2. The degree of demand-side flexibility needed for the transition, indicative of consumer engagement within the transition process.

Each pathway is described in the context of a whole-system transformation, outlining how following its strategy would influence energy demand, supply, and emissions. NESO highlights the importance of demand and supply-side communication, with progress in both areas being critical to meeting key milestones.

[5] http://fes.nationalgrid.com/

SPEN have used FES 2025 to inform DFES 2025, using these pathways as well as a "Falling Behind" scenario provided by NESO which does not meet Net Zero targets, although makes some positive progression in reducing GB's reliance on fossil fuels. This change reflects NESO's calls for "decisive action within the next two years to deliver the fundamental changes required to achieve a fair, affordable, sustainable and secure clean energy system by 2050."[6]

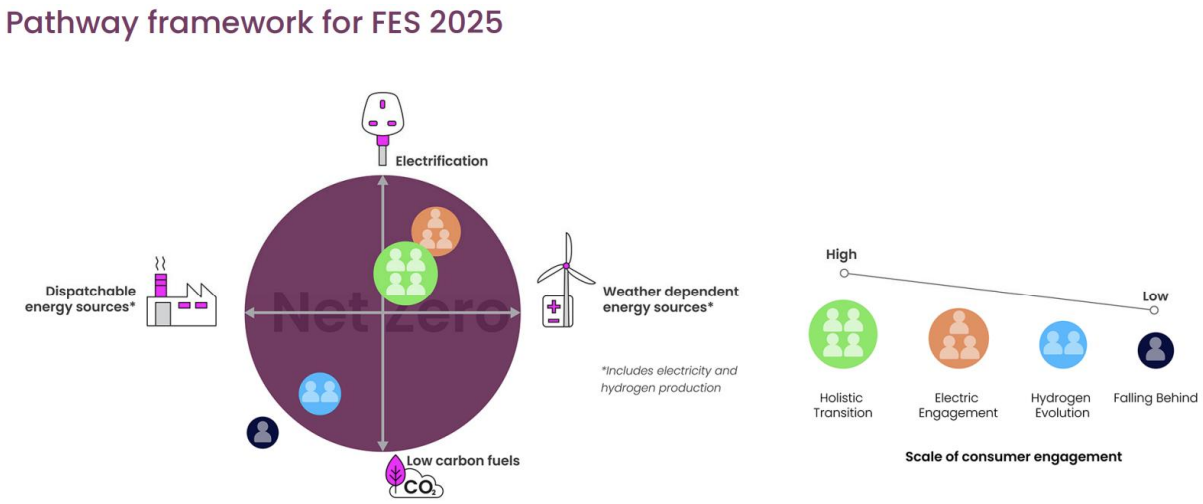


Figure 1 – NESO's Future Energy Scenarios 2025[7]

The following FES pathway descriptions have been reproduced from the 2025 FES main document:

Holistic Transition (HT)

Net Zero is met through a mix of electrification and hydrogen, with hydrogen mainly used around industrial clusters. Hydrogen is not used for heat except as a secondary fuel for heat networks in small quantities. Consumer engagement is very strong through adoption of energy efficiency improvements and demand shifting, with smart homes and electric vehicles providing flexibility. A high-renewable capacity pathway, with unabated gas dropping sharply. Pathway sees moderate levels of nuclear capacity and lowest levels of hydrogen dispatchable power. Supply side flexibility is high, delivered through electricity storage and interconnectors. No unabated gas remains on the network in 2050.

Electric Engagement (EE)

Net Zero is met mainly through electrified demand. Consumers are highly engaged in the transition through smart technologies that reduce energy demand, such as electric heat pumps and electric vehicles. Pathway with the highest peak electricity demand, requiring high nuclear and renewable

[6] https://www.neso.energy/document/321046/download

[6] https://www.neso.energy/document/364556/download

capacities. It also has the highest level of bioenergy with carbon capture and storage across all Net Zero pathways. Supply side flexibility is high, delivered through electricity storage, interconnectors and low carbon dispatchable power.

Hydrogen Evolution (HE)

Net Zero is met through fast progress for hydrogen in industry and heat. Widespread access to a national hydrogen network is assumed. Some consumers will have hydrogen boilers, although most heat is electrified. There are low levels of consumer engagement within this pathway. Hydrogen is used for some heavy goods vehicles, but electric vehicle uptake is strong. Pathway sees high levels of hydrogen dispatchable power plants, leading to reduced need for renewable and nuclear capacities. Hydrogen storage provides the most flexibility in this pathway.

Falling Behind (FB)

Considers a scenario where some decarbonisation progress is made against today, but at a pace not sufficient to meet Net Zero. Used in downstream gas and electricity security of supply processes - it is important that Falling Behind is used alongside the Net Zero pathways to consider the full range of potential demand levels for possible remaining reliance on unabated fossil fuels. With the current level of low carbon projects in the pipeline and increased policy ambition, some level of progress in areas where there is increased certainty or progress is considered.

The three Net Zero pathways are largely in parallel with policy timelines for transport, heating, natural gas and industry.

Demand side decarbonisation policy can be found in the FES 2025 Publication[8].

FES use three time periods per year to assess how generation and demand may change. These periods are based on a coincident set of times for peak and minimum net demand seen on the GB transmission system. Effects of all distribution connection and behind the meter generation are also considered. The SPEN DFES stays consistent with these time periods.

- **Winter Peak:** a view of peak demand between the hours of 5pm and 6pm – typically November-February on a weekday. This period is of interest as these are the maximum demands on the system.
  - The GB peak demand figure split regionally is determined using the Average Cold Spell methodology – where this figure has a 50% probability of being exceeded by the actual peak value in a year due to weather variability.
  - EVs are a demand – smart charging behaviour assumed some Vehicle-to-Grid (V2G) considered as supply. Note EV smart charging behaviour is an assumption.
  - All storage considered as a supply.
- **Summer Minimum (AM):** a view of minimum morning demand – typically between 3:30am-6am, in May-August on a weekend. This period is of interest as these are the minimum demands on the system because of low underlying demand.

[8] https://www.neso.energy/document/364541/download

- Electric Vehicles are a demand – no smart behaviour assumed (people charge how they would charge assuming today's behaviour).

- **Summer Minimum (PM):** a view of minimum afternoon demand – typically between 1pm-3:30pm, in May-August on a weekend. This period is of interest due to being the lowest underlying demand period that coincides with a peak of solar PV generation, reducing transmission network demands.
  - Electric Vehicles are a demand – no smart behaviour assumed (people charge how they would charge assuming today's behaviour).
  - All storage considered as a demand – spread over 4-6 hours to avoid creating a new low demand point.

2.1.2 Macro assumptions

FES include several macro assumptions that influence the scenarios. In the main these have been left unchanged when developing scenarios for the SPEN area. The key assumptions in terms of driving changes to generation and demand that have been inherited when developing DFES are:

- **Population Growth:** In FES the population growth and housing stock growth is consistent across all scenarios and based on analysis from Oxford Economics.
- **Energy efficiency:** The FES pathways are more unified compared to previous years in their expectations on energy efficiency measures but differ in the modes with which these are achieved. All three pathways assume high levels of uptake in heat pumps to meet heating demand in residential homes, replace natural gas driven electricity generation with renewable means, and increase flexibility in the energy network.
- **Economic Outlook:** Industrial and commercial (I&C) demand in FES is modelled assuming that economic growth is fixed across all scenarios.
- **Electric Vehicle (EV) population:** The EV uptake in FES is mandated by the Government's legislation for all new cars and vans sold by 2035 to be zero emission[9]. All three pathways follow this expectation.
- **Generation technology load factors:** FES uses load factor assumptions for the expected output of generation and storage technologies at different times of the year. These assumptions are based on observed output from recent years and are selected to reflect stress on the system at periods of peak and minimum demand.
- **Hydrogen availability for heating:** The Hydrogen Evolution pathway assumes high levels of policy support for hydrogen production and distribution commencing in 2030 around industrial clusters, with a national hydrogen transportation network being developed by 2050. In the Holistic Transition pathway, hydrogen for heating is incorporated near hydrogen production locations associated with industrial clusters. The Electric Engagement and Falling Behind pathways assume no hydrogen for heating.

[9] https://www.gov.uk/government/news/pathway-for-zero-emission-vehicle-transition-by-2035-becomes-law

In developing DFES the following additional high-level assumptions have been made:

- **GSPs and PSSs:** The SPM and SPD DFES results are provided for all current GSPs, GGs, and PSSs, without assuming any splitting or new substation sites. The changes in generation and demand at existing sites identified in the SPEN DFES will be used by SPEN when planning investment, which may include splitting sites or other changes – but any changes will be a result of the analysis described in this report rather than being an input to it.
- **Network constraints are not a barrier to change:** Changes in generation and demand technologies for DFES have been applied without consideration of current or future network constraints, except in the case of dispatchable technologies, which are used to increase network flexibility (see section 2.3.8). SPEN are committed to providing a network that is not a barrier to changes in energy production and consumption, in particular with respect to facilitating future decarbonisation targets, and will use the DFES to ensure that appropriate investments are made to allow this at lowest cost.

2.1.3 Net Zero FES Adjustments

SPEN has made a number of key adjustments to the 2025 FES to better reflect the Scottish Government's legally binding target for Scotland to become Net Zero by 2045, which is five years ahead of the UK Government target. Adjusted projections are produced through the use of revised input data created by SPEN which reflect this accelerated ambition.

2.1.4 Technologies considered

In developing the scenarios, a wide range of demand and generation technologies have been considered, at different levels of the distribution network (at PSS, GG, and GSP level). Demand and generation have been divided into the categories shown in Table 2.

Table 1 – Technologies considered

DEMAND	DISTRIBUTED CONNECTED GENERATION
DOMESTIC	WIND
INDUSTRIAL AND COMMERCIAL (I&C)	SOLAR – DISTRIBUTED GENERATION
AIR-SOURCE HEAT PUMPS (DOMESTIC)	SOLAR – BEHIND-THE-METER
AIR-SOURCE HEAT PUMPS (I&C)	HYDRO
GROUND-SOURCE HEAT PUMPS (DOMESTIC)	CHP – RENEWABLE
GROUND-SOURCE HEAT PUMPS (I&C)	CHP – NON-RENEWABLE
HYBRID HEAT PUMPS (DOMESTIC)	DISPATCHABLE – RENEWABLE
HYBRID HEAT PUMPS (I&C)	DISPATCHABLE – NON-RENEWABLE
EVS (PURE ELECTRIC CARS)	STORAGE – DISTRIBUTED GENERATION
EVS (PURE ELECTRIC VANS)	STORAGE – BEHIND-THE-METER
EVS (PURE ELECTRIC MOTORBIKES)	

EVS (PURE ELECTRIC BUSES)

EVS (PURE ELECTRIC HGVS)

EVS (PLUG-IN-HYBRID CARS)

EVS (PLUG-IN-HYBRID VANS)

EVS (PLUG-IN-HYBRID MOTORBIKES)

EVS (PLUG-IN-HYBRID BUSES)

EVS (PLUG-IN-HYBRID HGVS)

DISTRICT HEATING

These technologies are mapped to the Building Blocks provided by NESO in their FES Workbook. The FES Building Blocks represent a top-down breakdown of the national-level FES values, providing a consistent disaggregated view of FES demand and generation capacity for regional stakeholders. To align with FES projections at this disaggregated level, the FES Building Blocks are used as the starting point for SPEN's modelling of distributed connected generation technologies. For demand technologies, PSS and GG volumes are derived using Building Block proportions as a proxy to disaggregate demand from regional FES values, forming the starting point for projections.

For a full list of building blocks and their mapped DFES technologies, see Appendix D.

For each technology the key metric is the generation/demand on the system at specific points in time: the winter peak, summer minimum AM and summer minimum PM. Capacity projections for each technology, and an understanding of how each technology may operate has been developed, to understand how much generation could help offset peak demand.

2.1.5 Alignment of SPEN DFES 2025 with tRESP and CPAs

Regional Energy Strategic Planning (RESP) is a fundamental step in NESO's ambitions to deliver a whole-system approach to strategic energy planning in Great Britain. The transitional RESP (tRESP)[10] is the first publication in the journey towards transforming and improving local energy infrastructure. tRESP has been designed as a bridge between the current approach to energy distribution network planning and the enduring RESP approach which is expected to be in place from 2027.

One of the core components of tRESP is the Consistent Planning Assumptions (CPAs), which drive consistency across Distribution Network Operator (DNO) models by setting out requirements for modelling approach and assumptions for assessing the network impacts of low-carbon technologies under each of the Net Zero pathways. This ensures that network impact assessments and business plans for the next electricity distribution price control period from 2028 to 2033 (known as ED3) are developed on a comparable and transparent basis and helps provide a common framework for translating national decarbonisation pathways into regionally relevant signals for network planning and investment.

[10] transitional Regional Energy Strategic Plan (tRESP) | National Energy System Operator

For tRESP, NESO has prioritised key demand and generation 'building block' technologies which are most relevant to the upcoming ED3 price control period, particularly electric vehicles, heat pumps and district heating. Analysis based on the FES 2025 Holistic Transition pathway indicates that these technologies account for the majority of future peak demand growth, representing approximately 93% of peak demand increase by 2035 and over 80% by 2050.

SPEN has used the tRESP Pathways and CPAs to inform ED3 business plans. Alignment with tRESP through the CPAs is a key consideration in the 2025 SPEN DFES methodology update. Therefore, SPEN has applied all Heat Pump and EV CPAs in its modelling, as stated in Sections 2.4.5.2 and 1.1.1. There are no CPAs to be applied for district heating.

Table 2 – Building blocks impacted by CPAs

TECHNOLOGY	FES BB ID NUMBER	TECHNOLOGY DETAIL
Electric Vehicles	Lct_BB001	Pure Electric (vans, cars & motorbikes)
Electric Vehicles	Lct_BB002	Plug-in-hybrid (vans, cars and motorbikes)
Electric Vehicles	Lct_BB003	Pure Electric (buses, coaches, and HGV)
Electric Vehicles	Lct_BB004	Plug-in-hybrid (buses, coaches, and HGVs)
Heat Pumps	Lct_BB005	Domestic – Non-hybrid
Heat Pumps	Lct_BB006	Domestic – Hybrid

2.2 High level overview of approach

The DFES model is fundamentally a spatial allocation model which means that it does not perform capacity siting based on market fundamentals but instead allocates growth projections from NESO's Future Energy Scenarios (FES) to mapped areas, using building-block specific suitability criteria and SPEN data on existing and expected capacities for each building block-scenario combination.

This section describes at a high level the allocation logic as it is used in the model. Capacity siting is driven primarily by "suitability factors". The general approach for how these factors are determined is documented in Section 2.2.1.

Both generation and demand forecasting follow the same underlying modelling logic, but input data and how it is sourced, as well as detailed modelling steps might differ slightly across building blocks. These nuances are described in Sections 2.3 and 2.4, where applicable.

2.2.1 Capacity siting

All distribution, generation and storage capacity must be assigned to either a PSS, GG or GSP, to allow the net demand/generation at each point to be calculated for winter peak and summer minimum (AM and PM) to be used by SPEN in its network development planning.

The allocation is performed bottom up: to-be-allocated capacity is connected to PSSs first and subsequently aggregated up to GG and GSP levels using SPEN's substation hierarchy mapping, where directly connected capacity is added. Capacity connected at any given level thus consists of directly connected capacity for that level plus aggregated capacity from lower levels.

2.2.1.1 Determine the licence-area level capacity growth curve

To calculate a starting point for generation and demand figures out to 2050 for each scenario in each licence area, (SPM/SPD), building block data from the FES Data Workbook is used.

Note that capacity growth can also be negative, as is the case for non-renewable generation technologies. The capacity siting logic does not change for negative growth, except the connected capacity at any site cannot drop below zero as a result of capacity allocation.

2.2.1.2 Adjust capacity growth curve using SPEN baseline data

Next SPEN's known baseline figures are summed to adjust the starting position for the capacity growth curve for each building block at the licence area level. The FES-derived growth curves are then adjusted (in either absolute or percentage terms) to the previous year's capacity growth.

Note that the baseline numbers, and therefore the starting positions for the capacity growth curves, are the same for all scenarios.

2.2.1.3 Determine capacity growth share per grid level

Fundamental to capacity siting is the ratio of capacity that needs to be allocated to a GSP versus GG versus PSS for a given building block. SPEN baseline data is used to determine this ratio, which varies between different building blocks but is assumed to stay constant out to 2050 for each building block.

2.2.1.4 Pre-allocate current and expected site-specific capacity data

Prior to allocating the capacity growth derived from the previous two steps, site specific capacity is pre-allocated. This is done using SPEN project pipeline data which provides a view on projects and their expected connection dates for each building block.

Note that unlike the baseline data, the pipeline data is scenario specific because the different assumptions underpinning the four FES scenarios translate into different weightings for the realisation of proposed/announced projects out to 2050.

2.2.1.5 Allocate remaining capacity based on relative suitability

The final step in capacity siting is to allocate capacity that is not pre-allocated using SPEN baseline and pipeline data using suitability factors. These suitability factors, which are described in general in Section 2.2.2 and per building block in Sections 2.3 and 2.4, can include spatial proxies, key technology characteristics and site characteristics. They provide an indicator for the suitability of an asset for a specific building block to connect to a site, which is interpreted as the likelihood to connect. The still-to-be-allocated capacity is allocated to grid sites (e.g. PSSs) based on their relative suitability factors.

When capacity is allocated spatially, this is subject to a minimum allocation size, to make sure that immaterially small amounts of capacity are not assigned to an area.

Similarly, spatial allocation only occurs if sufficient space is available at a site, to prevent unrealistic levels of technology deployment at an location.

2.2.1.6 Apply load factors (generation only)

This step applies to generation only. To understand how technologies contribute to generation, load factor assumptions are used to scale rated capacity into expected output, considering diversification effects, intermittency, and outages.

Load factor assumptions for all generation or storage technologies are taken directly from the FES GB wide assumptions. These vary by technology and year (though many technologies do not change by year), and are given for winter peak, summer minimum AM and summer minimum PM periods.

Where multiple FES technologies have been aggregated into the categories used in the DFES model, the capacity weighted load factor across all grouped technologies for each year have been used, to ensure the same energy output as in the FES.

2.2.1.7 GSP net demand and generation

Using technology load factor and capacity assumptions, the total expected generation output for each GSP can be calculated for winter peak and summer minimum periods. By subtracting the total generation from the metered demand at each GSP, the net demand (or generation) from each GSP to the SPEN network can be calculated.

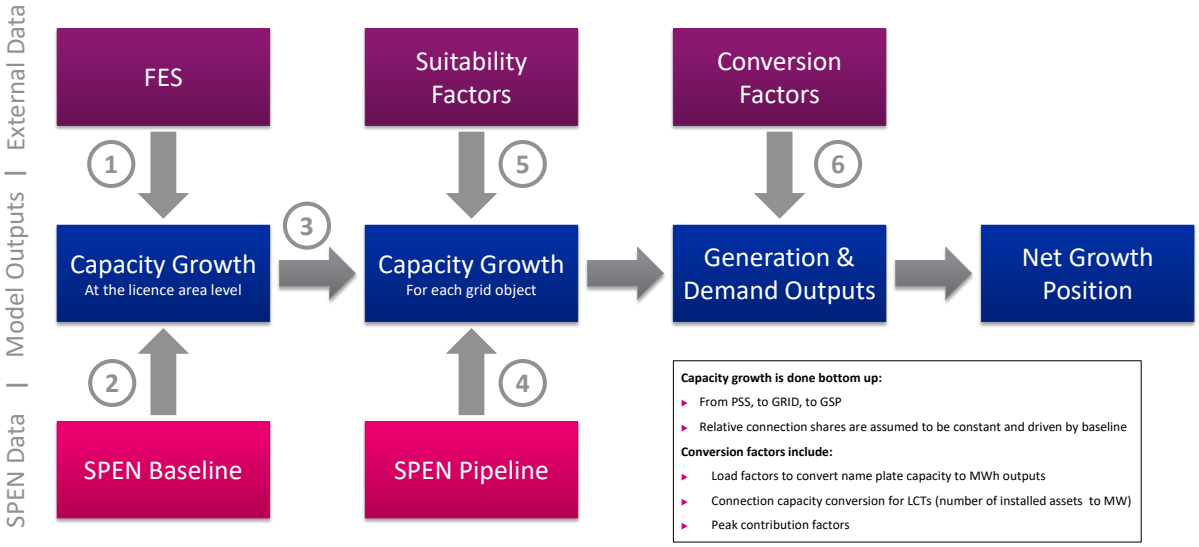


Figure 2 – High level overview of approach, in this case for generation, with previously calculated demand being factored in at the end to determine the net growth position. Numbers in the figure correspond to modelling steps in this section.

2.2.2 Spatial mapping

In the 2025 FES, data of many components are provided at GSP level by NESO. Some of this data can be used directly by the model (for GSP-level analysis), but in the majority of cases extra analysis is performed to improve the spatial allocation. This is also required for the analysis to be taken down to a PSS level.

For the required spatial disaggregation of demand and generation components, a key requirement is to understand – at a granular level – the associated areas which are connected to each PSS. This allows the development of spatial proxies which, combined with other characteristics, helps to spatially disaggregate scenario components (e.g. onshore wind generation or underlying domestic building demand) from the FES in a more robust manner given the specific circumstances within the SPD and SPM licence areas.

The approach of having a mapped area to each PSS/GSP allows for various spatial proxies to be collected from a broad array of data sources. These are then used for the allocation of the different scenario demand and generation components and are described in Sections 2.3 and 2.4, respectively. The spatial mapping of PSSs for SPM is shown in Figure 3, and for SPD in Figure 4.

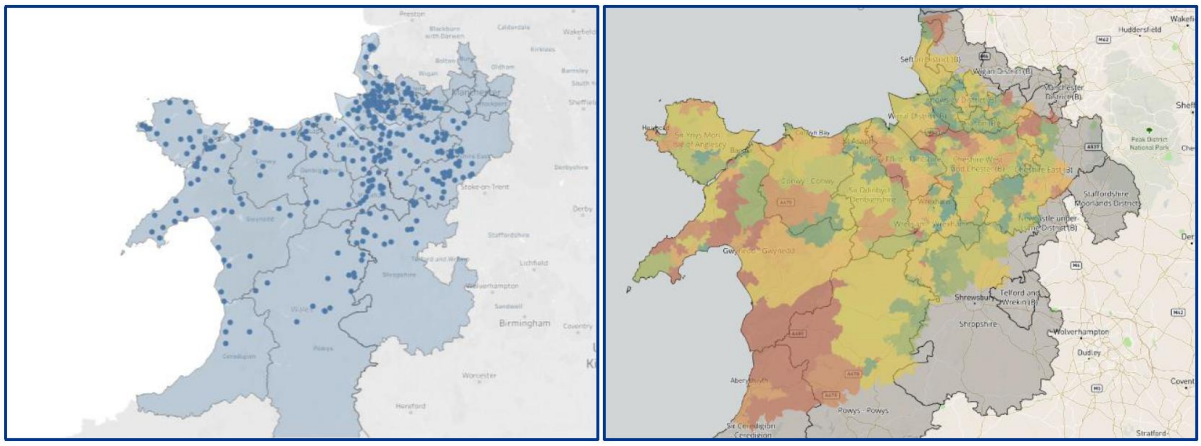


Figure 3 – SPM area with PSSs and arbitrary exemplar values to show boundaries of PSS areas

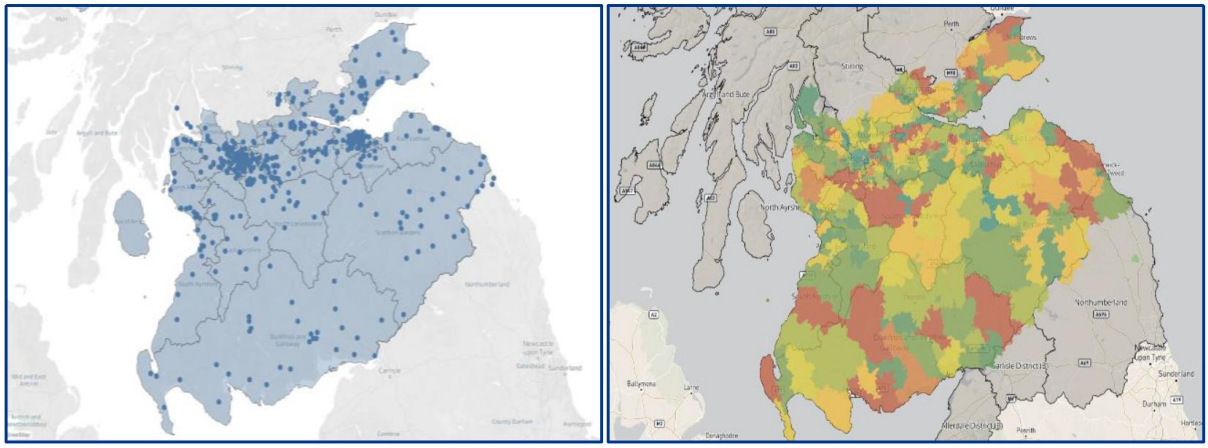


Figure 4 – SPD area with PSSs and arbitrary exemplar values to show boundaries of PSS areas

Suitability factors are calculated by multiplying three types of inputs:

- **Spatial proxies** – These represent the suitability of an area for a building block, e.g. wind speed for onshore wind (large and small) and the number of households for underlying residential demand. For some building blocks multiple spatial proxies are combined to create a single weighting for each PSS/GSP region. See Section 2.4 for examples of this.
- **Key technology characteristics** – These are factors that determine the suitability for allocation from a technology characteristic perspective. Unless stated differently in the descriptions of the modelling specifics of the individual building blocks, all use a rurality threshold: large onshore wind will not be allocated to densely urban areas and conversely district heating is not a suitable technology for rural areas.
- **Site characteristics** – These mainly apply to aspects of the grid object (PSS or GSP) and its mapped area. Available headroom is the key grid object parameter that is taken into account. Spatial maximum caps are also set so that there is a limit to the amount of capacity that can be allocated to a single area. Surface area covered by Areas of

Outstanding Natural Beauty (AONBs) is subtracted from each mapped area as it is typically not available for the build of assets. This predominantly affects the allocation of generation capacity as demand (new or from electrification of fossil fuel demand) is typically associated with less rural areas.

Suitability factors are largely static from year to year (e.g. environmental and technology elements are assumed constant out to 2050) but site characteristics are updated based on allocation results of the previous year, to prevent over-allocation at individual sites.

Suitability factors ensure a sensible selection of allocated generation and demand is allocated to particular areas. This essentially results in more "favourable" areas receiving more connected capacity – up to any imposed cap – allowing each of the scenarios to build up accurate likely projections of how capacity will be allocated within the SPEN regions.

2.2.3 Modelling of low-carbon technologies

For low-carbon technologies (LCTs), volumes are not directly provided at the regional level in the FES workbook. Furthermore, our modelling operates at a more granular level than the FES Building Blocks for both Electric Vehicles and heat pumps (HPs). Therefore, volumes must be derived using a combination of bespoke data sources and FES Data Workbook values:

- **EV Disaggregation:** Domestic-charged EV volumes for cars, vans, and motorbikes; PHEV volumes for cars and vans; and depot-charged EVs for HGVs and buses have been modelled. These volumes are calculated by applying the ratio of the sum of the technology's associated building blocks for the SPEN regions to the sum of the same building blocks across all regions, multiplied by the GB-level volumes for the relevant EV technology type provided in the ED5 FES table. The resulting volumes are then adjusted to align with the known SPEN baseline or pipeline.
- **Heat Pump Disaggregation:** Domestic and I&C non-hybrid heat pumps (LCT_BB005 & LCT_BB007) are split into air-source and ground-source heat pumps using a similar approach. Volumes are derived using the ED7 table[11] (which provides GB-level figures for ASHP and GSHP) and the BB1 table[11] to calculate SPEN-region ratios for regional volume estimation.

2.3 Distribution connected generation and storage

2.3.1 Introduction

Several generation building blocks were modelled for each of the scenarios:

- Onshore wind: Gen_BB0015 and Gen_BB016
- Offshore wind: Gen_BB014
- Solar generation large (G99): Gen_BB012

[11] https://www.neso.energy/document/364551/download

- Solar generation small (G98): Gen_BB013
- Hydro: Gen_BB017 and Gen_BB018
- Combined Heat and Power (CHP):
  - Non-Renewable CHP: Gen_BB001 (>=1MW), Gen_BB002 (<1MW) and Gen_BB003 (Micro CHP Domestic (G98/G83))
  - Renewable CHP: Gen_BB010 (Biomass & Energy Crops) and Gen_BB011 (Waste Incineration)
- Flexible Technologies:
  - Renewable Dispatchable: Gen_BB004
  - Renewable Dispatchable: Gen_BB004
  - Non-Renewable Dispatchable: Gen_BB005 to Gen_BB009
  - Hydrogen Fuelled Generation: Srg_BB023
  - Batteries: Srg_BB001
  - Domestic batteries (G98): Srg_BB002
  - Pumped Hydro: Srg_BB003
  - Storage (Other): Srg_BB004

Generation and storage technologies that connect directly to the distribution network contribute to offsetting increases in demand seen on SPEN's network through PSSs and GSPs. Estimating the quantities and locations of these technologies is critical to planning investment on the SPEN network. In the following subsections the specific methodologies used for each of the generation and storage building blocks is discussed.

2.3.2 Onshore wind

Gen BB015 and Gen BB016

The main spatial proxy used to allocate capacity is wind speed, the data collected from the Met Office datasets for each PSS/GSP area[12]. This is the primary measure used to drive an allocation weighting – the assumption being that more favourable wind conditions are more attractive for generation buildout.

The other proxy for onshore wind is rurality. Rurality is calculated from the ONS census on households[13], and a Scottish Government source in Scotland[14]. To calculate the rurality percentage these sources were used to understand how many households classified as either "urban" or "rural" and using this to understand the split for each PSS/GSP. This rurality percentage is then applied to the model as a threshold, of which an area must reach before it is possible to allocate to that area. This stops wind capacity being allocated to overly urban areas, where it would be unrealistic.

[12] Met Office / CEDA (Centre for Environmental Data Analysis) HadUK-Grid – 2017 Data

[13] Office for National Statistics (ONS) Census 2011 in England & Wales (Table RUC2011)

[14] Scottish Government in Scotland (Table SCUrbanRural2016)

2.3.3 Offshore wind

Gen_BB014

The spatial proxy for offshore is the length of coastline of the service area. This prevents offshore wind from being allocated to areas with insufficient coastline.

2.3.4 Solar generation large (G99)

Gen_BB012

The main spatial proxy used to allocate capacity is bright sunlight hours with the data collected from the Met Office/CEDA datasets for each PSS/GSP area as per wind. This is the primary measure used to drive an allocation weighting – with the assumption that sunnier areas are more attractive for generation buildout. As well as existing capacity as previously mentioned, the final proxy used is rurality. This is calculated in the same manner as for wind; however, PV has a lower threshold due to smaller space requirements.

2.3.5 Solar generation small (G98)

Gen_BB013

Small scale solar generation is spatially allocated according to the distribution of residential EVs. The logic is that the socio-economic factors and preferences that would incentivise households to purchase an EV are also well aligned with those for rooftop PV.

2.3.6 Hydro

Gen_BB017 and Gen_BB018

Number of waterways was the spatial proxy used to allocate hydro power; the data collected from the Ordnance Survey[15]. The logic is that the larger the number of waterways in an area the higher the probability that new hydro capacity would be allocated.

2.3.7 Combined Heat and Power (CHP)

Gen_BB001, Gen_BB002, Gen_BB003, Gen_BB010 and Gen_BB011

CHP capacity is assigned to GSPs according to different types of expected heat demand. CHP is split into renewable (i.e. biomass) and non-renewable (i.e. natural gas) variants, with a differing approach for each.

Non-Renewable CHP: Gen_BB001 (>=1MW), Gen_BB002 (<1MW) and Gen_BB003 (Micro CHP Domestic (G98/G83))

Non-renewable CHP is assumed to be built primarily for district heating, which is assumed likely to be located in areas of high heat density. A proxy for heat density per PSS/GSP is calculated in a similar manner to that for district heating (see section 2.4.6).

[15] OpenRivers 2019 database

Increases in non-renewable CHP capacity at the SPEN area level are then spatially allocated to individual PSS/GG/GSPs based on the relative heat density of each, i.e. with more capacity being built in areas of high heat density. There is also a minimum threshold heat density, which a PSS/GG/GSP must exceed in order to have any heat density allocated.

Renewable CHP: Gen_BB010 (Biomass & Energy Crops) and Gen_BB011 (Waste Incineration)

It is assumed that due to air quality restrictions renewable CHP (likely biomass fired) will be sited away from residential areas and will instead be sited near large industrial centres to cover significant industrial heat demand. As a proxy for the industrial heat requirement, which is not spatially disaggregated in the FES data, the I&C electricity load for each GSP has been used, calculated as described in Section 2.4.3.

2.3.8 Flexible Technologies

Srg_BB001 to Srg_BB004, Gen_BB004 to Gen_BB009 and Gen_BB023

Dispatchable generating capacity (and battery storage) can be classed as "flexible", in that the output can be increased or decreased quickly in response to price signals and/or system need.

Where flexible technologies are sited is dependent on the system need/opportunity they are being built for. Currently, much of the new flexible capacity on the distribution system is built to either supply power at the system peak load or be used for system services (e.g. primary and secondary response). As a result, there is an incentive to be sited in areas of low distribution network constraint, to ensure that there is full access to national-level balancing markets. As the Distribution System Operator (DSO) model evolves, there will likely be incentives for flexible assets to site in areas of high constraint, as DSOs seek to manage local balancing issues, reducing the need for investment in the distribution network itself.

The analysis presented here, assumes that initially capacity is sited in GSPs of low constraint (matching what is seen currently) but that after a user-defined year SPEN will be able to provide the necessary incentives to encourage some capacity to site in areas of high constraint, so the model will site capacity in those areas.

The high-level methodology for siting dispatchable capacity is as follows:

1. Calculate the headroom of each PSS/GG/GSP site in each year:
    a. Take **thermal capacity** of each GSP, using SPEN supplied data;
    b. Take calculated metered **demand** for each PSS/GG/GSP in each year, for winter peak, summer minimum AM and summer minimum PM periods;
    c. Take calculated distribution connected **generation** for Wind, PV, Hydro, CHP and BtM PV technologies, using load factors at all appropriate time periods – consistent with FES assumptions, to calculate the total generation at each PSS/GG/GSP;
    d. Calculate the thermal **headroom** for both winter peak and summer minimum at each PSS/GG/GSP using the following parameters: **thermal headroom**, **thermal capacity** of substations, **distribution generation** at peak, and **metered peak demand**.
    e. Find the constraining headroom by taking the lowest headroom of the time periods (this is nearly always at winter peak when demand is high);
2. For years prior to the local balancing model implementation, share new capacity over the PSS/GG/GSPs with the higher thermal headroom (areas of low constraint).

3. For year after the local balancing model implementation, share new capacity over the PSS/GG /GSPs with the lowest thermal headroom (areas of high constraint).

Renewable Dispatchable: Gen_BB004

As with CHP, we assume that a new renewable plant (i.e. biomass or biogas) is only sited in more rural areas for air quality reasons. The annual capacity increase is assigned to GSPs with highest or lowest headroom, as described above.

Non-Renewable Dispatchable: Gen_BB005 to Gen_BB009

This uses the same methodology as Non-Renewable Dispatchable.

Hydrogen Fuelled Generation: Gen_BB023

This uses the same methodology as Non-Renewable Dispatchable.

Batteries: Srg_BB001

Battery storage is a flexible technology and is sited in areas of the highest headroom.

Domestic batteries (G98): Srg_BB002

BtM storage is spatially allocated according to the distribution of residential EVs. The judgement is that the socio-economic factors and preferences that would incentivise households to purchase an EV are also well aligned with those for Storage.

Pumped Hydro: Srg_BB003

There is limited additional potential for pumped storage within the SPEN area. This is allocated using the same methodology as Batteries (Srg_BB001).

Storage (Other): Srg_BB004

This is allocated using the same methodology as Batteries (Srg_BB001).

2.3.9 Summary

The FES provide a reasonable range of possible capacity evolutions for generation and storage in the SPEN area, subject to the adjustments for creating more Net Zero aligned scenarios. Our approach has been to:

- Use current SPEN data at PSS, GG, and GSP level, to provide a baseline for all known connected generation capacity.
- Use project status knowledge for named projects (assigned to GSPs) for the near-term connections.
- Assume the same growth rates at a total SPEN licence area level as seen in the FES for the period 2020-2050 but use bespoke methodologies for siting capacity to GSPs and PSSs based on various spatial data to give insight into local suitability (summarised below in).
- Use the FES data for load factors of all generation and storage technologies to create net-load positions for specific time periods.

2.4 Demand spatial allocation

2.4.1 Introduction

Several demand building blocks were modelled for each of the scenarios:

- Baseline Domestic True Demand (underlying): Dem_BB008a
- Non-domestic Demand (underlying): Dem_BB008b
- Pure Electric (vans, cars & motorbikes): Lct_BB001
- Plug-in-hybrid (vans, cars and motorbikes): Lct_BB002
- Pure Electric (road vehicles other than vans, cars and motorbikes): Lct_BB003
- Plug-in-hybrid (road vehicles other than vans, cars and motorbikes): Lct_BB004
- Heat Pumps – Domestic, Non-hybrid: Lct_BB005
- Heat Pumps – Domestic, Hybrid: Lct_BB006
- Heat Pumps – I&C, Non-hybrid: Lct_BB007
- Heat Pumps – I&C, Hybrid: Lct_BB008
- District Heat: Lct_BB009

For all building blocks, except underlying demand, which is modelled only at GSP level, each of these components is modelled at PSS, GG, and GSP levels and then combined to determine the total demand per PSS/GG/GSP at the winter peak, summer minimum AM and summer minimum PM periods. This aggregate demand is then combined with distribution connected generation to determine the net demand/generation balance at PSS/GG/GSP level.

The following subsections describe additional considerations or assumptions which have been made when disaggregating demand side technologies.

Table 3 – Summary of key spatial disaggregation proxies for demand

Scenario element	Spatial disaggregation proxy	Granularity	Source
Underlying domestic demand	Building floor area (domestic)	Postcode	DESNZ
I&C demand	Building floor area (I&C)	Building level	Ordnance Survey
Heat pumps	On/Off-gas grid properties	Postcode	Xoserve
	Building type (detached, semi-detached, flat, terraced)	Building level	Ordnance Survey
	New build	PSS	MHCLG/SPEN

District Heating – Large Scale Heat Pumps	PSS area and number of domestic flats	PSS	Ordnance Survey
Electric Vehicles – Residential	Bespoke EV-Up model developed for SPEN	Building level	Field Dynamics
Electric Vehicles - Other	Non-domestic buildings by type (e.g. office, filling station)	Building level	Ordnance Survey
BtM PV and storage	Aligned with distribution of residential EV uptake		

***Note:** the table does not include the presence of existing capacity, which is also a key driver for siting of additional capacity for offshore wind and district heating.

2.4.2 Underlying domestic demand

Dem_BB008a

In order to determine whether there is enough space at a SPEN site level (GSP) for additional underlying domestic demand, the BEIS postcode household demand data is used to calculate domestic floorspace in m^2. It is important to note that numbers of electric storage heaters are captured within the underlying domestic demand values within the FES data. The contribution to winter peak, summer minimum AM and summer minimum PM from these storage heaters is proportionally very small, due to the way they operate – only in the winter and requiring demand during the night.

The starting point for both domestic and I&C underlying demand is calculated using a similar process as for the LCTs. The regional proportions for demand type are calculated using the Building Block proportions of regional demands as a proxy. Before this proportion is applied to the GB level demand value, a calculation is done to remove losses from the figures provided in the FES ED1 table for the residential and I&C technologies, to leave true domestic and I&C demand, respectively.

2.4.3 Underlying I&C demand

Dem_BB008b

When determining the share of I&C demand per GSP, the model uses the spatial proxy of I&C floor space for the allocation, based on building-level Ordnance Survey data[16].

[16] OS AddressBasePremium, and OS MasterMap

2.4.4 EVs (Pure Electric and Plug-in-Hybrid)

Lct_BB001 to Lct_BB004

2.4.4.1 Introduction

In the 2025 FES multiple EV types are considered. Privately owned electric cars are expected to contribute much of the impact on the network at peak time. The total number of vehicles to be allocated to the SPEN areas is calculated using FES national numbers adjusted to reflect regional targets. Additionally, forecasts of electric cars were provided using bespoke modelling of SPEN region households and their probability of acquiring EV cars in the future. The percentage of EVs in the SPEN areas was then calculated using the regional breakdown FES data.

2.4.4.2 Spatial allocation of Pure Electric and Plug-in-Hybrid vans, cars, and motorbikes: Lct_BB001 and Lct_BB002

This process was undertaken at PSS level using the EV-Up tool developed by Field Dynamics for SPEN[17]. EV-Up enables SPEN to map additional demand from new EVs as consumers continue to replace conventional internal combustion engine (ICE) vehicles, delivering an increased understanding of individual households' ability and desire to transition to low carbon transport. It also provides an indication of the potential increased demand and impact on the LV network.

At the foundation level, the methodology assumes that the ability to park off-street will be a core driver for EV uptake. Using detailed Ordnance Survey MasterMap data, domestic properties are identified and tagged with the corresponding available parking area established. Key metrics are reviewed to determine a parking opportunity score base on several variables' measurements, such as proximity to road or pavement, ability to park multiple vehicles and type of property.

EV-Up also combines the physical ability of consumers to park off-street with key demographic information derived from Experian Mosaic data which provides a pin-sharp picture of today's UK consumer, reflecting consumer and societal trends. By obtaining a deep understanding at the household level of the geodemographic group and type, the household can be linked to a probability to own a type of vehicle. This enables an improved understanding of ownership likelihood of EVs according to income, lifestyle, and changing behaviours.

The allocation of the foundation data set has been developed based on UK statistics of mileage, EV efficiency and average domestic demand based on the demographic groups identified. In addition, it assumes early EV adoption will be dominated by owners who live in properties with off-street parking where they can park their EV and charge using their own electricity supply. The methodology ensures that the results can be justified and backed up with credible evidence rather than a series of subjective assumptions. displays EV-Up uptake distribution for both SPM and SPD areas in the early 2030s.

For DFES 2025, allocation logic in this model has been updated to align with electric and hybrid vehicle CPAs due to tRESP, as stated in Section 1.1.1.

[17] https://www.spenergynetworks.co.uk/pages/evup.aspx

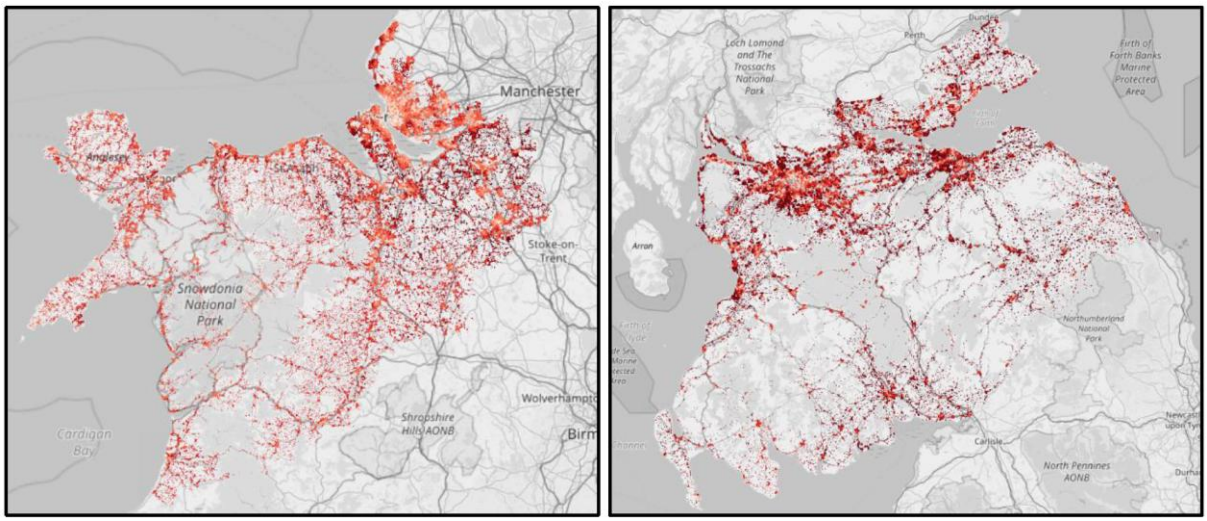


Figure 5 – SPM (left) and SPD (right) illustrative EV uptake distribution in the early 2030s

2.4.4.3 Spatial allocation of Pure Electric and Plug-in-Hybrid buses, coaches, and HGVs: Lct_BB003 and Lct_BB004

FES details many other EV types in its analysis, these include buses, coaches, commercial vehicles, Light Goods Vehicles (LGVs), and Heavy Goods Vehicles (HGVs). While home charging personal EVs are likely to be the cause of the majority of demand changes, there are significant point loads that are likely to occur from other EV types and charging behaviours.

To allocate other EV charging types, OS Address Base data was used to inform where there are existing buildings that are likely to result in increased charging demand, these were then used as spatial proxies for allocation.

below details the different types of EVs that are included, and a brief overview of how they are modelled, and what data was used to inform their allocation.

Table 4 – EV type allocation metrics

EV type	Charging location	Spatial proxies used from OS database
Consumer owned EV (charging away from home)	Work	*"Office"*
	Public	*"Public convenience"*
		"Maintenance depot"
	Rapid	*"Petrol filling station"*
Buses & Coaches	Depot	*"Public coach parking"*
		"Bus/Coach station"
		"Bus/Coach depot"
Heavy Goods Vehicle (HGV)	Depot	*"Maintenance depot"*
		"Petrol filling station"
Light Goods vehicle (LGV)	Depot	*"Maintenance depot"*
		"Petrol filling station"

2.4.4.4 tRESP and CPA alignment for EVs

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. To achieve this, EV modelling for DFES 2025 has been conducted in alignment with all CPAs and methodology provided by NESO. This includes:

- All EV CPAs which are defined for building blocks Lct_BB001 (Pure electric vans, cars, & motorbikes), Lct_BB002(hybrid equivalent of Lct_BB001), Lct_BB003 (Pure electric vehicles other than vans, cars, & motorbikes), and Lct_BB004 (hybrid equivalent of Lct_BB003)
- All EV CPAs which are defined to be applied based on vehicle charging type (domestic, residential, public slow/fast, public rapid, and HGV depot charging)

2.4.4.5 EV contribution to system load

The aggregated EV charging profile by network asset for each representative day is derived using CPA methodology. CPA assumptions for EV yearly mileage, distance travelled in EV mode and EV efficiency are used to calculate the annual consumption for SPEN Region EVs for each EV type. This is disaggregated into annual consumption per charger type according to CPA provided assumptions of

the proportion of utilisation of each charger type per EV type. Disaggregation of charging profiles to network asset levels includes a diversity correction check, using the CPA provided minimum count for diversification at GSP level and applying a diversity scaling factor where appropriate. Finally, CPA provided assumptions on consumer behaviour and normalised half-hourly profiles are used to determine EV charging profiles by charger type and aggregated to network asset level.

2.4.5 Heat pumps

Lct_BB005, Lct_BB006, Lct_BB007, Lct_BB008

2.4.5.1 Spatial proxies

NESO's building blocks split heat pumps into domestic non-hybrid/hybrid and I&C non-hybrid/hybrid. The SPEN model breaks that down further, making a distinction between Air Source Heat Pumps and Ground Source Heat Pumps and applying a different approach to each. In order to make the heat pump demand more representative several spatial proxies are used as suitability factors, chosen to appropriately allocate the heat pump demand. These are different for different types of heat pumps:

- Air Source Heat Pump (ASHP)
  - Domestic: Lct_BB005a
  - I&C: Lct_BB007a
- Ground Source Heat Pump (GSHP)
  - Domestic: Lct_BB005b
  - I&C: Lct_BB007b
- Hybrid Heat Pump (Hybrid HP), which is an electric heat pump operating to supply baseload, with a gas boiler when necessary to operating to meet heat demand or alleviate grid constraints.
  - Domestic: Lct_BB006
  - I&C: Lct_BB008

There are several factors influencing heat pump allocation:

- The type of residential building plays a key role in heat pump allocation. According to the tRESP CPAs, residential buildings are classified into four categories for this purpose: detached, semi-detached, terraced, and flats. Specific assumptions have been made regarding the suitability of these building types for different heat pump technologies. Ground Source Heat Pumps (GSHPs) are generally unsuitable for flats because they require outdoor space for installation. Similarly, Hybrid HPs demand more space, making flats an impractical option. Consequently, flats are excluded from GSHP and Hybrid HP allocation, under the assumption that they are more likely to be served by District Heating (DH) networks or Air Source Heat Pumps (ASHPs). In contrast, ASHPs are considered suitable for all building types.
- GSHPs/ASHPs are more likely to be installed in buildings off the gas grid, which are likely to currently be using relatively expensive fuels (e.g. oil-fired heating). Off-gas postcode

data from Xoserve18 has been used to determine the number of off-gas grid homes per PSS, which has been used as one of the suitability factors. This does not apply to Hybrid HPs which require gas to operate.

- Heat pumps perform best in well-insulated highly efficient buildings and are therefore more likely to be installed in new builds. Statistics on the new builds have been mapped down to PSS level to come up with the growth of new build housing per PSS, based on recent historic growth in number of meter termination points from SPEN's data. Priority of installation has been given to new build homes when allocating heat pump growth year-on-year.
- The model limits heat pump allocation according to housing stock - there is logic in place to ensure the total number of a heat pump type doesn't exceed the suitable housing stock for that heat pump.

Building count and off-gas grid areas are shown in Figure 6 for the SPM licence area and in Figure 7 for the SPD licence area. Table 5 below is a summary of which of these spatial proxies was used for the allocation of each heat pump type.

Table 5 – Heat pump allocation spatial proxies

Allocation Factor	ASHP	GSHP	Hybrid HP
Gas connection type	Off-gas grid	Off-gas grid	On-gas grid
Residential building type	All residential building types	All residential building types **excluding flats**	All residential building types **excluding flats**

These suitability factors were used to produce a relative suitability score for each PSS. This was then used to disaggregate SPEN licence area total number of heat pumps, determining the fraction of the total heat pumps demand that are assigned to each PSS.

It is worth noting that even in the high uptake scenarios a large percentage of heat pump allocation is driven by new build, due to the high numbers when compared to off-gas grid properties.

[18] www.xoserve.com

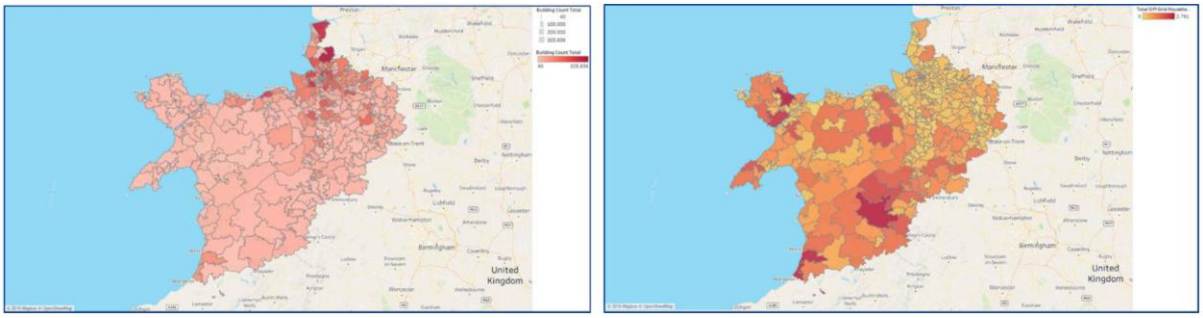


Figure 6 – SPM area building count (left) and off-gas grid areas (right)

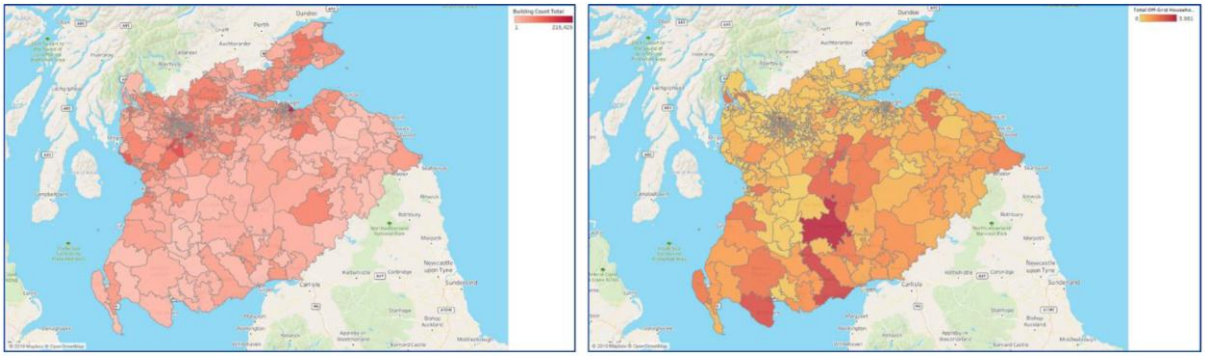


Figure 7 – SPD area building count (left) and off-gas grid areas (right)

2.4.5.2 tRESP and CPA alignment for Heat Pumps

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. To reflect this, we have worked closely with NESO's RESP team to ensure that the tRESP CPA's and pathways and subsequent forecasting methodology draw from industry best practice developed in previous DFES publications.

2.4.6 District heat

Lct_BB009

To disaggregate the spatial allocation of district heating systems domestic heating demand density has been used as a spatial proxy. Domestic heating demand density was calculated by dividing the area covered by a PSS boundary by the number of domestic buildings in that area. This comparable number was then used to allocate the DH demand – i.e. proxy for heat density assuming an average heat demand per building. A minimum scale was also selected to avoid unrealistically small DH systems.

2.4.7 Demand flexibility

2.4.7.1 Introduction

The numbers output by the model represent the "actual peak demand" as assumptions on Demand Side Response (DSR), peak avoidance and smart charging are already taken into account prior to this. In order to get a better understanding of the impact of flexible demand, information on the assumed

flexibility that has been provided by NESO enables us to present how flexibility assumptions vary over time and understand the impact of these.

It should be noted that this flexibility is assumed to be based around the winter peak analysis which has the greatest need for flexibility. At summer minimum AM and minimum PM, it is assumed that no flexibility is active, consistent with the FES. In reality, there is the potential for demand turn up, but this is expected to be small and hence is not explored in this analysis.

There is significant uncertainty around the rate of development of flexibility markets. The 2025 FES shows variation in the extent of residential, industrial and commercial flex capacity among the three Net Zero scenarios, reflecting their differences in predicted consumer engagement on the journey to Net Zero. Figures for flexibility provided by NESO include up to 20% of the entirety of peak demand and 30% of residential demand in the Holistic Transition scenario. These assumptions were derived from a combination of stakeholder engagement and evidence from current DSR markets[19]. Considering these flexibility projects in conjunction with what would happen to peak demand without flexibility allows for an understanding of how much peak demand is mitigated, and hence the impact of the FES flexibility assumptions.

2.4.7.2 Underlying domestic demand

In the case of domestic demand flexibility, NESO's assessment of the impact of smart appliances, time of use tariffs and consumer behaviour has been used directly. The FES model has a wide range of flexibility and peak avoidance for domestic demand, depending on various factors. These are included in the underlying FES data for domestic contribution to peak demand and are therefore included in this modelling.

2.4.7.3 I&C demand

The FES provide the total GW that will become available through I&C DSR in GB as a whole, and this has been scaled to calculate the percentage of DSR based on the total I&C peak demand. The current levels of flexibility for I&C demand are already significant and larger than the flexibility of underlying domestic demand. The main reasons for this are that larger I&C customers are easier to engage and their electricity consumption is half-hourly metered, which is required to determine the actual amount of demand reduced and hence, the flexibility payment. For the two most highly decarbonised scenarios (HT and EE) it is assumed that the percentage of flexible load will increase significantly towards 2050, whilst for the other two scenarios little change is expected (HE and FB). It should be noted that the increase in flexibility between now and 2050 is significantly less prominent for I&C than domestic, because of the relatively higher "starting point".

2.4.7.4 Electric Vehicles

NESO provides flexibility assumptions for EV charging, consistent with the 2025 FES data - the DFES assumptions have been kept consistent with these. For residential EV charging, engagement with smart charging is expected to develop over time in all scenarios, which results in a large amount of flexible EV load available to the network particularly in terms of shifting load away from peak for overnight charging. The same is true for fleet vehicles charging at depots overnight. For non-residential (i.e. destination and forecourt) charging, the flexibility of the non-residential EV demand is

[19] https://www.neso.energy/document/321416/download

assumed to be 0% for all scenarios, as these are likely to be on demand requirements where flexibility is therefore not appropriate. This lack of flexibility for non-residential charging is based on analysis undertaken as part of the CVEI study.

2.4.7.5 Heat Pumps

Heat Pump demand is assumed to be entirely inflexible in the non-decarbonisation centric scenarios in the 2025 FES, because consumers are expected to not engage with reducing their heating demand at peak times. One of the principal reasons for this is that few consumers have dedicated thermal storage and therefore cannot shift their heating demand without reducing their comfort levels, which they are unlikely to do. In the decarbonisation centric FES scenarios there is some peak demand reduction for heat pumps, which assumes hot water tank storage that can be used to provide some amount of heating demand peak avoidance.

2.4.8 Summary

The underlying scenario demand elements have been modelled in close alignment with the 2025 FES. FES numbers have been used but adjusted where appropriate to reflect better the specifics of the SPEN licence areas. Numerous adjustments have been made to current values based on better informed SPEN data. Growth rates have been directly taken from FES, and various separate data sources were used to significantly improve the spatial allocation down to the required PSS granularity to inform network modelling (summarised in Table 6).

Table 6 – Summary of key spatial disaggregation proxies for demand

Scenario element	Spatial disaggregation proxy	Granularity	Source
Underlying domestic demand	Household annual electricity demand	Postcode	BEIS
I&C demand	Building floor area	Building level	Ordnance Survey
Heat pumps	On/Off-gas grid properties	Postcode	Xoserve
	Building type (large/small)	Building level	Ordnance Survey
	New build	PSS	MHCLG/SPEN
District Heating – Large Scale Heat Pumps	PSS area and number of domestic buildings	PSS	Ordnance Survey
Electric Vehicles – Residential	Bespoke EV-Up model developed for SPEN	Building level	Field Dynamics

Electric Vehicles - Other	Non-domestic buildings by type (e.g. office, filling station)	Building level	Ordnance Survey
BtM PV and storage	Aligned with distribution of residential EV uptake		

Appendix A Figures

Figure 1 – NESO's Future Energy Scenarios 2025 9
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Appendix C Acronyms

Acronym	Description
AONB	Area of Outstanding Natural Beauty
ASHP	Air Source Heat Pump
BEV	Battery Electric Vehicle
BECCS	Bioenergy with Carbon Capture and Storage
BtM	Behind the Meter
CCUS	Carbon Capture Utilisation and Storage
CHP	Combined Heat and Power
CPA	Consistent Planning Assumptions
CVEI	Consumers, Vehicles and Energy Integration Project
DACCS	Direct Air Carbon Capture and Storage
DESNZ	Department of Energy Security and Net Zero
DFES	Distribution Future Energy Scenarios
DH	District Heating
DNO	Distribution Network Operator
DSO	Distribution System Operator
DSR	Demand Side Response
ESO	Electricity System Operator
EU	European Union
EV	Electric Vehicle
FES	Future Energy Scenarios
GB	Great Britain
GDP	Gross Domestic Product
GG	Grid Group (Specific to SP Manweb)
GSHP	Ground Source Heat Pump
GSP	Grid Supply Point
HP	Heat Pump
HV	High Voltage
I&C	Industry and Commercial
ICE	Internal Combustion Engine
LGV	Light Goods Vehicle
LNG	Liquefied Natural Gas
LV	Low Voltage
MHCLG	Ministry of Housing, Communities and Local Government
NESO	National Energy System Operator
OCGT	Open Cycle Gas Turbine
ONS	Office of National Statistics

OS	Ordnance Survey
PHEV	Plug-in Hybrid Electric Vehicle
PV	Photovoltaic
PSS	Primary Substation
(t)RESP	(transitional)Regional Energy Strategic Planning
SPD	SP Distribution
SPEN	SP Energy Networks
SPM	SP Manweb
UK	United Kingdom
UKCS	UK Continental Shelf
V2G	Vehicle to Grid
WANDA	Weather Normalised Demand Analytics

Appendix D FES Building Block Mapping

FES Building Block ID	FES Building Block Name	DFES Technology
Gen_BB001	Non-renewable CHP >=1MW	**COMBINED HEAT AND POWER – NON-RENEWABLE**
Gen_BB002	Non-renewable CHP <1MW	**COMBINED HEAT AND POWER – NON-RENEWABLE**
Gen_BB003	Micro CHP	**COMBINED HEAT AND POWER – NON-RENEWABLE**
Gen_BB004	Renewable Engines (Landfill Gas, Sewage Gas, Biogas)	**DISPATCHABLE – RENEWABLE**
Gen_BB005	Non-renewable Engines (Diesel) (non CHP)	**DISPATCHABLE – NON-RENEWABLE**
Gen_BB006	Non-renewable Engines (Gas) (non CHP)	**DISPATCHABLE – NON-RENEWABLE**
Gen_BB007	Fuel Cells	**DISPATCHABLE – NON-RENEWABLE**
Gen_BB008	OCGTs (non CHP)	**DISPATCHABLE – NON-RENEWABLE**
Gen_BB009	CCGTs (non CHP	**DISPATCHABLE – NON-RENEWABLE**
Gen_BB010	Biomass & Energy Crops (including CHP)	**COMBINED HEAT AND POWER – RENEWABLE**
Gen_BB011	Waste Incineration (including CHP)	**COMBINED HEAT AND POWER – RENEWABLE**
Gen_BB012	Solar Generation Large (G99)	**SOLAR – DISTRIBUTED GENERATION**
Gen_BB013	Solar Generation Small (G98)	**SOLAR – BEHIND-THE-METER**
Gen_BB014	Offshore Wind	**WIND**
Gen_BB015	Onshore Wind >=1MW	**WIND**
Gen_BB016	Onshore Wind <1MW	**WIND**

Gen_BB017	Tidal Stream, Wave Power, Tidal Lagoon	**HYDRO**
Gen_BB018	Hydro	**HYDRO**
Gen_BB019	Geothermal	**NOT MODELLED**
Gen_BB020	Nuclear	**NOT MODELLED**
Gen_BB021	Coal	**NOT MODELLED**
Gen_BB022	Interconnector	**NOT MODELLED**
Gen_BB023	Hydrogen fuelled generation	**DISPATCHABLE – NON-RENEWABLE**
Gen_BB024	Offshore-Wind (off-Grid)	**NOT MODELLED**
Srg_BB001	Batteries	**STORAGE – DISTRIBUTED GENERATION**
Srg_BB002	Domestic Batteries (G98)	**STORAGE – BEHIND-THE-METER**
Srg_BB003	Pumped Hydro	**STORAGE – DISTRIBUTED GENERATION**
Srg_BB004	Other	**STORAGE – DISTRIBUTED GENERATION**
Dem_BB008a	Baseline Domestic True Demand	**DOMESTIC DEMAND**
Dem_BB008b	Non-domestic Demand	**I&C DEMAND**
Lct_BB001	Pure Electric (vans, cars & motorbikes)	**PURE ELECTRIC CARS**
Lct_BB001	Pure Electric (vans, cars & motorbikes)	**PURE ELECTRIC VANS**
Lct_BB001	Pure Electric (vans, cars & motorbikes)	**PURE ELECTRIC MOTORBIKES**
Lct_BB02	Plug-in-hybrid (vans, cars and motorbikes)	**PLUG-IN-HYBRID CARS**
Lct_BB02	Plug-in-hybrid (vans, cars and motorbikes)	**PLUG-IN-HYBRID VANS**
Lct_BB02	Plug-in-hybrid (vans, cars and motorbikes)	**PLUG-IN-HYBRID MOTORBIKES**

Lct_BB003	Pure Electric (road vehicles other than vans, cars and motorbikes)	**PURE ELECTRIC HGVS**
Lct_BB003	Pure Electric (road vehicles other than vans, cars and motorbikes)	**PURE ELECTRIC BUSES**
Lct_BB004	Plug-in-hybrid (road vehicles other than vans, cars and motorbikes)	**PLUG-IN-HYBRID HGVS**
Lct_BB004	Plug-in-hybrid (road vehicles other than vans, cars and motorbikes)	**PLUG-IN-HYBRID BUSES**
Lct_BB005a	Domestic - Non-hybrid	**AIR-SOURCE HEAT PUMPS – DOMESTIC**
Lct_BB005b	Domestic - Non-hybrid	**GROUND-SOURCE HEAT PUMPS – DOMESTIC**
Lct_BB006	Domestic - Hybrid	**HYBRID HEAT PUMPS – DOMESTIC**
Lct_BB007a	I&C - Non-hybrid	**AIR-SOURCE HEAT PUMPS – NON-DOMESTIC**
Lct_BB007b	I&C - Non-hybrid	**GROUND-SOURCE HEAT PUMPS – NON-DOMESTIC**
Lct_BB008	I&C - Hybrid	**HYBRID HEAT PUMPS – NON-DOMESTIC**
Lct_BB009	District Heat	**DISTRICT HEAT**