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POST

POSTnote 715

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Demand side response: A tool for lowering household energy bills

Overview

- Demand side response is changing when devices use electricity in a way that is beneficial to the electricity system. For example, an electric vehicle could charge during times of low demand at night.
- Demand side response is one method of reducing the amount of infrastructure investment required to meet an increasing electricity demand.
- Demand side response is used for two main reasons: to manage peak demand to reduce the amount of network investment required to meet an increasing electricity demand, caused by the electrification of heating and transportation; and to match demand with the output of renewable electricity generation, which tends to be intermittent.
- Demand side response could make household energy bills cheaper, and the British electricity system £3-8 billion per year cheaper to run by 2050. For reference, the projected annual electricity system cost in 2050 is about £70 billion.
- The role out of smart meters is an important component to demand side response services because they measure electricity use in real time.
- Consumers have differing abilities to understand what they have to do to engage effectively and provide demand side response. For example, electric vehicles offer greater flexibility compared to an electric cooker.

Introduction

The Climate Change Act, as amended in 2019, requires the UK to reach net zero greenhouse gas emissions by 2050.[1] Carbon budgets act as stepping stones on the way to net zero, setting a cap on greenhouse gas emissions over five-year budget periods.[2,3] In line with these carbon budgets, the Government has committed to fully decarbonise the power system by 2035, subject to security of supply.[4–6]

To reach the UK's net zero targets, the Climate Change Committee[a] estimates that all domestic heating and light transportation must be decarbonised by 2050.[7] A significant proportion of that demand is likely to be electrified, potentially doubling electricity demand in 2050 compared to 2022.[7,8] The government has committed to install 600,000 heat pumps[b] per year by 2028, and for all new cars to be zero emission by 2035.[4,5,9]

These changes create two challenges for the electricity system:

- A significant amount of new electricity generation and network infrastructure will be needed to meet demand. National Grid ESO,[c] forecasts that £21.7 billion in investment will be required in Great Britain's onshore transmission system by 2030 to meet the increasing demand for electricity.[10,11]

- New technologies will be needed to continue to balance supply and demand for electricity. This flexibility has historically been provided by gas turbines.[12]

Supply needs to meet demand for electricity on a second-by-second basis.[13] Historically, electricity generation, provided by gas and coal, have been controllable. This means output can be changed depending on demand. The renewable generation that is replacing fossil fuels, such as wind and solar, tends to be intermittent. This means output cannot be changed to match demand. A previous POSTnote covers intermittent electricity generation (PN 464).

According to academia, industry and the government, demand side response is one method of reducing the amount of infrastructure investment required to meet an increasing electricity demand.[14–16] Demand side response can also help balance electricity supply and demand as the number of gas turbines in the electricity system reduces.[17–19]

The Government projects that 30 gigawatts (GW) of low-carbon flexibility, or enough to power three hundred million 100W lightbulbs, will be needed by 2030, and 60 GW will be needed by 2050, up from 10 GW today.[20] This increase in demand for low carbon flexibility is needed to both replace existing high carbon flexibility and meet the increasing need for more flexibility as electricity demand also increases.

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[a] The Climate Change Committee is the government's independent advisory body on climate change.

[b] Heat pumps heat homes and other buildings by transferring heat from the external environment into the building. They are powered by electricity. A previous POSTnote covers heat pumps (PN 699).

[c] National Grid ESO is Great Britain's electricity system operator. They operate the high voltage transmission infrastructure which is used to move electricity long distances around the country.

What is demand side response?

Demand side response is changing consumption of electricity, in a way that is beneficial to the electricity system.[21] For example, an electric vehicle could charge during times of low demand at night.[14]

There are two reasons demand side response might be used:

- *Peak demand reduction:* The electricity system is built with enough capacity to meet the maximum demand it experiences.[22,23] However, this peak demand is often only experienced for short periods of time.[24] Demand side response can be used to move demand away from these peak times, reducing the local network and infrastructure capacity needed.[25,26] For example, demand side response could be used to move electricity demand away from the evening peak[d].

- *Supply and demand balancing:* Intermittent generators such as wind turbines and solar panels cannot adjust their output based on demand.[17,27] Demand side response can be used to move electricity demand to times of high output from intermittent renewable generators. For example, encouraging electricity use in the middle of the day when solar generation is highest. Shifting demand in this way reduces the need for energy storage, such as batteries[28], or for additional non-renewable generation capacity used only at peak periods.

Large industrial and commercial electricity users have been providing demand side response since the 1980s.[29] This POSTnote focuses on demand side response from domestic and small non-domestic electricity users. Long-term demand reduction measures, such as energy efficiency measures in buildings, are a separate topic and are covered by a previous POSTnote (PN 550).

There are two types of demand response markets. *Implicit* demand response markets encourage changes in demand through variable electricity prices,[30] for example, time-of-use tariffs charge higher prices during peak times.[31,32] *Explicit* demand response schemes make payments to customers who change their electricity demand at particular times.[30] The demand side response request in this case is made by a 'DSR Service Provider', which responds to real-time requests from grid operators. The Demand Flexibility Service was an example of an explicit demand response scheme (see Box 1).

Future energy systems will need to store electricity over different time periods, ranging from less than a second to more than a year.[8] Demand side response is likely to typically provide flexibility over time periods ranging from minutes up to a day.[8] Other technologies, such as hydrogen and pumped hydro, will be needed for providing flexibility over longer time scales.[21,33] A previous POSTnote covers longer duration energy storage (PN 688).

[d] Electricity demand varies throughout the day. Typically electricity demand peaks in the morning and evening, with a low during the middle of the day and overnight.

Automated and manual response

Demand side response can be automated or manual.

Manual demand side response is people manually choosing to use electricity at different times.[34] For example, someone choosing to run their dishwasher overnight instead of at 6pm in response to high peak time prices. Delay timers, such as those used in electric storage heaters to activate during periods of off-peak demand, are an example of manual demand side response because they are set by the consumer.

Automated domestic/smaller non-domestic demand side response is when electrical devices are programmed by a third party to respond to energy price or another signal.[35] An example is an electric vehicle charger that does not start charging immediately when plugged in at 6pm but only switches on, possibly intermittently, when prices are lower (hence optimising against a tariff incentive).

Benefits of demand side response

The Government projects that low-carbon flexibility, including demand side response, could reduce the cost of running the electricity system by £10 billion per year in 2050, around 14% of the system cost, with a cumulative cost saving of £30-70 billion between 2020 and 2050.[20] Other analyses find that savings from demand side response are likely to be in the range of £3-8 billion per year in 2050.[36–40] For reference, the projected annual electricity system cost in 2050 without flexibility is £72 billion.[20]

The majority of savings from a flexible electricity system come from lower electricity generation capital costs.[20,41] To a lesser extent, flexibility also reduces network investment and balancing costs.[20,41]

All electricity system costs are recovered through energy bills.[42] Savings in operating costs therefore translate into lower energy bills for consumers.

Policy context

Several recent consultations, legislation and regulations have examined different aspects of demand side response. See Table 1 for details.

Table 1: Recent demand side response consultations and legislation

Consultation or legislation	Date	Details
Smart Systems and Flexibility Plan 2021[20]	Published July 2021	The Plan lays out actions to increase the amount of flexibility in the British electricity system.[20] The term 'flexibility' in the

		Plan covers energy storage, demand side response and interconnectors.[e]
The Electric Vehicle (Smart Charge Points) Regulations 2021[43]	Came into force June 2022	Regulations governing the design and functionality of domestic electric vehicle charging points. These regulations require domestic charge points to have the necessary equipment to provide demand side response.
Review of Electricity Market Arrangements (REMA)[44]	Consultation ran Jul-Oct 2022	The Review examined the design of wholesale electricity markets[f]. One of the motives for REMA is improving electricity price signals so that they encourage times when it is beneficial to the electricity system. A previous POSTnote provides more detail on REMA (PN 694).
The future of distributed flexibility[45]	Call for input ran Mar-May 2023	This call for input considers different levels of flexibility market coordination and control. Currently, different organisations run their own markets that procure demand side response. Multiple markets may try to procure demand side response from the one device. However, primacy rules dictate which market the device will respond to.
Towards a more innovative energy retail market[46]	Call for evidence ran Jul-Sept 2023	The call for evidence examines, amongst other things, changes to retail electricity markets[g] that might encourage domestic and small non-domestic consumers to provide demand side response. The Government has ruled out an overhaul of the retail market in the short or medium term.[47]
Energy Act 2023[48]	Enacted Oct 2023	The Energy Act 2023 gave the government powers to regulate load controllers.[48] Load controllers are entities that provide instructions to devices providing demand side response. Load controllers may be existing energy suppliers or may be separate companies. A House of Commons Library briefing provides more details on load controllers in the Energy Act 2023 (CBP 9787).

[e] Interconnectors are subsea cables which allow Britain to export electricity to or import electricity from other countries. Britain's electricity system is connected via interconnectors with France, the Netherlands, Belgium, Denmark, Norway, Northern Ireland and the Republic of Ireland. A previous POSTnote covers electricity interconnectors (PN 569).

[f] Wholesale electricity markets are markets for electricity generators can sell electricity to market participants such as energy supplier, who act on behalf of final energy consumers such as households.

[g] Retail electricity markets are where households and businesses can purchase electricity from energy suppliers.

Examples of demand side response

Time-of-use tariffs

Domestic demand side response has existed for some time through time-of-use tariffs. Time-of-use tariffs charge different prices depending on when energy is used.[49] They are a form of implicit demand response. In Great Britain, Economy 7 tariffs, which offer cheaper electricity for seven hours overnight, have existed since 1978.[50,51] Economy 7 tariffs aim to shift electricity demand to off-peak times during the night.[51] The day- and night-time Economy 7 rates do not change day-to-day.

More recently, some energy suppliers have offered more complex time-of-use tariffs with half hourly prices that are published the day ahead.[52,53] These more complex tariffs may be used by devices to automatically change their electricity demand depending on the price. Tariff rates can vary dramatically. For example, the Agile Octopus tariff rates from Octopus Energy can go as high as 100 pence per kilowatt-hour (p/kWh) at times of high demand, fall below 2 p/kWh, and reach negative prices, at times of low demand.[52] For comparison, the standard variable tariff price cap is 27 p/kWh between October and December 2023.[54]

Demand Flexibility Service

During the winter of 2022/23, the Demand Flexibility Service, a new explicit flexibility market aimed at households, was run for the first time.[55] National Grid ESO launched an updated Demand Flexibility Service, which began in November 2023.[55] Box 1 provides more detail about the demand flexibility service trial.

Box 1: 2022/23 Demand Flexibility Service Trial

National Grid ESO's Demand Flexibility Service trial asked users including households and small businesses to reduce their energy demand during peak periods to help balance the electricity system.[55] It ran from November 2022 to March 2023.[56] Consumers were asked to reduce their demand for periods of 1-2 hours.[56] A total of 22 such events ran during winter 2022/23, 20 test events and 2 live events.[56] A total energy reduction of 3.3 gigawatt-hours was achieved during the Demand Flexibility Service, roughly the amount needed for everyone in Great Britain to make a mug of tea.[56]

Most people participated in the Demand Flexibility Service trial through their energy supplier. National Grid ESO, the Centre for Sustainable Energy and several energy suppliers have examined people's motivations and experience of participating in the trial. The majority (76%) of people were motivated by rebates on energy bills offered by energy suppliers in return for participation.[56] A significant minority (37%) of people were motivated by avoiding blackouts and reducing energy bills for all.[56] A smaller minority were motivated by reducing carbon emissions and gas imports (24% and 22% respectively).[56]

The most common problem reported with the Demand Flexibility Service trial was that the level of reward was too low (reported by 38% of respondents).[56] The majority (51%) of people reported receiving between £1-5 in total compensation for participating in the service.[56] Other commonly reported issues included problems with changing routine (31%), remembering the events were happening (27%), and understanding what action to take (21%).[56] Another common criticism was baselining, and the ability to understand what someone's electricity demand would have been had they not provided demand side response – see below.

Distribution network operator flexibility markets

All of Britain's distribution network operators[h] have flexibility markets developed through the ENA's Open Networks programme.[57] Historically, network operators have installed new infrastructure as old ones reach their capacity. Flexibility markets allow network operators to reduce demand using demand side response, instead of upgrading infrastructure.

These markets are locationally specific, as each market covers a separate geographical area. Since 2018, the first year for which data is available, the amount of power capacity available has always exceeded the agreed upon contracted capacity.[58] As of 2023, distribution network operators were only able to secure half of the total amount of flexibility services tendered.[59]

Trial projects

Several trial projects have examined possible future market structures, and how groups of electrical devices might be able to provide demand response. Optimise Prime examined how a fleet of electric vehicles could be coordinated to provide demand side response.[60] Project TraDER examined how a flexibility market could be operated by a neutral third party[i] rather than by a distribution network operator.[61]

[h] Distribution network operators own and maintain Britain's low voltage distribution networks. These are used to distribute electricity to premises.

[i] Distribution network operators may not be viewed as neutral operators of flexibility markets because they are also responsible for maintaining the distribution network. In their capacity as distribution network owners and maintainers, distribution network operators are compensated for constructing new infrastructure. Flexibility markets may reduce the amount of infrastructure which is built. There may be a perception of a conflict of interest on the part of the distribution network operator if they also operate the flexibility markets.

Technical barriers to demand side response

Reporting Energy Information

Demand side response requires not just knowing how much electricity is being used, but when it is being used. One way to provide this information is through the use of smart meters, which provide this data unlike traditional meters.[62] The Demand Flexibility Service (see Box 1) used smart meter data. In PAS 1878, an option is included to be able to measure or calculate the power consumption of the Energy Smart Appliance with an upper accuracy of 10%.[63] This enables for the use of a lookup table method.

Smart meters are boundary meters, meaning that they measure the total energy demand of a house. Boundary meters do not provide information on the electricity usage of individual devices (like EVs), or any information for demand side response[64]. The alternative to boundary metering is device-level (also known as asset) metering.

An asset meter measures the energy consumption of a single device. The Electric Vehicle (Smart Charge Points) Regulations 2021 requires electric vehicle chargers installed in homes to be configured with asset meters.[43]The Government has committed to requiring heat pumps to have asset meters in the future[9,65].

Calculating the amount of demand side response

Demand side response includes the abilities to change charge profiles or shift a devices' electricity usage in time.[21] To determine whether demand side response has been provided, the electricity usage that would have occurred without demand side response is needed.[66] This counterfactual is the baseline. Baselines can be hard to obtain for households because their energy demand is erratic.[67–69]

The Demand Flexibility Service (see Box 1) created a baseline by averaging the last ten comparable periods (same time on the same day of the week), and adjusted the baseline based on the three hour period ending one hour directly before the response period (when people have been asked to reduce their demand) to account for weather differences.[70] Some commentators had previously criticised the baselining methodology for allowing people to artificially inflate the response they appeared to provide.[j][71] For example, if someone ran their dishwasher just before the response period, it would increase their baseline demand making it seem like they reduced their demand by more than they did.

[j] After significant industry debate, the terms of service for the Demand Flexibility Service were updated in November 2023 to remove the baseline adjustment and potential for artificial response inflation. Baseline continues to be calculated from demand in the preceding two weeks and is no longer calculated from the demand in the three hour period ending one hour directly before the response period.

Connectivity, interoperability and cyber security

To provide automated demand side response, devices must have the ability to receive and respond to signals.[72] The Electric Vehicle (Smart Charging) Regulations 2021 required all new domestic and workplace electric vehicle chargers to have smart functionality and so to be able to respond to these signals.[43] The Government has committed to similar measures for heat pumps.[9]

In 2022, the Government consulted on the connectivity[k] and cyber security requirements of the energy system to enable small devices such as heat pumps and electric vehicles to provide demand side response.[65] In the consultation response, published in March 2023, the Government committed to making larger load controllers Operators of Essential Services[l] under the Network and Information Systems Regulations 2018, as they also have an obligation to manage the risks that they pose to energy system.[65]

Fairness of demand side response

The ability of different households and businesses to provide demand response may significantly differ[74]. This could lead to perceived or actual fairness issues if some people benefit more than others. A previous POSTnote has examined inequality issues in the energy transition (PN 706).

Access to devices

Heat pumps, domestic battery energy storage systems (installed with and without solar generation) and electric vehicles are the devices most likely to provide demand response in homes. A range of practical and social factors affect people's access to these devices:

- Electric vehicles, domestic battery energy storage systems and heat pumps are expensive. Wealthier households are more likely to be able to afford these devices,[75–77] although some social housing providers have energy efficiency schemes that include installing heat pumps.[78,79]
- The type of dwelling and occupancy type affects its suitability for having a heat pump or electric vehicle charger. Dwellings without driveways are unlikely to have electric vehicle chargers. Heat pumps might not be suitable for flats due to the space required. People in rented accommodation have less control over whether they have a heat pump or electric vehicle charger installed than people who own their home[80].

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[k] Connectivity is a device's ability to send and receive signals. For example, a device might receive signals to adjust its electricity demand, or might send signals to provide meter readings.

[l] An Operator of Essential Services is an organisation which provides a service that could have a significant negative effect if it were to be disrupted. The Network and Information Systems Regulations 2018 requires Operators of Essential Services to identify and manage risks such as cyber security to decrease the risk of disruption to the services they provide.[73]

- A heat pump can provide demand response by pre-heating the home prior to the period of demand response, then reducing its energy demand during the response period. A well-insulated home, or one with some thermal storage, will cool down slower when the heat pump is turned off, increasing the amount of time demand response can be provided for.

- With an electric vehicle, the benefits of providing flexibility could accrue to the electric vehicle itself, or to the electric vehicle charger. The Electric Vehicle (Smart Charging) Regulations 2021 envisage the charger as the entity providing demand response.[43] However, these regulations do not apply to public chargers, but only to domestic and workplace chargers. The owner of the electric vehicle and the operator of electric vehicle charger are not necessarily the same person, for example in the case of on-street chargers. It is not yet clear whether the benefits of providing demand side response will accrue to the owner of the vehicle or the charger.

Ability to shift demand

People will have differing abilities to shift their demand. People with children, shift workers, and households with medical devices may need to consume electricity at peak times. Households with less ability to shift may end up paying more for their electricity.

Households with low electricity demand

Explicit demand side response is compensated based on the amount of demand reduction that is achieved compared to the baseline demand.[66] Households in energy poverty often continuously minimise their electricity demand.[81] This means that their baseline electricity demand will be low and they will be less able to reduce their demand in order to receive compensation.[82]

Implicit demand side response could be considered fairer in this regard. Time-of-use tariffs charge for total demand, rather than for changes in demand. Two households with the same demand in a particular time period will be charged the same amount, irrespective of their baseline demand.

Understanding the technical requirements

Providing manual demand side response requires people to understand the signals being provided to them and take appropriate actions. Complex time-of-use tariff prices change every half-hour. There is likely to be a significant proportion of people who do not understand the signals provided by time-of-use tariffs and either take no action to shift their energy demand, or move energy to times of higher prices.[56] Automated demand side response may not face the same challenge as people do not need to take manual actions based on incentives.

Explicit demand response requires a signal to be sent to a device or person, and for that device or person to provide a response.[30] This is likely to require households to have an internet connection and be relatively technology literate. If the response is provided manually, as it was in the Demand Flexibility Service, there is a chance that people will respond in a manner different to that expected.[56] Under some flexibility market designs, there is a risk people would be penalised if they do not respond as expected; this also applies to some time-of-use tariffs.

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