Insight paper

CORNWALL INSIGHT

CREATING CLARITY

The power of flex: Rewarding smarter energy usage

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Getting to grips with the intricacies embedded in energy and water markets can be a daunting task.There is a wealth of information to help you keep up-to-date with the latest developments, but finding what you are looking for and understanding the impact for your business can be tough. That's where Cornwall Insight comes in, providing independent and objective expertise.

You can ensure your business stays ahead of the game by taking advantage of our:

- Publications – Covering the full breadth of the GB energy industry, our reports and publications will help you keep pace with the fast moving, complex and multi-faceted markets by collating all the "must-know" developments and breaking-down complex topics
- Market research and insight – Providing you with comprehensive appraisals of the energy landscape helping you track, understand and respond to industry developments; effectively budget for fluctuating costs and charges; and understand the best route to market for your power
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For more information about us and our services contact us at 01603 604400 or enquiries@cornwall-insight.com

This independent research paper prepared by Cornwall Insight was commissioned by Smart Energy GB.

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2. Foreword by Smart Energy GB

A smarter, more flexible energy system, enabled by smart meters, is on the horizon. This report demonstrates how Britain could save £14.1bn in 2040 if we, as consumers, embrace opportunities to use energy flexibly. The great news is that doing so can help us save on our energy bills, fight climate change and support our energy security.

To understand the benefits of a smart meter enabled flexible energy system we commissioned this report from Cornwall Insight.

It considers how if we, as consumers, use our energy more flexibly (increasing, decreasing or shifting electricity use) we can save money on our bills, and support a low carbon system – a system that will, in turn, cost less and ensure against over-building of energy infrastructure.

The way this would work in practice, for example, is that your energy supplier offers you incentives to use energy differently at specific times. This might typically be to use less electricity at peak times and more at off-peak times. As a result, the system will cost less to operate and will better support cheaper renewable energy, the benefits of which are passed back to us, at home. To make this happen we need to be able to measure our usage in near real time, which is what smart meters do.

Indeed the modelling in this report demonstrates it is in fact a ‘win-win-win’ for using energy more flexibly at home: consumers win, the environment wins and the energy system wins. We all win.

In 2040:

- households can save over 52% of wholesale electricity costs
- 45% more carbon is saved; and,
- overall national savings stand at £14.1bn.

The report highlights that using energy flexibly reduces wholesale electricity costs for everyone, even for those who don’t or aren’t able to participate in flexible energy use. But for those in a position to participate most, the benefits are greatest.

The added beauty of household flexibility is that it doesn’t just add up to direct financial savings. In 2030, with flexibility, we could avoid the need to build the equivalent of four new gas fired power stations, to cope with peak demand. Whilst peak demand generation is more likely to be met with gas fired power plants, this is the generation capacity equivalent to 1,000 wind turbines. Household flexibility could allow us to avoid the cost of building, as well as the disruption to local communities and environments that four new gas fired power stations would likely incur.

The energy system of the future will have us, as consumers, and flexibility at its heart. Smart meters are a cornerstone technology for this win-win-win future providing the data and information critical to support future benefits for people, environment and the energy system.

Dan Brooke
CEO
Smart Energy GB

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3. Executive summary

What is household flexibility?

Household flexibility involves consumers increasing, decreasing or shifting their electricity use in response to a signal (for example, a message from their energy supplier or a change in electricity price), to help manage the electricity system. This helps reduce energy costs for all consumers and reduce carbon emissions from electricity generation by maximising the use of renewable energy sources and reducing infrastructure costs. Participants benefit through financial incentives, a lower carbon footprint and playing an active role in the energy security and net zero agendas.

Why do we need household flexibility?

Delivering the benefits of a net zero economy requires a combined focus on decarbonising our electricity system, transport and our home heating. Decarbonisation will increase our requirement for electricity (e.g. replacing use of natural gas and petrol).

Greater uptake of electric vehicles and electric heating will add to the daily peak in electricity demand, which typically occurs between 4pm-7pm. Times of peak demand are often linked to an increase in fossil fuel generated electricity. These fuels are more expensive and emit more carbon than renewables such as wind and solar. This increases the cost of wholesale electricity at peak times, which is factored into the price paid by consumers.

What's the opportunity for households?

Household flexibility benefits individual households, the national energy system and the environment. It provides an opportunity for households to actively participate in the net zero agenda, save money, reduce carbon emissions and improve energy security. Even households that do not actively participate in household flexibility will see an overall reduction in their bill, as a result of a more efficient system.

National annual savings

£4.6bn in 2030

£14.1bn in 2040

Carbon savings increase 45% in 2040

Consumer annual savings

£115 in 2030 — 14% savings

£375 in 2040 — 52% savings

The financial savings relate to single year scenarios modelled for 2025, 2030 and 2040. The scenarios are stand-alone, and are not cumulative for the time periods between the scenarios. Savings relate to modelled wholesale electricity costs in the relevant year, reflecting expectations around the changing generation mix. For more information on our scenarios, please see our accompanying Technical Report.

What would happen if we didn't have household flexibility?

Without household flexibility, we would need to build the equivalent of four new gas-fired power stations in 2030 to meet peak demand, at a cost of more than £2.5bn, alongside the associated carbon emissions. The additional electricity demand at peak times would also require costly upgrades to the networks, which could reach almost £1bn.

Building gas-fired power stations

Build time	**3-5 years**
Operational lifespan	**25-30 years**
Cost to build	**£0.5-£0.8mn/MW (Keadby 2 in North Lincolnshire reported to cost £350mn)**
Cost to run	**Influenced by global gas prices**

How can consumers engage with flexibility?

Consumers have demonstrated the benefits of responding collectively to a signal to reduce consumption at times of peak demand, through the Demand Flexibility Service which occurred during Winter 2022/23. This type of response can include using household energy intensive appliances at different times of day, e.g. a washing machine or tumble dryer, turning off light switches and plug sockets that aren't in use, or using an alternative to an electric oven or hob to cook dinner. In the future, this could also be a signal to increase consumption, when renewable electricity generation is high.

The opportunity for household flexibility increases with the installation of electric technologies, such as an electric vehicle and charger, solar PV and battery, or a heat pump. These technologies are more likely to be considered "shiftable" in the time of day they consume energy, and/or support consumers in reducing their consumption over times of peak demand. While some of these technologies have a prohibitive upfront cost for some consumers right now, changes in policy, financing propositions and cost are expected to drive greater levels of uptake in the future.

Realising the benefits of household flexibility is expected to become easier as technologies are upgraded to be smart-enabled. As uptake of electric technologies increases, we also expect to see more propositions available with some form of automation. This could allow consumers to set parameters for comfort and convenience, and deliver automation of household flexibility around these set parameters. For example, charging an electric vehicle at lower demand, cheaper periods, but ensuring it is always 50% charged, or a heat pump responding to price signals to vary consumption and reduce running costs, while continuing to adequately heat homes.

Smart meters are an enabling tool which help consumers access the benefits of moving consumption away from times of peak demand, providing near real-time information about energy usage and access to Time of Use Tariffs. Without a smart meter, benefits including those from the Demand Flexibility Service cannot be accessed, because most traditional meters do not tell your supplier when you use energy. The information about energy usage from a smart meter supports the development of household flexibility propositions and trials, ensuring there are a range of opportuinities in place for consumers with different technologies and consumption patterns.

4. Introduction

In this section we outline the research aims, the approach taken to developing our modelling scenarios, and the report structure.

4.1 Research aims

The research underpinning this report aims to understand the financial and environmental benefits of household flexibility for consumers and the national energy system. We have analysed the difference between a scenario where households participate in flexibility, and one where they don't. Our analysis covers three time periods (2025, 2030 and 2040) to understand how the benefits change over time.

4.2 Glossary of key terms

Figure 1: Key terms

Term	Definition
Demand side response (DSR)	Involves consumers increasing, decreasing or shifting their electricity use in response to a signal, to help manage the electricity system
Market Wide Half-Hourly Settlement (MWHHS)	Consumers' electricity use will be settled based on their actual usage in each half hour period, rather than based on an assumed annual profile. This usage data will give suppliers and network providers better visibility about customer usage and response to price signals, and is seen as a key enabler to delivering better billing accuracy, greater network efficiency, reduced costs and lower carbon emissions. It is important to note that just because a domestic customer is being settled half-hourly, unless they have chosen to be on a time-of-use product they will still be billed on the same basis, with costs still being calculated using unit rates applied to the consumption since their last bill
Peak demand	Peak demand refers to the daily increases in demand on the electricity system, when households, commercial businesses and industry consume electricity at the same time, usually on a weekday between 4-7pm
Price signals	Where information is conveyed to consumers through the price offered to increase or decrease consumption of electricity. For example, a price signal may encourage consumers to use electricity when prices are low if there is high renewable electricity generation, or discourage use when prices (and demand) are high
Time of Use tariffs (ToU)	Electricity tariffs where the prices vary at different times of the day. These are designed to encourage people to use energy outside of peak times when costs are typically higher. Similar to peak and off-peak transport tickets
Virtual Power Plant	Networks of small energy-generation or storage devices (like solar PV and batteries) that are pooled together to supply to the electricity grid when additional electricity is required (like at times of high demand)

4.3 Our approach

The modelling we have undertaken includes numerous assumptions about the future energy system. At the highest level, we assume current UK Government policy aims, including:

- Achieving net zero emissions by 2050
- Decarbonising electricity by 2035

We have developed two electricity scenarios to compare the benefits of enabling households to participate in a flexible energy system. In each scenario we have assumed a credible level of flexible technology uptake by households based on a current market view. We have also assumed a corresponding increase in electricity consumption due to these new use cases.

- **Flexibility Scenario** – where customers take up smart technologies and Time of Use tariffs in line with the customer segments described below, and the energy demand associated with these can be used flexibly to support system needs and reduce customer costs

- **No Flexibility Scenario** – where customers take up technologies to meet net zero obligations (e.g. transitioning to EVs and heat pumps), but do not engage with flexibility opportunities and consumption patterns see limited change. We assume consumers in the No Flexibility scenario do not take up batteries, as these are primarily used to access the benefits of flexibility

Our modelling approach assumed decisions are made in a similar manner to today; consumers engage in the energy sector in a range of different ways, influenced by their circumstances, access, motivations and technology developments. This is represented by our different consumer segments, within which consumers are assumed to make decisions based on a range of factors:

- **Segment 1 – "Active & asset equipped"**: Households in this segment have the ability to undertake demand side response (DSR) through their smart meter-enabled Time of Use (ToU) tariffs and have a high take up of low carbon technologies (e.g. heat pumps, EVs, and solar PV) with smart controls which operate them, potentially supported by battery storage. Flexible capacity from these technologies is used as part of the overall demand side response potential for these households

- **Segment 2 – "Smart customer response":** Households in this segment have smart meters and ToU tariffs, but no significant uptake of technologies (e.g. heat pumps, battery storage, and solar PV)

- **Segment 3 – "Static state"**: Households have smart meters installed but consumers choose not to move their consumption in response to price signals through ToU tariffs, for a variety of reasons

We assume the majority of consumers have smart meters installed by 2025, based on current targets.[1] Market Wide Half Hourly Settlement (MWHHS) is expected to be in place for our 2030 and 2040 scenarios, although we assume a small amount of elective half hourly settlement and associated elective ToU customers at 2025. We assume that technologies (heat pumps, batteries, electric vehicles, DSR etc) can respond to wholesale market price signals through a ToU tariff if a consumer opts to engage in this way.

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1 On 6 July 2023 it was confirmed that energy suppliers will be required to install smart meters in a minimum of 74.6% of the customers domestic premises by the end of 2025. We assume 10% of all households are actively responding to price signals at this point, well below the minimum installation target level by the end of the Targets Framework

We do not include assumptions regarding capital expenditure (CAPEX) for generation and consumption technologies through the scenarios. Changes in technology may incur a cost, but it is unclear where and to what degree the cost will have an impact in the energy market or be faced by customers. For example, we might expect changes in financial support provided by government or private companies, "as a service" propositions may become more widely available, and technology costs may change over time. As the level of technology uptake is broadly the same across the two scenarios (both have similar levels of rollout), we consider the delta between the two scenarios to be valid without considering CAPEX.

We have used the two scenarios to assess the comparative benefits available from smart meter-enabled flexibility as we transition to a net zero energy system. We have evaluated the results of this comparative analysis in three snapshot years: 2025, 2030, and 2040. We have then assessed how the impacts of flexible household demand change as we progress on the net zero transition across those years. Detailed information about the modelling approach, assumptions and scenarios can be found in our Technical Annex.

5. What is household flexibility?

In this section we introduce the market context for this research, describing household flexibility as a concept, outlining the impact of technological change, peaks in demand and the role household consumers can play in supporting decarbonisation across the energy system.

Delivering the transition to a net zero economy requires a combined focus on decarbonising our electricity system, our transport and our home heating. Electrification is an important pathway to delivering some of these changes, with uptake of electric vehicles and heat pumps driving household decarbonisation developments in their respective sectors today. Higher uptake of these technologies brings a significant increase in the overall volume of electricity consumed by households, as high-carbon petrol and gas consumption is transitioned to lower-carbon (and eventually zero-carbon) electricity.

Households currently contribute to the daily peaks in electricity demand, which occur on weekdays, usually between 4pm and 7pm when there is a crossover between industrial, commercial and household usage. An increase in fossil fuel generated electricity is often required at times of peak demand. As these fuels are more expensive and polluting than renewables such as wind and solar, this increases the cost of wholesale electricity at peak times, which is factored into end customer prices set by energy suppliers. Building electricity system infrastructure (across networks and power plants) to meet peak requirements also increases the cost associated with high peak consumption.

Household demand for electricity at peak times is set to increase as decarbonisation efforts develop. For example, peak demand from residential EVs and heat pumps in 2040 is expected to reach up to 26.5GW, according to National Grid ESO's 2022 Future Energy Scenarios (FES). This is greater than the peak demand of all households in 2022.

However, there is potentially significant flexibility in how and when this electricity use can take place, without negatively impacting the user experience or requirement of electricity for transportation or heating. For example, a driver could return home in the evening, having used the EV for their daily commute. Although there are 12 hours before the driver needs to use the car again, only a fraction of that time is needed to refill the battery. This means that the charging demand can be flexible and aligned with the cheapest times to use electricity

that night. Similarly, heat pumps could vary their output and scheduling in line with price or other signals while continuing to heat the home, or appliances that are not in use could be turned off (or on). All of these actions could deliver rewards to consumers directly, or through better alignment with cheaper pricing periods.

These actions support the electricity network by reducing demand for electricity at peak times. Lower peak demand reduces the need to build additional fossil fuel power stations and for additional upgrades to the electricity network.

Household demand is not flexible by default, so different approaches may be required to unlock these opportunities. These factors come together to enable greater control of energy demand. These range from technological factors like having the necessary communication and control systems, to market factors like the level of incentives or rewards that are being offered to do so, to behavioural factors like how and when consumers need to use the technologies.

Smart meters are a key enabling tool for helping customers to move their consumption away from times of peak demand. Using the half hourly data from smart meters, customers can be rewarded for reducing their use of electricity at certain times. This would not be possible with a traditional meter, as the supplier cannot see when energy is being consumed within a day, which is essential for receiving any associated reward.

This kind of consumption management is also known as Demand-Side Response (DSR). DSR supports the overall energy system by using smart technologies to increase consumer demand for energy when supplies are high (and typically prices are low) or reduce demand when supplies are low (and typically prices are high)[2]. The two terms, household flexibility and DSR, are used interchangeably throughout this report to discuss the optimisation of household consumption against signals on electricity price and / or electricity system needs.

Our research uses a prevailing view of policy, regulatory and commercial market factors. We assume consumer incentives arise from wholesale market pricing signals passed through Time of Use (ToU) tariffs, which encourage consumers (through automation or manual input) to change behaviour in response to price fluctuations. In reality, we expect there to be many different retail tariff structures available to consumers from energy suppliers, just like we have seen various time-banded, fixed-rate, and tracker-style tariffs in the market to date. These service structures could pass through the benefits of delivering flexibility services without requiring households

2 https://es.catapult.org.uk/report/what-consumers-want-from-demand-side-response/

to be on ToU tariffs directly linked to wholesale electricity prices. These structures could target different consumer requirements, risk appetites and levels of market engagement, and could even be separated from the energy tariff completely.

ToU tariffs are not currently utilised at scale and are typically aimed instead at owners of assets like heat pumps and electric vehicles, that can make the most of cheap off-peak prices. In the future, ToU tariffs could comprise of a range of different structures and time periods to suit a range of user needs. Suppliers and technology companies are currently trialling ToU structures to understand the relative benefits to different consumer types.

While we assume that ToU tariffs are the main financial incentive for consumers in our research, there are also likely to be many mechanisms that encourage household flexibility. These include local and national level schemes that can reward customers for increasing or decreasing electricity consumption in response to signals based on network needs at the time.

One example of such a service is the Demand Flexibility Service, launched in winter 2022-23 by National Grid Electricity System Operator (ESO), described further in Figure 2. Looking forward, there may be further initiatives developed to manage flexibility in local areas. Similar services to the Demand Flexibility Service could arise on a regional level, with financial reward relative the scale of network constraints in the area.

Figure 2: Case study on Demand Flexibility Service

The Demand Flexibility Service was introduced in winter 2022-23 to support National Grid ESO's operation of the electricity system. It offered financial incentives for consumers to reduce electricity demand over peak periods.

According to National Grid ESO, 1.6 million households and businesses participated in the Demand Flexibility Service, delivering demand reduction across 22 events held across the winter.

Overall, the National Grid ESO data showed that the DFS delivered 3,300MWh in electricity reductions at peak times across the 22 events. This is approximately equivalent to the amount of electricity that 9.9mn households would use at peak times across a single hour[3].

Octopus Energy was one of the service providers that took part in the DFS, with its "Saving Sessions" service allowing customers to benefit from providing flexibility into the service. The supplier stated that its customers delivered an estimated 50% of the demand shift required by the National Grid ESO, with £5.3mn paid to Octopus customers in total. The top 5% of Octopus participants reportedly saved an average of £41 over the winter[4].

Overall, National Grid ESO note that the smart metering network played an important role in facilitating consumer participation in the service, helping to connect consumers to a range of smart applications used by providers for the DFS.

3 https://www.nationalgrideso.com/news/demand-flexibility-service-delivers-electricity-power-10-million-households
4 https://www.current-news.co.uk/octopuss-saving-sessions-displace-almost-2gwh-of-electricity-demand/

Today, household flexibility services are offered by a range of parties, from energy suppliers to third-party virtual power plant (VPP) operators or e-mobility service providers, with the potential for new and innovative opportunities set to come as the market evolves. This means that customers can engage with DSR opportunities in various ways, from setting their own schedules and managing activities like EV charging themselves, or setting parameters (e.g. making sure their car is fully charged in the morning) and leaving the optimisation to specialist service providers.

The management of technologies and delivery of flexible responses can be achieved through manual changes (e.g. manually adjusting heat pump schedules when a saving window is sent through) or via automation from a wide range of parties across the market. Both can achieve value by responding to price signals of different kinds, including wholesale price signals. Beyond managing the import of electricity for different EVs, heat pumps, and other household appliances, there are also opportunities for households to provide DSR through exporting electricity, from the installation and management of technologies including solar PV, static batteries, and bi-directional EV charging (also called Vehicle-to-Grid or V2G). Households may be able to sell back electricity to the grid when it's not needed, or to be paid for delivering additional network support.

Figure 3: Case study on individual benefits of household flexibility

Grahame lives in a four-bedroom detached house in West Lothian with his wife and two children, and had his smart meter installed in February 2019. He is passionate about decarbonising his home and helping Great Britain to use energy more efficiently, and sees time-of-use tariffs and smart meters as key to both these things.

"The smart meter has been a great addition to our household, helping us to lower our bills and keep a close eye on our EV charging costs, but one of the main benefits has been access to cheaper and greener energy on a smart time-of-use tariff.

My smart meter provides half-hourly readings to my energy supplier, and my supplier gives me really cheap electricity between 00:30 and 04.30 every night in return. That means I can charge my home battery at a minimal cost overnight, and then use the stored energy the next day to power all the day-to-day activities in our house. I worked out recently that if I had remained on a standard tariff it would have cost me £2000 for 125 days electricity use, but through using my smart time-of-use tariff I only paid £526 for the same amount.

Without a doubt the main benefit of having access to this tariff through my smart meter is the huge cost saving. If you want to go down the home battery route rather than using your energy at the prescribed times, then that is becoming an increasingly affordable option – you can make your money back pretty quickly through the savings on your energy bills. A secondary benefit of this tariff is that it allows me to access cleaner energy, because off-peak is greener. My goal in life is to make no negative impact on the planet, and to live as sustainably as possible."

Source: Smart Energy GB

6. Results

In this section we set out the headline findings from the research, highlighting the cost and carbon savings at a national and individual level.

Meeting peak demand often requires increased use of fossil fuel power stations. While renewables and low carbon generators have relatively low costs to run and usually operate when they can, other generators require fuel, meaning that the most expensive fuelled generators are only dispatched when needed to meet peak demand. In Britain, gas fired generation tends to be used to meet peak demand and when wind generation is low. This means that meeting high levels of peak-time consumption typically has a higher electricity cost for the consumer, has a higher carbon intensity from the generation used to meet this demand, and can require additional network and generation infrastructure to be built to accommodate it.

Overall, smarter use of electric technologies increases the ability to move household electricity consumption away from times when electricity demand on the wider network is greatest, and prices for electricity are generally highest. This reduces the level of peak demand on the overall electricity system and reduces the need to build additional fossil fuel power plants and additional upgrades to the electricity network.

6.1 Household flexibility could deliver an annual saving for GB consumers and the energy system of £14.1bn/year in 2040

In the Flexibility Scenario, we see consumers and the energy system **benefit from £14.1bn in savings in 2040** compared to the "No Flexibility Scenario", arising from three key areas:

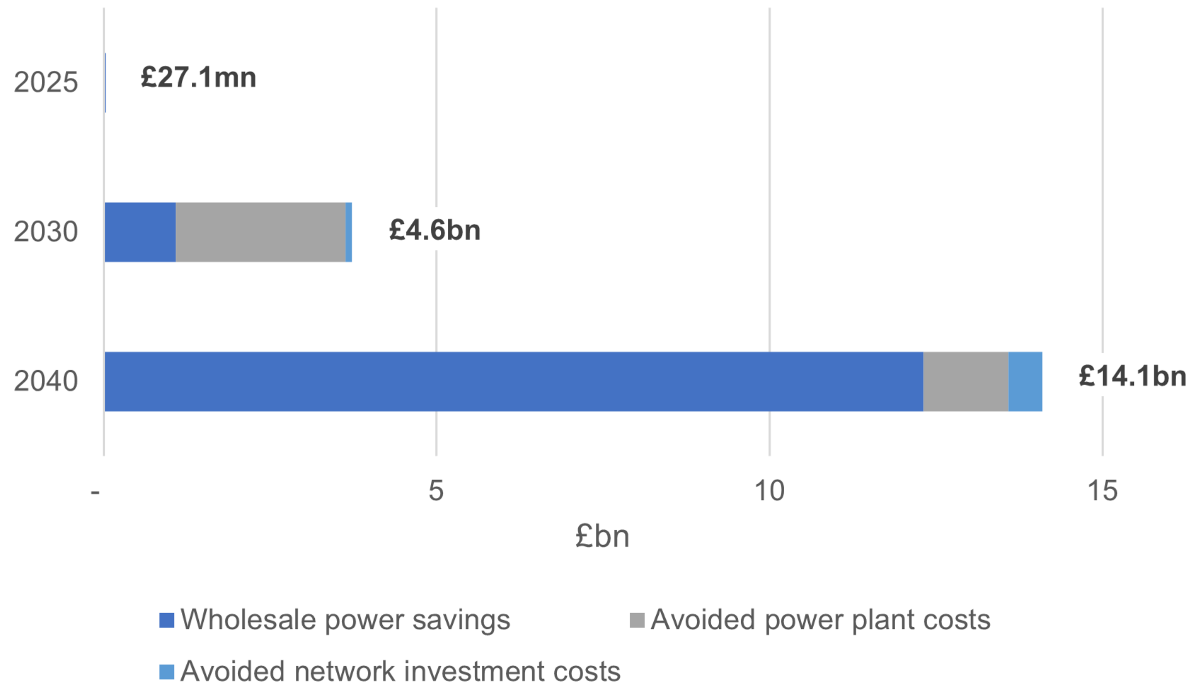
- **Lower wholesale electricity prices account for £12.3bn in savings.**
  - By the time we reach 2040, the responsive household demand from electric vehicles, heat pumps, solar PV, battery storage and smart appliances, have enabled a significantly lower-cost electricity system in our "Flexibility Scenario".
- Lower peak demand reduces the need to build additional power stations, **delivering a saving of around £1.2bn.**
- Lower peak demand reduces the need to build additional network assets, **a saving of around £0.5bn.**

The financial savings relate to single year scenarios modelled for 2025, 2030 and 2040. The scenarios are stand-alone, and are not cumulative for the time periods between the scenarios.

Looking nearer term, in 2030 we see significant savings at a national level from smart use of key sources of electricity consumption like EV charging and heat pump schedules. Overall, **£4.6bn of savings are available in 2030 alone** under our Flexibility Scenario, compared to making the same net zero technology transition in our No Flexibility Scenario, shown in Figure 4 below.

Even as soon as 2025, the ability to shift some consumption out of expensive peak periods supports wholesale power price savings, with **overall power costs £21mn lower in the Flexibility Scenario in 2025**.

Figure 4: Overview of total savings between Flexibility and No Flexibility scenarios, £bn



Source: Cornwall Insight

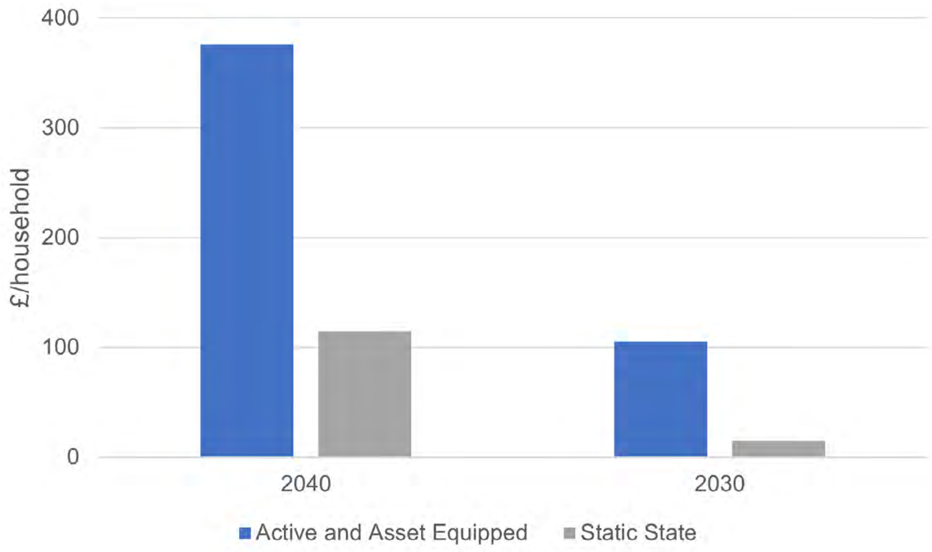
6.2 Individuals engaged in flexibility could save 52% in wholesale electricity costs in 2040

Individual households can make savings across the market. As a baseline, households in our Static State segment, with none of the flexible assets deployed and which are not active in moving their consumption in response to wholesale price changes, **wholesale electricity costs are 38% lower in our Flexibility Scenario in 2040, saving £105 on expected wholesale electricity costs compared to the No Flexibility Scenario equivalent in 2040** (see Figure 5). This is because the overall wholesale market cost reductions described in Section 4.1 translate into lower costs for all participants, i.e. the whole system and all its users benefit from operating in a more efficient way. The electricity bill and cost savings for these customers reflects lower overall electricity usage, as we assume gas continues to be used for heating purposes, while personal vehicles have not been transitioned to EVs. The costs of these fuels would be additional, and have not been included in the analysis.

Additional value can then be captured for those households with EVs, heat pumps and other smart-capable assets that are managed in-line with flexibility incentives and that are influencing this change. For households in our “Active and Asset Equipped” segment – those most likely to have taken up EVs, heat pumps, solar, storage, and smart appliance controls – **wholesale electricity costs are 52% lower in our Flexibility Scenario**, **saving £375[5] on expected wholesale electricity costs** compared to the No Flexibility Scenario equivalent in 2040. These savings take account of the additional electricity demand required to transition to electrified heating and transport and come from these households being rewarded for moving the flexible parts of their electricity consumption into cheaper periods. This means these customers won't face additional costs from petrol and gas.

5 Household level energy cost savings are based on expected energy costs at 2040 and presented in real terms.

Figure 5: Household level savings across customer segments in 2040 and 2030



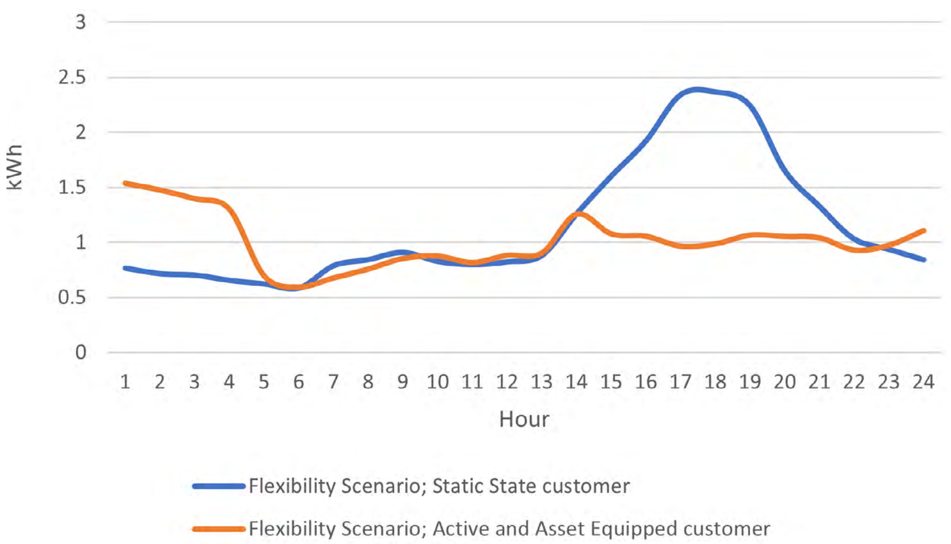
Source: Cornwall Insight

Even nearer-term, "Active and Asset Equipped" households can see material reductions on their wholesale electricity cost under our Flexibility Scenario, with **£115 (14%) of savings realised in 2030 compared to having the assets installed and not using them flexibly**.

6.3 Peak consumption cut by 3GW through smart meter-enabled flexibility

Household flexibility supports substantial reductions in peak consumption, **equivalent to four new gas-fired power stations**. Whilst peak demand generation is likely to be met with gas fired power plants, this is the generation capacity equivalent to 1000 wind turbines. Figure 6 shows the average daily demand of households in different customer segments, with a more typical demand profile from Static State consumers, where there is a rise in consumption between 4pm and 7pm, and a flatter profile shape for Active and Asset Equipped consumers that are using technology to enable DSR.

Figure 6: Average daily demand across customer segments, 2030



Source: Cornwall Insight

Managing flexible demand technologies like EV charging, heat pump operation, and solar and storage activities to market prices and system requirements means we **avoid 3GW of peak demand on the network overall in 2030**, saving almost £1bn in spending on the electricity network (wires and other infrastructure which delivers electricity to homes). To meet this demand, the market would also need to build **the equivalent of four new gas-fired power stations in 2030**.

The cost of building these stations to meet the expected equivalent demand in our No Flexibility Scenario is more than £2.5bn.

Further savings are seen in 2040, with a 1.5GW reduction in peak demand facilitated by household flexibility, saving £1.7bn in avoided network upgrades and build of new gas-fired power stations compared to the No Flexibility Scenario. These lower relative reductions arise because the system assumed to be in place in 2040 has much greater inherent flexible capacity, including some household flexibility (because we are 10 years further through the system-wide transition to a more flexible, net zero system), which means the additional flexibility from households in our Flexibility Scenario has a lower relative impact than it does in 2030.

6.4 Carbon savings increase 45% with engagement of household flexibility

Engagement with household flexibility results in a **45% increase in carbon savings compared to the No Flexibility scenario, the equivalent of planting 630,000 trees**. By engaging with flexibility, households can have a positive environmental impact, shifting consumption from peak times when gas-fired power stations are often used to meet demand, to other times of day when renewable energy is generating more. In the Flexibility Scenario in 2030, the electricity system delivers net negative emissions of 844,000 tonnes of CO2. In addition to these carbon savings, we can also consider the avoided emissions from the gas-fired power stations that do not need to be build in our Flexibility Scenario, compared to the No Flexibility base case. When these are included, this adds a further circa. 630,000 tonnes of CO2 avoided in the Flexibility Scenario.

Our power system modelling is devised in a way that ensures the sector meets the binding net zero commitments put in place, with overall net zero emissions achieved and electricity decarbonised by 2035. This means that both our Flexibility and No Flexibility scenarios see net-negative emissions in the electricity sector. This is driven by carbon sequestration via carbon capture usage and storage (CCUS) and bioenergy with carbon capture and storage (BECCS).

6.5 Role of smart meters

In this research, we have focussed on the system-facing benefits that can be realised by managing and deploying the flexibility potential in household electricity use. The flow of relevant data between different parties engaged across the energy system is essential to delivering opportunities, from the household, to the party managing its demand and delivering flexibility actions through to energy suppliers, local networks operators, National Grid ESO, and central parties like Elexon. Smart metering infrastructure is a core component in ensuring this information is available to all of the parties that need it, when they need it, in a secure and accessible manner.

Using the half hourly data from smart meters, customers can be rewarded for reducing their use of electricity at certain times, in a way that would not be possible with a traditional meter. With a traditional meter, suppliers typically do not have visibility of consumption at different times of day, and therefore could not reward customers for making a change in their consumption pattern. While consumer participation in household flexibility has been fairly manual to date (e.g. through the Demand Flexibility Service), emerging opportunities and services are expected to unlock the benefits of household flexibility through a wider variety of services, many of which will not require consumers to have an active role in managing energy usage. While the smart meter in-home display may not always be the mechanism used to delivery flexibility, the data flows enabled by smart metering infrastructure will remain key to realising the benefits.

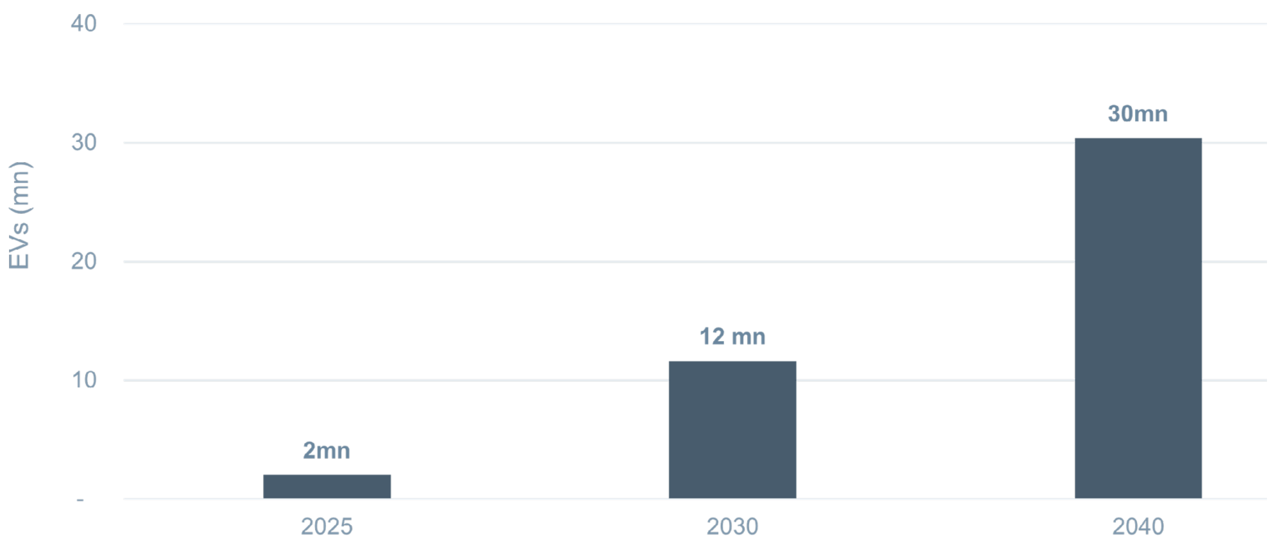
7. Flexibility by technology

In this section we outline the drivers of cost and carbon savings in each scenario, setting out the capabilities of specific technologies to deliver flexibility benefits.

7.1 Electric vehicles

Electric vehicles (EVs) are a critical part of the UK's transport decarbonisation trajectory, supporting the transition towards a net zero economy and removing harmful tailpipe emissions associated with internal combustion engine (ICE) vehicles. EVs can also provide substantial flexible capacity, whether charging at workplaces, other destinations, or at home. Uptake is expected to increase significantly over time, particularly as the ban on new internal combustion engine vehicles comes into effect in 2030. We have outlined our assumptions of electric vehicle uptake used in our scenario modelling in Figure 7, with 30.4mn battery EVs on the road by the time we reach our 2040 snapshot.

Figure 7: Uptake of electric vehicles used in scenario modelling



Source: Cornwall Insight

This level of EV uptake is informed by the comprehensive modelling conducted by National Grid ESO in its 2022 Future Energy Scenarios (FES)[6] and is aligned with the net zero achieving scenarios developed in FES. Flexibility from electric vehicles can be provided in different ways, outlined in Figure 8.

6 National Grid ESO, https://www.nationalgrideso.com/future-energy/future-energy-scenarios

Figure 8: Types of flexibility provided by electric vehicles

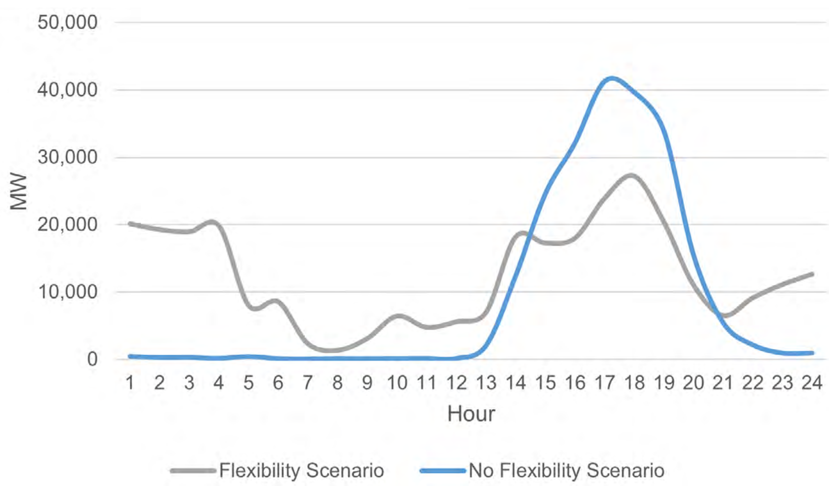
Smart charging: Allows scheduled charging by a consumer or a third-party (like an energy supplier) allowing them to manage smart charging sessions remotely via a smart chargepoint. This may be at times when electricity prices are cheaper, or when there is a high volume of renewable electricity produced. Smart charging typically allows consumers to set their charging preferences, including their minimum charge level at all time, their preferred charge level, and the time they want the charge level to be completed by.

Vehicle to grid (V2G): Allows consumers to flow electricity from their vehicle back onto the electricity network, typically in exchange for lower bills or financial reward. This requires specially designed charging technology in the vehicle to allow a two-way flow of energy. Vehicles typically charge their batteries when the price of electricity is lower, and sell back the electricity when consumption (and prices) are highest. Consumer preferences described above for smart charging also apply for V2G.

Our modelling assumes a range of uptake of smart charging, vehicle to grid and non-smart charging across consumer segments, with the different charging patterns across the two scenarios shown in Figure 9. Ultimately, access to charging equipment and charging times will need to be convenient for consumers to support savings delivered by flexibility. Over time, charging patterns may also alter in response to changes in access and use of public transport, working patterns and technological capabilities.

In our Flexibility Scenario, there is 110TWh of overall EV electricity demand in 2040. This is around 40% higher than in our No Flexibility Scenario, due to the increased battery cycling to deliver services and V2G, which make the most of the opportunities to be flexible. Even though more electricity is used for EV charging in the Flexibility Scenario, it is also provided at lower cost with over £330mn of savings realised for EV charging compared to the No Flexibility Scenario. This reflects a higher level of charging outside peak times when prices are lower, and smarter use of car batteries to provide electricity back to the network when demand is high. The Flexibility Scenario charging profile in Figure 9 below includes the net position of households participating in Vehicle to Grid charging.

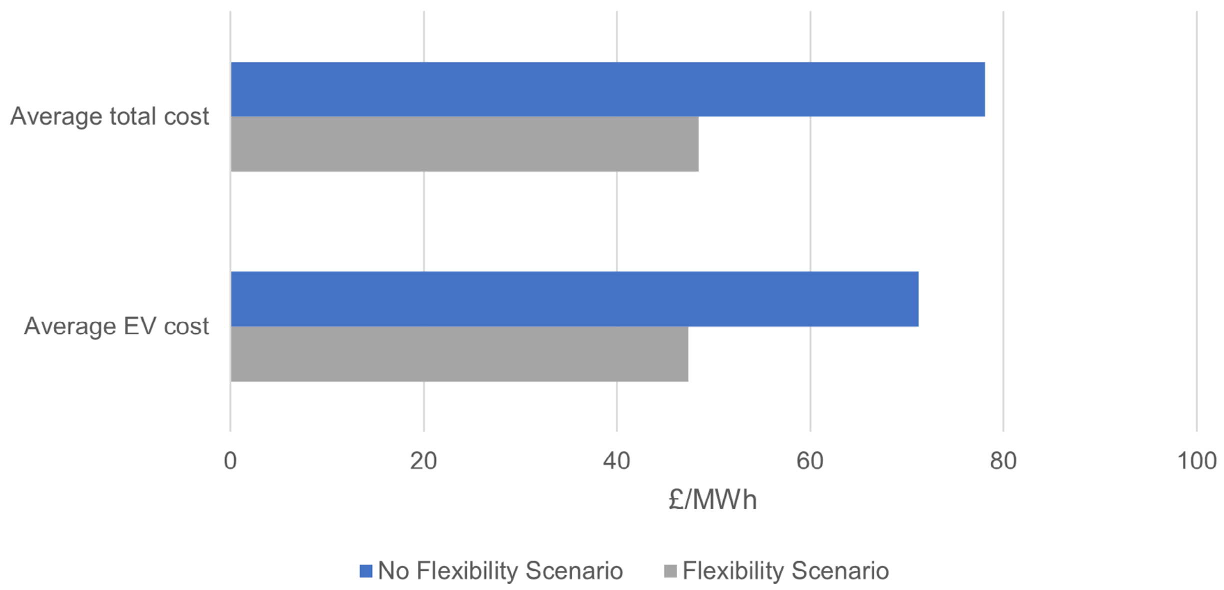
Figure 9: Average daily overall EV charging demand, 2040



Source: Cornwall Insight

These savings are most apparent when we look at the costs faced for charging at times of peak electricity demand, when costs are expected to be highest. Moving charging out of these times helps reduce the overall peak electricity price by 40% between our Flexibility and No Flexibility Scenarios. Overall, this flexibility means that EV charging is delivered at an average cost of £47/MWh in 2040, two-thirds the cost of meeting needs in our No Flexibility Scenario base case, shown in Figure 10 below.

Figure 10: Average electricity costs for EVs and overall demand, 2040



Source: Cornwall Insight

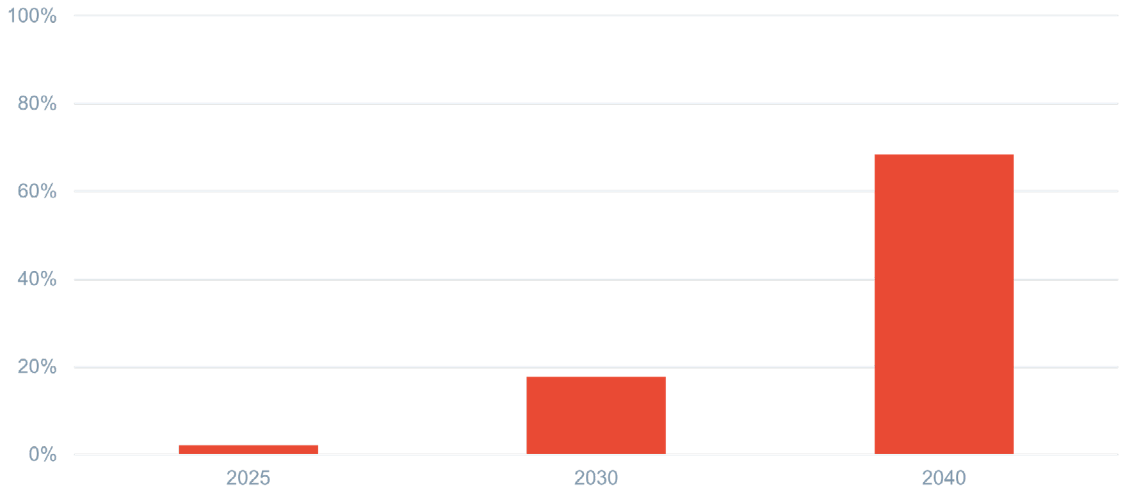
7.2 Household heating

Decarbonising heat is key to delivering overall decarbonisation and is a focus of current policy discussion, although there is currently no clearly defined pathway for household heat decarbonisation. The government has an ambition to phase out all new and replacement natural gas boilers by 2035 and is considering the best approach to heating homes with electricity. Several technologies have been identified which could play a role in the future decarbonised technology mix, with changes in technology expected to occur parallel to increased energy efficiency measures. This includes heat pumps, hybrid heat pumps, heat networks, electric storage heating, and hydrogen.

These technologies will not all be taken forward at scale as the primary technology choice for households. In our scenarios, we assume heat pumps to be the primary technology used, supported by a mix of other technologies. However, we note that under different policy recommendations and incentives, consumers may use a different primary technology for heating in the future.

Heat pump uptake is expected to start at a slow pace, with most consumers continuing to access the gas grid as their primary heating technology in the 2020s, with greater levels of uptake as we move towards 2040. Figure 11 shows the uptake of heat pumps used in the scenario modelling.

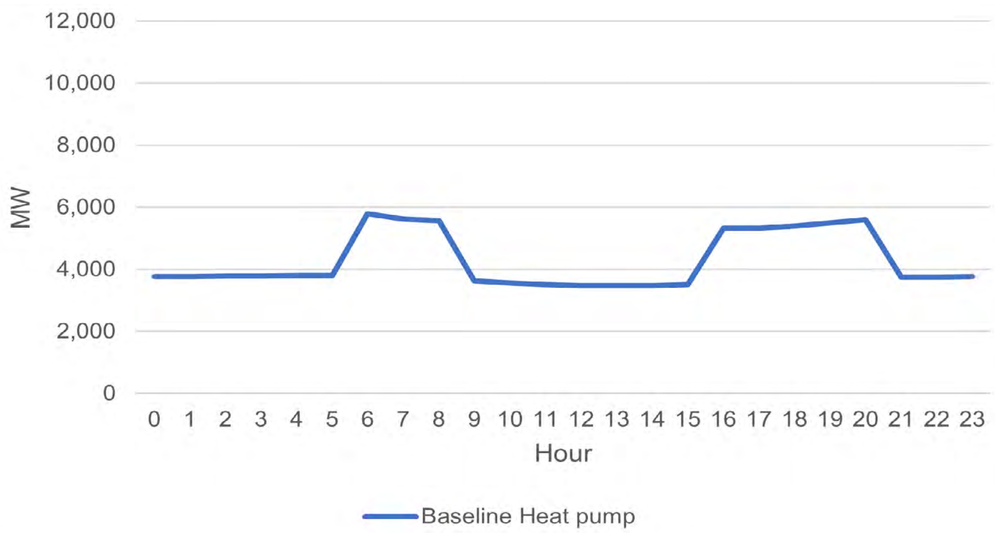
Figure 11: Household heat pump uptake used in scenario modelling



Source: Cornwall Insight

Currently, around 23 million homes are heated by mains gas supply in the UK, with around 37% of gas consumed in the UK used by households. More than half of the gas consumed in the UK is imported. Switching away from gas heating is crucial to decarbonisation in the energy sector. While this will create higher demand for electricity, technologies such as heat pumps are more energy efficient than gas boilers and can benefit from the increasingly low carbon electricity system, lowering carbon emissions. If used at scale, heat pumps may add significant demand at times when demand is already highest across the electricity system. Figure 12 shows our baseline view of a heat pump demand at 2040. With no demand management this would create a peak demand from heat pumps in 2040 of 22GW – equivalent to approximately half of all total peak system demand in 2022-23[7].

Figure 12: Average total heat pump consumption under a typical demand profile during a 24 hour period

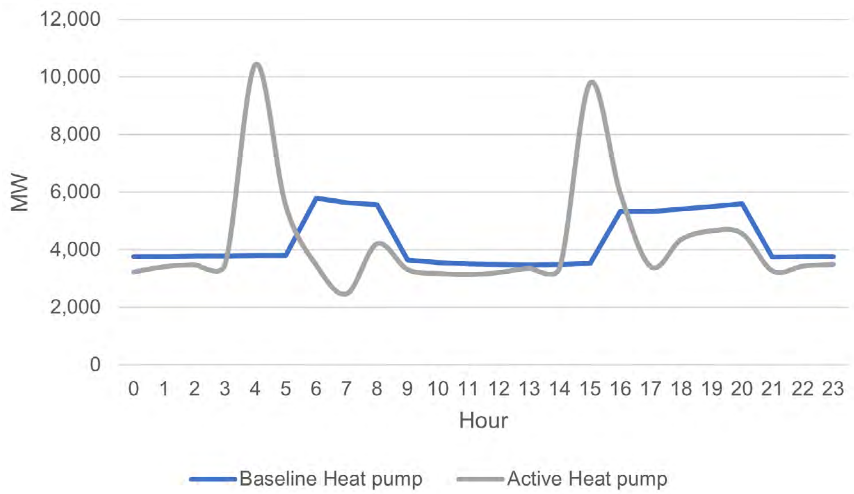


Source: Cornwall Insight

7 National Grid ESO, https://www.nationalgrideso.com/document/278476/download

Heat pumps can provide flexibility and can respond to price signals and vary consumption from this baseline behaviour to reduce overall running costs while continuing to adequately heat homes. In our modelling we have applied an alternative demand profile for heat pumps deployed in customer segments that are participating in flexibility opportunities. This is shown in Figure 13, which illustrates the heat pumps significantly increasing consumption in periods before peak pricing windows where wholesale electricity is cheaper and using the latent heat stores that homes can provide to maintain the same delivered temperature in the home, while reducing the overall electricity cost faced. This sees the same number of warm hours delivered, but at a lower cost and more flexible demand profile.

Figure 13: Flexible heat pump consumption during a 24 hour period



Source: Cornwall Insight

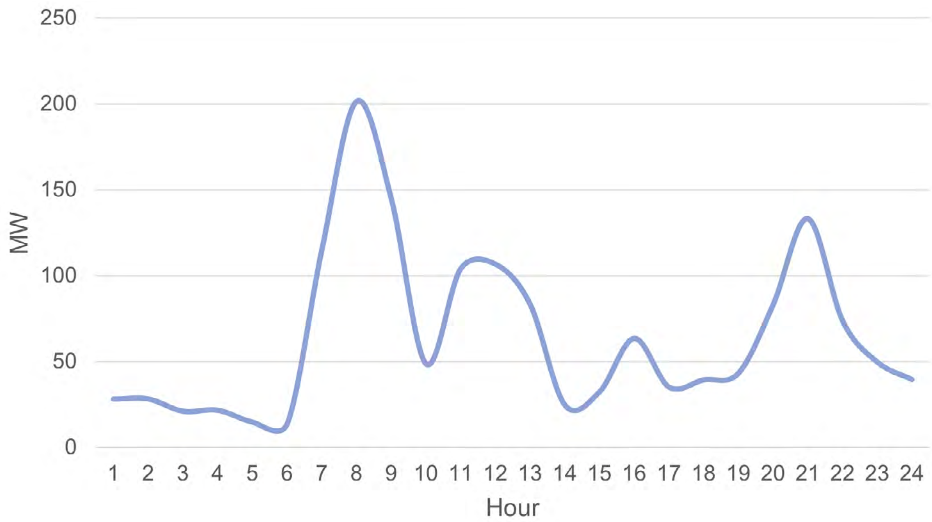
7.3 Household appliances

Alongside examining the potential from smart control of new, large-scale sources of electricity demand in the home, like EVs and heat pumps, we have also looked at the opportunities for smart appliances to provide flexibility to the electricity system and for households to be rewarded for doing so. We have drawn on National Grid ESO's 2022 Future Energy Scenarios to inform the level of response available from smart control of white goods, with overall demand from these appliances accounting for approximately 13% of peak residential electricity demand under National Grid ESO's projections.

In our modelling we have specifically looked at opportunities for smart control of white goods, as these represent higher volume demand for electricity and are expected to have greater opportunities for varying when they need to draw electricity. This variation is used in our modelling to provide load shifting, where total electricity demand remains constant but is moved around in time in response to price signals. In 2040, smart appliances are providing load shifting throughout the day. This is shown in Figure 14, where "DSR" represents the level of turn-down response provided by household smart appliances. For example, this could be delaying running white goods until after peak price periods have passed. Over 400MW of peak demand response is provided when we look across the full year in 2040 – greater than the largest onshore windfarm in the UK[8], with this response concentrated around morning and evening periods of peak network demand. On average, the greatest response is provided in the morning, with 200MW of demand side response delivered on average at this time across the year, equivalent to boiling 67,000 kettles.

8 https://www.statista.com/statistics/896600/onshore-wind-farm-capacity-united-kingdom-uk/

Figure 14: Demand response provided by smart appliances, daily average profile, 2040



Source: Cornwall Insight

As smart home controls develop, the range of appliances and scale of response from this segment could grow. We have focused our modelling on the DSR potential of white goods, but control of other items such as lighting or computers could also provide value, from turn-down or turn-up DSR actions. Although an early-stage trial in the market, the levels of household response under the Demand Flexibility Service (see Figure 2), suggests the potential for even greater levels of flexibility than those assessed in this research.

7.4 Solar PV and batteries

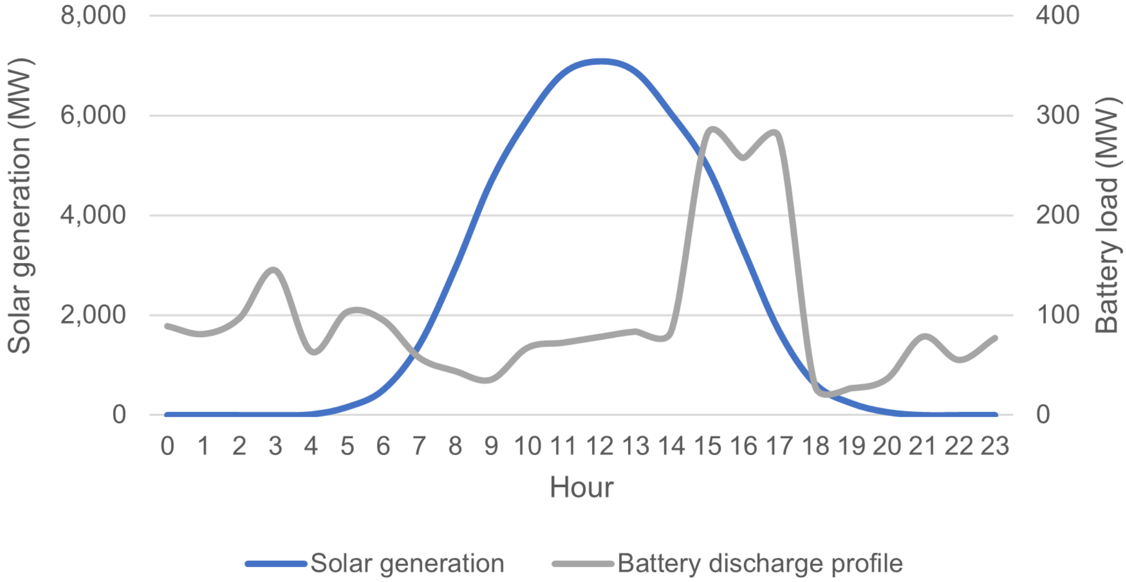
Through the installation of solar PV households can be rewarded for exporting self-generated electricity to the grid, or they can use electricity produced to meet their own consumption needs. The addition of static[9] batteries enables additional flexibility by allowing households to store power generated by solar PV until it is needed and/or to charge at times of low prices to meet household demand at times of high prices at lower cost.

In this research, we have assumed that overall levels of solar and storage are in-line with the levels expected under National Grid ESO's Future Energy Scenarios, with around 21GW of solar PV and 3GW of battery storage installed at 2040. All solar PV and storage technology uptake is assumed to be within our "Active & Asset Equipped" consumer segment, with correlation expected between a household taking solar PV and those that take up a battery, as storing and using solar generation is likely to be a key value stream supporting the operation of household batteries.

As we reach 2040, our modelling shows the combined output of household solar PV averages 2.2GW over the course of an average day (covering both summer and winter periods). This is equivalent to the annual electricity consumption for more than 700,000 homes. Figure 15 below shows the average output profile for these solar panels, overlaid with the average export profile of the installed batteries, with discharge from the batteries principally focussed on reducing household imports over the evening peak. This is when we expect electricity costs to be at their highest and reducing imports in this period supports the £375 a year energy cost savings achieved by households with solar PV and battery storage installed in our Active & Asset Equipped segment in 2040.

9 We use the term static batteries to differentiate from batteries in EVs which can also provide flexibility through smart charging and V2G

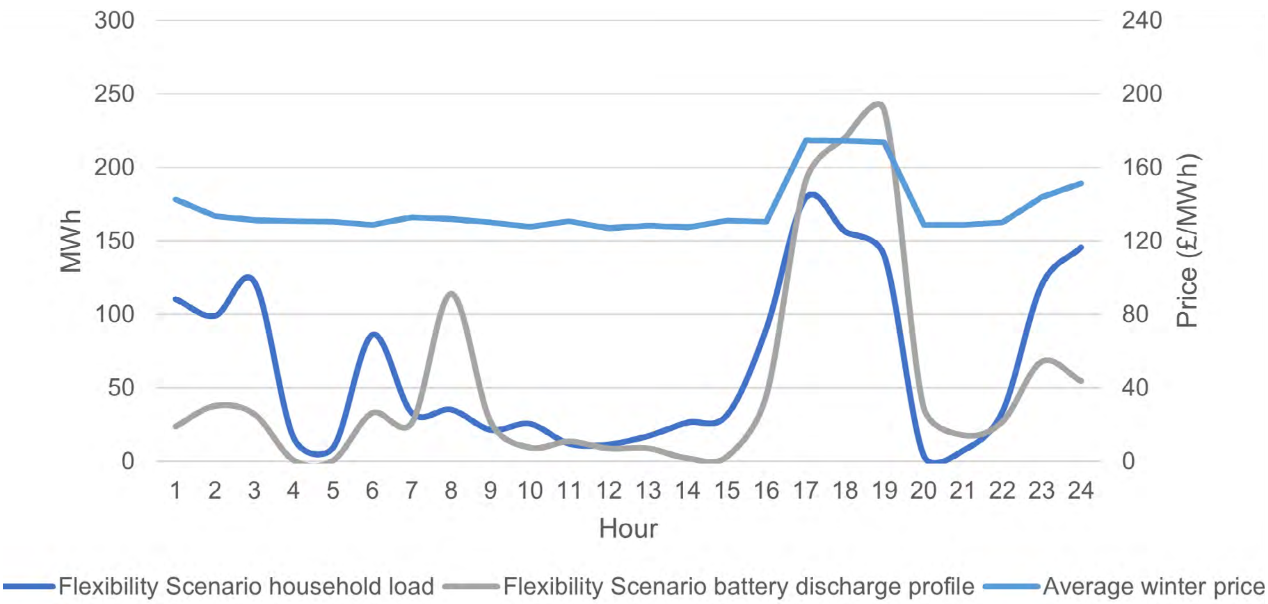
Figure 15: Average solar PV and battery storage daily profile, 2040, all-household level



Source: Cornwall Insight

Value from these assets arises in 2030 as well as 2040. Figure 16 shows the average battery storage profile over the course of a day in 2030, including the baseline demand profile for the household. This shows that the same approach – to minimising household imports in peak periods – is being taken. On average, aggregated battery storage exports which occur over the morning and evening peaks are greater than the expected household consumption during the same time periods. During these times, equipped households are expected to become net exporters, selling electricity back to the energy system. This sees these customers being paid for providing electricity to the network when prices are likely to be highest, supporting the relative energy cost savings seen across our Flexibility Scenario. Figure 16 shows the average day ahead power price over winter in 2040, showing the time of use signals that are driving this saving.

Figure 16: Average daily storage and household demand profile, 2030, overall system level



Source: Cornwall Insight

8. Conclusions

This section summarises the key conclusions from the research.

Household flexibility will deliver benefits for households, the environment and the national management of the electricity system.

Up to 52% wholesale electricity savings in 2040

Households that can and choose to engage with household flexibility through the transition (over time) to electric heat and transport solutions, will see the greatest financial benefits, as larger volumes of electricity are shifted away from peak times.

4 fewer power stations

Without household flexibility, the transition to decarbonisation will see increased electricity demand at peak times. This will require building up to four gas-fired power stations to meet peak demand in 2030, at cost of around £2.5bn. Upgrades to the electricity network would also be required to meet peak demand, costing almost £1bn.

Equivalent to 630,000 trees

By engaging with flexibility, households can have a positive environmental impact, shifting consumption from peak times when gas-fired power stations are often used to meet demand, to other times of day when renewable energy is generating more.

Positive consumer experience

Consumer participation in household flexibility is expected to become easier as new technology and services come onto the market. The rewards are expected to increase, as our energy system decarbonises to use greater volumes of electricity, and household electricity consumption increases through electric heating solutions and electric vehicles. Today, consumers can take first steps into participating through the installation of a smart meter, which opens up access to services such as the Demand Flexibility Service and existing Time of Use tariffs, while providing accurate data around consumption which can be used by suppliers in the design and trials of new propositions.

The authors

Anna Moss
Senior Consultant
Cornwall Insight
a.moss@cornwall-insight.com

Jacob Briggs
Consultant
Cornwall Insight
j.briggs@cornwall-insight.com

Tom Edwards
Senior Modelling Consultant
Cornwall Insight
t.edwards@cornwall-insight.com

Tom Musker
GB & Ireland Modelling Manager
Cornwall Insight
t.musker@cornwall-insight.com

CORNWALL INSIGHT

CREATING CLARITY

Contact Us

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

T 01603 604400
E enquiries@cornwall-insight.com

www.cornwall-insight.com