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# Electricity Demand-Side Response


Demand-Side Response describes electricity users (the demand side) changing their patterns of use in response to incentives. It is one of several options eligible for Government support introduced by the 2013 Energy Act. This POSTnote outlines DSR, how it is provided, its role for the UK and its potential future development.

## Overview


- Electricity demand and supply both fluctuate throughout the day. Some fluctuations are predicted, such as a peak in demand in the evening, while others are unpredicted.
- Demand-Side Response (DSR) is used to match supply with demand when unpredicted fluctuations occur, and to shift demand, including reducing peak demand.
- Industry and commerce provide most DSR by turning machines on and off. The Energy Act and household roll-out of smart meters could support further uptake of DSR.
- The expansion of DSR has the potential to lower consumer bills, electricity system costs and greenhouse gas emissions.
- However, there is uncertainty about levels of end-user participation, and its effect on emissions and low-income household bills.


## Background

'Keeping the lights on' is a central part of energy policy. To maintain electricity supply, the supply and demand of electricity must be flexible enough to allow them to match each other. At present, this flexibility is mostly provided by the supply-side, by switching on or off fossil-fuelled power plants. However, fossil-fuelled generation is decreasing and the need for flexibility is increasing with more supply from intermittent sources (Box 1). These developments will challenge the UK electricity system's ability to be sufficiently flexible and may necessitate further fossil-fuelled generation. Alternative ways to provide this flexibility include using electricity storage (POSTnote 306), electricity imports and demand-side response.

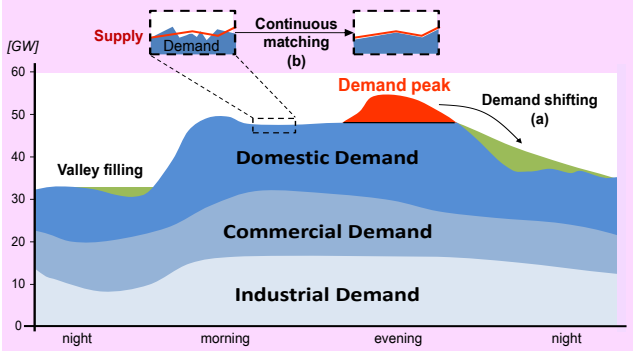
**Box 1. Future Developments for the UK Electricity System**

- **Intermittent supply sources such as wind are increasing.** They are planned to deliver around 24% of total UK electricity by 2020. These intermittent technologies offer less supply-side flexibility.
- **Flexible generation will decrease** by around 15% from 2012-2015 because of the closure of some coal-fuelled power plants.
- **The range between minimum and maximum demand may increase** because of the electrification of heating and transport. This will increase the requirement for stand-by supply capacity.

### What is Demand Side-Response (DSR)?

In contrast to managing supply, DSR is used to manage demand. DSR can help to reduce peak demand by redistributing end-users' electricity demand to other times of the day (Figure 1-a). This lowers the need for supply capacity designated for use at times of peak demand. DSR can also provide the flexibility to match supply and demand every second when unpredicted fluctuations occur (Figure 1-b). Finally, DSR can be used to keep the amount of electricity demand within the limitations of the national and local power grids.

**Figure 1. Effects of DSR on Typical UK Demand Profile**



DSR differs from Demand-Side Management, which is a catch-all phrase that also includes permanent Demand Reduction (for example, using energy efficient light bulbs).

## How DSR is Provided

DSR is provided by electricity end-users temporarily changing their electricity demand in the following ways.

- **Turn-down DSR**: users temporarily reduce demand from the electricity grid by reducing their consumption.
- **Turn-up DSR**: users temporarily increase demand from the electricity grid by increasing their consumption.
- **DSR by on-site generation**: users temporarily reduce demand from the grid by using on-site generation or stored energy.

DSR can be provided in different ways. In **households**, the use of storage heaters and white goods, such as fridges and freezers, can be shifted away from times of peak demand (turn-down DSR) to periods where electricity is cheaper. In the **industrial and commercial sector**, flexible tasks can be shifted to off-peak times (turn-up DSR). Also, on-site back-up generation, such as diesel generators (for example in hospitals) can be used to reduce demand from the grid (DSR by on-site generation).

### Automated and End-user Controlled DSR

DSR may be automated or end-user controlled.

- **Automated**: The consumer agrees that a contractor (an organisation paying for DSR) can turn on or off their machines and appliances remotely.
- **End user-controlled**: The consumer is offered incentives to change their patterns of use, either manually or through pre-programming (for example, through setting up appliances with timers)

In order to trigger DSR, communication between the end-user and contractor often requires communication technologies (Box 2). The data transmitted between the consumer and contractor can include the amount and price of electricity and the time of response. There is a requirement by the Department for Energy and Climate Change (DECC) for these data to be encrypted for security, the use of which must also comply with the Data Protection Act. DECC guidelines allow suppliers access to monthly data without the need for consumer consent. For daily consumption data, consumers can opt-out and half-hourly data are only provided to suppliers if consumers opt-in.[1]

To encourage end-users to sign up to DSR normally requires suppliers or DSR contractors to offer an incentive. In the case of automated DSR, to compensate users for relinquishing some control an initial incentive is needed. In the case of end-user controlled DSR, to encourage the user to change their patterns of use ongoing incentives are needed.

In both automated and end-user controlled DSR, incentives are typically financial, either using contracts or tariffs. Contracts usually offer fixed rewards in return for concessions, such as the right of the contractor to interrupt supply at any time. They are primarily offered to industry and commerce. Tariffs offer end-users from all sectors variable rewards based on their participation. For example, *time-of-use tariffs* such as 'Economy 7' charge lower electricity prices at night, so if users shift their use to the night they benefit from reduced bills.

**Box 2. Communication and Control Technologies for DSR**

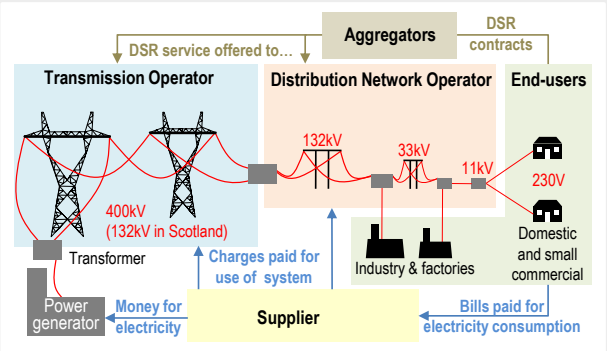
- **Teleswitches** on night time heaters receive signals sent via BBC Radio 4. These turn the heaters on or off.
- **Appliances with timers** allow the user to pre-set a programme. Example appliances include dishwashers.
- **Smart appliances** can react autonomously to stresses on the whole electricity grid or price signals from suppliers.
- **Smart meters** (POSTnote 301) record information about users' energy use for the benefit of both suppliers and users, and could be used to control appliances, while **In-Home Displays** can provide price information.
- **Mobile phone or land lines** are used to transmit prices or commands to change demand, either automatically or by voice.

## Role of DSR in the Electricity System

DSR is not new in the UK. It helps to redistribute predicted electricity demand to different times of the day, manage unpredicted changes in supply and demand, and manage constraints of the electricity transmission network. These actions involve many stakeholders, who are outlined in Box 3.

**Box 3. Electricity System Stakeholders Relevant for DSR**

- **Network operators** maintain, operate and reinforce the electricity network and charge for the use of their networks.
  - **Distribution Network Operators (DNOs)** run localised networks and are responsible for the connection of electricity end-users.
  - **Transmission Operators** run the national high voltage (up to 400 kilovolts (kV)) transmission network.
- **National Grid** (the national electricity system operator) ensures that supply and demand in the electricity system are always equal.
- **End-users** from industry, commerce and households consume electricity bought from suppliers and are connected to the distribution network. It is their demand which can be used for DSR.
- **Suppliers** purchase electricity from **generators** to sell to end-users. Some large suppliers in the UK own generation too.
- **Aggregators** co-ordinate end-users offering small amounts of DSR and combine these to offer to National Grid or DNOs. They cover the risk for not delivering DSR, providing security to National Grid and end-users.



*Redistributing Predicted Demand*
Electricity demand varies during the day with peak demand in the evening and lower demand at night (see Figure 1). In 2012/13, the winter peak reached 56 GW (gigawatts). DSR can shift demand away from peak times and decrease the need for back-up generation capacity and electricity network capacity.[2,3] Shifting demand to off-peak times allows plants to be run at full capacity, which is more efficient as it reduces stopping and starting and spreads fixed costs across more of the electricity output.

Currently most DSR used to shift predicted demand comes from three main approaches:
- Incentives are offered to 117,000 large electricity end-users (which make up 50% of UK electricity use) to change their patterns of electricity use.
- Tariffs, such as 'Economy 7', encourage 2 million household customers to shift electricity use to the night, moving 20% of annual household demand from the day.[4]
- Network charges encourage industry, suppliers and aggregators (Box 3) to decrease demand during the winter peaks, as the size of annual peak demand determines the network charges. This leads to a reduction of annual peak demand by 2% (1GW).

*Responding to Unpredicted Supply and Demand Changes*
To maintain the stability of the electricity system, the total electricity supply must match demand for electricity continuously, second by second. However, constant fluctuations in demand and sudden changes in supply (for example, when a power plant breaks down) cause mismatches. To resolve these mismatches National Grid responds by adjusting supply and demand (Box 4).

Currently DSR used to balance unpredicted changes in supply and demand comes from two main sources:
- Industry and commerce, which contribute1.1 GW, with most provided by on-site (usually diesel) generation.
- Households, which contribute 0.25 GW through storage heaters that automatically turn on at night.[4]

*Managing National or Local Network Constraints*
DSR can be used to keep the amount of electricity demand within the limitations of the national and local power grids. If the amount of electricity flowing through the grid is too high it may lead to damage or failures. Transmission and Distribution Network Operators (DNOs, Box 3) can use DSR's temporary demand reductions to prevent these high local electricity flows. Also, if an unexpected failure occurs, DSR can be used to reduce electricity flow in the remaining network capacity to prevent further damage. In the extreme case of a black-out, it can help to restart the system by assisting a synchronised start-up of supply and demand.

## DSR Policy

### The Capacity Market

The capacity market introduced by the 2013 Energy Act aims to ensure that there is sufficient reliable electricity capacity. It will do this by offering payment for commitment to deliver electricity or temporary demand reduction when required. Payments for a set amount of UK capacity will be offered to companies (and their different technologies including electricity storage, generation and possibly demand reduction); they will compete for the payments via auctions. DSR will be eligible for payment from 2015, in contrast to generation, which will receive payment for generating from 2018. This is part of a transitional agreement designed to support the development of DSR and electricity storage. It will include preparatory auctions in which it will be easier for DSR to participate. For example, suppliers of DSR will only be required to provide demand reductions for short periods, such as from 4-8pm.

**Box 4. Current National Grid Reserve Services**
National Grid contracts reserves of demand (it pays end-users for the option of temporarily reducing their demand) and supply. The reserves can be called upon to compensate for unpredicted changes in supply and demand, so they are kept in balance. The reserves differ in their required response time.
- *Short Term Operating Reserve* must be delivered within 20 minutes (or sometimes up to four hours) and sustained for two hours. National Grid typically procures about 2.8 GW of which DSR provides 43%, mostly from on-site generation.
- *Fast Reserve* must be delivered in two minutes and sustained for 15 minutes. National Grid procures 0.8 GW of which DSR contributes 38% at night through automated storage heaters.
- *Frequency Response* must be delivered within 2-30 seconds and maintained for 10-30 minutes. National Grid typically procures 1.2 GW with DSR contributing 8% through turn-down DSR.

### Smart Meter Roll-out and DSR Trials

DECC is due to roll-out smart meters (Box 2) to all UK homes and businesses between 2015 and 2020. The roll-out is expected to enable households to provide DSR because smart meters will increase communication between customers and suppliers. The energy market regulator Ofgem is also currently (2010-15) funding trials, including research on DSR, via the Low Carbon Network Fund. These trials will enable DNOs to gain more experience with DSR. This follows on from supplier trials[5] with 60,000 households, which looked at consumer electricity usage bills (see below). DECC and Ofgem also run the Smart Grid Forum that discusses barriers to DSR.

## Future Development of DSR in the UK

There is potential for more DSR in the UK. Most of the UK's DSR is provided by industrial and commercial consumers. Households only contribute significantly to redistributing predicted demand.

### Potential Areas for Growth

*Turn-down DSR*
Households currently provide relatively little DSR despite making up 50% of Britain's 56 GW winter peak demand. However, the roll-out of smart meters is expected to make households more available for DSR. For example, suppliers and aggregators may encourage household DSR using time-of-use tariffs, partly controlled by smart meters. Trials in the UK show that this could reduce peak demand by up to 10%.[5-6] In addition, future demand from heat pumps (POSTnote 426) and electric vehicles (POSTnote 365)

could provide a significant household demand suitable for DSR. Outside households, a recent study suggests that 4.5 GW of DSR could come from commerce, education and retail, mainly from lighting, heating and air conditioning.

*DSR from On-Site Generation*
Studies have concluded that significant amounts (1 to 20 GW) of unused on-site generation in the industrial and commercial sector could potentially be used for DSR. In addition, an increase of small-scale gas-fired Combined Heat and Power plants could provide additional capacity in the commercial and household sectors.

## Potential Effects of Expanding DSR

*Costs of Electricity System Operation*
Studies suggest that expanding DSR could lead to around a 10% reduction of electricity system costs.[7] The reduction is due to the use of DSR for peak shifting and responding to unpredicted changes. This is less expensive than using large-scale generation, which match the peaks.

Studies also suggest DSR could reduce the need for annual investment in the electricity transmission network capacity by £800m[8] and in peak generation capacity by £266m.[7]

*Carbon Dioxide ($CO_2$) Emissions*
DSR has mixed effects on emissions. It can cut emissions:
- by making current fossil fuelled generation more efficient
- by reducing the use of $CO_2$ intense peak generation
- by reducing curtailment (the wastage of wind energy).

For example, it has been estimated that with more DSR, reduced wind curtailment could reduce $CO_2$ emissions by up to 1.2 megatonnes in 2030 (emissions from energy supply were 192 megatonnes in 2012).[8] However, these studies assume the use of turn-down DSR as opposed to DSR by on-site generation which currently provides most DSR and uses fossil fuels.

*Consumer Electricity Usage and Bills*
Trials have shown that DSR in households, particularly those using smart meter displays combined with time-of-use tariffs, lead to 10-14% of demand being shifted away from peak times.[5] Consumers shifting their use to lower cost times can reduce their bills. DECC has conducted a review of a number of world-wide trials, which shows that most consumers who participate in DSR can lower their electricity bills if they respond to time-of-use tariffs, with reductions from 2-39%. However, prices rise at other times and for those who do not respond bills could rise. The evidence on the responsiveness of vulnerable and low-income consumers, and therefore their bills, is mixed.[5]

## Challenges for DSR

*Encouraging Consumer Participation in DSR*
Ofgem has stated that consumers will need to be engaged to sign up for DSR. However, the interaction of suppliers with household and commercial users is currently limited to billing, while DNOs have little direct interaction. This may lead to difficulty encouraging participation. Trials suggest that relationships between aggregators (Box 3) and end-users are more successful. Furthermore, there is uncertainty about the amount and reliability of consumer demand shifting once customers are signed up for end-user controlled DSR; some may lose interest.

*Data Privacy and Cyber Security*
Although regulation and guidelines are in place, there is concern about automation, data protection and privacy, including misuse for commercial purposes or theft of data. For example some have raised the concern that if household data are accessed, it would be possible to tell when a house is unoccupied. Cyber security (POSTnote 389) concerns include terrorists cutting electricity to users.

*Cost of DSR in Households and Small Businesses*
The initial cost of setting up DSR in households and small businesses often includes an analysis of consumption patterns as well as the installation and operation of communication technology. Currently savings made from DSR do not provide a sufficient financial return on the initial investment in these sectors as the total demand that can be shifted is too small and the installation and operation of DSR is expensive. This may change with the smart meter roll-out and with potentially larger shiftable demand from expected growth in the use of electric vehicles and heat pumps.

*Inefficient Use of DSR*
Some DSR providers are not used as often as they could be. On occasion, contractual conditions stipulate that the same DSR provider cannot be contracted by multiple parties, such as National Grid and a DNO. However, stakeholders, including National Grid, have suggested that it is possible to have both organisations contracting the same DSR provider because their usage patterns differ and would not significantly interfere with each other. These stakeholders are discussing how to optimise the DSR use.

*Lack of Data*
There is a lack of data on DSR for the UK, particularly for household DSR. Experiences outside the UK are only partly applicable, because of the different context in other countries, including factors such as energy demand, the climate, appliances (such as air conditioners) and market structures. In future, the increased use of electric vehicles, heat pumps and wind generation on the network, would change the quantity and type of DSR that would be needed to ensure a stable electricity system.

**Endnotes**

1 DECC, Dec 2012, Smart Metering Implementation Programme - Data access and privacy.
2 Ofgem 2013, Creating the Right Environment for Demand-Side Response.
3 Poyry, Dec 2011, Assessment of DSR Price Signals
4 Sustainability First, 2011, GB Electricity Demand – Context and 2010 Baseline Data.
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7 Redpoint and Element Energy, 2012, Electricity System Analysis – future system benefits from selected DSR scenarios.
8 Strbac G, *et al*, 2012, Strategic Assessment of the Role and Value of Energy Storage Systems in the UK Low Carbon Energy Future.


POST is an office of both Houses of Parliament, charged with providing independent and balanced analysis of policy issues that have a basis in science and technology. POST is grateful to Christoph Mazur for researching this briefing, to the Grantham Institute for Climate Change for funding his parliamentary fellowship, and to all contributors and reviewers. For further information on this subject, please contact the co-author, Dr Aaron Goater. 