Technical background document

Electrification: the local grid challenge

Author:	Frank Hodgson	Date:	Version 1.1 - May 2024
In partnership with:	MCS Foundation	Approved by:	Merlin Hyman Chief Executive, Regen

Supporting technical background document to Regen's Electrification: the local grid challenge report.

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Section 1:
Demand is increasing

1.1. Group demand

The networks use demand profiles to calculate the “Design Demand” of a customer on a network asset. If a network asset serves one customer (or if there is no demand diversification) then the design demand equals the expected peak demand of that customer. Where a group of multiple customers use power at different times then the design demand can be lower than the peak demand of each customer multiplied by the number of customers. DNOs currently size the network assets using the ACE49 (Area Control Error, 49th report) standard.

As the chart below shows, small numbers of customers require higher design demand (kW per customer) than larger groups, due to greater diversification of demand profiles. This is important for the local networks as many network assets feed power to very small groups of customers.

Demand per customer drops dramatically with larger groups of customers

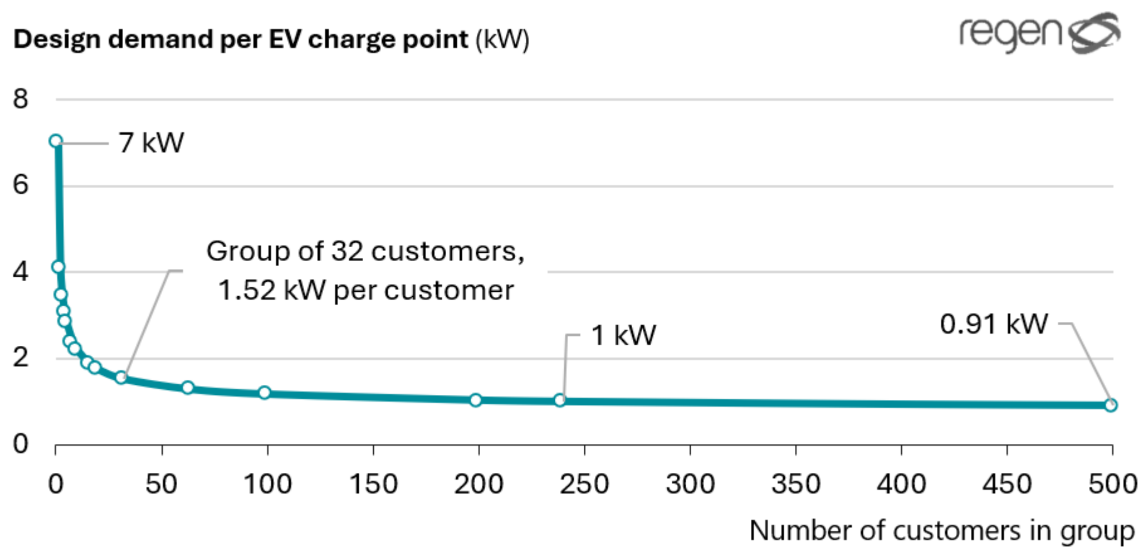

Figure 1: Design demand per EV charger, using the ACE49 methodology and data from the Electric Nation EV charging trial. Regen analysis. LH and RH chart shows same data, RH chart uses log scale.

Section 2:

When will network upgrades be needed?

2.1. Network technical limits

There are three principle technical limits that could be breached with the adoption of low carbon technologies:

Thermal	The maximum load the equipment can carry without overheating. The amount of spare thermal capacity is known as headroom.
Voltage	The maximum load a length of cable can carry whilst staying within statutory voltage limits of 216V and 253V. Demand causes voltage drop and generation causes voltage rise. Voltage changes increase with cable distances.
Phase imbalance	Power is transferred via 3-phase alternating current. Each phase has a separate cable. Power is then delivered on just one of the three phases to domestic properties. Demand and generation must be roughly equal across phases.

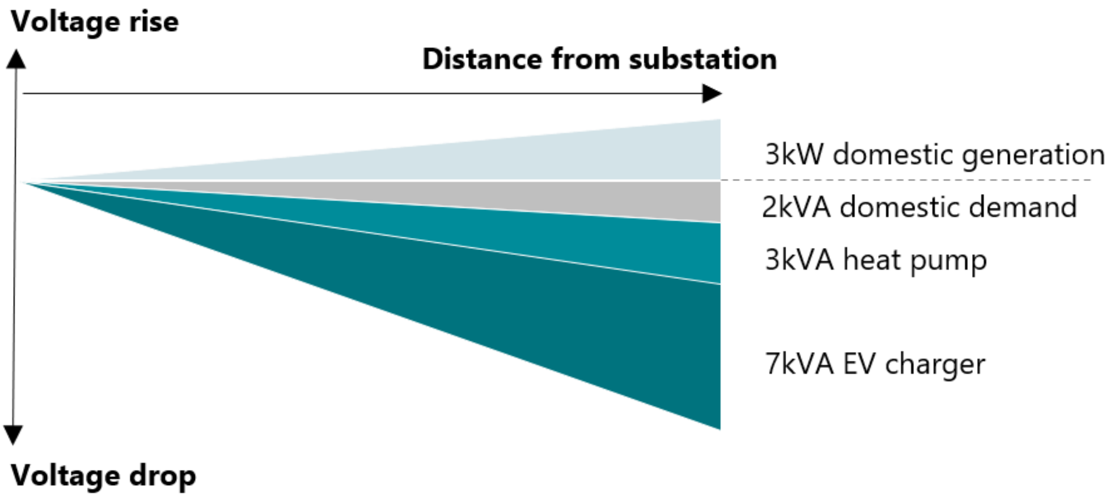

Figure 2: Illustration of voltage drop and rise. Voltage changes increase with distance from the substation.

2.2. Regen analysis of primary substation capacity

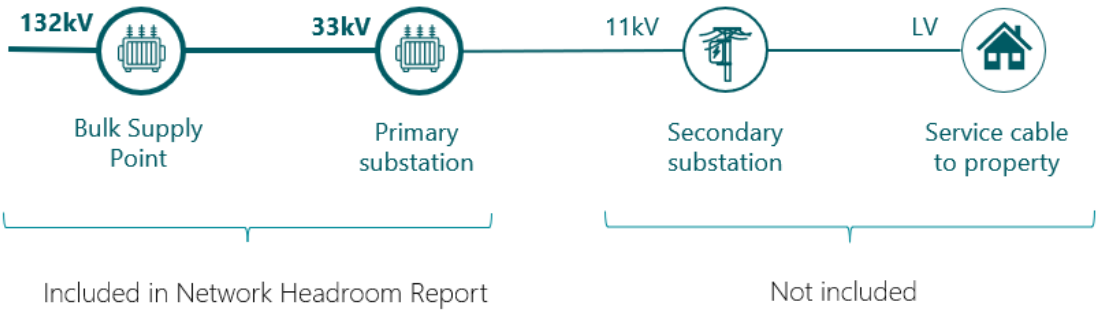

Figure 3: distribution network hierarchy.

The DNOs use DFES projections of changes to demand and generation to model when and where they expect to see capacity constraints on their networks. Projections of remaining capacity ("headroom") are published in Network Headroom Reports at bulk supply points and primary substations.

For this study Regen compiled all Network Headroom Reports under the FES Consumer Transformation scenario into a single dataset. The FES Consumer Transformation scenario best represents an accelerated electrification of home heating and transport and most closely aligns with the Climate Change Committee's balance pathway scenario. The only exception was SP Energy Networks which does not use the ESO's Future Energy Scenario framework in their DFES, where their high electricity demand scenario was used.

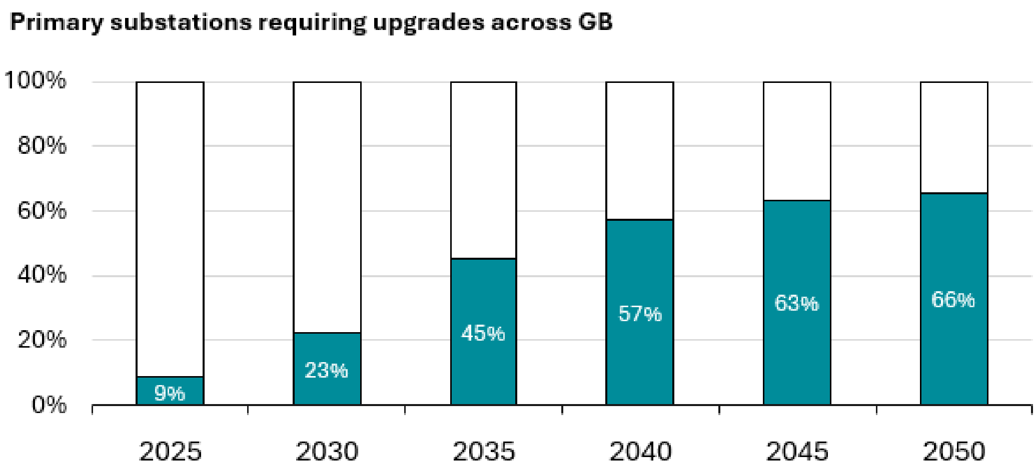

Figure 4: Chart showing the proportion of primary substations across GB with no remaining thermal capacity for demand under the Consumer Transformation DFES scenario. This decarbonisation scenario aligns closest to the CCC's Balanced Pathway scenario and the NIC's 2nd Assessment. Source: DNO data provided with the support of DNO Open Data platforms. Net Zero High demand used for SP Energy Networks licence areas.

Table 1: summary of DNO network headroom report information.

DNO	NHR publication date	Scenario used
Electricity North West Limited	2023	ENWL DFES Consumer Transformation
National Grid Electricity Distribution	2022	NGED DFES Consumer Transformation
Northern Powergrid	2022	NPG DFES Consumer Transformation
SP Energy Networks	2022	SPEN DFES High demand scenario
Scottish and Southern Electricity Networks	2022	SSEN DFES Consumer Transformation
UK Power Networks	2023	UKPN DFES Consumer Transformation

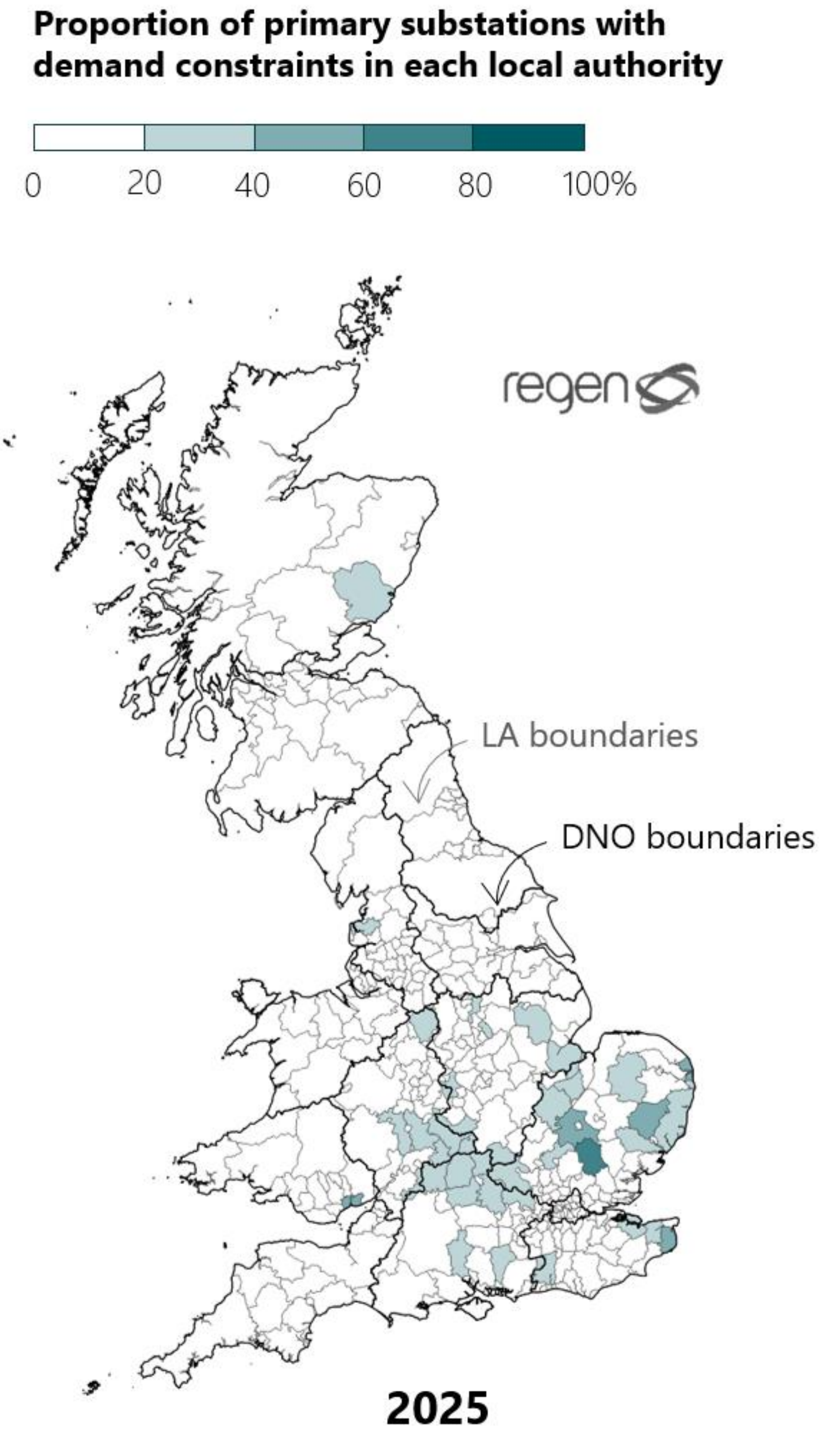

Figure 5: Map shows proportion of primary substations in each local authority with no remaining thermal capacity for demand under the Consumer Transformation DFES scenario. Source: DNO data provided with the support of DNO Open Data platforms. Net Zero High demand used for SP Energy Networks licence areas.

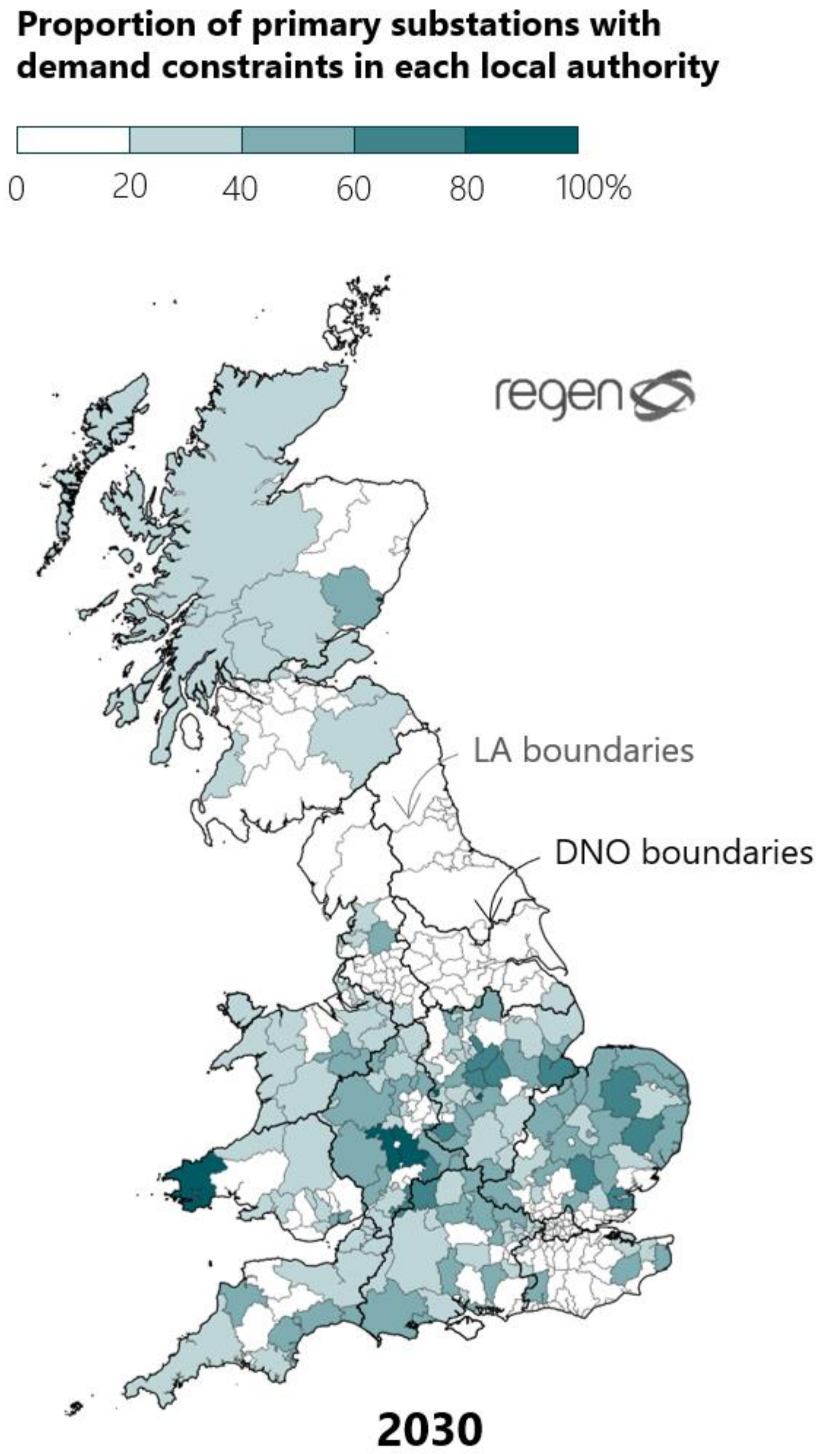

Figure 6: Map shows proportion of primary substations in each local authority with no remaining thermal capacity for demand under the Consumer Transformation DFES scenario. Source: DNO data provided with the support of DNO Open Data platforms. Net Zero High demand used for SP Energy Networks licence areas.

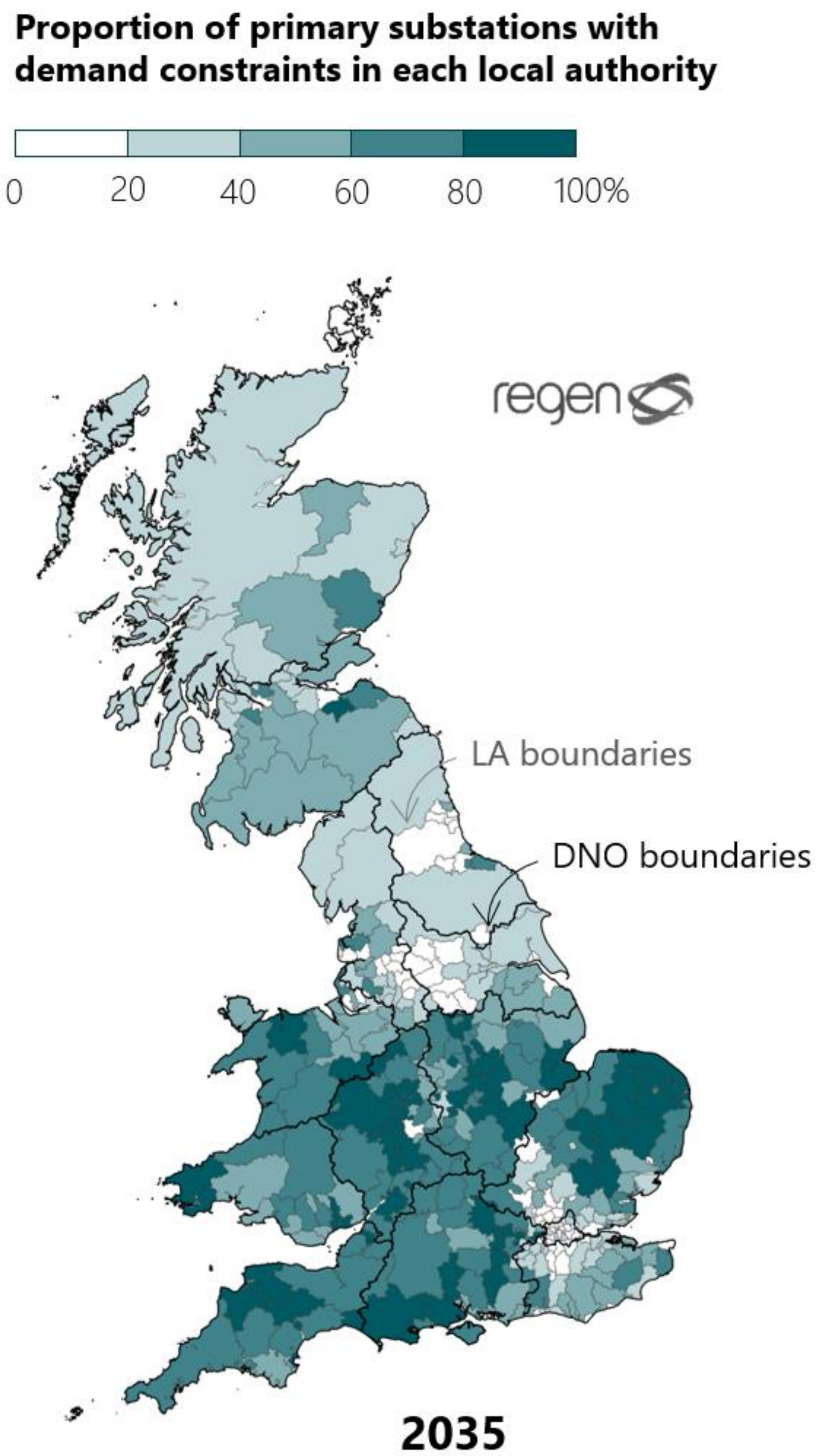

Figure 7: Map shows proportion of primary substations in each local authority with no remaining thermal capacity for demand under the Consumer Transformation DFES scenario. Source: DNO data provided with the support of DNO Open Data platforms. Net Zero High demand used for SP Energy Networks licence areas.

2.3. Secondary network capacity projections

Table 2: summary of secondary substation data published by DNOs.

DNO	Current network utilisation	Projected capacity	Planned upgrade date
Electricity North West Limited	**Published**	Not published	Not published
National Grid Electricity Distribution	**Published**	Not published	Not published
Northern Powergrid	**Published**	Not published	Not published
SP Energy Networks	Not published (but signposted)	Not published	Not published
Scottish and Southern Electricity Networks	Not published	Not published	Not published
UK Power Networks	**Published**	Not published	**Published**

Section 3:

How can the need for upgrades be minimised?

3.1. Breakdown of future flexibility capacity

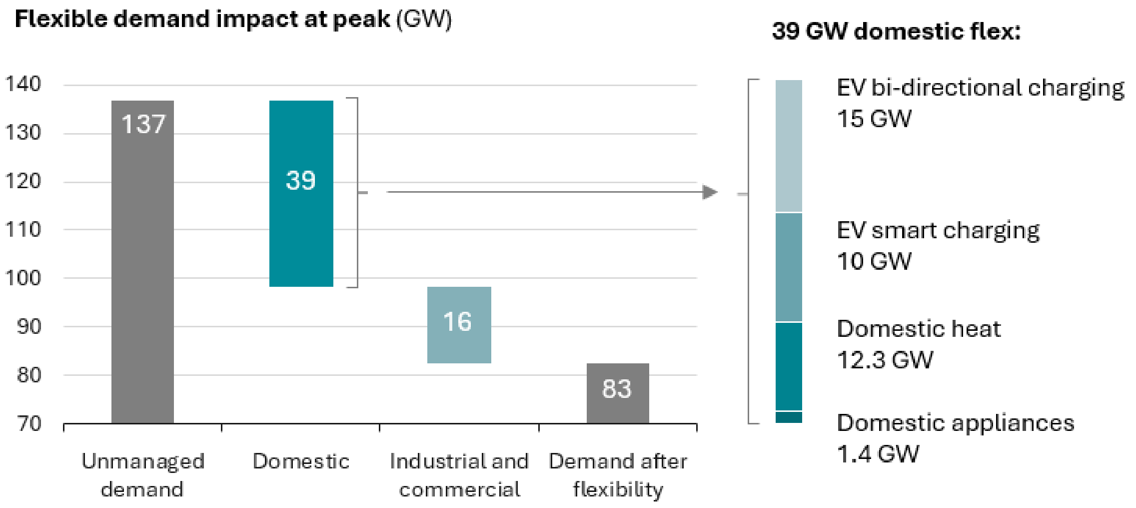

Figure 8: Regen analysis of GB wide demand side flexibility projections in 2050 from FES 2022, Consumer Transformation Scenario.

Table 3: summary of DNO network headroom report information.

Technologies	FES data	Domestic	Industrial and commercial
EV Smart Charging*	11.6 GW	10.0 GW	1.6 GW
EV Bi-directional Charging*	17.2 GW	14.9 GW	2.3 GW
Domestic Heat	12.3 GW	12.3 GW	0 GW
Domestic Appliances	1.4 GW	1.4 GW	0 GW
Industrial and commercial processes	9.3 GW	0 GW	9.3 GW
Industrial and commercial heat	2.6 GW	0 GW	2.6 GW
Total flexibility demand impact at peak	**54.3 GW**	**38.6 GW**	**15.8 GW**

*The split of domestic and commercial EV charging was determined by Regen, using the proportion of vehicles on the road as a proxy. According to the SMMT, 13.1% of vehicles on the road are commercial and the rest privately owned. This proxy may underestimate commercial smart charging and bi-directional because those vehicles will have larger batteries charged with higher capacity (kW) chargers. However, this will be balanced by possible lower smart charging and bi-directional charging adoption among businesses than private owners.

Section 4:

How should we plan and invest for reinforcement?

4.1. Distribution Future Energy Scenarios

The DNOs all carry out Distribution Future Energy Scenarios (DFES) to develop their Network Development Plans. The DFES are updated annually. The latest DFES for each network can be found here:

- Electricity North West Limited
- National Grid Electricity Distribution
- Northern Powergrid
- Scottish and Southern Electricity Networks (Southern England, Northern Scotland)
- SP Energy Networks
- UK Power Networks

4.2. Intervention rates at primary substations

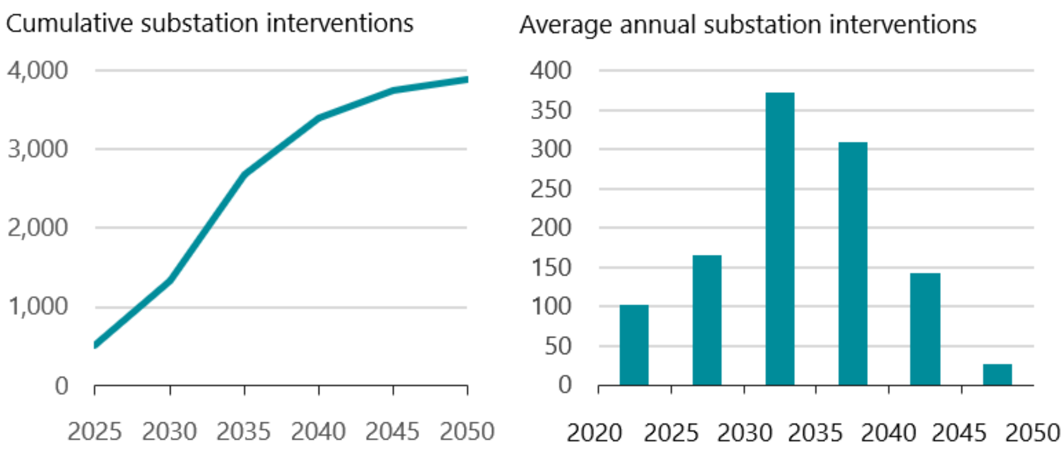

Figure 9: LH chart shows cumulative interventions required at primary (33kV to 11kV) substations across all DNOs. RH chart shows annualised intervention rate for each five year period. Source: Regen analysis of DNO primary substation headroom data under an accelerated electrification scenario (FES Consumer Transformation).

Analysis of the compiled primary substation headroom data detailed in Section 2.2 was used to derive a nationwide rate of substation intervention, illustrated above. Note that interventions do not necessarily require traditional network upgrades (i.e. additional or upgraded transformers) but could be solved by non-traditional solutions such as flexibility procurement. The annual intervention rate is shown in five-year averages because most DNOs publish capacity projections in 5-year intervals after 2035.

4.3. Upgrade costs

Table 4: costs that DNOs can recover from bills for upgrades to different assets .

Cable

	LV cable	HV cable (11kV)
Overhead	£49,800 / km	£127,300 / km
Underground	£141,300 / km	£39,600 / km

Transformers

Pole mounted secondary substations	**£89,500 / MVA**
Ground mounted secondary substations	£63,300 / MVA

MVA stands for Megavolt Amperes and refers to the nameplate capacity of the substations.

4.4. Age related replacement

Distribution Network Operators have a duty to maintain a reliable network and so they proactively replace their assets using condition information to avoid unplanned failures which would result in network outages. It is well known that across DNOs a significant portion of the secondary substations (11kV>LV) were installed over 50 years ago, with some assets installed as early as the 1940s still in operation today. The plots below from SSEN's ED2 engineering justification papers show that assets installed during the electrification push of the 1950s and 1960s are still in operation and make up a significant proportion of all assets.

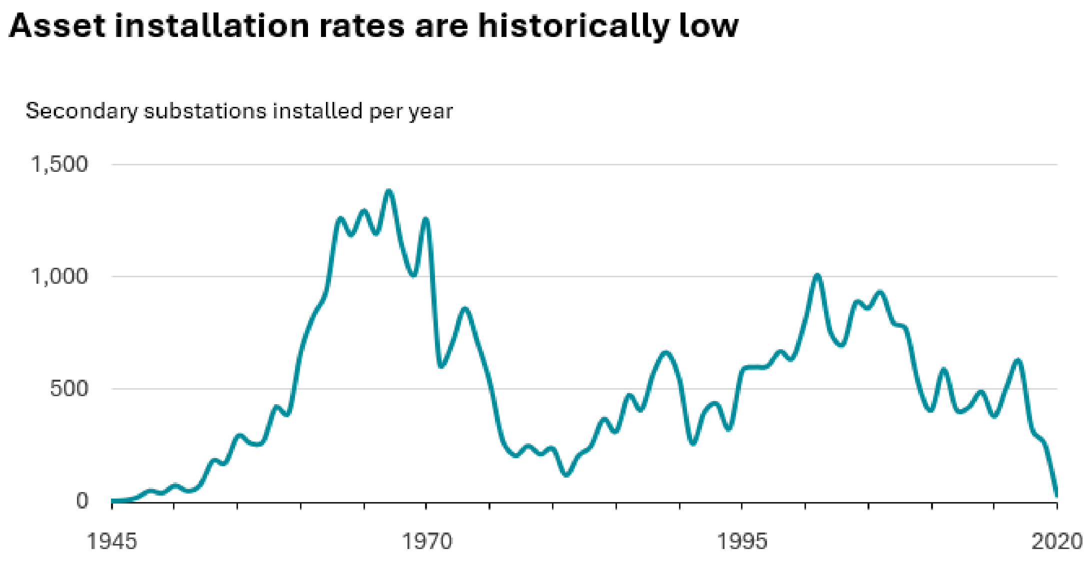

Figure 10: chart shows the number of secondary (11 kV/LV) transformers in operation in 2022 by installation year across both SSEN licence areas.. Source: SSEN ED2 Engineering Justification Papers.

"This variance in the rate at which the network was initially built can result in a sudden increase or decrease in future investment as the transformers previously installed in the same time period collectively reach the end of life condition."

Quotation source: page 8, SSEN RIIO-ED2 Engineering Justification Paper (EJP), 6.6/11kV Transformers (Ground Mounted), Investment Reference No: 308/SSEPD/NLR/HV_TRANSF.

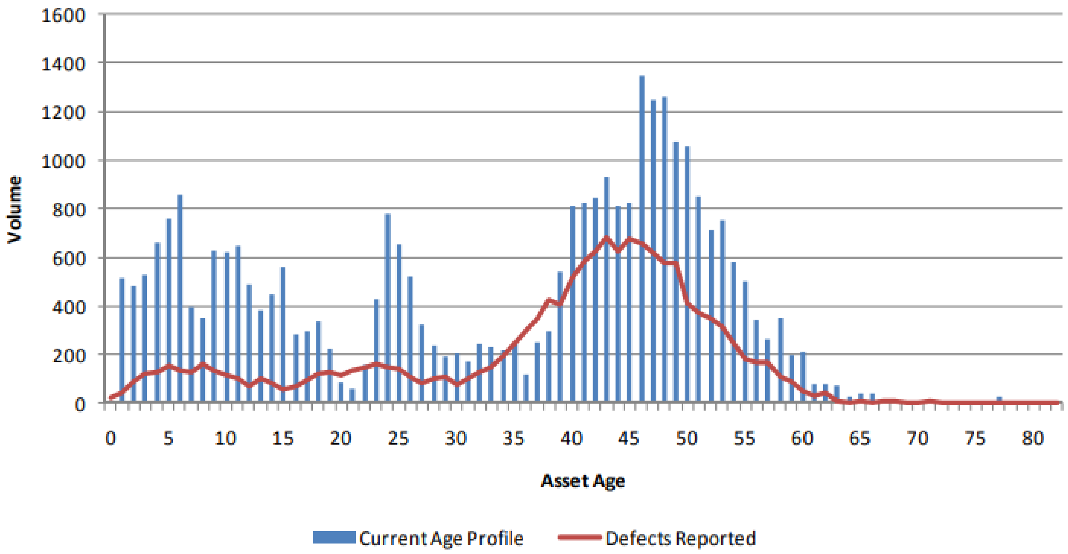

Figure 11: Secondary substation asset condition data from UKPN Asset Stewardship Report.

UKPN asset analysis from 2014 highlights that there is a strong correlation between age and defects. Whilst the analysis is almost a decade old, the asset age profile appears to resemble that of SSEN's licence areas.

DNOs across the country will likely face increasing rates of condition-based replacement as these assets collectively age, coinciding with replacement due to increasing loads. It is important therefore that DNOs ensure that they take opportunities to increase asset capacities whilst making condition-based asset replacements.

Section 5:
How can customers get connected quickly and easily?

5.1. Fuse ratings

Two DNOs have changed policy and stopped fitting 100A fuses to single phase electricity supplies. Not all operators have adopted this policy.

Table 5: summary of fuse ratings fitted by DNOs.

DNO	Maximum fuse rating (single phase)
Electricity North West Limited	100A
National Grid Electricity Distribution	80A
Northern Powergrid	80A – though not stated on website
SP Energy Networks	100A
Scottish and Southern Electricity Networks	Not stated on website
UK Power Networks	100A