CORNWALL INSIGHT
CREATING CLARITY

Consumer-led engagement in electricity flexibility

Technical Annex

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Anna Moss, Jacob Briggs, Tom Edwards

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2 About Cornwall Insight

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3 About the Technical Annex

This is a technical annex that accompanies our research report "Consumer-led engagement in electricity flexibility", an independent research project commissioned by Smart Energy GB and published in October 2025.

It sets out further information on the approach taken and key assumptions used to develop the modelling and analysis used in this report.

Our detailed modelling was conducted through Q1 2025, and aimed to understand:

- The potential for consumer-led flexibility to support the requirements for electricity flexibility in 2030 and 2050
- The level of support that could be delivered by households with a range of low carbon technologies installed, including households with no low carbon technologies

This annex details our process and assumptions across two overarching areas:

- Determining national flexibility requirements in each year
- Understanding the role for household flexibility in meeting this

4 Modelling Approach

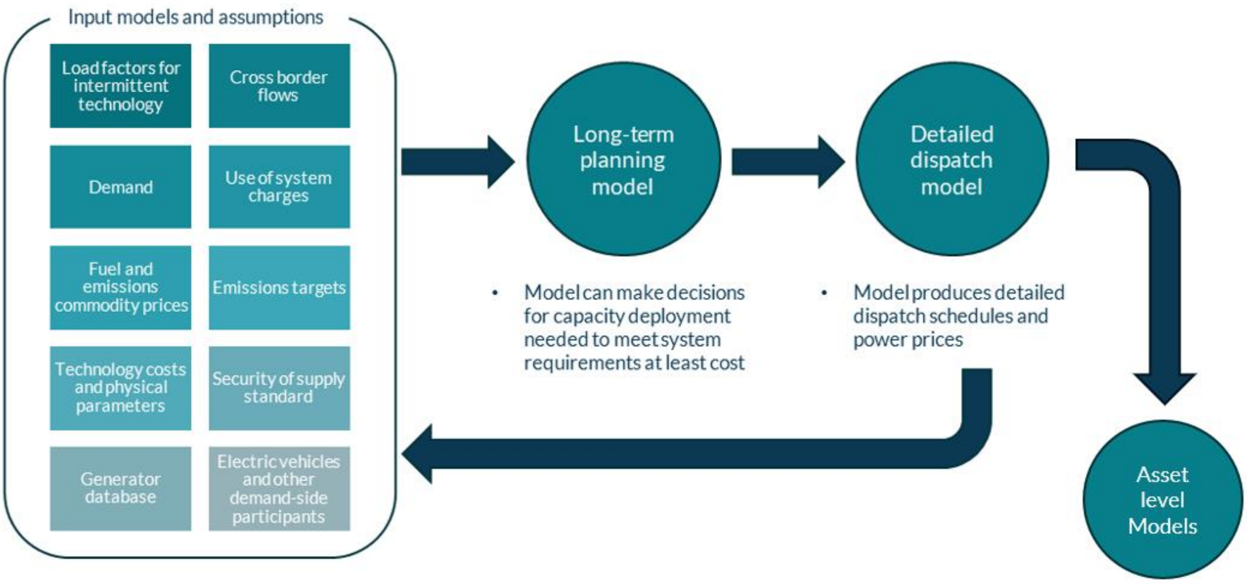
4.1 Core modelling parameters

The core modelling assumptions used in this research are based on our detailed Wholesale Power Curve models, which describe the power system of the British Electricity Trading and Transmission Arrangements (BETTA) Market, from resources to final demand. These models help frame our views of the future of the electricity market, based detailed fundamental drivers that affect the market now and in the future.

Our Central scenario, used in this research, is our expected view of commodity prices and the capital cost of different technologies to 2055, and includes assumptions about the power generation mix and demand. We model the connected and generating capacity on the energy system using, based on a series of model inputs and assumptions set out in Figure 1. We also establish a series of key objectives for the model to achieve, which drive behaviours. These include:

- **Lowest possible cost** – every option the model considers aims to minimise the total cost of the system
- **Security of Supply** – ensuring security of supply is essential, every hour capacity is dispatched in cost order to meet demand, reserve and response capacity are maintained to ensure loss of Load Hours are consistent with the government target of three hours loss of load expectation
- **Delivering Net Zero** – achieving the country's ambitions against the Climate Change Act to reduce GB emissions to Net Zero by 2050. The model has an explicit carbon target which it must adhere to when planning capacity and running generation, this has been set in relation to the Climate Change Committee Net Zero technical report

Figure 1: Power model structure



Source: Cornwall Insight

Our modelling focuses on two snapshot years (2030 and 2050), aligned to key government targets:

- Clean Power 2030 – "In a typical weather year, the 2030 power system will see clean sources produce at least as much power as Great Britain consumes in total over the whole year, and at least 95% of Great Britain's generation"[1]
- Net Zero 2050[2] – total greenhouse gas emissions would be equal to the emissions removed from the atmosphere

Our baseline view of the generation capacity (including flexible generation capacity) connected to the network for 2030 and 2050 was developed using our long-term Capacity Expansion model, which optimises capacity deployment needed to meet system requirements. This was aligned with the 2030 and 2050 targets and informed by the three objectives set out previously. Capacity deployment also accounted for limitations in new capacity development (e.g. build times for different types of generation technologies).

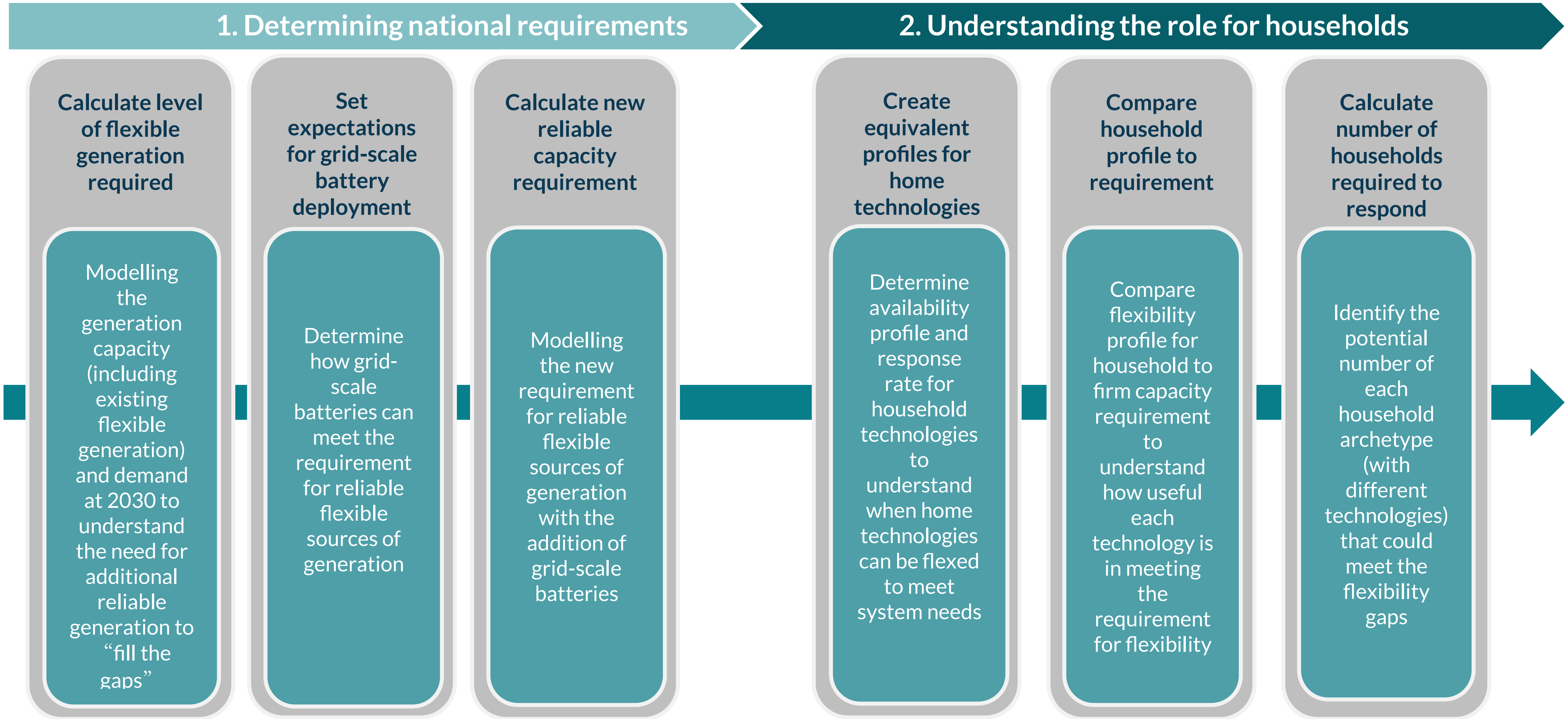
[1] Clean Power 2030 Action Plan, UK government, December 2024, Link

[2] The Climate Change Act 2008 (2050 Target Amendmet), UK government, 2019, Link

4.2 Analysis Methodology

To answer our core aims, we built on this core modelling capability to undertake a bespoke multi-stage modelling assessment, summarised in Figure 2.

Figure 2: Modelling approach



Our assessment focused on two snapshot years – 2030 and 2050, selected to align with the core policy targets of Clean Power 2030 and Net Zero, discussed above. Elements of our approach were specific to each of the snapshot years, detailed in the following section.

5 Determining National Requirements

5.1 Approach for 2030

To provide an initial baseline of flexible assets deployed in 2030, we modelled the level of current, planned and additional generation reasonably expected to be operational in the energy system, but limiting the model's ability to build out any additional flexible technologies beyond those expected to be deployed in the latest Capacity Market auctions.

Our assumptions included a specific deployment trajectory for grid-scale battery assets (BESS):

- For the 2030 snapshot year, the model uses a BESS capacity that reflects an average increase in capacity of 2.9GW per year from 2025-2030
- This reflects a balance of NESO projections on BESS deployment, observed deployment trends in the market, Capacity Market auction results, and an assessment of the BESS pipeline for abandoned and pre-planning approval projects

We subsequently identified the total system requirements for flexible capacity:

- Instead of forecasting specific new flexible technologies beyond this expected pipeline, we instead allowed the Capacity Expansion model described above to deploy a generic, uncapped "Flexible Generator". This "Flexible Generator" represents the generic need for flexibility regardless of source across the forecast horizon, accounting for dynamics such as changes in renewables capacity, emissions, and electricity demand
    - We assigned a suitable initial capital cost for the Flexible Generator, to prevent the model from deploying this generic 'asset' instead of renewable generation assets
- Our detailed simulation determined the dispatch of the generic Flexible Generator, how many hours it was needed to run, and what length of time it was needed to generate for

The outputs of this process set the requirement for reliable flexible sources of generation, reflecting the presence of grid-scale batteries. This total flexibility requirement was then used when evaluating the ability of consumer-led flexibility to support total system needs.

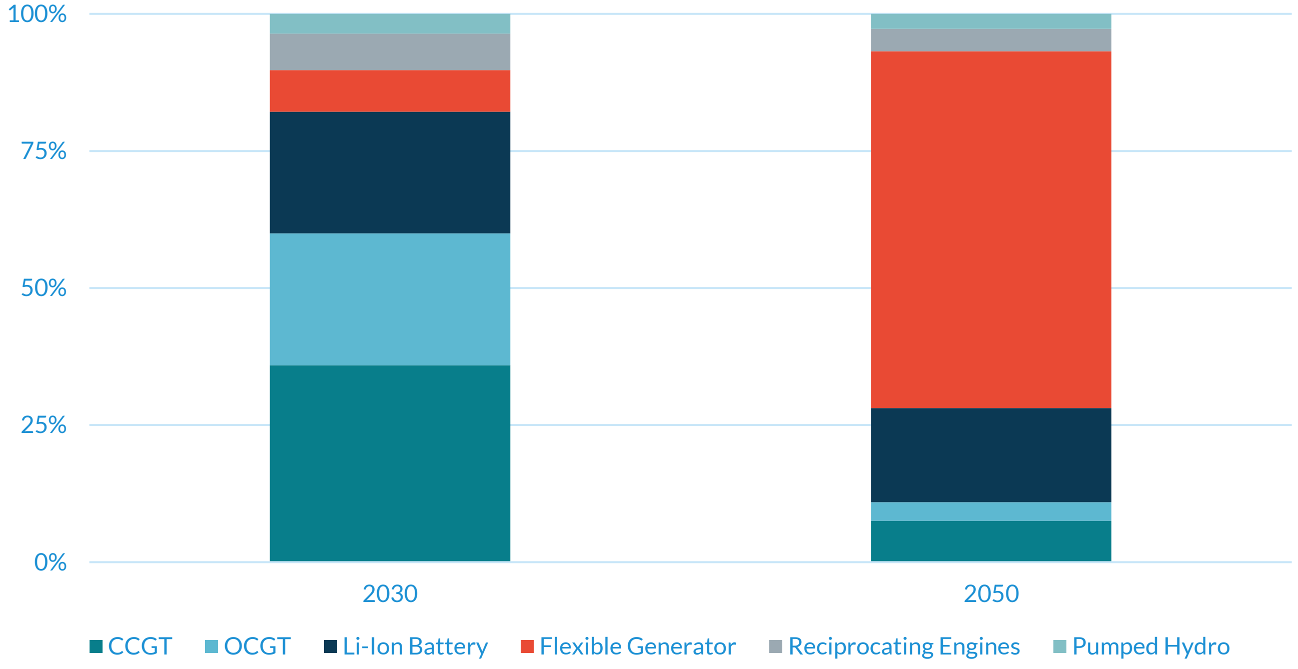
After accounting for current, planned and additional generation reasonably expected to be operational in the energy system, we identified a "gap" for other sources of flexibility still required in 2030. This equates to around 10% of the modelled flexible capacity on the system (see **Error! Reference source not found.**). This "gap" could be met by a range of generation technologies, and is the opportunity against which we have evaluated consumer-led flexibility's contribution in 2030 (discussed further in Section 6).

5.2 Approach for 2050

For 2050, we assessed the potential for consumer-led flexibility to reduce the need to build more flexible generation assets, based on reasonable expectations of uptake and capacity.

The short time to 2030 means that our restriction on new flexible capacity beyond the current pipeline has a limited effect. This is much more pronounced in 2050, where the Flexible Generator represents 65% of 103GW of total modelled flexible capacity required. This is set out in Figure 3, below.

Figure 3: Share of total flexible power plant capacity



Source: Cornwall Insight

The Flexible Generator's high share of capacity captures the amount of time available for new dispatchable generation assets to be built and the variety of different paths that could be taken. Multiple generation technologies could help to meet this requirement for dispatchable power, including carbon capture usage and storage (CCUS), battery storage, and additional nuclear power plants. The exact technologies deployed would depend on delivery timeframes, investment approaches, and market dynamics.

Because of the relatively long development time available between now and 2050, there is not a "gap" in flexible capacity against our existing pipeline of assets in the same way as was assessed in 2030. Therefore, rather than evaluate how consumer-led flexibility can fill the capacity "gap" represented by the generic Flexible Generator, as we did for 2030, we instead considered the level of flexible capacity that could be provided from different types of consumer-led flexibility and compared this to the overall requirements for all types of flexible capacity expected in 2050. Our approach to establishing the flexibility potential of household consumer-led flexibility is detailed in the following section.

6 Understanding the Role for Households

6.1 Modelling Consumer-led Flexibility

To understand the potential for households to support flexibility requirements and reduce the requirement for investment in additional generation assets, we modelled domestic low carbon technologies (LCTs) and consumption patterns reasonably expected to be available in 2030 and 2050. When looking at household electricity flexibility in this project, it refers to moving consumption to a different time period or pre-heating a home, recognising parameters of comfort and convenience.

We focused our analysis on the opportunity for electricity flexibility from three domestic LCTs:

- Electric vehicles (EVs)
- Heat pumps

- Solar and BESS

We have considered these LCTs operating on an individual basis and a category where all of the above are installed in combination (a "Smart Home" in the main Consumer-led Engagement report). We also considered the opportunity for demand flexibility for households without additional technologies installed, instead shifting everyday consumption patterns to different periods (e.g. use of washing machine or tumble drier). This is referred to as Home DSR here and in the main report.

For each of these technologies, we first established their respective availability profiles and response rates for flexibility signals. This took account of:

- The day-to-day requirements on those technologies (e.g. the power requirements for driving or heating from EVs and heat pumps)
- Their technical characteristics (e.g. the duration and capacity of domestic batteries)
  - Peak flexibility response has a direct impact on the scale of each technology deployment required. For example, around eight-times more homes delivering Home DSR would be needed to deliver the same outcome as one Heat Pump home, where overall availability is similar
- Other restrictions on availability for flexibility throughout a day (e.g. the maximum amount of time that electricity use can be deferred for)

Our assumptions drew on a combination of manufacturer information, third-party public research, and in-house research and analysis. A summary of these elements is shown below**Error! Reference source not found.**.

Figure 4: Overview of LCT characteristics

Metric	Electric Vehicles	Heat Pumps	Solar PV and BESS	Home DSR
Peak flexibility response	7kW	4 kW	5 kW	0.5 kW
Flexibility response constraints	• 1 cycle per day maximum • Domestic charging profile used • Available state of charge reflects annual travel behaviours • A 50% minimum state of charge by 08:00 is maintained	• A maximum pre-heating window of 2 hours • A maximum "flexibility action" window of 2 hours • Limited overnight pre-heating capacity	• 2-hour battery duration • 81% round trip efficiency • 1 cycle per day maximum • UK installed capacity weighted average load factor used for solar PV	• 2 uses per day maximum • Maximum response time of 2 hours • Minimum time between activations of 2 hours

Source: Cornwall Insight

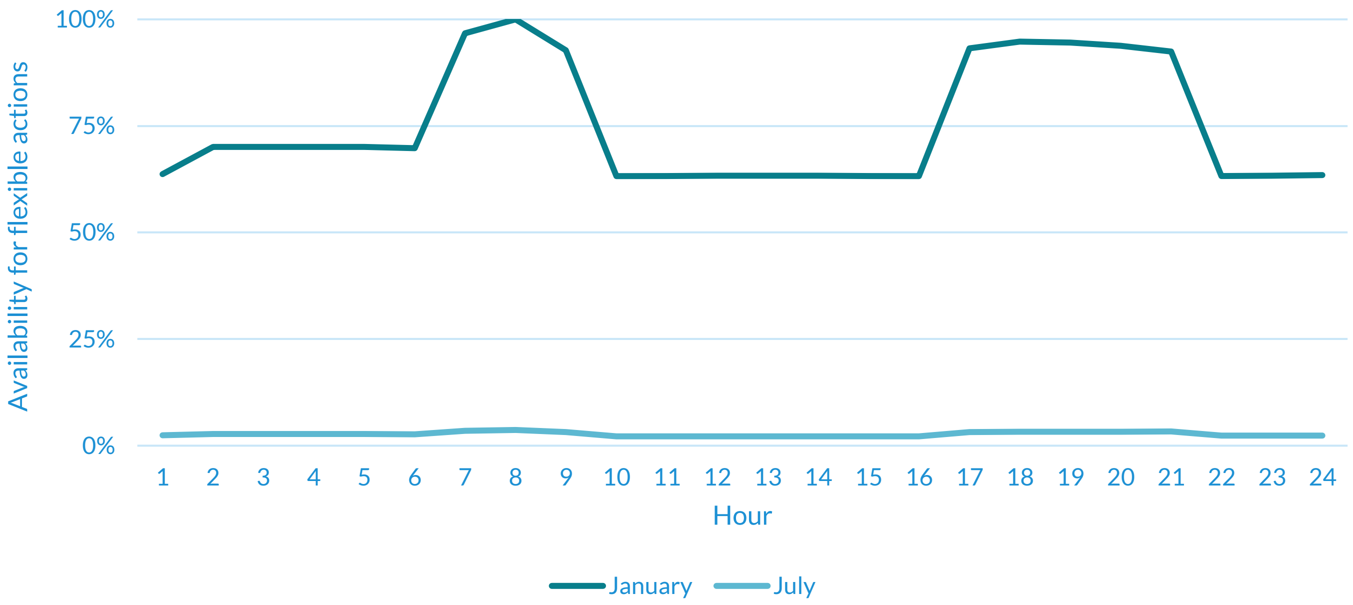
These characteristics were used to determine an availability profile and response rate for household technologies and to understand when home technologies can therefore be flexed to meet system needs. For example, when evaluating heat pump flexibility potential, we:

- Developed a view of heat pump electricity demand

- This was informed by considerations on average GB building stock, thermal efficiencies, consumer comfort preferences, and seasonal dynamics

- Used this view to inform an availability profile for the heat pump to provide flexibility (see **Error! Reference source not found.** for **Error! Reference source not found.** an illustration of this profile)
    - This reflected the changing level and timing of electricity demand across a day and year and was consistent across 2030 and 2050
- Matched this availability profile against the system level demands for flexibility actions
    - In each of the two snapshot years, we simulated the dispatch of the heat pumps' demand shifting capabilities against price and flexibility signals. These signals were determined through the system-level analysis discussed in Sections **Error! Reference source not found.** and 4.2

Figure 5: Average daily flexibility availability profile for domestic heat pumps, January and July

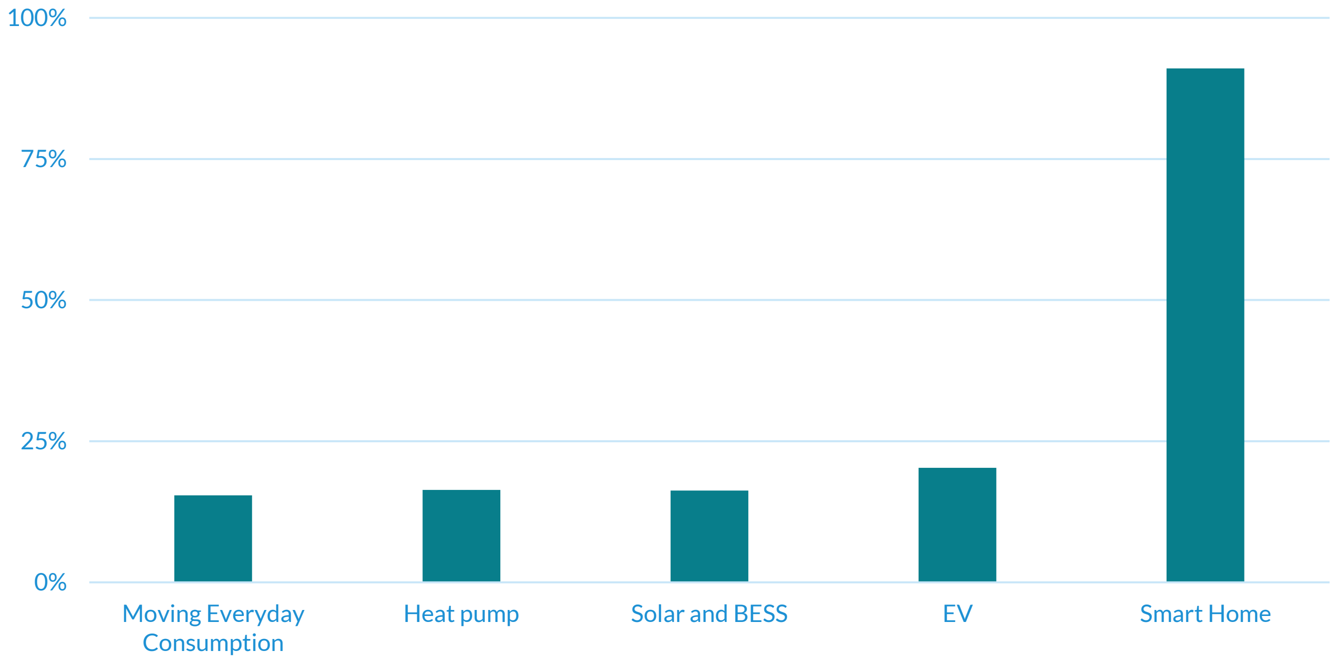


Source: Cornwall Insight

We did this for each of the standalone LCT categories, including "Home DSR", and the all-inclusive "Smart Home" combined technology scenario. In developing the combined-technology Smart Home category, we completed this analysis for combinations of different LCTs and home demand side response. This process combined the separate availability profiles for each constituent LCT into a combined household profile that reflects the different availability of each technology to respond to flexibility signals. For example, the combined EV and Heat Pump profile reflects both the heat pump requirements shown above and the availability of the EV to modify its charging behaviour, considering its changing daily travel needs (informed by analysis of Department for Transport (DfT) data) and minimum state of charge requirements.

This modelling identified the equivalent firm capacity for each of these categories – i.e. the proportion of required flexibility volumes that each domestic flexibility source was able to provide. This was calculated by dividing the output from each domestic flexibility category by the output from the Flexible Generator and provided the measure of flexibility that can be provided by different domestic technologies in 2030 and 2050. The equivalent firm capacity of each household flexibility category is shown in Figure 6 below. For example, for the Heat Pump category, the 16% equivalent firm capacity rating means that this asset provided 16% of the volumes in response to flexibility signals that were provided by the generic Flexible Generator.

Figure 6: Equivalent firm capacity associated with different types of household flexibility



Source: Cornwall Insight

We also considered the peak capacity associated with each type of household. This affects the level of flexibility available from each technology at a national level. As noted with Figure 4: , where Home DSR (15%) and Heat pump (16%) have similar equivalent firm capacity ratings, around eight-times more homes delivering Home DSR (0.5kW peak capacity) would be needed to deliver the same outcome as one Heat Pump home (4kW peak capacity).

The Smart Home category can meet a significantly higher share of required flexible volumes (91%) than each of the standalone low carbon technologies (maximum 20% for EVs). The Smart Home combines each of the availability profiles from the constituent technologies into a single home-level profile. This benefits from complimentary elements in availability timing across the different technologies and additional sources of demand to utilise solar and BESS output flexibly within the home, allowing a greater share of flexibility signals to be met.

6.2 Establishing Households' Contribution

As discussed in the previous section, having identified the different levels of domestic consumer-led flexibility available, our approach to assessing their contributions varied across the two snapshot years.

6.2.1 Approach for 2030

For 2030, the modelling showed that household flexibility could meet the ~10% flexible capacity "gap" required. This is based on the established equivalent firm capacities for each of the technology categories and their respective peak response capacities.

To examine the range of household contributions that could be achieved across the different technology categories, we scaled the household flexibility sources to meet 100% of the generic Flexible Generator required capacity (the flexibility "gap") and compared this required contribution to the number of households needed to deliver that MW outcome. This ranged from –

- The equivalent of 19mn households providing actions under the Home DSR category

- This category requires the largest number of households due to the small peak capacity associated with typical household demand (e.g. running white goods) compared to larger-scale LCTs (as shown previously in Figure 4) and the relatively lower equivalent firm capacity (see Figure 6)

- 1mn households in the Smart Home category responding to flexibility signals
    - The significantly higher equivalent firm capacity for this category, coupled with the higher peak capacity associated with the different LCTs installed, drive the greater flexibility contribution (and therefore lower number of households required) for this category

When providing these comparisons to the number of households required, we have assumed that all households within each category are responding perfectly to the signals required. The availability profiles we have developed reflect the overarching need for travel, heating, and wider domestic electricity use associated with each of these categories, and the impact this has on flexibility provision. However, we have not assessed wider factors that could impact levels of household engagement with flexibility, e.g. the propensity for customers to take up flexibility propositions, or deeper customer segmentations affecting electricity demand. Although they can affect delivered flexibility outcomes, these broader elements were outside the scope of our research for this project.

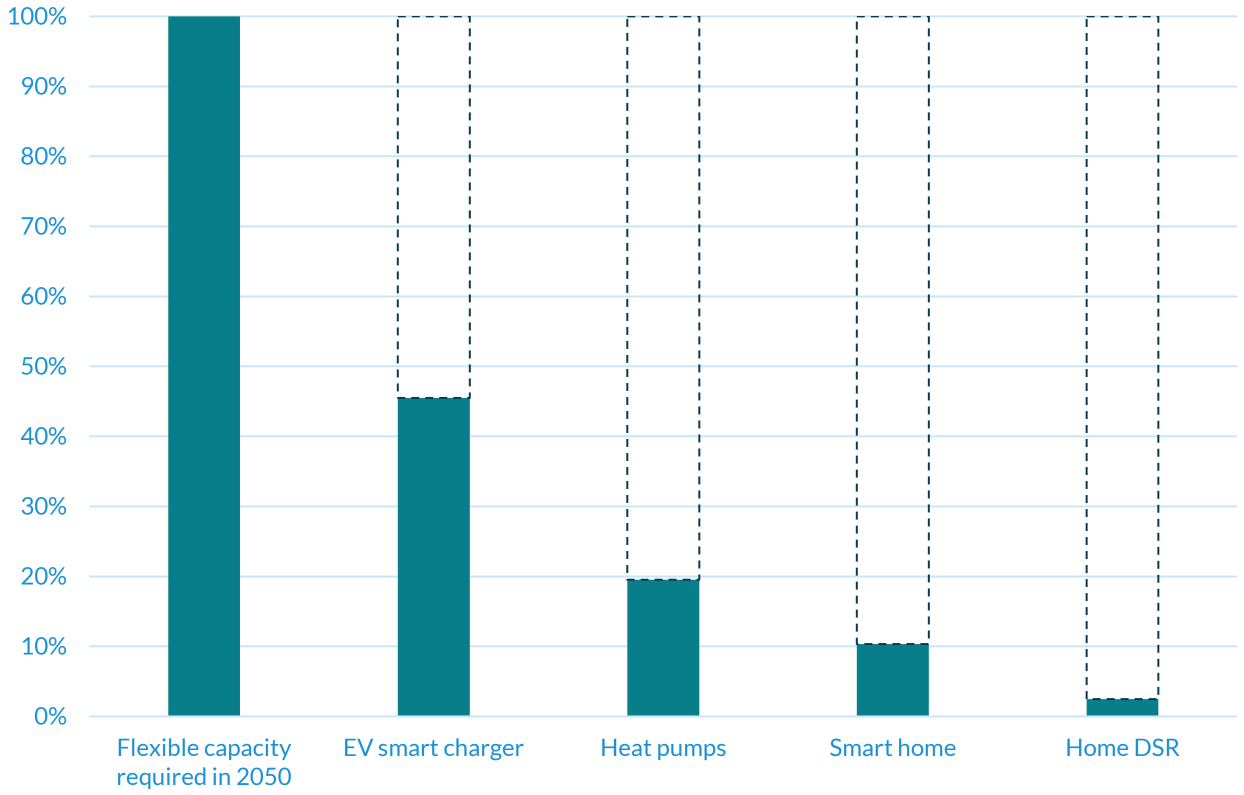
To help provide context to the levels of flexibility required overall, and those contributed by households, in the report we have provided comparisons to some other generation technologies that could to national flexibility requirements. References to gas peaker and grid-scale battery assets draw on our in-house data and assumptions to present the different ways in which flexibility requirements could be met. Information we used includes data on typical asset capacities, associated capital and operating costs, and asset efficiency rates.

6.2.2 Approach for 2050

As noted, in 2050 there is no "gap" in flexibility, due to the timescales involved. Instead, our modelling showed that 103GW of dispatchable capacity will be needed from all types of flexible generation and demand sources. To evaluate the role for households' consumer-led flexibility, we:

- Started with the same peak capacity and equivalent firm capacity information for each of the LCT categories, as detailed in the previous section
- Combined this with a forecast of each technology's deployment levels by 2050 to determine the capacity available to respond to flexibility signals
    - For each of the individual LCTs, this is based on information provided on asset uptake in NESO's 2024 Future Energy Scenario pathways. To convert solar and BESS MW capacity projections from NESO to an equivalent number of households for this analysis, we used our in-house assumptions on average domestic-scale asset sizing
    - The forecast total number of households used is based on our in-house assumptions, developed as part of the core power system modelling presented in Section 4.1
- Taken the resulting domestic flexible capacity and compared this to the total 103GW requirement for flexible technologies to assess the role that different types of household category could play
    - Summarised in Figure 7, this shows that the EV category can make the largest single contribution to total flexibility requirements in 2050. This is primarily driven by the high levels of uptake expected at this point, alongside the 7kW peak capacity associated with home EV charging in this research and the 16% equivalent firm capacity rating

Figure 7: Equivalent proportion of the total level of all flexible capacity that could be provided by household technologies and the remaining gap to meet with other flexibility sources



Source: Cornwall Insight. The total number of "Smart homes" is expected to be limited by the expected national take up of the individual technologies installed

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Cornwall Insight
The Atrium
Merchant's Court, St George's Street
Norwich, NR3 1AB

T: 01603 604400
E: enquiries@cornwall-insight.com