**Sustainability *First***

**GB Electricity Demand – *realising the resource***

# Paper 3: What demand side services could household customers offer?

**By Gill Owen, Maria Pooley and Judith Ward.**
**Sustainability First**

**April 2012**

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**Sponsored by** : BEAMA ; British Gas ; Cable & Wireless ; EdF Energy ; Elexon ; E-Meter Strategic Consulting; E.ON UK ; National Grid ; Northern Powergrid ; Ofgem ; ScottishPower Networks ; UK Power Networks.

**Smart Demand Forum Participants** : Sponsor Group ; Energy Intensive Users' Group ; Consumer Focus ; Which? ; National Energy Action ; Brattle Group ; Lower Watts Consulting ; DECC ; Sustainability First.

## Preface

### Sustainability First

Sustainability First is a UK environmental think-tank with a focus on practical policy development in the areas of sustainable energy, waste and water. Sustainability First undertakes research, publishes papers and organises policy seminars. It is a registered charity with independent trustees – www.sustainabilityfirst.org.uk.

Since 2006, Sustainability First has produced a series of major multi-sponsor studies on GB household smart energy meters and brings significant knowledge and insight in the fields of energy efficiency, smart metering, smart energy tariffs and demand response[1].

The Sustainability First project on **GB Electricity Demand** began in April 2011. It is supported in its first year under the Northern Powergrid Low Carbon Network Fund project - and thereafter for a further two years to April 2014 via a multi-sponsor group.

Sponsors include : BEAMA ; British Gas ; Cable & Wireless ; EdF Energy ; Elexon ; E-Meter Strategic Consulting; E.ON UK ; National Grid ; Northern Powergrid ; ScottishPower Networks ; UK Power Networks.

Work is coordinated through a **Smart Demand Forum** whose participants also include a number of key consumer bodies: Energy Intensive Users Group, Which?, Consumer Focus and National Energy Action; plus DECC and Ofgem, and the sponsor group members.

The project aims to identify the potential resource which the electricity demand side could offer into the GB electricity market through demand response and through demand reduction. The project aims to:

- Evaluate and understand the potential GB electricity demand-side resource across all economic sectors (including the role of distributed and micro-generation).
- Develop a clearer understanding of the economic value of this resource to different market actors and to different customers over the next 10-15 years.
- Evaluate the key customer, commercial, regulatory and policy issues and interactions.

[1] Sustainability First published smart meter papers are available on the website – www.sustainabilityfirst.org.uk

The project will develop a substantive knowledge-base, and provide visibility and thought-leadership for GB electricity demand-side issues. The project is undertaking work relevant to:

- GB smart meter deployment.
- Low Carbon Network Fund projects – emerging lessons and insights from the LCNF projects will be fed into the project.
- Proposals for Electricity Market Reform.

The work programme is being delivered through the Smart Demand Forum, through annual wider stakeholder events, and through a series of published papers and other materials. The project is run by Sustainability First. The Sustainability First team is Gill Owen, Judith Ward and Maria Pooley.

Additional expertise and inputs are provided by Serena Hesmondhalgh of Brattle Group who is developing a quantitative all-sector demand model. Stephen Andrews is supporting the project on Distributed Generation and Micro-Generation.

**Key themes for the project include:**

- **Customer Response and Consumer Issues –** A key focus for the project is to understand successful and cost-efficient demand-side participation from a customer and consumer perspective (household, industry, commercial and public sectors). This will include experience provided through the LCNF trials (e.g. tariffs, remote control of appliances, technologies such as micro-generation, electric vehicles etc.) and other similar initiatives in the UK and elsewhere. For households, this will include any particular issues for the fuel poor and potential distributional impacts.
- **Commercial** - Practical realisation of demand-side services - given different roles and requirements in the value chain. Issues likely to include: the nature of commercial agreements, the role of third parties (DNOs, ESCOs, aggregators), the kind of information-sharing likely to be necessary between parties etc. – drawing from practical experiences of the LCNF Trials and other experience in the UK and elsewhere.
- **Regulatory** – near and longer term regulatory factors that impact upon development of an active electricity demand-side for Great Britain – including current agreements between market actors, statutory codes, incentives in price controls, settlement, and third-party requirements. This will include experiences within the LCNF trials, and also feed into future considerations for price controls, RIIO and other thinking on innovation incentives.
- **Public Policy Issues –** likely economic value and potential contribution of the demand side to: cost-efficiency across the electricity sector; security of supply; carbon-emission reductions. Business models, approaches and incentives for integrating the demand side into the electricity market, including its interactions with Electricity Market Reform, smart meter roll-out and energy efficiency schemes such as the CRC Energy Efficiency Mechanism, Green Deal and Energy Company Obligation.

The project will also draw upon relevant information from demand side developments in other countries (notably the EU and US) to inform its work.

Papers in Years 1 and 2 of the project will include:

**Paper 3: What demand side services could household customers offer? April 2012**

**Paper 1:**
**GB Electricity Demand in 2010 - baseline data and context** (October 2011).

**Paper 2:**
**GB Electricity Demand 2010 and 2025 – Initial Brattle Electricity Demand-Side Model: scope for demand reduction and flexible response** (February 2012).

**Paper 3:**
**What demand-side services could GB customers offer?**
(Interim Industry paper – March 2012.
Final paper – Industry & Households. Expected – May 2012).

**Paper 4:**
**What demand-side services can provide value to the electricity sector?**
(expected - August 2012).

**Paper 5:**
**The electricity demand-side and wider policy developments**

**Paper 6:**
**The electricity demand-side and distributed generation**

Future topics in Years 2 and 3 are also likely to include:

- **Evolution of commercial arrangements, alignment of commercial drivers, regulatory incentives and prospective business models for development of a more active electricity demand-side**
- **Electricity demand and consumer issues**
- **Active I&C Customers**
- **Active Household and Micro-business Customers**
- **Longer-Term Demand-Side Innovation and Realisation**

**Sustainability First**
**April 2012**

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# 1. Introduction to household demand paper

There is a need to understand what household customers might be able to offer by way of electricity demand response and demand reduction, on what basis, and the reasons why they might want/not want to participate. In this paper we are therefore aiming to drill down below models to identify:

- **Technical potential of household customers** to provide electricity demand reduction and demand flexibility.
- **Willingness of household customers** to provide electricity demand reduction and demand flexibility.

The key questions to address for the household sector are as follows:

- What appliances –e.g. fridges, heat-pumps etc., customers possess ;
- How customers use appliances (i.e. how many units at what times of day)
- What electricity demand are household customers willing and able to shift or reduce – i.e. which appliances/equipment ?
- What are the times of day that households are willing to be flexible with specific appliances/equipment ?
- What incentives would households require to shift or reduce demand – e.g. what level to set TOU tariffs ?
- Role of automation and customer willingness to accept it.
- What are the barriers to customer willingness to engage in demand reduction or shifting – e.g. time, cost, worry about impact on bills etc.?
- How behaviour can persist or how it can be automated (and in the latter case how far customers will use over-ride).

## 2. Executive summary

In this paper we aim to drill down below models of demand to identify:

- Technical potential of household customers to provide electricity demand reduction and demand flexibility.
- Willingness of household customers to provide electricity demand reduction and demand flexibility.

To do this we have:

- Examined the prevalence and trends in electric heating, hot water heating and appliance usage.
- Examined survey information on customer response to incentives to shift demand.

Some of the key findings of the paper are as follows:

1. There is some scope to shift some electric on peak heating to off peak (this would help to reduce winter, but, clearly, not summer peaks) – around 500,000 households in GB use electric on peak as their main source of heating. But it would require good levels of insulation as well as new heating. Electric on peak heating used as instant supplementary heating is not likely to be shiftable but may be reducible with better insulation. It is not clear how much of the on-peak demand is which of these two types though main source heating is likely to be larger.

2. It is worth noting that the term "on-peak" as used above means all usage outside the night time hours of 11pm-7pm, so not all of this "on peak usage" is in the evening 5-7pm peak. Therefore, it is sensible to examine the scope to reduce or shift at the "peak" and at what might be termed the "shoulder" periods. And clearly "peak" periods can vary for different parts of the electricity value chain (e.g. between DNOs and retailers) (something we will be considering in our Paper 4).

3. Switching to storage heaters for the 500,000 households who use on peak electricity could largely remove electric heating demand from those households in the morning peak period. As far as demand in the evening is concerned, the extent to which demand could be eliminated at the evening peak (5-7pm) would depend upon the efficiency of the heaters, the possibility of the heaters being given a boost in the afternoon and the insulation levels in the property. If any usage of electric on-peak heating could be postponed to later in the evening however, then this could be a very valuable amount of demand response.

4. Electric water heating. Until 2008 it was assumed that electric water heating accounted for 14% of electricity usage in the household sector. This has now been reduced to 6% based on field trial research on water heating, although the trials did not include any homes using electricity to heat hot water (the findings for gas water heating were assumed to apply equally to electricity).

5. Most electric water heating is likely to be off-peak (i.e. 11 pm-7 am) already (either in homes using electric heating or summer time use by those with gas or oil systems). But we don't actually know the proportions that are peak and off-peak (although Brattle have made an estimate for their modelling for us).

6. The scope to shift more households to electric water heating (from gas/oil) and thus create scope for storage may be declining. More households are installing combination boilers (which provide instantaneous hot water) and many who do so are removing their hot water cylinders. (numbers of households in England with hot water cylinders fell from 16.7 million in 1996 to 12.5 million in 2009) This would warrant some further investigation.

7. There is some willingness amongst households to shift some types of electricity demand even for quite modest financial savings- at most this seems to be up to 10% of electricity demand based on current consumption patterns (evidence from EDRP, Ireland and EPRG survey).

8. A key barrier to shifting is the difficulty of linking behaviour to bill impacts. Some participants in Ireland trial significantly over-estimated the savings potential and the consequences if reduction was not achieved, so when confronted with the actual limited impact on bills they lost interest. This is a challenging issue because reduction in peak usage does not necessarily translate into a large reduction in the bill. Another key barrier is the effort required to reduce or shift usage which can override the effect of the price signal.

9. There is also some willingness to sign up to direct control of appliances for small financial benefits (EPRG survey).

10. Appliances where households seem most willing to shift their time of use are washing machines, tumble driers and dishwashers (EPRG survey).

11. There is very limited availability of up to date data on appliance usage at different times of day. However, we consider the following to be a reasonable working assumption at this stage, based on the data and consumer surveys we have analysed. Peak use (AM and PM) is mainly attributable to heating, lighting, cooking, TV and consumer electronics. Evening weekday peak (5-7pm) use of electricity by households would appear to be mainly attributable to heating, lighting and cooking, TV and consumer electronics. Usage of wet appliances (washing machines, dishwashers and tumble dryers) appears to be spread out during the day and at weekends (although dishwashers seem to be used slightly more in the evening peak than other wet appliances); therefore there could be a limited match in the household sector between what contributes to morning and evening peak (i.e. household lighting, TV, consumer electronics and cooking or showers and hair-dryers in the morning) and what households may be willing to shift which appears to be mainly wet appliances.

12. We have some evidence on the factors that will encourage or discourage households from signing up to TOU tariffs or direct control (EDRP/Ireland evidence; Ofgem customer panel).

13. Reduction in overall electricity demand - the impact of appliance standards. Lighting seems likely to continue becoming far more efficient. If it does it will both reduce overall demand and give rise to lower evening and morning peaks. Other appliances like fridges, wet appliances etc. may become more efficient – and so reduce overall demand – but not necessarily reduce evening or morning peaks as much of their usage is probably already at other times of the day. Showers, cooking, TVs / home electronics are used to a significant extent at evening and morning peaks, so increased efficiency of them could contribute to reductions overall and at peaks.

14. Clearly there could be greater potential in the future for shifting, if there is greater use of electric heating with storage and electric vehicles. Some of this demand however, as far as networks and retailers are concerned may materialise as reduced rather than shifted demand. For example, some households with PV who are at home in the daytime are probably shifting demand (notably use of wet appliances) to maximise electricity use during the day when they can use their own self generated electricity, rather than having to import from the network,[2] as it would be taking place "off grid". Some research on households with PV would be useful.

15. As the amount of wind generation on the system increases, high-cost periods may correspond with low-wind periods. In that case household automation and potentially load-limiting may be valuable to enable demand response at low wind periods (particularly if there are new large loads from EVs etc.), although it is worth noting that these periods will not necessarily be the same as the winter evening peak.

[2] Anecdotal evidence from a number of households with PV.

# 3. Available data sources on how households use electricity

## 3.1 Data sources available include:

- Modelled data (from the Market Transformation Programme) on the proportions of electricity used by different types of appliances;
- Modelled data (based on profiles and a sample of 600 households for whom usage is measured) on how much electricity households use at different times of day (Elexon);
- English, Scottish and Welsh Housing Surveys collect data on how many households use electricity for heating and hot water;
- The EDRP trials have collected half hourly data for households involved in the trials who had smart meters (18,000). These data are not yet available, although some analysis based on them has been published (AECOM report) and has been referred to in this paper;
- Energy suppliers have some data from their own trials and surveys, although much of this is commercial information and thus not always publicly available;
- Household attitudes to ToU tariffs, remote control of appliances etc. – e.g. work by Ofgem and a Mori survey.

In producing this paper we have used a number of the sources indicated above plus some data and evidence from other countries as a "sense check" on what is available in GB - notably data from the Ireland smart meter trials and the Smart A **– www.smart-a.org -** European Commission funded project on appliance use.

The following are sources of data which may help to shed more light on household electricity demand but which were not available for this paper.

- A forthcoming joint EST, DECC and DEFRA study 'The Home Electricity Study 2010-11'. The Home Electricity Study 'took detailed measurements of about 90% of the domestic energy use in 240 monitored households across the demographic spectrum. Of these, 60 were monitored for a year. The aim of the study was to provide reliable data on all electrical appliances in the home (including kitchen goods, lighting, computers) – especially products, and consumption patterns that have significant impact on peak electricity demand – to enable more accurate projections of expected future use' [3] ;
- Electricity Association research in the 1990s which although historic may provide some useful insight. These papers were based on household electricity appliance monitoring in several hundred households and thus provide data on how households use different appliances at different times of day. Most of the data are no longer publicly available. We have used some publicly available data[4] from this work in the modeling undertaken for paper 2 of this series of papers;
- There should be useful data on household use of electricity from the LCNF trials over the next couple of years;

[3] Referenced in The Elephant in the Living Room – how our appliances and gadgets are trampling the green dream'. Energy Saving Trust. September 2011. page.7)
[4] See Load Research website.

- Detailed daily demand-profiles should become available from smart meter roll-outs over the next couple of years – although it is not yet clear whether these will provide better information about appliance use.

## 3.2 Further empirical research on households that would be useful

The following are areas that would merit more empirical research.

- The extent to which households with PV are shifting their electricity usage into daytime hours to make use of "free electricity" and/or the extent to which such households have a pre-existing demand pattern that includes a lot of daytime use (this may be the case, for example, if they are retired);
- The extent to which households who are installing combination boilers are removing their hot water cylinders and possible trends in this behaviour.
- The extent to which households with storage heaters have them in most rooms or only in some rooms and what they use in other rooms;
- Economy 7 tariffs – how many households are actually on Economy 7 tariffs (as opposed to the number of households with Economy 7 meters);
- The behaviour of households with Economy 7 – i.e., the extent to which they maximise off peak use;
- Field trials to assess electricity usage by households using electricity for water heating and for on-peak electric heating;
- The value that households place on being able to use as much electricity as they wish, when they wish and the extent of willingness to make trade-offs between this and lower prices.

# 4. Household electricity consumption

## 4.1 Overall consumption

As at September 2011, total annual domestic electricity consumption in the UK was 115.2TWh and the breakdown between Profile classes 1 and 2 is shown below.

**Table 1. GB Non-Half Hourly Domestic Annual Energy Consumptions Recorded (TWh) at Sep 2011**

| GB Non-Half Hourly Domestic Annual Energy Consumption Recorded (TWh) at September 2011 | | |
|---|---|---|
| **Load Profile Class** | **MSIDs**[5] | **Annual Energy (TWh)** |
| **Domestic Customers** | | |
| **LP 1 –** Domestic Unrestricted | 22,240,503 | **86.1** |
| **LP 2 –**Domestic Economy 7 | **5,053,598** | **29.1**<br>Estimated broad split:<br>35% night load (10 TWh) ; 65% day load (19 TWh) |

Source: Elexon

From January 2011, the Ofgem benchmark figure for average household electricity consumption is 3,300kWh pa (median) [6]– unchanged from a 2003 base-line[7]. For households on an off-peak tariff (e.g. Economy 7) the typical consumption figure (total units, day and night) (median) adopted as a benchmark by Ofgem is 5,000 kWh p.a. – down from 6,600 kWh[8] in 2003. The average for those on off-peak tariffs is higher than the average of all households because many more on off-peak tariffs use electricity for heating (e.g. storage heaters).

## 4.2 Household electricity use by time of day

For non half hourly (NHH) metered customers – which includes most households at present apart from those who have had smart meters installed – the data on how electricity consumption varies during the day is, of necessity, estimated. The basis of the estimates is as follows. For each NHH meter, total consumption is recorded between two meter reading dates (or estimates if the meter is not actually read) and then annualised using historical information and the profile relating to that "profile class". Elexon then uses actual data from its sample of half hourly meters in that profile class to produce daily half-hourly load curves for that profile class. For profile class 1 (households with standard – i.e. not Economy 7 – meters) this is a sample of 600 households (see Annex for a more detailed explanation on methodology)

[5] Metering System Identifiers (MSID)
[6] Ofgem. Factsheet 96. Typical domestic energy consumption figures. 18 January 2011. Range - Typical low consumption value : 2,100kWh ; Typical high consumption value : 5,100kWh
[7] A mean consumption figure – and not median consumption - was used as the 2003 baseline.
[8] Mean figure

It is generally observed that peak electricity loads occur in the morning, 7–9 AM, and in the evening, 5–7 PM. [9] Individual household demand at any particular time of day varies widely depending on appliance ownership, usage etc. However, it is assumed that there is "diversity" (statistical averaging) amongst any group of properties connected to the same sub-station, so that average household maximum demand is 1.5 kW (which includes a safety margin). This averaging avoids the costs of over-engineering distribution networks. Household and service cables are designed to take a considerably higher load. A typical kettle is 2-3 kW. A typical power shower may be ~ 10 kW.[10] Other estimates of maximum household demand at any one time include:

- National Grid estimate maximum household demand after diversity in 2010 – range 1.5 -3 kW (range 5-24 kWh/ day per household)[11].
- IHS Global Insight: average residential demand across all 26 million residential customers is around 0.8kW to 1kW at peak times but this hides a wide degree of diversity[12].

The Ofgem DSR paper (July 2010) assumed that around half of total demand from households was at peak, continuing in a long 'tail' into the evening.

## 4.3 Economy 7

- Number of household economy 7 meters – 5 million (Elexon);
- Total number of households with electric storage heating in GB – c. 2 million (English, Scottish and Welsh housing surveys);
- Number of households with an economy 7 tariff – estimate is 3- 3.5 million based on information from some energy suppliers.

There is an often quoted figure of 25.5 TWh (21% of all household units supplied) assumed to be Economy 7 units. However, our research and discussions with Elexon have revealed that this figure is in fact the total number of units supplied to households with Economy 7 meters (i.e. total units supplied to households in Profile class 2). Brattle estimate therefore that the correct figure for night time units supplied to those on an Economy 7 tariff is probably much lower (possibly only one third to one half of the 25.5 TWh total) . It is also worth noting that most of this consumption (other than water heating and appliances) would be seasonal (in the winter heating months). Brattle have also modelled this.

The next three sections examine the three main types of electricity use by households (heating, hot water, appliances), and the split between peak and off-peak use.

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[9] 2010 EPRG Public Opinion Survey: Policy Preferences and Energy Saving Measures EPRG Working Paper 1122 Cambridge Working Paper in Economics 1149 Laura Platchkov, Michael G. Pollitt, David Reiner, Irina Shaorshadze ESRC Electricity Policy Research Group University of Cambridge.

[10] Service fuses are rated at an equivalent of 60 amps - or 100 amps in modern properties - i.e. a maximum load of ~15 kW or ~20 kW respectively . (Source : e-mail communication with a distribution network – October 2011)..

[11] Presentation to Low Carbon London (LCL) Learning Workshop – 17 October 2011.

[12] IHS Global Insight. Demand Side Participation Report for DECC. July 2009. P.37

# 5. Electric space heating

## 5.1 Electricity as primary heating source

Electricity is used as the primary source of space heating by around 10% of households in Great Britain. Most of this is electric storage heating for which all or most of the electricity is consumed at off-peak times. The breakdown within GB is given below.[13]

**Table 2. Primary heating source in Great Britain[14]**

| **Country** | **On-peak electric heating** | **Off-peak (electric storage heating** |
|---|---|---|
| England | 514,000 (2.3% of households in England) (2009) | 1.67 million (2009) |
| Scotland | 27,000 (1% of households in Scotland) (2010) | 300,000 (2010) |
| Wales | 21,000 (1.6% of households in Wales) (2009) | 45,000 (2009) |
| Total | 562,000 (2.4% of households in GB) | 2 million (8% of households in GB) |

## 5.2 Peak and off-peak electricity use for heating

14% (~16 TWh) of all electricity units used by households are used for space heating. The estimated split between peak and off-peak consumption in 2009 was[15] :

- off-peak – 47-55%
- peak - 45-53%

At first glance it seems odd that so much of the electricity used for heating is consumed on-peak, given that 2 million households use storage heating as their primary heat source and only 560,000 use on-peak electricity as their primary heat source. However, it must be noted that on-peak electricity use for heating will come from three groups of people:

- those households for whom on-peak electric heating is their primary heating source;
- households with electric storage heating as their primary heating source but who also make some use of on-peak electric heating – there could be substantial numbers of households who do this depending upon the adequacy of the heating from the storage heaters;

[13] Household numbers in total (2010) Wales – 1.3 million; Scotland – 2.4 million ; England – 22 million Total GB – 26 million

[14] Source of data: English, Scottish and Welsh Housing Surveys for years as indicated in Table.
[15] Based on estimates from DUKES and Elexon and Brattle Group modelling for Paper 2.

- households with other sources (e.g. gas, oil) as their primary heating source who make some use of on-peak electric heating. This may typically be supplementary heating to give instant heat (e.g. where only one person is at home during the day and uses an electric fire to avoid heating the whole house).

Electricity is used as a secondary heating source by 3.3 million households in Great Britain. 2.9 m of these households have gas as their primary heating source.[16]

It is also interesting to note that many households who have electric storage heaters will be using them in conjunction with other forms of heating and it may not always be a whole house solution, in contrast with gas central heating. The energy company Eon undertook a survey of 800 households in 2005 to ascertain the main and secondary heating systems that they were using[17]. 85% of the people with storage heating described it as their main heating system - the comparable figure for those with gas central heating was 97%. Of the households with storage heaters:

- 49% had only storage heaters;
- 31% had storage heaters plus other electric heaters (includes fan heaters, electric fires, etc.);
- 11% had storage heaters plus a gas fire;
- 5% had storage heaters plus a solid fuel fire;
- 4% had storage heaters plus gas central heating.

Current scope to shift peak use of electricity for heating into off –peak periods and/or the scope to reduce on-peak usage without shifting to other times of day will depend upon the type of usage being made of electricity for heating.

- In the case of the 560,000 households using on-peak electricity as their primary heating source, then assuming suitable appliances are available (e.g. if the household can install storage heaters), coupled with good thermal insulation-levels and attractive off-peak tariffs, some (and possibly most) of this could be shifted to off-peak periods;
- Use of electric on-peak heating to supplement storage heating – this is not likely to be shiftable to other times of day but may be capable of some reduction if the efficiency of the storage heating and/or insulation of the property could be improved;
- Use of electric on peak heating to supplement other sources of heating – this is not likely to be shiftable to other times of day but might be capable of some reduction if insulation levels are improved in those properties.

It must be noted however that "on peak" usage of electric heating as described above refers to all usage outside the Economy 7 hours of 11pm-7am. On the assumption that the main concern at present is the evening (5-7pm) and to some extent the morning (7-9am) peaks, not all current "on peak" usage of heating will contribute to these peaks. However, it is likely that

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16 English, Scottish and Welsh Housing Surveys

17 Survey unpublished. Data kindly supplied by Eon for this paper.

usage at the two peak periods will account for a significant proportion of "on peak" electricity usage by heating.

Switching to storage heaters for the 560, 000 households who use on peak electricity could largely remove electric heating demand from those households in the morning peak period. As far as demand in the evening is concerned, the extent to which demand could be eliminated at the evening peak (5-7pm) would depend upon the efficiency of the heaters, the possibility of the heaters being given a boost in the afternoon and the insulation levels in the property. If any usage of electric on-peak heating could be postponed to later in the evening however, then this could be a very valuable amount of demand response.

Growth in electric heating (heat pumps or new generation storage heating) before 2020 seems most likely off the gas grid. Scope in on-gas areas before 2030 is most likely to be in new homes and major refurbishments where high levels of insulation can be built in more cost effectively than into the existing stock. Uptake of electric heating will be highly dependent on the level and duration of RHI / incentives / Green Deal etc.[18]

## 5.3 Distribution of electric heating in England

The tables below show the prevalence of electric heating by income, tenure, household type, property type, property age and property size in England.

**Table 3. Electric storage heating in England– breakdown by income, tenure, and other factors[19]** (Source: EHS Summary statistics 2009- Stock Summary Statistics Tables 6.1 & 6.3)

| **Category** | **Number of households or properties with storage heating** | **% of this type of household or property with electric storage heating** |
|---|---|---|
| **Income quintiles** | | |
| Quintile 1 (lowest) | 324,000 | 7.6% |
| Quintile 2 | 402,000 | 9% |
| Quintile 3 | 334,000 | 7.9% |
| Quintile 4 | 224,000 | 5.5% |
| Quintile 5 | 242,000 | 5.4% |
| **Tenure** | | |
| Owner occupied | 778,000 | 5.2% |
| Private rented | 495,000 | 13.8% |
| Local authority | 157,000 | 8.7% |
| Housing association | 236,000 | 12% |

[18] Sources: Hoggett, R, Ward, J and Mitchell, C. Heat in homes: customer choice on fuel and technologies. University of Exeter, July 2011. IPPR, Heat paper Sept 2011.
[19] Total number of households with electric storage heating in England: 1.67 million

| | | |
|---|---|---|
| **Household type** | | |
| 1 person under 60 | 464,000 | 16% |
| 1 person over 60 | 354,000 | 11.8% |
| Couple under 60 | 183,000 | 4.7% |
| Couple over 60 | 176,000 | 4.9% |
| Couple children | 160,000 | 3.4% |
| Lone parent | 92,000 | 5.5% |
| Multi person | 74,000 | 4.9% |
| **Property type** | | |
| Purpose built low rise flats | 725,000 | 23.9% |
| Purpose built high rise flats | 122,000 | 32.9% |
| Converted flats | 146,700 | 16.3% |
| Bungalow | 162,000 | 7.9% |
| Detached | 53,000 | 1.4% |
| Semi-detached | 177,000 | 3.1% |
| Terraced | 290,000 | 4.5% |
| **Property age** | | |
| Pre-1919 | 302,000 | 6.3% |
| 1919-44 | 106,000 | 2.9% |
| 1945-64 | 220,000 | 4.9% |
| 1965-80 | 412,000 | 8.9% |
| 1981-90 | 275,000 | 13.9% |
| Post 1990 | 355,000 | 13% |
| **Property size** | | |
| Less than $50m^2$ | 601,000 | 24.2% |
| $50\text{-}69m^2$ | 571,000 | 10.6% |
| $70\text{-}89m^2$ | 289,000 | 4.5% |
| $90\text{-}109m^2$ | 117,000 | 3.8% |
| $110m^2$ or more | 88,000 | 1.8% |

**Table 4. On peak electric heating (room heaters) in England[20],[21] – breakdown by income, tenure, and other factors.** (Source: EHS Summary statistics 2009 - Stock Summary Statistics Tables 6.1 & 6.3)

| **Category** | **Number of households or properties with on peak electric heating** | **% of this type of household or property with on peak electric heating** |
|---|---|---|
| **By income quintile** | | |
| Quintile 1 (lowest) | 107,000 | 2.4% |
| Quintile 2 | 117,000 | 2.6% |
| Quintile 3 | 94,000 | 2.2% |
| Quintile 4 | 63,000 | 1.5% |
| Quintile 5 | 37,000 | 0.8% |
| **Tenure** | | |
| Owner occupied | 252,000 | 1.7% |
| Private rented | 189,000 | 5.3% |
| Local authority | 39,000 | 2.2% |
| Housing association | 39,000 | 2% |
| **Household type** | | |
| 1 person under 60 | 145,000 | 4.9% |
| 1 person over 60 | 108,000 | 3.5% |
| Couple under 60 | 68,000 | 1.7% |
| Couple over 60 | 40,000 | 1.1% |
| Couple children | 52,000 | 1.1% |
| Lone parent | 38,000 | 2.2 % |
| Multi person | 32,000 | 1.1% |
| **Property type** | | |
| Purpose built low rise flats | 203,000 | 6.7% |
| Purpose built high rise flats | 63,000 | 17.1% |
| Converted flats | 18,000 | 8.4% |
| Bungalow | 24,000 | 1.2% |
| Detached | 34,000 | 0.5% |
| Semi-detached | 57,000 | 1% |
| Terraced | 140,000 | 2.2% |
| **Property age** | | |
| Pre-1919 | 162,000 | 3.4% |
| 1919-44 | 66,000 | 1.8% |
| 1945-64 | 63,000 | 1.4% |

[20] On peak electric heating figure is calculated by taking the figure for households with electricity as their main fuel type, and subtracting the figure for households with storage heating. Totals for each variable (income, tenure etc) vary as sample sizes in the survey are quite small for some variables and hence have an impact on level of accuracy within variables.

[21] Total number of properties in England with direct electric heating is estimated to be 524,000.

| | | |
|---|---|---|
| 1965-80 | 87,000 | 1.9% |
| 1981-90 | 71,000 | 3.6% |
| Post 1990 | 68,000 | 2.5% |
| **Property size** | | |
| Less than 50m$^2$ | 207,000 | 8.7% |
| 50-69m$^2$ | 149,000 | 2.8% |
| 70-89m$^2$ | 119,000 | 1.9% |
| 90-109m$^2$ | 25,000 | 0.9% |
| 110m$^2$ or more | 36,000 | 0.9% |

Electric heating (storage and on peak) is most common:

- in flats;
- smaller properties (less than 50 square metres – i.e. mostly flats);
- single person households over and under 60;
- the lowest 2 income quintiles.

It is also more common in the owner occupied and private rented sectors than in local authority and housing association properties.

For electric storage heating there also seems to have been a growth in properties built since 1980. This probably reflects the fact that since 1980 there have been lots of small flats built, including for older people and students.

# 6. Hot water heating

## 6.1 Usage of electricity for water heating

Up to and including 2008, the official BRE estimate for the proportion of household electricity usage attributable to water heating was 14%. However, since 2009 this has been reduced to 6%. According to the research contractor who produced the revised estimate for DECC, this was based on new hot water use field trial data from the EST.[22] However, the field trials did not include any households who heat their hot water by electricity. DECC's research contractor confirms that the BRE applied the same reduction in energy use for water heating as was found in households with gas boilers in the trials. DECC's contractor has told us that "there is still some uncertainty about the precise split of space heating and hot water energy use in homes, but I am hopeful we can improve our understanding of this through the Energy Follow-up Survey for the current EHS."[23]

We don't know how much electric water heating is undertaken at night time (there do not appear to be any figures for how much water heating is off-peak and how much on-peak). Households who use electricity to heat their hot water will split into two main types:

- those without gas or oil central heating who therefore use electricity to heat their hot water all year around (this will include most of the households whose primary heat source is electric on peak of off-peak – 2.5 million households in GB);
- those who may use their gas or oil central heating in winter to heat hot water but who use an electric immersion heater in summer. The number of households who do this is not known but it is likely that the numbers are falling, as more households install combination boilers and the numbers of hot water tanks fall.

To the extent that households in these two groups do not currently heat water off-peak there could be scope to push more of this usage into the off-peak periods.

With the increasing take up of combination boilers, the number of dwellings with hot water cylinders has decreased over time – from 16.7 million in 1996 to 15.1 million in 2003 and 12.5 million in 2009 (England data only) [24].

If fewer homes have hot water cylinders then fewer could provide the storage option – and once someone has removed a cylinder they may be reluctant to re-install one due to the space it would take up.

[22] Energy Saving Trust. Measurement of domestic hot water consumption in dwellings. Report for DEFRA, 2008.
[23] E mail correspondence with DECC and Cambridge Architectural Research, January 2012.
[24] English Housing Survey, 2009 http://www.communities.gov.uk/documents/statistics/pdf/1937212.pdf

## 6.2 Distribution of electric water heating

This follows a similar pattern to electric space heating, being more common in flats, smaller properties, single person households and the lower income quintiles. Table 5 below shows the distribution of electric immersion water heating as the main source of water heating across different income, tenure and household types, and by property type, age and size.

**Table 5. Electric immersion water heating in England, as main source of water heating – breakdown by income, tenure, other factors**[25] (Source: EHS Summary statistics 2009 - Stock Summary Statistics Tables 6.1 & 6.3)

| Category | Number of households or properties with electric immersion water heating | % of this type of household or property with electric immersion water heating |
|---|---|---|
| **Income quintiles** | | |
| Quintile 1 (lowest) | 473,776 | 11.1 |
| Quintile 2 | 526,474 | 11.8 |
| Quintile 3 | 461,849 | 10.9 |
| Quintile 4 | 314,173 | 7.7 |
| Quintile 5 | 336,596 | 7.5 |
| **Tenure** | | |
| Owner occupied | 1,157,091 | 7.7 |
| Private rented | 629,473 | 17.5 |
| Local authority | 226,869 | 12.5 |
| Housing association | 271,917 | 13.8 |
| **Household type** | | |
| 1 person under 60 | 610,469 | 20.8 |
| 1 person over 60 | 467,898 | 15.2 |
| Couple under 60 | 293,788 | 7.4 |
| Couple over 60 | 265,858 | 7.4 |
| Couple children | 236,814 | 5.0 |
| Lone parent | 125,874 | 7.5 |
| Multi person | 112,167 | 7.3 |
| **Property type** | | |
| Purpose built low rise flats | 866,384 | 28.5 |
| Purpose built high rise flats | 152,880 | 41.2 |
| Converted flats | 183,289 | 20.4 |
| Bungalow | 183,086 | 8.9 |
| Detached | 96,685 | 2.5 |

[25] Total number of households with electric immersion water heating in England: 2.28 million

| | | |
|---|---|---|
| Semi-detached | 300,922 | 5.3 |
| Terraced | 502,104 | 7.8 |
| **Property age** | | |
| Pre-1919 | 446,377 | 9.3 |
| 1919-44 | 187,917 | 5.1 |
| 1945-64 | 314,576 | 7.0 |
| 1965-80 | 565,428 | 12.2 |
| 1981-90 | 354,723 | 17.9 |
| Post 1990 | 416,329 | 15.2 |
| **Property size** | | |
| Less than 50m$^2$ | 733,564 | 29.5 |
| 50-69m$^2$ | 752,245 | 14.0 |
| 70-89m$^2$ | 471,229 | 7.3 |
| 90-109m$^2$ | 173,794 | 5.6 |
| 110m$^2$ or more | 154,518 | 3.1 |

# 7. Appliance ownership and usage

Key data sources on appliances are:

- Market transformation programme - has information on usage (e.g. how many times per year washing machines are used on average);
- EST report (Elephant in the living room) Information on ownership of appliances;
- Smart –A report. An EU project examining usage of certain electrical appliances in a number of EU countries.

## 7.1 Usage of electricity by household appliances

For appliances what we are aiming to establish are the nature and characteristics of usage, i.e.:

- What is peak-use all year round – e.g. lights, cooking, electronics, TV;
- What is peak and winter use – i.e. mostly lights ; also as above – and also some on-peak heat;
- What is 'during-the-day' use – including in winter - but not necessarily 'peak' e.g., wet appliances, some cooking;
- What is 24-hour use – e.g. refrigeration (and presume in the future – heat pumps);
- What could peak-shift for long periods – e.g. in cold winter anti-cyclonic spells.

Total usage of electricity by appliances continues to increase. This is because improvements in appliance efficiency for white goods and lighting, are off-set by: more and smaller households; higher disposable incomes (pre-2009 and one assumes will recover in due course!); more individual appliance ownership; more types of appliance; (including, small domestic appliances, IT and consumer electronics). The trend to more households (up 16% since 1990) and to smaller households contributes to increased electricity consumption per person, against a generally downward overall energy consumption per household[26].

[26] Owen G & Ward J. 'Smart Tariffs and Household Demand Response for Great Britain'. Sustainability First. March 2010. p.55

**Table 6. Estimated UK Domestic Electrical Appliance End-Use 2009 (minus heating and hot water)**

| **Estimated UK Domestic Electrical Appliance End-Use 2009 (minus heating and hot water)**[27] | | |
|---|---|---|
| **Domestic Electrical Appliance Use** (estimates from MTP Ownership Stock Model based) | **% of domestic electrical appliance load 2009** (estimated) | **TWh pa in 2009** (estimated) |
| **Domestic Wet Appliances** | 17% | 14.2 |
| **Cold Appliances** | 17% | 14.4 |
| **Cooking *of which***<br>Electric ovens - 3.8 TWh<br>Electric hobs - 3.2 TWh<br>Microwaves - 2.4 TWh | 11% | 9.4 |
| **Kettles** | 5% | 4.2 |
| **All Consumer Electronics**<br>*Includes*<br>TVs - 8.3 TWh<br>Power Supply Units - 3.6 TWh<br>Videos DVDs - 3.1 TWh<br>Games Consoles - 0.6 TWh | 24% | 20.8 |
| **Lighting** | 19% | 15.8 |
| **PCs / Domestic ICT**<br>*Includes*<br>PCs - 3.9 TWh<br>Laptops - 0.7 TWh<br>Monitors - 1.5 TWh<br>Imaging - 0.4 TWh | 7% | 6.5 |
| **TOTAL** – Estimated UK domestic Electrical Appliance End-Use - **Minus heating and hot water 2009** | 100% | 85.3 TWh per annum |
| Domestic heating and hot water electricity consumption 2009 - estimated at 32.8 TWh[28]. | | |

Source: Sustainability First. Paper 1. GB Electricity Demand – Context and 2010 Baseline Data. October 2011

## 7.2 Usage of selected appliances

The information that follows is taken from the Smart-A Project report.[29] This was a European Commission funded project to examine how domestic appliances could contribute to load management. The table below summarise some key information on washing machines,

[27] Owen G & Ward J 'Smart Tariffs and Household Demand Response for Great Britain'. Sustainability First. March 2010 p.82
[28] 25.5 TWh off-peak units supplied for domestic use in 2010. DUKES. P.139. Table 5.3. July 2011.
[29] Synergy potential of smart appliances. A report prepared as part of the EIE (Intelligent Energy Europe) project "Smart domestic appliances in sustainable energy systems (Smart-A)". University of Bonn, 2008.

tumble dryers and dishwashers whilst sections below provide more information on these and some other appliances.[30]

**Table 7. Wet appliance ownership and usage** (Source: Smart-A report)

| **Appliance** | **Penetration (UK)** | **Average energy consump. (EU)** | **Wash temperatures (UK) % of all wash cycles** | **Start /delay % with (UK)** | **Usage of start delay feature (UK)** | **Time of day usage (EU)** |
|---|---|---|---|---|---|---|
| Washing machine | 95% | 150 kWh per annum | <30C – 14%<br>40C – 58%<br>50C – 12%<br>60C – 13%<br>90C – 3%<br><br>average nominal temp – 44.6C | 31% | Most times – 16%<br>1 p/wk – 15%<br>1 p/month – 15%<br>never – 54% | Main usage is 6-10 AM; 2-6pm & 6-10 pm<br><br>More than 50% never use at night (10pm- 6 am) |
| Tumble dryer | 53% | 251 kWh per annum | N/A | 32% (EU figure) | No data but assumed to be more limited than for washing machines, as drying usually done straight after washing. | Mainly morning and evening (2 hours after washing cycle starts). Low usage at night. |
| Dishwasher | 28% | 241 kWh per annum | 35/45C – 20%<br>50/55C – 30%<br>65C – 38%<br>70C – 12%<br><br>average nominal temperature – 58.6C | 32% | Most times – 26%<br>1 p/wk – 10%<br>1 p/month – 4%<br>never – 60% | Mainly 6-10 pm<br><br>36% use often or always at night<br><br>45% never use at night |

[30] Some data are country specific, whilst others are EU-wide. Data are from a range of years depending upon availability – most data are from 2003-2005.

## 7.3 Washing machines

As Table 7 shows, most UK households have a washing machine and most washing (58%) is done at 40C. The UK has the highest proportion of washes done at 40C and one of the lowest proportions of low temperature and cold washes (Germany, Italy, France and Spain all do significantly more washing at 30C or below). The average washing temperature for most countries in the study is between 43-50C, the one notable exception being Spain where it is significantly lower at 33C. This may suggest therefore that there could considerable scope to reduce UK energy use from washing machines by reducing wash temperatures – a 30C wash uses only 60% of the energy used by a 40C wash.[31] Cold washing would reduce energy use even further (40% of all washes in Spain are cold washes).

Around 31% of UK households have a start delay function on their washing machine, but more than half never use it and only 16% use it regularly for most washes. So there could be scope to use this function more to shift washing times. At the EU level (unfortunately the report does not have separate data for the UK) there is significant use at morning and evening peak times and more than 50% of households never use the washing machine at night. Assuming these data are reasonably representative for the UK this would suggest some potential for shifting using start delay function.

It is interesting to note that the start delay function is more common in some other EU countries – over 40% in France and 37% in Sweden. Assuming more machines have this function in future the scope for shifting could increase.

## 7.4 Tumble dryers

According to the Smart-A report around 53% of UK households have tumble dryers. The EST estimate that 45% of UK have them but that a further 15% have washer dryers thus giving a total of 58%.[32] The Smart-A study also found that tumble drying is done more often in winter than summer – 24% of consumers from 10 EU countries said they always or often used their tumble dryer in winter compared to 11% in summer.

The Smart-A report found that consumers mostly use their tumble dryers straight after washing with very limited use made of start delay function even though 32% of machines have this function. This would suggest there could be scope for shifting here.

## 7.5 Dishwashers

According to the Smart-A report around 28% of UK households have dishwashers (EST also estimate that 28% have dishwashers[33]). Dishwashing is mainly done in the evening (between 6-10 pm) thus suggesting that there is load at the evening peak period that would be worth shifting. 36% often or always use dishwashers at night, but 45% never do, again suggesting some scope for shifting to off-peak periods.

[31] Source : Which ? web site.
[32] The elephant in the living room. Energy Saving Trust, 2011 http://www.energysavingtrust.org.uk/Publications2/Corporate/Research-and-insights/The-elephant-in-the-living-room
[33] The elephant in the living room. Energy Saving Trust, 2011

32% of dishwashers have a start delay function but 60% of those with it never use it, again suggesting some scope for changes in usage patterns. Interestingly, in Italy and France over 50% of dishwashers have this function, and usage of it is much more common (this may be related to the use of tariffs to incentivise off-peak use in those countries, although this has not been checked).

# 8. Potentially shiftable load

For the modelling in their 2010 DSR report, Ofgem assumed 5-15% peak-shift[34] potential in the household sector: Sustainability First in its 2010 report[35] estimated that around one-fifth to one-quarter of household electrical load today could be discretionary or potentially price-responsive (excluding heating and most direct water-heating). National Grid have modelled domestic appliance-use (wet appliances, refrigeration, ovens) by time-periods throughout the day. They estimate that ~4 GW in total of domestic wet appliances and refrigeration may operate between 16.00h to 20.00h and, of this, they assume that 200 MW (i.e. 5% of the total demand in that 4-hour window) could be discretionary[36].

There is very limited availability of up to date data on appliance usage at different times of day. However, we consider the following to be a reasonable working assumption at this stage, based on the data and consumer surveys we have analysed). Peak use (AM and PM) is mainly attributable to heating, lighting, cooking, TV and consumer electronics. Evening weekday peak (5-7pm) use of electricity by households would appear to be mainly attributable to heating, lighting and cooking, TV and consumer electronics. Usage of wet appliances (washing machines, dishwashers and tumble dryers) appears to be spread out during the day and at weekends (although dishwashers seem to be used slightly more in the evening peak than other wet appliances) ; therefore there could be a limited match in the household sector between what contributes to morning and evening peak (i.e. household lighting, TV, consumer electronics and cooking or showers and hair-dryers in the morning) and what households may be willing to shift which appears to be mainly wet appliances.

There is also the question of the contribution that more efficient appliances could make to overall demand reduction and shifting demand between different times of day.

- Lighting: greater efficiency will reduce demand overall and could also lower morning & evening peaks in the winter;
- Wet appliances– will reduce overall demand. Reductions in peak demand - National Grid estimate 5% of household load could be shifted from a 4 hour evening period (4-8pm) via shifting wet appliances (200MW)[37];
- Cold appliances – will reduce overall demand. Automation of cold appliance demand response could provide useful instantaneous short term demand reduction if large numbers were aggregated;
- Consumer electronics – improved efficiency likely to help reduce evening peaks – winter and summer – (assume little seasonal difference).

It is worth thinking also about the differences between summer and winter, as the work by Brattle explores in Paper 2. If the most pressing problem to be solved is to shift winter

[34] Based on IHS Global Insight. Report for DECC.'Demand Side Participation'. 2009.
[35] Owen G and Ward J. 'Smart Tariffs and Household Demand Response for Great Britain'. March 2010. p.58
[36] National Grid. Operating the Electricity Transmission Networks in 2020 (Update). June 2011. Table 12. Potential Demand Response from Domestic Appliances (MW) p.89
[37] National Grid. Operating the Electricity Transmission Networks in 2020 (Update). June 2011. Table 12. Potential Demand Response from Domestic Appliances (MW) p.89

evening peak load – which largely results from household lighting, cooking, TV and consumer electronics – then those are the end-uses which may need a policy or regulatory focus.

# 9. Household demand response and reduction

This section of the paper examines two main types of evidence on the extent to which households are currently willing to reduce or shift electricity demand. These are:

- Field trials of interventions (technologies and incentives such as tariffs). These trials also include some evidence on consumer attitudes;
- Surveys of consumer attitudes and willingness to respond to incentives.

## 9.1 Field trials

The main sources examined are:

- **GB Energy Demand Research Project –** limited findings, but suggests an electricity peak-load reduction in response to a time-of-use tariff of 7- 9% and an overall electricity demand reduction of 2-4 % with concerted advice;
- **Ireland Smart Meter Trial –** findings for households on time-of-use tariffs with customer-stimuli were an 8.8% reduction at peak (and a 2.5% demand reduction). Existing off-peak customers were excluded from the trial. It should be noted that there is more electric water heating in Ireland than in GB.

## 9.2 GB Energy Demand Research Project

EDRP was a major project in Great Britain to test consumers' responses to different forms of information about their energy use. Four energy suppliers each conducted trials of various interventions (individually or in combination) between 2007 and 2010. The interventions were primarily directed at reducing domestic energy consumption, with a minority focused on shifting energy use from periods of peak demand. The project involved over 60,000 households, including 18,000 with smart meters. Measures were generally applied at household level but one supplier also tested action at community level. The findings outlined here are taken from an analysis by AECOM for DECC.[38]

Two trials (EDF and SSE) tested time-of-use (TOU) tariffs for electricity in combination with smart meters and other interventions (advice, historic and real-time feedback, and incentives to reduce overall consumption). These trials showed effects on shifting load from the peak period of 7-9%, with bigger shifts at weekends than on weekdays. In the EDF trial the effect was stronger with smaller households (1 or 2 people). There was no convincing evidence of an overall reduction in demand as a result of ToU tariffs in the EDRP trials.

Neither of the TOU tariff trials involved any automation of energy-consuming appliances to facilitate load shifting. No data were gathered during the trials to provide evidence on what appliances or behaviours were responsible for the observed shifting.

[38] Energy Demand Research Project. Final Analysis. Gary Raw & colleagues. AECOM for DECC. June 2011.

A second full year of in-trial data was not available for the EDF TOUT group. However, based on the data available, the initial effect on overall consumption was eroded over the first few quarters. In the SSE trial, there were no initial effects and the time-course beyond the first year could not be tested. Similarly, the persistence of load shifting could not be examined.

### 9.2.1 TOU trial - EDF

The trial found that in general peak electricity use is around 4% higher for each extra person in a household, aged 16-64 and under 16, above two people. There was no significant effect on peak usage of the number of people aged 65 and over, ACORN code or whether the household has a heating programmer. Although no explanation is given for the extra use based on number of people, it arises presumably at least partly because in non pensioner households the occupants are more likely to be in different rooms using appliances (e.g. multiple TVs, computers etc.) as well as there being more people using hot water for showers etc.

The type of heating used makes a difference to the proportion of consumption in the peak period. Those that have paraffin/oil heaters or no recorded heating have a larger proportion of their consumption in the peak period than households heated by gas or electricity. Those households with electric storage heaters have a smaller proportion of their consumption in the peak period than those heated by gas (this finding is also supported by data used for modeling by Brattle).

EDF found a small but significant difference in electricity consumption between the time of use tariff (TOUT) trial group and the control group, not accounting for baseline consumption. Comparing with baseline, there was a large reduction in energy use but it was not statistically significant because the sample size was too small for households where both in-trial and pretrial data were available. The effect on overall consumption is therefore unproven but plausible.

Overall, EDF found that differences in energy consumption between trial and control groups were more clear-cut for smaller households (one or two people). Comparing households on the TOUT with the control group, peak load was reduced in the TOUT group only by smaller households (people aged 16-64) – for larger households, relative peak time consumption actually increased. At weekends, there was a significant overall reduction in the percentage of consumption that occurred in the peak tariff period. On weekdays less load was shifted from the peak.

### 9.2.2 TOU trial – SSE

SSE's incentive to shift intervention was based on electricity tariffs varying with time of day, season and day of the week (weekday versus weekend). Consumption was higher at night in the high season for customers on the "Shift" incentive (for electricity). The percentage shift from peak to night electricity usage is estimated as 8.5-10%, based on peak season consumption at night (overall shift from peak is not estimated). AECOM's analysis confirmed that the percentage of consumption that falls in the peak period is reduced by the incentive to shift but by only a small amount – from 19.8% to 19.5% on weekdays and from 19.4% to 18.9% at weekends.

SSE's "incentive to shift" consumption from the peak period had no overall effect on electricity or gas consumption.

### 9.2.3 Willingness to take part

EDF recruited from its customer base in London and the southeast of England. At first, the recruitment agency sought to persuade households to join the trial with a pro-environmental message but this was not successful so, after the first month, they adopted a four stage approach, promoting the benefits as: saving money; accurate bills; saving energy; and saving carbon. Some specific issues raised:

- The variable tariff trial group was difficult to recruit to because customers did not understand the principle of load-shifting and did not believe that the company would want to help them save money. EDF had to provide the recruitment agency with a special training session specifically on this intervention;
- Across all groups, recruitment was easier in the south-east because people were at home more often when the agency called;
- EDF required its smart meter customers to sign a set of terms and conditions before installation. This was presented as a legal document, leading to an initial 90% fallout rate between recruitment and installation. The terms and conditions were revised in line with customer comments and were subsequently only ostensibly responsible for a fraction of the fallout rate. However, EDF expects that many more of its customer cancellations were due to the terms and conditions though customers did not explicitly said they would not sign them. EDF also noted that the terms and conditions were quite manually intensive in terms of managing, answering customer queries and chasing customers to return;
- Practical issues raised as concerns by some customers included: the time taken to install equipment (i.e. how long installers were in their homes); and the amount of equipment installed.

SSE used its national customer base as its sampling frame. An initial 1.4 million customers were selected as potential candidates on the basis of (a) having single rate electricity tariffs and (b) having good consumption records (4 actual reads over the past 2 years).

The initial recruitment rates were between 3% and 10%. A sample of customers who had received letters was telephoned to identify their reasons for not responding. The recruitment survey was identified as a key reason for refusal due to the length and complexity of the questionnaire and the income question. "A very large number" of customers also said they were simply not interested. Various changes were made to address these problems:

- Withdrawing the recruitment questionnaire;
- The addition of a two-week deadline in a revised letter for prospective trialists;
- Systematically following up letters with telephone calls;
- Latterly, accepting a telephone rather than written statement of commitment from customers.

### 9.2.4 Experiential findings

EDF reports the following key points about motivation to change consumption:

- Although the trials have prompted some behavioural change, some respondents were happy to benefit from no more meter readers or estimated bills and nothing else;
- Positive attitude and intentions were not always translated into less consumption or lower expenditure;
- Core triggers to uptake are emerging: *cost* savings, desire for *control* and less *hassle*;
- Customers expected, and could have benefited from, more engagement and instruction during installation of equipment;
- Core triggers to motivation emerging: *cost* savings, desire for *control* and less *hassle*. The cost savings motivation is most directly met by TOUT. The immediacy of feedback in TOUT was preferred to retrospective information in the Web, TV and Paper groups.

SSE findings:

- While 72% of those in the "Incentive to reduce" groups were aware of the incentive; 37% of them never met the target and a further 9% did not know whether they had ever met the target (46% in total). The target may have been too challenging (or progress too difficult to monitor) to have any effect;
- 83% of those in the "Incentive to shift" groups are aware of the incentive, although only 75% were aware and had some understanding of how it worked. Of those who were aware, 40% thought they had shifted consumption and made savings, 33% that they had shifted but without making savings and 28% that they had not shifted consumption;
- The TOUT was generally perceived as complex and this may be worse when it is combined with the incentive to reduce because cost saving is confused with energy saving;
- Customers who had been in neither incentive group were asked "How much cheaper than the peak daytime tariff would the night tariff have to be to encourage you to move some of your consumption?" Group average figures ranged from 19-32% (the mean of the group averages was 25%).

## 9.3 Ireland customer behaviour trials [39]

### 9.3.1 Trial outline

The overall objective of the Irish Customer Behaviour Trials was to ascertain the potential for mart metering technology, when combined with time of use tariffs and different DSM stimuli, to effect measurable change in consumer behaviour in terms of reductions in peak demand and overall electricity use.
The Residential Customer Behaviour Trial included the additional objective of seeking to identify a "Tipping Point", that is a point at which the price of electricity will significantly change usage.

Usage was monitored (using smart meters) for one year before TOU and other stimuli were introduced and then for the test group for a further year to see what impact the TOU and stimuli had. A control group (no TOU or stimuli) also had a further year's monitoring.

There were 5,028 households in the trial – selected to be representative of the population. There was also a trial with SME customers.

The time-of-use structure (time bands) was based on system demand peaks and thus contained three bands:

- Day rate –8am-5pm and 7pm-11pm (plus 5-7pm on weekends);
- Night rate – 11pm-8am;
- Peak rate – 5pm-7pm (weekdays only).

The trial used four specific time of use tariffs A, B, C and D offering different unit prices for the night time, day time and peak times, in combination with specific DSM initiatives, which included:

- bi-monthly electricity bill with detailed energy statement;
- monthly electricity bill with detailed energy statement;
- electricity monitor;
- an Overall Load Reduction (OLR) incentive.

Participants also received supporting information - a fridge magnet and sticker. The fridge magnet outlined the different time bands and cost per band, customized for each tariff group. The sticker provided details of the time bands. The tariff rates are given in Table 8 below.

[39] Commission for Energy Regulation. Electricity Smart Metering Customer Behaviour Trials Findings Report CER/11/080a. May 2011

**Table 8. Residential Time-of-Use tariffs 1st January to 31st December 2010** (Source: Electricity Smart Metering Customer Behaviour Trials Findings Report CER/11/080a)

| | **Cents/ kwh** | **Night** | **Day** | **Peak** |
|---|---|---|---|---|
| Tariff A | Cents/ kwh | 12.00 | 14.00 | 20.00 |
| Tariff B | Cents/ kwh | 11.00 | 13.50 | 26.00 |
| Tariff C | Cents/ kwh | 10.00 | 13.00 | 32.00 |
| Tariff D | Cents/ kwh | 9.00 | 12.50 | 38.00 |

### 9.3.2 Trial Findings

Response to tariffs and DSM stimuli:

- ToU tariffs and DSM stimuli reduced overall electricity usage by 2.5% and peak usage by 8.8%;
- the combination of bi-monthly bill, energy usage statement and electricity monitor was more effective than other DSM stimuli in reducing peak usage with a peak shift of 11.3%;
- analysis of the load distribution suggests shifting of load from peak to the post-peak period and in general to night usage from peak;
- of the tariff groups tested, no single one in combination with DSM stimuli stands out as being more effective than the others;
- the peak and overall load reductions detected for most of the stimuli tested proved to be statistically significant;
- the Trial provides no evidence of a tipping point, with demand for peak usage estimated as being highly inelastic relative to price.

Demographic, behavioural and experiential conclusions:

- Participants adapted usage to reduce their bills. 82% of participants made some change to the way they use electricity due to the trial, with 74% stating major changes were made.
- Simple information can be effective: The fridge magnet and stickers achieved 80% recall with 75% finding the magnet useful and 63% finding the sticker useful.
- The electricity monitor (RTD) was deemed to be effective as a support to those achieving peak reduction (91% rated it as important) and shifting to night rates (87% deemed it important).
- The detected benefits of the Trial were behaviour changes in response to the price signals and DSM stimuli applied. No secondary benefits were identified in increased awareness of general energy efficiency or investment in energy efficiency in the home.
- The Trial succeeded in making participants more aware of energy usage (54% agreed) which is in keeping with the reduction in usage recorded. Only 18% stated that there had been no impact on the way their household uses electricity.
- Households with higher consumption tended to achieve greater reductions in overall energy usage.
- Households headed by individuals with greater educational achievement or social grade also achieved higher levels of reduction (and hence higher bill savings) than those with lower levels. However, this was in part related to the higher level of usage associated with these households, so the impact of education or social grade per se appears more limited.

It is concluded that a combination of education and social grade contributes to the overall level of usage reduction. While efforts were made in the communications strategy to be inclusive, the difference may reflect more fundamental barriers to engagement among those with lower levels of educational achievement and those in lower social grades.

- Recipients of the Free Electricity Allowance (low income households) reduced peak usage by a lower amount than the average for all households in the trial (5.3% compared to 7.6%).
- Where participants stated that they could not keep their home adequately warm, two questions were used to define Fuel Poor: First definition: "I cannot afford to have the house as warm as I would like" Second definition: "Have you had to go without heating during the last 12 months through lack of money". Of those households identified as fuel poor on this basis, reductions in peak consumption were similar to the average of all participants in the trial although their overall level of consumption did not change.

Barriers to peak reduction include the difficulty of linking behaviour to bill impacts. Many participants significantly over-estimated the savings and the consequences if reduction is not achieved, so when confronted with the actual limited impact on bills they can lose interest. Barriers to shifting to night usage relate to safety and convenience. Another barrier is the effort required to reduce or shift usage which can override the effect of the price signal. Among participants who had successfully reduced or shifted usage, 25% found it difficult to shift peak usage, while 14% found it hard to shift usage to night-time.

The tables below show the main reasons given by participants who had not succeeded in reducing peak or overall usage. In the case of peak reduction, the lack of a significant impact on the bill was identified by 59% of those who had not reduced usage. As noted above, this is a challenging issue because reduction in peak usage does not necessarily translate into a large reduction in the bill.

**Table 9. Reasons for not reducing peak demand** (Source: Electricity Smart Metering Customer Behaviour Trials Findings Report CER/11/080a)

| Reasons for not reducing peak | Agree | Disagree |
|---|---|---|
| We did not know enough about how and when we use electricity to reduce our usage during peak hours | 29% | 55% |
| The difference between the peak price and the other prices was not enough to get me [us] to move my [our] usage | 28% | 53% |
| We tried to reduce but the bill seemed to be the same so we gave up | 59% | 21% |

**Table 10. Reasons for not switching to night usage** (Source: Electricity CBT Findings Report (CER/11/080a))

Electricity CBT Findings Report (CER/11/080a) Residential User Trial

In the case of switching to additional night usage, concerns about convenience (53% agree) and safety (53% agree) act as barriers.

| Reasons for not switching to night usage | Agree | Disagree |
|---|---|---|
| It was too inconvenient to move usage to night time | 53% | 36% |
| We did not know enough about how and when we use electricity to move usage to night-time | 24% | 59% |
| I was concerned about the safety implications of using appliances at night-time | 53% | 38% |
| I was concerned about the noise associated with using appliances at night-time | 31% | 59% |
| The difference between the night time price and the other prices was not enough to move usage | 25% | 55% |
| We tried to reduce but the bill seemed to be the same so we gave up | 15% | 67% |

**Table 34: Reasons for not switching to night usage**

**7.8 Participant attitudinal and behavioural impact**

There is no published information from the Irish trials on what appliances or what behaviours led to the switching or reduction

Three separate impacts on customer bills were assessed. It should be noted that the tariffs were designed to be cost neutral over all customers in the trial (ie.no overall extra costs to customers or extra revenue to the supplier), therefore inherent in that structure is the expectation that impacts would be modest.

- **Measure 1 Reduction in the bill associated with the reduction in usage**: This compares the bill based on actual usage during the Trial using the tested tariff, with the bill based on usage if no reduction was achieved using the tested tariff;
- **Measure 2 Impact on the bill of participation in the Trial**: The comparison between the bill, based on actual usage and the tested tariff and a bill if no reduction was achieved and using the cost of electricity at the start of the Trial (i.e. if the participant had not been part of the Trial) The Measure 2 figures therefore produce lower savings than Measure 1, reflecting the impact of the Time of Use tariff on the cost of peak usage;
- **Measure 3 The impact of the tariff on the bill**: The comparison between the bill size with the tested tariff compared with the bill calculated using the same usage and the cost of electricity at the start of the Trial.

**Table 11. Impact on participant bills using different measures of impact** (Source: Electricity Smart Metering Customer Behaviour Trials Findings Report CER/11/080a)

| Average annual saving | Tariff A | Tariff B | Tariff C | Tariff D |
|---|---|---|---|---|
| Measure 1 | €19.06 | €26.08 | €18.76 | €25.47 |
| Measure 2 | €18.22 | €22.81 | €17.75 | €21.62 |
| Measure 3 | €0.67 | €1.11 | €5.61 | €6.79 |

Households in lower socio economic grades tended to achieve slightly lower bill reductions than those in higher socio economic grades.

However, as the figure below demonstrates, whilst most participants were clustered around this level of a small impact on the bill of the TOU tariff on its own (without behaviour change) there were some participants who experienced much more substantial impacts on their bills (negative and positive).

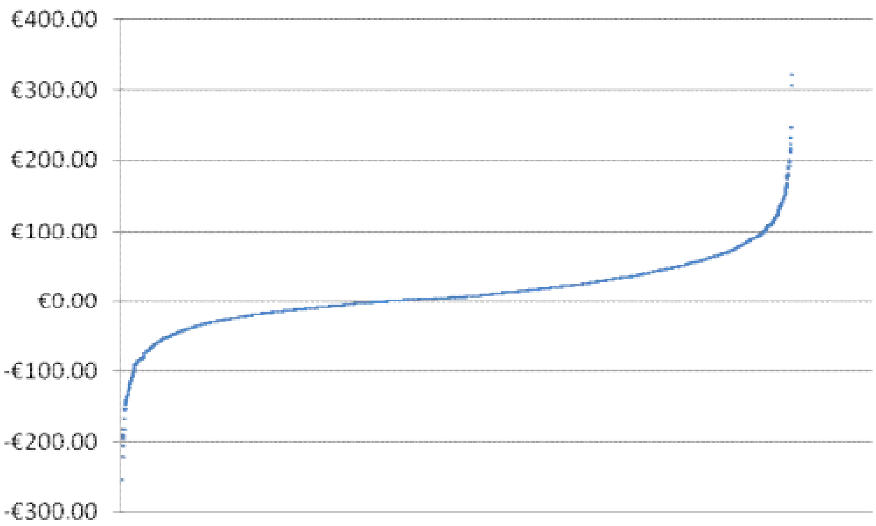


**Figure 1 Financial impact of the introduction of time of use tariffs across the trial participants** (Source: Electricity Smart Metering Customer Behaviour Trials Findings Report CER/11/080a)

## 9.4 Customer attitudes to demand response and reduction

Customer surveys, focus groups and other methods can be used to ascertain consumer receptiveness to interventions such as time of use tariffs, load control and soon. However, such responses need to be viewed with some caution – what customers say they might be willing to do can be very different from how they would actually respond when faced with a real choice.

### 9.4.1 EPRG 2010 Survey

The EPRG Public Opinion survey of 2010 inquired about the willingness of respondents to shift appliance usage as a response to ToU tariffs.[40] It also asked about their willingness to accept four hypothetical load-shifting scenarios through smart appliances in exchange for discounts on the total electricity bill.

Respondents were asked which appliances they were using between 7–9 PM. It then presented the hypothetical scenario that the electricity provider would offer a discount for consuming electricity after 9 PM (ToU tariff) and asked them which of the activities they would they be willing to delay until after 9 PM. The key findings were as follows:

- Over half of the respondents using dishwashers and washing machines between 7–9 PM would shift their usage to after 9 PM if electricity were cheaper at that time. However, only a quarter of the respondents were currently using their washing machines between 7–9 PM, and only 18% of respondents indicated that they used their dishwashers 7–9 PM;
- The activity that over 90% of respondents engage in between 7 and 9 PM is watching TV, and almost half of the respondents cook at these times. Less than 20% of those individuals who cook or watch TV from 7–9 PM, would willingly postpone these activities till after 9 PM;
- Overall, respondents are least flexible to change their cooking habits in response to the incentives of a lower tariff;
- In terms of the number of respondents stating they would delay usage of the appliances listed, the TV and washing machine are the highest contributors to load-shifting, while the dishwasher is the least.

The EPRG survey of 2010 also aimed to assess the potential of load shifting through smart appliances. The survey presented four hypothetical scenarios of load shifting using smart appliances and dynamic supplier intervention (see Table 12 below). The respondents were first asked if they would accept each of these four scenarios if they received a 5% discount on their total electricity bill. If they did agree, they were asked if they would be willing to accept a 2% discount, and if yes, then if they would be willing to change for a 1% discount. If respondents did not accept the 5% discount, they were offered a 10% discount, and if they still refused, were finally offered a 20% discount.

[40] 2010 EPRG Public Opinion Survey: Policy Preferences and Energy Saving Measures EPRG Working Paper 1122 Cambridge Working Paper in Economics 1149 Laura Platchkov, Michael G. Pollitt, David Reiner, Irina Shaorshadze ESRC Electricity Policy Research Group University of Cambridge

**Table 12. Hypothetical Load-Shifting Scenarios through Smart Appliances** (Source: EPRD Public Opinion Survey – EPRG Working Paper 2010)

| **Appliance Usage Modification Scenario** | **Description** |
|---|---|
| Run wet appliances longer | Having wet appliances (dishwasher, washing machine,<br>tumble dryer) run for longer periods of time |
| Interrupt white appliances | Having white appliances (refrigerators, freezers) interrupt<br>for 1- to 3-minute intervals |
| Preset wet appliances | Having wet appliances (dishwasher, washing machine,<br>tumble dryer) preset to operate only after 9 PM |
| Limited use of cooker | Having usage of cooker/oven capped, so household<br>would not be able to use it for 30-minute intervals more<br>than 15 times per year during peak demand spikes. |

Respondents claim to be willing to accept the proposed changes even for small discounts.

- Over 16% of respondents would agree to have wet appliances run longer in exchange for a mere 1% off the total electricity bill;
- Over 17% of respondent would agree to preset wet appliances to be used after 9 PM for 1% off the electricity bill;
- Over 20% of respondents would agree to having white appliances being interrupted in exchange of only 1% reduction of the electricity bill;
- There was no significant difference between consumer acceptance rates of extending appliance cycles, interrupting white appliances, and presetting wet appliances;
- By contrast, a cap on energy use of a cooker has lower acceptance rates: around 11% of respondents would agree to limited use of cookers for a 1% discount.

Acceptance of appliance usage modification in exchange for a discount did not vary by respondents' subjective perceptions of whether they were experiencing hardship. There was no significant difference in acceptance rates by household per capita income. Similarly, there was no significant difference in acceptance rates between the average and those with a degree level of education. Respondents who mentioned environment as one of the top three areas requiring urgent policy attention, had significantly higher acceptance rates for having wet appliances run longer and not being able to use cookers for a 2% discount compared to acceptance rates for all respondents combined. They are also more likely to accept having white appliances interrupted for 1% and 2% discounts. Men have higher acceptance rates than women. Younger respondents are more likely to accept having limited access to cookers, but they are less likely to accept having white appliances interrupted.

### 9.4.2 Ofgem Consumer First Panel

Ofgem's Consumer First Panel (a group of 100 domestic energy consumers recruited to take part in a series of research events and surveys) provided views on different forms of tariffs in 2009.[41]

A small proportion of the Panel felt there should be no choice of tariff as it would make bills more complicated and make it even harder to compare different suppliers. The majority disagreed with this view, but new tariffs would mainly be judged beneficial if they helped save the consumer money and provided choice, rather than for their impact on energy use. Most agree that tariffs need to be simple (easy to understand), have a consistent format and structure (across suppliers) and be relevant to their usage patterns. It was suggested that tariffs should be structured to reward customers who are energy efficient. Many voiced concern that some types of tariffs could penalise some high users who cannot easily reduce consumption, such as those with a big family but a low income and those with medical conditions that require equipment. There is also concern about tariffs that penalise low users who may be single person households and elderly people. Most Panel members did not know if they are a high or low user, but assumed they are the latter, and so assessed tariff options on that basis.

'Time of use' tariffs received a mainly negative reaction. Many suggested they would need to make substantial behaviour changes, such as having appliances on a timer, or changing the time of day when they do their cooking or washing, to make cost savings. Most Panel members felt these changes are too much effort, making this tariff quite undesirable to the majority. There was a limited understanding of the purpose of such tariffs.

[41] Ofgem Consumer First Panel. Research Findings from the Third Events October 2009

# 10. Household demand in 2025

We will be looking at 2025 during 2012-13 (Year 2 of the project) when we have a stronger basis to make some judgements, based on a clearer understanding of the 2010 baseline and more up to date estimates from Government and industry sources. However, it is worth noting that there are a number of key factors that could make 2025 different from 2010:

- smart meters – all homes that can have them (circa 90%?) will have them by 2020;
- take up of heat pumps (and extent to which they have storage);
- take up of new generation electric storage heating;
- electric water heating and storage - likely trends;
- take up of electric vehicles;
- take up of home based electricity generation (PV etc.);
- appliance efficiency standards;
- remote control of appliances built in to new appliances;
- further growth in penetration and usage of electrical appliances;
- demographic factors – household size; numbers of households;
- income changes;
- electricity prices.

For 2025, take up of electric heating, electric water heating, electric vehicles and microgeneration (mainly PV) will be crucial. As regards electric heating a key issue is how much will be heat pumps and how much new generation storage heating. Unless storage is developed for use with heat pumps they will consume electricity whenever heat is required from them - so demand would be spread throughout peak, off-peak and shoulder periods. Heat pumps could therefore increase evening peak demand. Increased use of electric water heating could offer useful scope for increasing storage and demand response, but if households are removing hot water cylinders (see above) this scope might be reduced.

Clearly a number of the factors outlined above suggest that there could be greater potential in the future for shifting – notably if there is greater use of electric heating with storage and electric vehicles. Some of this demand however, as far as networks and retailers are concerned may materialise as reduced rather than shifted demand. For example, some households with PV who are at home in the daytime are probably shifting demand (notably use of wet appliances) to maximise electricity use during the day when they can use their own self generated electricity, rather than having to import from the network[42] as it would be taking place "off grid".

As the amount of wind generation on the system increases, high-cost periods may correspond with low-wind periods. In that case household automation and potentially load-limiting may be valuable to enable demand response at low wind periods (particularly if there are new large loads from EVs etc), although it is worth noting that these periods will not necessarily be the same as the winter evening peak.

[42] Anecdotal evidence from a number of households with PV.

**Electricity demand reduction to 2025**

GB household electricity end-use demand reduction is likely from progressively improved product standards, being introduced under the EU Eco-Design Framework Directive. Currently, eight Eco-Design Regulations cover 50% of household electricity consumption – and by the end of 2012, for the household (and tertiary) sectors, there will be 100% coverage of product groups responsible for electricity consumption in those sectors.

Counter to this are demographic changes (more, smaller households), more small appliance ownership and, most notably, continued growth in personal electronics.

# 11. Conclusion

This paper has examined what household customers are currently able to offer by way of electricity demand response and demand reduction, on what basis, and the reasons why they might want/not want to participate. It has therefore looked at the types and times of day of electricity uses and likely willingness to shift or reduce usage of certain equipment. The paper has also examined data from some trials that have sought to establish customer responses to incentives to shift or reduce demand, such as time of use tariffs.

It is clear that there is some potential but that at the current time (2012) this is relatively modest. Clearly, this could change significantly in the coming decade and this will be investigated in further work on this project.

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